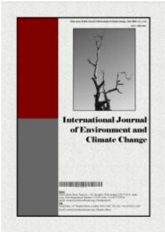

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Nigeria's Greenhouse Gas Emissions: Estimations Based on the 5th Assessment Report

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The lack of GHG emissions inventory and absence of standardized estimation methods necessitated this study. American Petroleum Institute's method of Greenhouse gas estimation methods combined with the global warming potential in the 5th assessment report and Nigeria's unique gas composition were used to estimate volume of GHG's resulting from gas flaring in Nigeria between 1965 to 2020, as reported by NNPC. The findings show the total CO_2, CH_4, N_2O and GHG emission between 1965 to 2020 were $1.86*10^9$ tons, $3.3*10^8$ tons, $5.76*10^9$ tons, and $7.94*10^9$ tons respectively. In the 56 years under review, the gas produced was estimated at $2,14*10^6$ MCM, while $9.44*10^5$ MCM of the gas was flared, accounting for 44% of the total gas produced over the years. Overall, the study revealed a striking cause for concern due to the predicted continuous increasing amount of gas flaring and release of greenhouse gas emissions which could have significant effects on the environment. Curbing gas flaring: increased gas utilization for domestic and export uses and standardization of GHG estimation methods were recommended.

Keywords: Greenhouse gas; GHG; gas flaring; Niger-Delta; emissions.

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1. INTRODUCTION

Gas flaring which brings about the release of greenhouse gases (GHGs) to the atmosphere. Overtime, they impact the climate negatively with severe environmental, human health, and agricultural consequences [1] (Al-Bashir, 2012). Like the rest of the world even worse off, Niger Delta is experiencing distortion in the Ecosystem formation because of the emission of harmful gases from the Petroleum industries, causing climatic change, freshwater acidification (acid rain), diverse human health problems most commonly which is the exponential increase in cases of cancer recorded in the past decades [2]. According to Emam (2015), lack of monitoring equipment and limited oversight make it difficult to quantify the amount of gas flaring around the world. In addition, many countries do not publicly report gas flaring volumes, leading to significant uncertainty regarding the magnitude of the problem (Oluduro and Oluduro, 2015). World Bank (2004), in its report acknowledged that flaring, and venting of associated gas contributes significantly to GHG emissions, with negative impact on the environment and estimated that Nigeria's gas flaring is close to 2.5 million cubic feet daily, amounting to about 70 million tonnes of carbon dioxide daily emission. In addition, the report estimated that Nigeria accounts for 12.5 percent of total flared natural gas in the world. Recent statistics ranks Nigeria as the second major gas-flaring country in the globe only next to Russia [3] (Ndubuisi and Olaode 2015). While Nigeria lost nearly $72 billion in generated revenues for the period 1970-2006, what translate to $2.5 billion yearly (Audu, 2013), the environmental effect associated with this is immeasurable, overwhelming, and far reaching [4].

The gas flaring give rise to atmospheric pollutants. These atmospheric pollutants comprise oxides of Nitrogen (NO_2), Carbon (CO_2, AND CO) and Sulphuric (SO_2), particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulphide (H_2S) (Obioh, 1999, cited in Ogawa-Onishi, & Berry, 2013; Alakpodia, 2000). These pollutants bring about has contributed greatly to global warming, climate change, and the depletion of the ozone layer, all of which are environmental hazards [5]. The global average surface temperature has increased by around $0.6^{\circ C}$ over the twentieth century, (Intergovernmental Panel on Climate Change IPCC; 2013). Global warming has an impact across the world, with varied degrees of impact. While some countries may gain from a shift to more temperate temperatures, others may be affected by low-lying Pacific islands. Sea levels, forests, agriculture, natural ecosystems, and population distribution could all be affected by the expected rise in global temperatures [6,7].

