Mitigating the Challenges of Global Warming by Harnessing the Electric Power Generation Potential of Gas Flaring in Nigeria

Lawal, Olatunji A[1]. Akinyemi, Toluwanimi O[2], Ramonu, Olayinka J[3],

Abstract— The UN Framework Convention on Climate Change had its Conference of Parties (COP 21) in Paris, 2015. This availed Nigeria an opportunity to strengthen her leadership role in the international climate negotiations. Nigeria's clarion voice was heard showing strong support for an equitably, just and legal binding climate change agreement that will provide the much needed support for developing countries to mitigate the global warming challenge. This study depicts the mitigation strategies of global warming and effects of gas flaring on the environment, economy and electric power generation capability of Nigeria as she hope to ratify the agreements made in Paris and meet up with the Intended Nationally Determined Contributions to cut CO_2 emission by 20%. The data of the gas flare taken in July, August, September, and October 2017 were selected to forecast for the year 2030 and a linear regression method was deployed for these analyses using Microsoft Excel and IBM SPSS 23.

The result shows a correlation value of 1.0 between the period and the variables e.g the weight of CO_2 emitted (tonnes). It was also observed from the analysis that over two hundred and eighty-one billion tonnes of CO_2 would have be flared between 2015 and the year 2030 and over 460 thousand GWh of electricity generation potential would be left untapped unless there are strict policies and proper planning to harness this vital natural resource during this period.

Index Terms— : Climate Change, Electric Power, Carbon dioxide, Flared Gases, Global warming, Mitigating CO_2 Emission, COP 21.

1 INTRODUCTION

IN 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change. Thirteen years later, precisely in 2005, the Kyoto Protocol became a legally binding treaty committing its parties to internationally binding emission reduction targets. This target ends in 2020, and Conference of Parties (COP21) is designed to take its place. The agreement of COP 21 which is to be ratified by at least 55 countries to cut the global emission of Green House Gases (GHG) by 55 per cent was adopted by all the parties present in the meeting. [22]

Before the announcement by the US and China in 2016, only 24 countries who are responsible for about 1% of global emissions had ratified the agreement, while 18 had signed it. [24]

This research hopes to examine the mitigation procedure in the COP21 agreement while looking into gas flaring as a hindrance for Nigeria to meet up with the agreement. It also depicts the electric power generating potential of the flared gas as well as the accrued fines levied on the companies involved.

The global emissions reduction target of 55% has been significantly boosted by China and the US, who between them represent 37.98% of global emissions. This brings the total parties who have joined the Agreement to 26, and the percentage of global emissions to 39.06%. CO_2 Emission per cent values of the United States, China and Other Countries of the world are given in fig. 1.3. This shows that the US and China are key players in this agreement with emissions more three-quarters the emissions of other countries of the world [27]

About 200 developed and developing countries spent two weeks in Paris in December 2015, hammering out the final wording of an agreement to keep global temperature increase well below 2^0C and if possible, below 1.5^0C. [16] The reduction in temperature can only be achieved through a significant reduction in the emission of greenhouse gases causing global warming. This convention was tagged COP21, (The 21st Conference of the Parties to the UN Framework Convention on Climate Change), it was one of the largest gatherings of world leaders ever seen.

Everyone who attended COP21 made emission-cutting pledges for their countries. These are known as "Intended Nationally Determined Contributions", (INDCs). The US, for example, pledged to reduce U.S. climate pollution by 26-28% from 2005 levels. China's target is to reach peak CO_2 emissions by 2030 at the latest, lower the carbon intensity of GDP by 60% to 65% below 2005 levels by 2030, and to increase the share of non-fossil energy carriers of the total primary energy supply to around 20%. CO_2 as shown in fig. 1.1 accounts for three-quarters of the world global emissions. 65 per cent of this comes from the burning of fossil fuels and other industrial use while 11 per cent of the CO_2 emissions are from forestry and other land use [10]

