Petroleum and Coal

Article Open Access

IMPACT OF POWER PLANT GREENHOUSE GASES EMISSIONS IN AN URBAN ENVIRONMENT

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Received June 24, 2018; Accepted September 28, 2018

Abstract

Greenhouse gases (GHGs) emission profiles of a thermal plant were investigated for different scenarios of fuel utilization. The scenarios were the proposed plant using natural gas only and the existing plant with a mix of low pour fuel oil (LPFO) and natural gas (NG). Emission inventory approach was adopted to quantify annual levels of three key GHGs while global warming potentials were used to determine the carbon dioxide equivalent of the GHGs. Results showed that the existing plant with a mix of LPFO and NG had total carbon dioxide equivalent (tCO_2eq) of 13330961.8 while the proposed plant had 10296349.7 (tCO_2 eq). The discontinuation of LPFO was observed to reduce GHGs emission profile by 22.8%. Given, the desire to reduce GHG emissions and its negative impacts globally, scenario 2 is seen as the preferred alternative.

Keywords*: Thermal plant; urbanization; greenhouse gas; emission inventory; carbon dioxide equivalent; global warming*

1. Introduction

The greenhouse effect is a natural phenomenon in the atmosphere and is essential to maintain the earth's temperature. In fact, without the greenhouse effect, the earth would be about 33°C colder than it is today and would be uninhabitable for humans and most other life forms. However, increasing concentrations of greenhouse gases will result in a continuous increase in earth's temperature, and this increase could significantly impact life on earth [1-2]. The primary causes of climate pattern change are the greenhouse gases (GHGs) which include water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) [3]. Increasing concentrations of these gases will allow the atmosphere to trap higher than the usual amount of thermal radiation, preventing heat loss into space and resulting in higher surface temperatures [4].

CO_2 is the leading GHG, accounting for about 80% of the impact [5]. CO_2 enters the atmosphere through fossil fuel and coal combustion, agricultural activities, industrial activities, energy use, fertilizer application and as a result of other chemical reactions [6]. It is removed from the atmosphere by the plant during photosynthesis and also by acid rain. CH_4 is emitted during production and transportation of coal, natural gas and petroleum products. It is also emitted from livestock, agricultural activities and decay of organic waste from municipal solid waste landfills. N_2O is emitted during combustion of fossil fuels and solid waste, as well as industrial and agricultural activities while fluorinated gases (HFCs, PFCs, SF_6) are synthetic gases emitted from a variety of industrial processes. They are emitted in smaller quantities but are referred to as High Global warming potential (GWP) gases. GWP is an index that represents the global warming impact of a greenhouse gas relative to carbon dioxide. GWP represents the combined effect of how long the gas remains in the atmosphere and its relative effectiveness in absorbing outgoing infrared heat [7].

While urbanization is a welcome development, it has been identified as the leading force driving anthropogenic activities which are the leading causes of GHG emission [8-10]. It occurs as a result of changes in social wellbeing, in-flow, and concentration of people and activities in cities. The dynamics of urbanization is driven by changes in population, employment opportunities, industrialization, consumption patterns, and availability of energy, international migration, and accessibility. Over the years increase in population growth and human activities in urban areas had led to increasing GHG emission and urban vulnerability to hazards of climate change.

One of the key factors driving urbanization but which is responsible for GHG emission is energy generation. The Nigerian energy generation systems comprise a mix of hydro and thermal plants but the latter forms the bulk of energy generated in Nigeria [11]. The drive to improve energy generation and at the same time limit the emission of GHGs is of major concern. Although most of the thermal plants in Nigeria are natural gas fired, there are still pockets of plants with a mix of natural gas and low pour fuel oil (LPFO). For instance, Egbin thermal station which is the largest contributor to energy generated in Nigeria uses a mix of natural gas and LPFO. Presently, plans are on-going to introduce additional natural gas fired thermal plants while discontinuing the use of LPFO. The present study was carried out to investigate how the proposed addition of gas fired plants and removal of LPFO fired plant from an existing thermal plant will impact on greenhouse gas emission.