Hence**,** it becomes very necessary to study the GHG emissions from gas flaring activities in Niger delta to ascertain the volume and determine Nigeria's contribution to the global pool of greenhouse gases and most importantly try to provide a clear understanding of the global warming potentials and step-by-step procedure for GHG estimation using stoichiometric equations.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in the Oil-rich Niger-Delta region of Nigeria. The region comprises of nine states (Abia, Edo, Ondo, Imo, Delta, Bayelsa, Rivers, Cross River and Akwa Ibom) where oil exploration is carried out on land and offshore along the coast of the country. The country's oil and gas reserves are majorly set down in the Niger Delta Area and they are the core of the economy. More than 90% or more of the country's foreign incomes have originated from crude oil and natural gas earnings for an extended period [8]. The area of study is well-known for its extraordinary biodiversity which now poses threats of all kinds, one of which is the subject under consideration – (GHG) emissions [9] Geographically, Niger Delta lies between latitude 4^{o} 0' 0''N and 8^{o} 0' 0''N, and longitude 5^{o} 0' 0''E and 7^{o}0' 0''E of the equator, and extends over about 70,000km^2 and makes up 7.5% of Nigeria land mass with approximately 31million people of not less than 40 ethnic groups. Fig. 1, is a map of Nigeria showing the oil and gas producing States in Niger Delta.

2.2 Data Collection

The data for this study is secondary data which are obtained from the monthly online reports from the Nigerian National Petroleum Corporation (NNPC) on gas produced, utilization and flared in the country from 1965 to date. The data gotten were divided into six decades (1965 −1974, 1975−1984, 1985−1994, 1995−2004,2005 −2013, 2014 - 2020) for better analysis. The flared gas data were used to estimate the GHGs (CO_2, CH_4 and N_2O) emitted for the period under consideration.

Map 1. The Map Nigeria displaying the Oil Producing States in Niger Delta Region [10]

2.3 Mathematical Methods

This study employed empirical formulae as stated by the Association of Petroleum Institute (API) used for the Oil and Gas industry to carry out the estimation (API, 2009). This study also used 98% flare efficiency as stated by the Environmental Protection Agency (EPA) for verified mixtures of gas under the condition of constant flame (API, 2009).

Emission from gas flaring was estimated by using the following equations:

$$\mathrm{ECO_2} = \left(\frac{\mathrm{Vf \times MWCO2 \times mass\ conversion}}{\mathrm{molar\ volume}}\right) x \left(\Sigma\left(\frac{\mathrm{mole\ Hydrocarbon}}{\mathrm{mole\ gas}}\right) x \left(\frac{\mathrm{Amole\ C}}{\mathrm{mole\ Hydrocarbon}}\right) \mathrm{x} \left(\frac{\mathrm{0.98\ moleCO2\ formed}}{\mathrm{mole\ C\ combusted}}\right) + \frac{\mathrm{B\ moleCO2}}{\mathrm{mole\ gas}}\right) \qquad \text{Equation (1)}$$

$$\mathrm{E_{CH4}} = \frac{\mathrm{Vf \times CH4mole\ fraction \times \%\ residual\ CH4 \times MWCH4 \times mass\ coversion}}{\mathrm{molar\ volume}} \qquad \text{Equation (2)}$$

$$\mathrm{E_{N2O}} = \mathrm{Vp} \times \mathrm{EFN2O} \qquad \text{Equation (3)}$$

$$\mathrm{Total\ GHG\ Emission} = ((1 \times \mathrm{CO2emissions}) + (28 \times \mathrm{CH4emissions}) + (265 \times \mathrm{N2O\ emissions}) \qquad \text{Equation (4)}$$

Where:

Molar volume = conversion from molar volume to mass (379.3 scf/lbmole or conversion 23.685m3/kgmole); MW CO_2 = CO_2 molecular weight; Mass conversion = tonnes/2204.62lb or tonne/1000 kg; *A* = the number of moles of Carbon for the hydrocarbon; and *B* = the moles of CO_2 present in the flared gas stream.

E_{CH4}= emissions of CH_4 (lb); V = volume Flared (scf); % residual CH_4 = non-combusted fraction of flared stream (default =0.5% or 2%); Molar volume = conversion from molar volume to mass, (379.3 scf/lbmole or Conversion 23.685 m3/kgmole); MW CH_4 = CH_4 molecular weight.

ECO_2 = CO_2 emissions (kg); ECH_4 = CH_4 emissions (kg); EN_2O = N_2O emissions (kg); Vf = volume flared (mcm); molar volume = 23.685 m^3/kg-mole; M_wCO_2 = molecular weight of CO_2; Conversion of mass = ton/1000 kg; A = number of moles of carbon contained in the individual hydrocarbon; B = moles of CO_2 existing in the stream of the flared gas; % residual CH_4 = non-combusted fraction of flared stream; M_wCH_4 =CH_4 molecular weight; Vp = volume produced (m^3); E_f N_2O =N_2O emission factor.