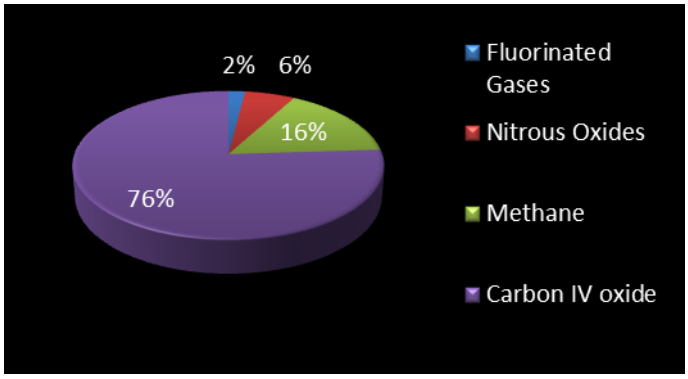


Fig 1.1: Greenhouse Gases

GAS FLARING IN NIGERIA

The flaring of associated gas may occur at the top of a vertical flare stack (as in the adjacent photo) or it may occur in a ground-level flare in an earthen pit. Preferably, associated gas is reinjected into the reservoir, which saves it for future use while maintaining higher well pressure and crude oil producibility [26]. Nigerian gas reserve is estimated to be about 124 trillion cubic feet (TCF) of gas in 2005 which in term of energy it is said to be twice as much as the nation's crude oil reserves. Natural gas in Nigeria is obtainable in two main forms which are Associated natural Gas (AG) and Non-Associated natural Gas (Non-AG). Approximately 75 per cent of the total gas output was flared in the year 2000. This may be broken down into 8 per cent of Non-Associated gas and 92 per cent of the Associated Gas output [31]

The first field was found in 1956 and the first export was made in 1958, the origins of gas flaring can be traced to the activities of Shell-BP with the epoch- making discovery of crude oil in commercial quantity at Oloibiri (Bayelsa State) in August 1906 [1], [20]

At the onset of oil exploration in Nigeria, practice of gas flaring became institutionalized as natural gas was deemed to be a waste product that resulted from the process of exploring crude oil from the ground and the practice became institutionalized throughout the industry The Natural Gas data in fig.1.2 shows that the Natural gas reserves for the years are fairly constant, the Natural Gas demand (mn std cum) was found to increase from 2011 to 2014, Natural Gas export (mn std cum) was found to fluctuate within this period as Natural Gas Reserve in (bn std cum) was fairly constant [18], [28]

- *Lawal Olatunji completed his master degree program in electric power systems engineering in the Universit of Ibadan, Nigeria, He is a lecturer at Kwara State Polytechnic, Ilorin, Nigeria. +2348139381343. E-mail: ahmlawal@yahoo.com*
- *Akinyemi Toluwanimi completed his master degree program in mechanical engineering (Thermo-Fluid Option) in the University of Ibadan, Nigeria. He is a lecturer at ESEP-LE BERGER Universite, Cotonou. +2347068364389, E-mail: engrtolu@gmail.com*
- *Ramonu Olayinka completed his master degree program in mechanical engineering (Thermo-Fluid Option) in the University of Ibadan, Nigeria. He is a lecturer at Federal Polytechnic, Ilaro, Ogun State, Nigeria. +2348107297152, E-mail: yinkard4mee@gmail.com*

Nigeria is ranked number one gas flaring country in the world ahead of other Organisation of Petroleum Exporting Countries (OPEC) and the United States and Canada in a 2004 report. [7], [8]

Over the years government after government has formulated policies and measures to try and capture the flared gas by the setting up and operations of the Bonny Liquefied Natural Gas (LNG) project in 1989. Nigeria's ambitious INDC, which aims to reduce emissions by 20% below BAU by 2030, rising to 45% with support from the international community will be revised to reflect the Decisions and Agreement of the COP21. This will allow us to ensure an implementation strategy that is results oriented and integrated into our national plans at all levels and in all key stakeholder constituencies [15]. According to fig. 1.3, China contributes approximately 30 per cent of global emissions, making it the top emitter. India, Indonesia, Brazil, Mexico and Iran are also contributing relatively large shares of global emissions as their economies grow. Although developed countries used to dominate the list of top 10 emitters, it is important, however, to consider a range of indicators that help differentiate the responsibility and capability of countries to act [29]