2. Methodology

2.1. Study area description

The study area is Egbin thermal power plant located at the suburb of Lagos State, Ijede area of Ikorodu (Figure 1). It is the largest power generating station in Nigeria with an installed capacity of 1,320 MW consisting of 6 units of 220 MW which was commissioned in July 1985. The station is located at latitude 6^0 33′ 48″ North and Longitude 3^0 36′ 55″ East. It is about 40 km north east of the city of Lagos, and is situated on low land in Ijede and bounded by the Lagoon to the south, Agura/Gberigbe to the north and situated in Ijede Local Council Development Area. The station is of reheat type with intermediate low pressure impulse reaction turbine design and a hydrogen cooled generator.

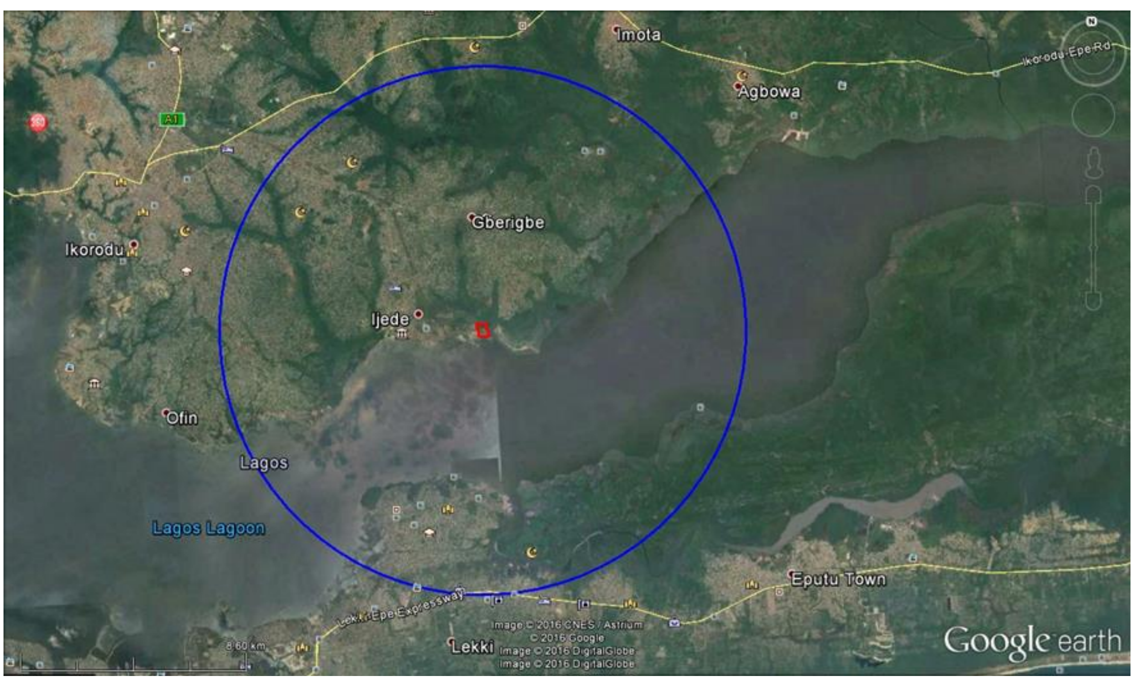

Figure 1. The Power plant location and zone of interest

2.2. Greenhouse gases (GHGs) emission sources

The existing power plants of capacity 1,320 MW in addition to the proposed three (3) units 450 MW capacity plants are the identified main sources of GHGs in the studied project. The existing Egbin power station has six units 220 MW Babcock- Hitachi Power Plants which are in operations to give 1320 MW are already contributing to GHGs. These power plants operate on dual fuel including Low Pour Fuel Oil (LPFO) and natural gas. The proposed three units 450 MW Mitsubishi Hitachi Gas Turbines are also expected to contribute GHGs to the proposed project airshed.