These formulas are consistent with published flare emission factors (E&P Forum, 1994 & API, 2009, IPCC, Volume 2, Chapter 4, 2006: INGAA, Section 2.4, 2005), control device performance, and results from the more recent flare studies.

Chart 1. Nigeria's gas composition obtained from Soku fields was used and 5th assessment report global warming potentials as shown in tables below

Common Name	Chemical Formula	GWP values for 100-year time horizon		
		Second Assessment Report (SAR)	**Fourth Assessment Report (AR4)**	**Fifth Assessment Report (ARS)**
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265

Source: IPCC (2016)

Chart 2. Natural gas composition in percentage mole/volume (Soku, Nigeria)

Methane	Ethane	Propane	Butane	Pentane	N_2	CO_2
92.51	2.78	1.66	0.78	0.30	0.11	0.22

Source: Umukoro and Ismail (2015)

2.4 Data Analysis

SPSS 20, Excel statistical packages and R-studio were employed to analyze the data in this study. Results were presented graphically with the aid of line graph and the use of tables.

3. RESULTS

This section of the study shows the results. Table 1 presents the summary of volume of gas produced, utilized, and flared in Nigeria across the decades. Fig. 1 shows the graphical summary of volume of gas produced, utilized, and flared.

the estimated greenhouse gas emission from 1965 – 2020, while Fig. 2 presents the cumulative greenhouse gas emissions and lastly, Fig. 3 is used to demonstrate cumulative predicted flared GHG.

Fig. 3 shows the estimated GHG emissions flared in the years under review.

4. DISCUSSION OF FINDINGS

The natural gas reserves in Nigeria have prospects to reduce energy-related costs through increased efficiency but gas flaring has been a major cause of environmental pollution contributing significantly to GHG emissions, a waste of a significant energy source and loss of revenue to the country [11-14]. The data in the current study showed that the gas produced between 1965 - 2020 was estimated at 2,140,600mcm, while 944,793mcm of the gas was flared, accounting for 44% of the total among of gas produced over the years. This finding is consistent with the reports of Otene et al. [15], which indicated that 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. Consequently, this has contributed to a loss of about 2.5 billion US dollars annually [16-18]. Although, there has been a progressive reduction in the proportion of gas flared compared to the gas produced over the last decade [19,20]. The observed decline in the observed emissions observed in 2005 to 2014 may be attributed to the relatively reduced production capacity due to insecurity in the oil producing region. Similarly, the improper maintenance of oil and gas installations could have stalled the production processes leading to the reduced production capacity in the different facilities [21,22]. The protracted gas flaring activities associated with oil exploration in the oil-rich Niger-Delta region have impacted the ecosystem and public wellbeing of the residents. Anomohanran, [23] reported that particulates from gas flaring activities are transported and disseminated to 2.61 x 10^6km from the point of origin with an average wind speed of 3m/s (Ede et al., 2011).

The total greenhouse gas estimates of CO2 flared over the past 56 years exceeds 1 Billion tons. While the average greenhouse gas emission of CH_4 and N_2O was higher than the estimated CO_2 emissions. The estimated N_2O observed in the current study is in contrast with the reports of Giwa et al [8] which adopted the use of volume flared instead of volume produced as stated in API compendium. In addition to these localized pollution hazards, it worthy of note that any gas flared denies its use as a fuel, i.e, economic loss. An economic study conducted in 2004 using the 2004 price of carbon dioxide per tonne showed that if the exploration companies continue to flare in the next 15 years, Nigeria will lose at least $63.4 million $40.9 million ($20 per tonne CO_2) [24]. The findings of the current study buttress the fact that CO_2 remains a significant contributor the cumulative greenhouse gas flared in the Niger-Delta region as previously reported in similar studies [25,26] (Ilevbare et al., 2015). The N_2O was estimated to be the highest contributor of the total greenhouse gas emissions observed over the years, closely followed by CH_4, while the estimated CO_2 contributed the least to the estimated greenhouse gas emissions.