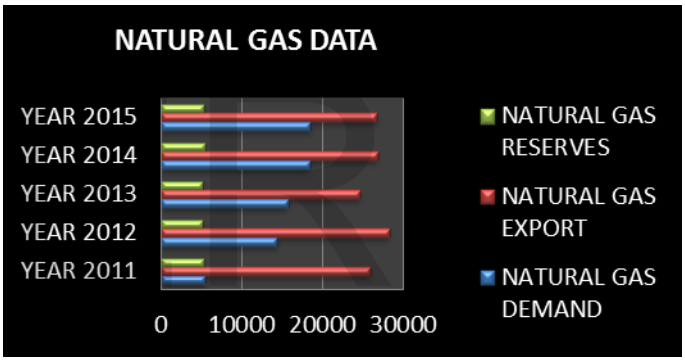


Fig. 1.2: Natural Gas Data

ELECTRICITY GENERATION IN NIGERIA

In September 2013, Transmission Company of Nigeria in its plan proposed a total of 11,200MW generation for the teaming population of over 167million Nigerians at the end of 2016. Due to the shortage in supply of gas and poor transmission network, the generation has been at 2,820MW of the 11,200MW total generating capacity. At this time demand has risen to 17,720MW in Transmission Company of Nigeria (TCN) daily report of the 2nd of June 2016 . The electric power generation capacity rose to 7000MW in December, 2017. 5000MW of this was transmitted and distributed due to distribution challenges. The Federal government of Nigeria has reportedly spent around US$31.45 billion on power sector from 1999 to 2013. However, the potential in Nigeria's power sector remains vast, and therefore, interest remains in investing in different parts of the value chain [13], [14], [25] and [30]. Some of the main challenges investors face in the Nigerian post- privatization world includes, insufficient gas supply

due to poor gas infrastructure, cost-unreflective tariff regime, Obsolete Transmission and distribution power sub-stations,

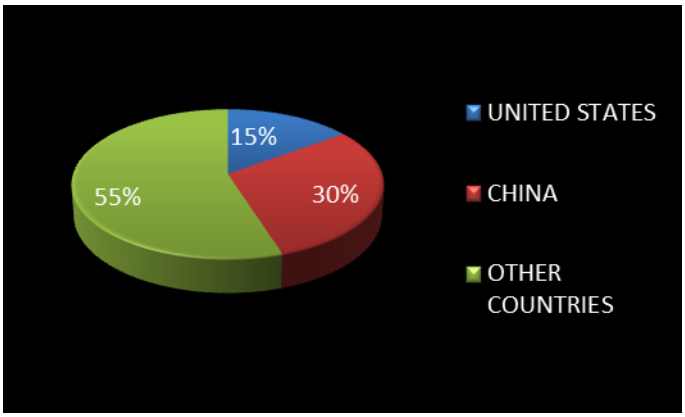


Fig 1.3: Countries' CO_2 Emission

Non- bankable gas supply agreements, Changes in government and uncertainties as to the future direction of government policies, Bureaucracy of government agencies, Lack of affordable long-term funding, Foreign exchange and currency issues as well as Inadequate natural gas due to vandalism of power gas pipes linking power plants as well as gas flare.