The emissions are as a result of fuel combustion activities in the power plants in addition to the other combustion products including criteria air pollutants and heat. During operation of the three units 450 MW Mitsubishi Hitachi Gas Turbines complete oxidation of carbon compounds available in fuel may result in the formation of carbon dioxide (CO_2) in the presence of complete combustion. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance thus the reference gas against which other greenhouse gases are measured. Its duration in the atmosphere is 50 – 200 with 100-year global warming potential of 1. Similarly, N_2O is generated during fuel combustion by oxidation of chemically-bound nitrogen in the fuel and by fixation of nitrogen in the combustion air. At about 600 – 1000 °C temperature during combustion activities in the power plants, the formation of N_2O may be encouraged especially from HCN produced in intermediate reactions. Its duration in the atmosphere is about 120 years with a 100-year Global Warming Potential of 310. The other important greenhouse gas is CH_4 because its molecules survive for about 12 ± 3 years in the atmosphere and it is about 30 times more effective in heat trap than CO_2. In thermal power plant stations, CH_4 sources include natural gas leakage and its escape from combustion activities.

The anticipated annual GHGs emissions from the proposed thermal station expansion were determined using a combination of fuel consumption and the IPCC emission factor for natural gas and LPFO combustion. The natural gas consumption in each of the proposed power plants is 80,234 m^3/h while it is 54,430 m^3/h in each of the existing plants. The LPFO consumption in the existing plant is 45,760 kg/h. Table 1 shows the emission factors for the investigated gases. The scenarios considered include the emission of GHGs from newly proposed power plants (Scenario 1) only, emission of GHGs from a combination of newly proposed power plants and the existing power plants operating on natural gas (Scenario 2) and existing plants running on natural gas and LPFO (Scenario 3). In addition, the total GHG emission (tCO_2 equivalent) which is the standard reporting procedure for GHGs were determined by multiplying the annual GHG (ton/year) with the corresponding global warming potential.

Table 1. Emission factor for GHGs from thermal plants

	EF for GHGs		
	CH_4	N_2O	CO_2
Natural gas	1.00	0.10	56 100.00
LPFO	3.00	0.60	77 400.00

3. Result and discussion

3.1. Annual tonnage of GHGs emission from proposed and existing system

As presented in Table 2 the anticipated greenhouse gases emissions from scenario 1 are 92.7 tons/annum, 9.3 tons/annum and 5.2 million tons/annum for CH_4, N_2O and CO_2 respectively but 183.3 tons/annum, 18.3 tons/annum and 10.3 million tons/annum from scenario 2. The Scenario 3 operations of the existing power plant will generate greenhouse gases of 411.9 tons/annum, 72.9 tons/annum and 13.4 million tons/annum for CH_4, N_2O and CO_2 respectively. While the annual Scenario 1 operation of the proposed project will generate CO_2 level that is 5.36% of the national CO_2 emission from energy generation as reported by CIA [12], its Scenario 2 operation will generate CO_2 level that is 10.61% of the national CO_2 emission from energy generation while CO_2 from its Scenario 3 operation will be 13.85% of the national CO_2 emission from energy generation.

Table 2. Emission sources characteristics of the proposed and existing gas turbines

Emission source	From natural gas (tons/annum)			From LPFO (tons/annum)		
	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2
Proposed 450 MW Mitsubishi Hitachi Power 1	30.90	3.10	1 734 690.90	-	-	-
Proposed 450 MW Mitsubishi Hitachi Power 2	30.90	3.10	1 734 690.90	-	-	-
Proposed 450 MW Mitsubishi Hitachi Power 3	30.90	3.10	1 734 690.90	-	-	-
Sub-Total	**92.70**	**9.30**	**5 204 072.70**	-	-	-
Existing 220 MW Bab-cock- Hitachi Power Plant 1	15.10	1.50	848 071.10	53.20	10.60	1 372 320.60
Existing 220 MW Bab-cock- Hitachi Power Plant 2	15.10	1.50	848 071.10	53.20	10.60	1 372 320.60
Existing 220 MW Bab-cock- Hitachi Power Plant 3	15.10	1.50	848 071.10	53.20	10.60	1 372 320.60
Existing 220 MW Bab-cock- Hitachi Power Plant 4	15.10	1.50	848 071.10	53.20	10.60	1 372 320.60
Existing 220 MW Bab-cock- Hitachi Power Plant 5	15.10	1.50	848 071.10	53.20	10.60	1 372 320.60
Existing 220 MW Bab-cock- Hitachi Power Plant 6	15.10	1.50	848 071.10	53.20	10.60	1 372 320.60
Sub-Total	**90.60**	**9.00**	**5 088 426.60**	**319.20**	**63.60**	**8 233 923.60**
Grand-Total	**183.30**	**18.30**	**10 292 499**	**411.90**	**72.90**	**1 3437 996**