Table 1. Volume of gas produced, utilized, and flared in Nigeria across Decades

Decade	Gas produced (Mcm)	Gas Utilized (MCM)	Gas flared (Mcm)	%Flared
1. (1965-1974)	101217	2029	99188	98%
2. (1975-1984)	198172	20372	177800	90%
3. (1985-1994)	259190	61308	197882	76%
4. (1995-2004)	442482	193794	248688	56%
5. (2005-2014)	651310	481747	169563	26%
6. (2015-2020)	488229	436558	51672	11%
Grand Total	2140600	1195808	944793	
Average	356767	199301	157465	
SD	205604	212636	70857	

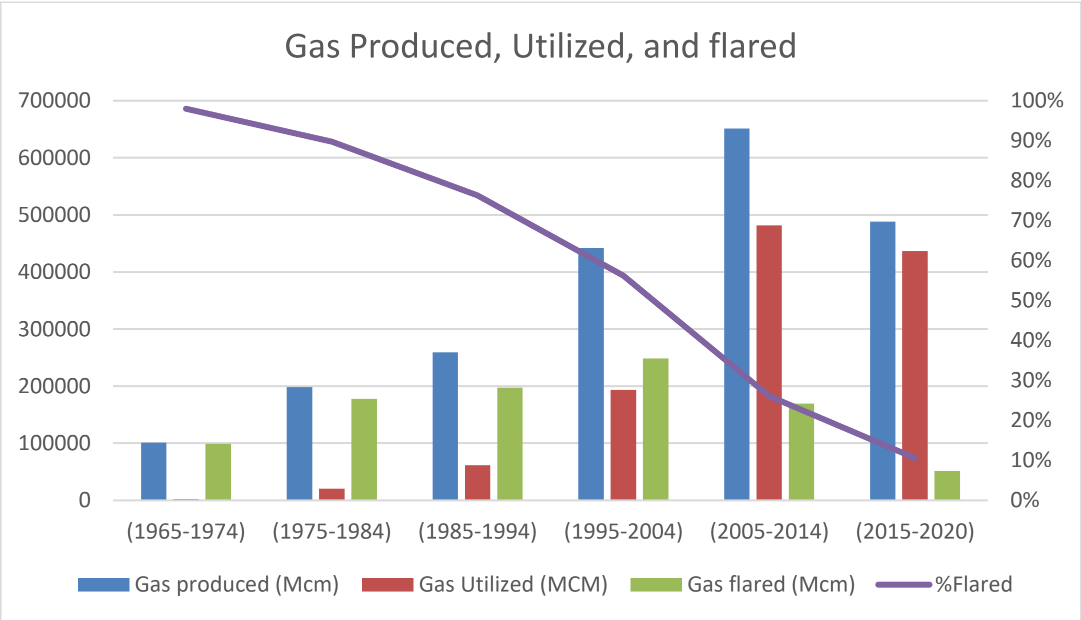

Fig. 1. Charts of Volume of gas produced, utilized, and flared in Nigeria across Decades

Table 2. Summary of Estimated greenhouse gas emissions from 1965 – 2020 by decades

Row Labels	Sum of Tghg for CO2	Sum of Tghg for CH4	Sum of Tghg for N2O	Sum of Greenhouse gas (tonne CO2e/yr)
1965-1974	194,833,558.31	34,712,223.63	604,550,860.00	834,096,641.94
1975-1984	349,249,976.48	62,223,589.16	1,083,691,000.00	1,495,164,565.64
1985-1994	388,696,759.54	69,251,565.08	1,206,090,790.00	1,664,039,114.62
1995-2004	488,494,252.82	87,031,833.20	1,515,753,360.00	2,091,279,446.01
2005-2014	333,069,867.72	59,340,884.78	1,033,485,590.05	1,425,896,342.55
2015-2020	101,498,038.90	18,083,243.23	314,939,208.82	434,520,490.95
Grand Total	1,855,842,453.76	330,643,339.08	5,758,510,808.87	7,944,996,601.71