According to the Chairman of the Nigeria National Committee of the World Energy Council, planning experts estimate that for the Nigerian economy to grow at a rate of 10%, the country's electricity requirement must reach 30,000 MW by 2020, and 78,000 MW by 2030. To therefore improve the economy's current GDP growth and reduce the current electricity supply gap, market intervention and fundamental power sector reform are vital. [5]

Current electricity generation is primarily from either gas-fired or hydro power plants, with natural gas as the main fuel source for power generation in Nigeria. According to McKinsey in 2013, the power-generation potential from domestic gas reserves in Nigeria was greater than 10,000 MW, which is relatively higher than the potential from domestic gas reserves in other African jurisdictions, but still falls significantly short of meeting the levels required. [15]

EMISSION IMPACTS

Methane and CO_2 which are major components of the gas flared are GHGs that have been proven to have a global warming effect on the climate. These gases as well as other GHGs are responsible for the increase in temperature experienced on the surface of the earth. They trap warmth in the atmosphere instead of releasing them to space. The overall increase in temperature has been responsible for stormier storms, chillier colds, drier deserts, drought and increased flooding. [11]

The flares associated with gas flaring give rise to atmospheric contaminants. These include oxides of Nitrogen, Carbon and Sulphur (NO_2, CO_2, CO, SO_2), particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulphide (H_2S) [12], [17]. These contaminants acidify the soil, hence depleting soil nutrient. Previous studies have shown that the nutritional values of crops within such vicinity are reduced. In some cases, there is no vegetation in the areas surrounding the flare due partly to the tremendous heat that is produced and acid nature of soil pH [9], [23].

The effects of the changes in temperature on crops included stunted growth, scotched plants and such other effects as withered young crops. Researchers concluded that the soils of the study area are fast losing their fertility and capacity for sustainable agriculture due to the acidification of the soils by the various pollutants associated with gas flaring in the area. When plants have stunted growth, livestock cannot be well fed with appropriate nutrients which may lead to a decrease in food supply and in extreme cases famine and war. The implication of gas flaring on human health cannot be overemphasized these are related to the exposure of those hazardous air pollutants emitted during incomplete combustion of gas flare. These pollutants are associated with a variety of adverse health impacts, including neurological disorder, cancer, reproductive and developmental effects. Deformities in children, lung damage and skin problems have also been reported

The impact of gas flaring is also felt in the economy aside from the health and environmental impacts. The impact of gas flaring and power plant emission on the socio economic environment of the Niger Delta people in Nigeria was examined. The results reveal that gas utilization has significant impact on the economy and it is also sustainable. It reveals further that since the imposition of fine on flared gas in 1984, no structural change has been observed. Therefore, there is an urgent need for the government to provide environment that is conducive for investment in the gas industry as this will lead to additional income to both the people and the government of Nigeria. The nation also loses billions of dollars' worth of gas which is literally burnt off daily in the atmosphere. Much of these can be converted for domestic use and for electricity generation. By so doing the level of electricity generation in the country could be raised to meet national demand.[4], [19] and [21]

Nigeria has recorded a huge revenue loss due to gas flaring and oil spillage Though more than 65 % of governmental revenue is from oil, it is estimated that about $2.5 billion is lost annually through gas flaring in government revenues. [3], [6]

MITIGATION STRATEGIES

Nigeria's minister of environment in a press briefing after COP21 said "among other things the agreement avails us an opportunity to ensure the diversification of the energy mix from fossil fuels towards renewables and efficient gas power. In particular, Nigeria plans to scale up off-grid solar power, delivering energy access to the poorest communities in a cheaper, healthier and less emissions intensive way"

It will help create a more efficient, lower carbon oil and gas sector. By ending gas flaring and using the gas for commercial purposes, including power generation, the country could earn as much as $7.5 billion of benefits.

Collectively, these opportunities will not only reduce emissions and improve climate resilience; they can also unlock economic opportunities and reduce poverty in the lives of Nigerians especially our women and youth. The World Bank estimates that far from increasing costs on the Nigerian economy, a collection of low-carbon activities could provide a boost to the economy as great as 2% of its GDP. The INDC serves as a veritable tool to reflect the new change agenda.

2. METHODOLOGY

Gas flare data since 2015 was accessed and it was discovered that over 300 billion Mscf per year of CO_2 had been flared, this amounts to over 700 billion US Dollars. As the Electricity generation potential of the sources of power generation in Nigeria stand far below 3000GWh at the second quarter of 2017, the power generation potential of flared gases is over 27 thousand GWh.