3.2. Carbon dioxide equivalent (tCO2 e) of the GHGs

The standard practice in the reporting of GHGs is to express their emissions in carbon dioxide equivalent (tCO_2 eq). This is to bring all GHGs to a common unit and to facilitate the determination of the total greenhouse gas concentration. The (tCO_2 eq) of GHGs from the individual unit of Egbin thermal plants as well as overall (tCO_{2eq}) from the different scenarios are reported in Table 3 and Table 4, respectively. The total GHG emission (tCO_2 eq) from scenarios 1, 2 and 3 are 5206019.4, 10296349.7 and 13330961.8, respectively. Considering the different scenarios of existing and proposed systems, the introduction of new sets of natural gas fired thermal plants and discontinuation of LPFO fired thermal plants as represented by scenario 2 is expected to result in about 22.8% reduction in the total GHG emission.

Table 3. Total GHG emission from Egbin thermal station

GHGs	Scenario 1* (CO_2 e)	Scenario 2** (CO_2 e)	Scenario 3*** (CO2 e)
CH_4	1 946.7	3 849.7	8 605.8
N20	2883	5 673	22 506
CO_2	5 204 072.7	10 292 500	13 322 356
Total	5 206 019.4	10 296 349.7	13 330 961.8

**Describes the contribution of proposed addition with natural gas only*
***Describes the existing and proposed system with the removal of LPFO utilization*
****Describes the existing system with utilization of natural gas and LPFO*

Table 4. Actual GHG emissions from proposed and existing gas turbines

Emission source	From natural gas (tons/annum)			From LPFO (tons/annum)		
	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2
Proposed 450 MW Mitsubishi Hitachi Power 1	648.9	961	1 734 691	-	-	-
Proposed 450 MW Mitsubishi Hitachi Power 2	648.9	961	1 734 691	-	-	-
Proposed 450 MW Mitsubishi Hitachi Power 3	648.9	961	1 734 691	-	-	-
Sub-Total	**1946.7**	**2883**	**5 204 073**	-	-	-
Existing 220 MW Babcock- Hitachi Power Plant 1	317.1	465	848 071.1	1117.2	3286	1 372 321
Existing 220 MW Babcock- Hitachi Power Plant 2	317.1	465	848 071.1	1117.2	3286	1 372 321
Existing 220 MW Babcock- Hitachi Power Plant 3	317.1	465	848 071.1	1117.2	3286	1 372 321
Existing 220 MW Babcock- Hitachi Power Plant 4	317.1	465	848 071.1	1117.2	3286	1 372 321
Existing 220 MW Babcock- Hitachi Power Plant 5	317.1	465	848 071.1	1117.2	3286	1 372 321
Existing 220 MW Babcock- Hitachi Power Plant 6	317.1	465	848 071.1	1117.2	3286	1 372 321
Sub-Total	**1 902.6**	**2 790**	**5 088 427**	**6 703.2**	**19716**	**8 233 926**
Grand-Total	**3 849.7**	**5 673**	**10 292 500**			

4. Conclusion

The study investigated the impact of discontinuation of LPFO unit and the introduction of the additional natural gas unit on GHG emission profile of a thermal plant. The Scenario 3 operations of the existing power plant were observed to generate greenhouse gases of 411.9 tons/annum, 72.9 tons/annum and 13.4 million tons/annum for CH_4, N_2O and CO_2 respectively. The replacement of LPFO unit with additional units that run on NG was observed to yield 183.3 tons/annum, 18.3 tons/annum and 10.3 million tons/annum for CH_4, N_2O and CO_2 respectively. These values represent a significant reduction in the annual emission rates of these gases. Considering the carbon dioxide equivalent of the three GHGs, the replacement of LPFO unit with additional units of NG was observed to reduce GHGs emission profile of the thermal plant by 22.8%. Given, the desire to reduce GHG emissions and its negative impacts globally, it is concluded that the NG fired thermal plant will be a better alternative.

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