TGHG: total greenhouse gas. E: Estimated

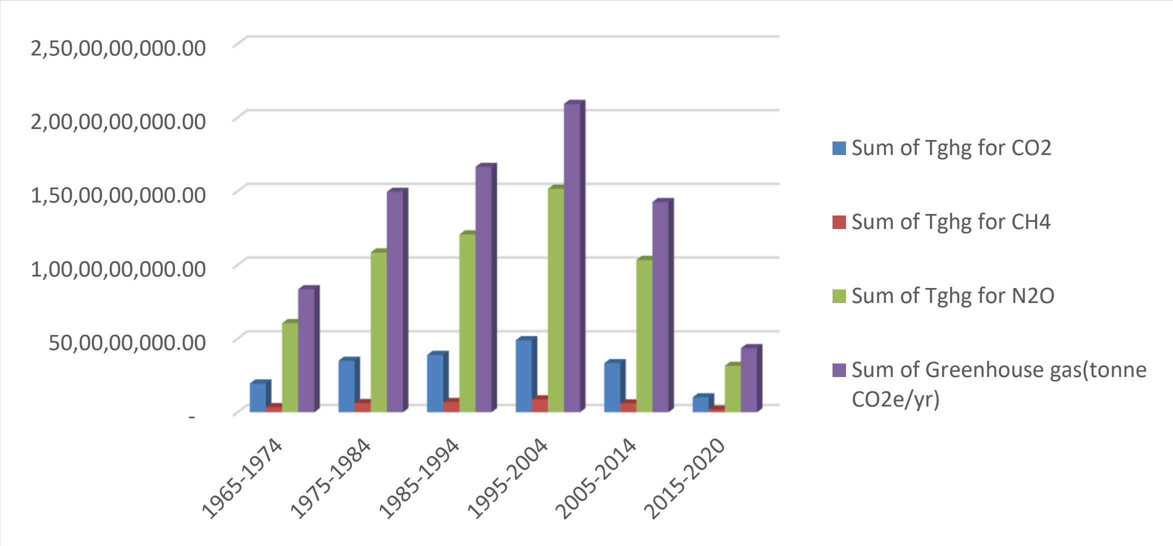

Fig. 2. Charts of Estimated greenhouse gas emissions across decades

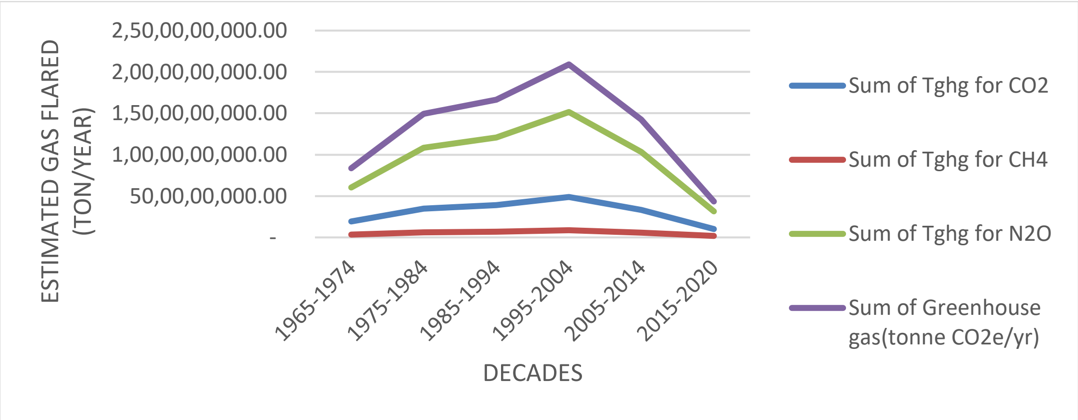

Fig. 3. Charts of Summary of Estimated greenhouse gas emissions across decades

5. CONCLUSION AND RECOMMENDATIONS

Overall, the study revealed a striking cause for concern due to the predicted continuous increasing amount of gas flaring and release of greenhouse gas emissions which could have significant effects on the environment. The volume of gas flared reported in the current study shows the relative huge revenue loss estimated in billions of dollars of the years. The findings indicate a continuous rise in the cumulative gas flared in the next 2 decades without strict implementation of controls as stated by policy documents. Based on the findings of the study, the following recommendations were made:

- An improvement in the collective efforts by government agencies to curtail the volume of gas flared and gas flaring activities.
- The adoption of modern technology and new techniques for the appropriate estimation and prediction of greenhouse gas emissions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ismail OS, Umukoro GE. Global impact of gas flaring. Energy and power engineering. 2012;290-302.
2. Amorin R, Broni-Bediako E. Major Challenges in Ghana's oil and gas discovery: Is Ghana ready? ARPN Journal of Science and Technology. 2013;3(1):21-25.