Current data of the gas flare taken in July, August, September, and October 2017 will be used to forecast for the year 2030. Linear regression will be deployed for these analyses in Microsoft Excel and SPSS 23.

2.1 ANALYSES

1st Step: Every time the gas flare data was taken, it brings an estimated volume of CO_2 emission, the cost of the gas flared and the power generation potential of the gas flared. These data are taken and recorded.

2nd Step: The strength of correlation (r value) between the number of hours and gas flare data is determined, this will show if there is a perfectly positive or negative correlation, positively strong or negatively weak correlation, moderately positive or negative correlation etc.

Pearson correlation will be used because the data taken are continuous variable and will be treated as scale data.

The normality of all the parameters measured was tested and the plots are as shown in the figures. The graphs plots show that the dataset are normally distributed and a linear regression analysis will be used to forecast what the weight of CO_2 emission (tonnes) will be by the year 2030.

A correlation value of 1.0 was gotten to show a perfectly positive correlation between the Period since 2015 and the weight of CO_2 emission (tonnes)

Choosing the weight of CO_2 emission (tonnes) as the dependent variable and the period since 2015 as the independent variable a linear regression equation $W = mt + k$

Where

W is the weight of CO_2 emitted (tonnes)

k is the equation constant or intercept

t is the period since 2015 in (hrs)

m is the gradient of the graph in tonnes/hr.

TABLE 1
GAS FLARE DATA TAKEN

DATE (2017)	16TH JULY	28TH JULY	11TH AUGUST	16TH SEPTEMBER	8TH OCTOBER
VOLUME (Mscf)	796816344.7	807476851.8	819523309.7	849881615.4	869084886.5
Fines (USD)	2788857206	2826168981	2868331584	2974585654	3041797102
Gas Value (USD)	1992040862	2018692129	2048808274	2124704038	2172712216
Power generation Potential (GWh)	68844.9407	69766.0086	70806.8227	73429.7807	75088.9435
CO_2 Emissions (tonnes)	42011782.16	42573852.59	43208996.65	44809624.61	45822108.41

Source: www.gasflaretracker.ng

The value of m was found to be 1887.206 tonnes/hr. This shows that over a thousand eight hundred tonnes of CO_2 is emitted every hour.

Fifteen years after 2015, precisely by the beginning of the year 2030, using the linear regression model equation, over two hundred and eighty one billion tonnes of CO_2 would have been emitted into the atmosphere via the gas flare procedure in Nigeria. This amounts to about eighty-nine billion tonnes of the combination of fluorinated gases, methane and Nitrous oxides.

Using the same procedure to forecast the volume of gas (Mscf) and the Power generation potential (GWh) of gas expected to be flared by the year 2030. It was found that over 5.3billion Mscf of gas would have been flared with an average volume of over 35thousand Mscf of gas flared every hour.

Over 460 thousand GWh of electricity generation potentials would be left untapped, this translates to about 3000MW of electricity which when added to our total generation capability will bring about a huge change in the epileptic power supply situation of the country. If strict policies and properly planned gas processing and utilization networks have not been put in place to harness this vital natural resources, a great environmental, financial and economic losses would have been incurred by the country by the year 2030.

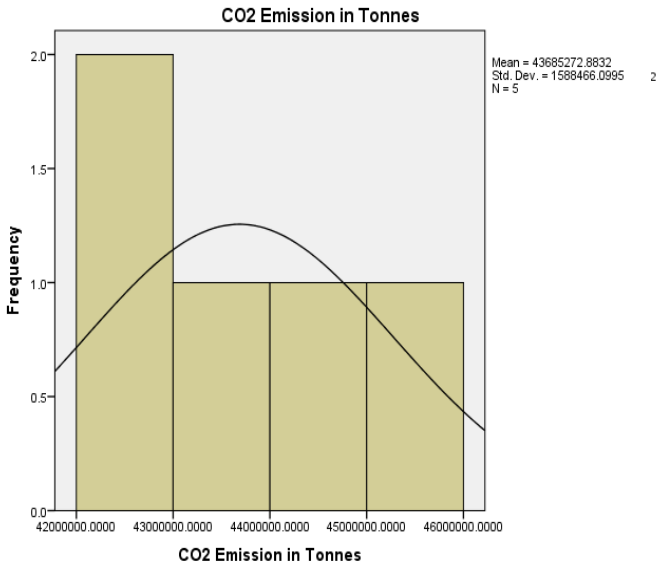
RESULTS

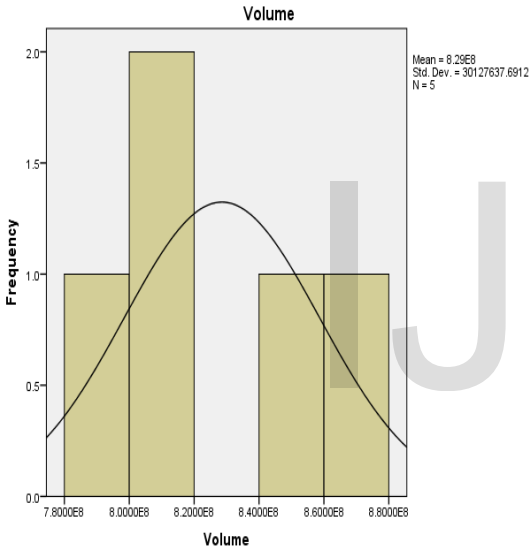
Correlations

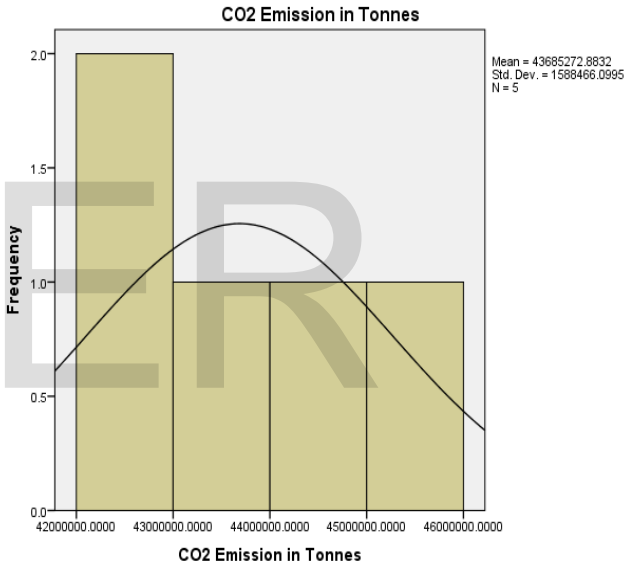
Table 1.2: Correlation Output

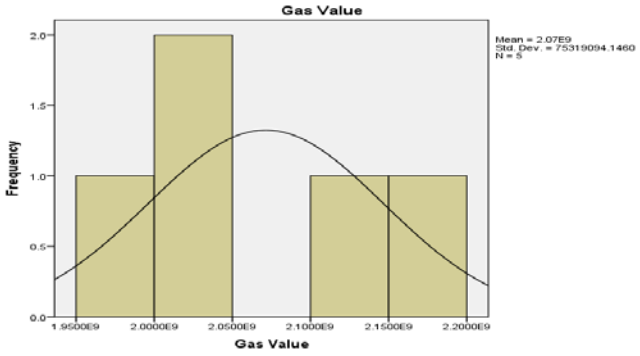
		CO2 Emission in Tonnes	Period in hours since 2015
CO2 Emission	Pearson Correlation	1	1.000**
	Sig. (2-tailed)		.000
	N	5	5
Period since 2015	Pearson Correlation	1.000**	1
	Sig. (2-tailed)	.000	
	N	5	5