3. IRIN. NIGERIA: Gas flares still a burning issue in the Niger Delta; 2015. [online].
Last accessed 19 May.
HYPERLINK
http://www.irinnews.org/report/95034/nigeria-gas-flares-still-a-burning-issue-in-theniger-delta
4. Odumugbo CA. Natural gas utilization in Nigeria: Challenges and oppurtunities. J Nat Gas Science Eng. 2010;2:310-316.
5. Oduneka AE, Effiom L, Ubi SP. An Econometric analysis of the determinants of electricity supply in Nigeria. International Journal Business Administration. 2012;3(4):73.
6. Birnie O, Boyle U, Redgwell W. International law and the environment. Oxford University Press. 2009;(3): 114-223.
7. Nwankwo C, Ogagarue D. 'Effects of gas flaring on surface and ground waters in Delta State, Nigeria. Journal of Geology and Mining Research. 2011;3(5): 131-136.
8. Giwa SO, Layeni AT, Nwakocha CN. Gas flaring attendant impacts of criteria and particulate. African Journal of Science, Technology Innovation and Development. 2017;241-322.
9. Ajugwo AO. Negative effects of gas flaring: The Nigerian experience. J. Environ. Pollut. Hum. Health. 2013;1(1):6-8.
10. Otene IJJ, Murray P, Enongene KE. The potential reduction of carbon dioxide (CO2) Emissions from gas flaring in nigeria's oil and gas industry through alternative productive use. Environments. 2016;3(4):31.
11. Nelson N. National energy policy and gas flaring in Nigeria. Gas. 2015;5(14).
12. NNPC Report. Oil firms still faring gas. Published on June 3, 2019 by the Tide.
13. Shaaban M, Petintin JO. Renewable energy potentials in Nigeria: Meeting rural energy needs. Renewable and Sustainable Energy Reviews. 2014;29:72–84.
14. Solomon OG, Oluwakayode OA, Olasunkanmi OA. Baseline black carbon emissions for gas flaring in the Niger Delta region of Nigeria. Journal of natural gas science and engineering. 2014;373-379.
15. Nnaji, C. E., Chukwu, J. O., & Nnaji, M. (2013). Electricity supply, fossil fuel consumption, CO2 emissions and economic growth: Implications and policy options for sustainable development in Nigeria. International Journal of Energy Economics and Policy, 3, 262-271.
16. Dung E, Bombom L, Agusomu T. The effects of gas flaring on crops in the Niger Delta, Nigeria. Geo Journal. 2008;73(4):297-305.
17. Egger PH, Christoph J, and Mario L. Impacts of trade and the environment on clustered multilateral environmental agreements. The World Economy. 2013;36(3):331-348.
18. ERA. Gas flaring in Nigeria: A human rights, environmental and economic monstrosity. Environmental Rights Action (Friends of the Earth Nigeria). 2005; 1-36.
19. Alakpodia I. Soil Characteristics under gas flare in Niger Delta, Southern Nigeria," Geo-Studies Forum'. An International Journal of Environmental and Policy Issues. 2002;1-10.
20. Canadian Association of Petroleum Producers, Flaring & venting,
Retrieved Oct. 10, 2020,
Available:http://www.capp.ca/environmentCommunity/airClimateChange/Pages/FlaringVenting.aspx
21. IPCC. IPCC fourth assessment report: climate change 2007. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge; 2007.
22. Natural gas and Energy. Natural gas flaring derived from satellite data. Energies. 1998;595-622.
23. Anomohanran O. Determination of greenhouse gas emission resulting from gas flaring activities in Nigeria, Energy Policy. 2012;45:666-670.
24. Giwa SO, Nwaokocha CN, Kuye IS, Adama KO. Gas flaring attendant impacts of criteria and particulate pollutants: A case of Niger Delta region of Nigeria. Journal of King Saud University - Engineering Sciences. 2019;31(3):209-217.

25. Aderogba KA. Greenhouse gas emissions and sustainability in lagos metropolis, Nigeria. International Journal of Learning & Development. 2011;1(2):46-61.

26. Amaechi CF, Biose E. Gas flaring: Carbon dioxide contribution to global warming. J. Appl. Sci. Environ. Manage. June. 2016; 20(2):309–317.

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