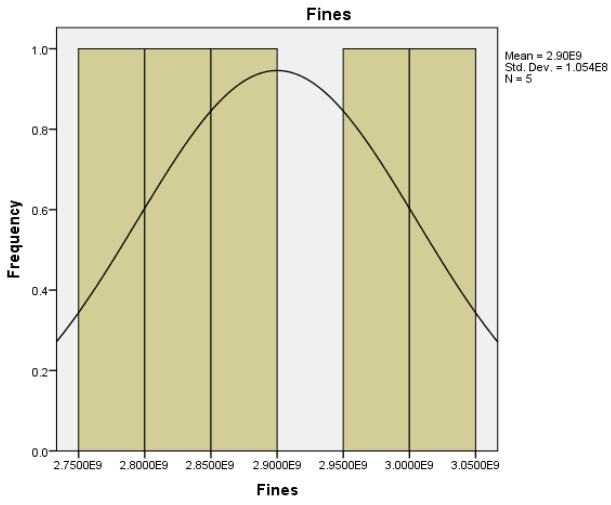
**. Correlation is significant at the 0.01 level (2-tailed).











4. CONCLUSION

The outcome of COP23, which was to evaluate COP21 showed a dramatic reality of recent extreme weather events and scientific findings that climate change is accelerating and that greenhouse gas emissions are again on the rise. These mean that climate action must speed up. With Nigeria's economy still dependent on the global price of oil, monthly and yearly increase in gas flared at oil exploration sites will still be a major factor contributing to the emission of GHGs from the shores of Nigeria. Inadequate power generation, transportation activities as well as agro-allied industries activities are factors contributing to the emission of these gases. INDC's target to reduce CO_2 emission by 30 per cent by the year 2030 cannot be met, likewise, the projection of a power generation of 78,000MW by the year 2030 will be a wild goose chase if the volume of Natural gas flared is not harnessed to complement the current power generation capacity of the country. A lot of revenue can also be generated from fines levied on the exploration companies if the government of Nigeria decides to take a more critical look into gas flaring.

REFERENCES

[1] S.O. Aghalino, (2000). Petroleum Exploitation and Environmental Degradation in Nigeria. In: HI Jimoh, IP Ifabiyi (Eds.): Contemporary Issues in Environmental Studies. Ilorin: Haytee Press, pp. 141-147

[2] S.O. Aghalino, (2000). Petroleum Exploitation and the Agitation for Compensation by Oil Mineral Producing Communities in Nigeria. Geo-Studies Forum, 1(1, 2): 11-20.

[3] A .A., Arowolo, & I. J. Adaja, (2011). "Trends of natural gas exploitation in Nigeria and the implications on the socio-economic stability and governance," 35th Nigerian Statistical Association annual conference.

[4] K.O Atoyebi, & J.O. Akinde, (2012). ''The Impact of Gas Flaring and Power Plant Emission on the Socio Economic Environment of Niger Delta Region'' International Journal of Scientific & Engineering Research, 3(4), ISSN 2229-5518

[5] Chairman of the Nigeria National Committee of the World Energy Council – Article titled "The Way Forward for Electricity Supply in Nigeria," 20 October 2015.

[6] S. A. Effiong & U. E. Etowa, (2012) "Oil spillage cost, gas flaring cost and life expectancy rate of the Niger Delta people of Nigeria," Advances in Management & Applied Economics. 2(2). 211-228;

[7] B.Garvet, (2007). 'Gas Flaring Emissions Contributes to Global Warming.' http://www.itu.se/polopoly_fs (Retrieved July 12, 2010)

[8] B. Garvet, (2007). Gas Flaring Emission Contributes to Global Warming. Renewable Energy Research Group, Division of Architecture and Infrastructure, Lulea University of Technology, Lulea, 2-14.

[9] A. A Imevbore,. & S. A Adeyemi,. ''Environmental monitoring in relation to pollution and control of oil pollution." Seminar on the petroleum industry and the Nigerian environment; 6, 135-142, 1981.

[10] IPCC ; (2014). **Climate Change 2014: Mitigation of Climate Change.** Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[11] T.R. Karl,& K.E. Trenberth *(2003).* "Modern global climate change". *Science.* ***302*** *(5651):1719-23.* Bibcode*:* 2003 Sci...302.1719K. doi:10.1126/science.1090228. PMID 14657489.

[12] W.D Kindzierski,. "Importance of human environmental exposure to hazardous air pollutants from gas flares," Environmental Reviews, 8, 41-62, 2000.

[13] Latham, & Watkins (2016). Article titled "Nigerian Power Sector: Opportunities and Challenges for Investment in 2016". February 23, 2016 | Number 1930, Pg 1 – 15.

[14] O. Lawal (2016). Improving Power System Steady State Voltage Stability Using Static VAr Compensation, Unpublished MSc Thesis. (Unplublished manuscript)

[15] A.,Mohammed, (2015). ''THE HONOURABLE MINISTER OF ENVIRONMENT, AMINA J MOHAMMED AT A PRESS BRIEFING ON THE OUTCOME OF COP21 PARIS'' www.climatechange.gov.ng.

[16] "NASA GISS: Science Briefs: Greenhouse Gases: Refining the Role of Carbon Dioxide". www.giss.nasa.gov. Retrieved 26-04-2016.

[17] I. B. Obioh, "Environmental Impact Assessment of Emissions from Major Facilities at QIT," Atmospheric Emissions and Dispersion Modeling; Faithlink Consults Nigeria Ltd., PortHarcourt. 1999.

[18] S.I Oni, & M.A Oyewo, (2011)''Gas Flaring, Transportation and Sustainable Energy Development in the Niger-Delta,Nigeria. www.researchgate.net/publication/228507046

[19] O. I., Orimoogunje, , A. Ayanlade, T. A. Akinkuolie, , & A. U. Odiong, (2010). "Perception on the effect of gas flaring on the environment," Research Journal of Environmental and Earth Sciences. 2(4). 188-193.

[20] A. Osuoka, & P. Roderick, (2005). Gas Flaring in Nigeria: A Human Rights, Environmental and Economic Monstrosity. A joint report written by the Environmental Rights Action / Friends of the Earth, Nigeria and The Climate Justice Programme, Amsterdam: Press.

[21] S. I Ovuakporaye,. C. P., Aloamaka, A. E. Ojieh, D. E Ejebe, & J. C,Mordi,. (2012). "Effects of gas flaring on lung function among residents of ib Gas flaring community in Delta State, Nigeria," Res. J. Env. Earth Sci. 4(5). 525-528.

[22] The Economist 2009: http:// www.economist.com/displayStory.cfm?story_id=1097980 (Retrieved May 3, 2010)

[23] E. C. Ubani, & I. M Onyejekwe,. (2013). "Environmental impact analysis of gas flaring in the Niger delta region of Nigeria." American J. of Scientific and Industrial Research. 4(2). 246-252.

[24] United states Environmental Protection Agency, Global Greenhouse Gas Emission Data, Retrieved 3rd of June 2017, www.epa.gov

[25] Venturer Africa – Article titled "It will take more than another grant to increase Nigeria's power generation above 4500 Megawatts," by Felicia Omari Ochelle, 16 October 2015.

[26] L, William (2008). Petroleum Refining in Nontechnical Language. Tulsa, OK: PennWell. p. 9.

[27] World Economic Forum, What is the Climate Change Agreement? www.weforum.org Retrieved: 3rd of June 2017.

[28] 2016 OPEC ANNUAL STATISTICAL BULLETIN. www.asp.opec.org Retrieved 20th of June, 2017

[29] T.A. Boden, G.Marland, and R.J Andres,. (2017). National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, doi 10.3334/CDIAC/00001_V2017.

[30] Premium Times News https://www.pmnewsnigeria.com/2018/02/13. Nigeria Govt, MAN Discuss Measures to Distribute 2000MW Unused Electricity. Retrieved: February, 20th, 2018)

[31] Nigeria National Petroleum Corporation (NNPC) (2008), https://www.nnpc.com/portals "Nigeria Annual Statistical Bulletin". Retrieved: 6th of July 2017