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Research Article

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Estimation of greenhouse gas emissions from fuel combustion in dana steel rolling miill, katsina, Nigeria

Lawal Abdu Daura

Department of Mechanical Engineering, Hassan Usman Katsina Polytechnic, Katsina, P.m.b. 2052, Katsina, Nigeria

Abstract This paper determines the Greenhouse gas emissions from combustion of fuel in Dana steel rolling mill Katsina, Nigeria. The result shows that the total carbon dioxide equivalent emission from combustion of the fuel oil for the year 2012 was 3,185.803 tonne at the rate of 0.1019 tonne of carbon dioxide per tonne of steel product (tC/t). In the years 2013 and 2014 the CO_{2e} emissions were 1,853.101 tonne and 556.224 tonne at rate of 0.0970 tC/t and 0.0849 tC/t respectively, while in the year 2015 the carbon dioxide emissions was 2,173.599 tonne at rate of 0.1533 tC/t of product. The trend of carbon intensity follows the trend of energy intensity and can be compared with what is obtained in the South East Asian (ASEAN) nation's bench mark for GHGs intensity in iron and steel industry for hot rolling of long steel products.

Keywords Greenhouse gas, Carbon dioxide equivalent, Emissions, fuel, Emission factor

1. Introduction

The production of iron and steel is an energy intensive activity that generates greenhouse gases (GHG) of carbon dioxide, nitrous oxide and methane during the production processes. Greenhouse gas emissions from steel production are caused by the combustion of fossil fuels, the use of electricity and the use of coal and lime as feedstock [1]. Worldwide output of greenhouse gases is of grave concern as from the time the industrial revolution began in 1760s to the year 2009, atmospheric carbon dioxide level had increased by about 38% and methane levels had increased a whopping 148% according to NASA, most of that increase had been in the past fifty years ([2]. Among the many human activities that produce greenhouse gases, the use of energy represents by far the largest source of emissions [3]. According to United Nation Framework on Climate Change (UNFCC) Carbon dioxide emissions from energy represent `over three quarters of the anthropogenic GHG emissions for Annex I countries, and about 60% 0f global emissions [3]. The global production of steel accounts for between 4% to 7% of total anthropogenic greenhouse gas emissions worldwide [4][5]. Scientists have observed that concentration of carbon dioxide in the atmosphere have been increasing significantly over the past century when compared with the pre- industrial era (about 280 parts per million). The 2014 concentration of carbon dioxide (397 ppm) was about 40% higher than in the middle 1800s, with an average growth of 2 ppm/year in the last ten years [3].

Dana steel rolling mill (formerly Katsina Steel rolling mill) was established in 1981 to produce steel rod products. The mill which has the capacity to produce 207,000 metric tons of steel products was privatized in 2006 and presently consists of steel melt shop producing steel billets from steel scraps. The mill uses low pour fuel oil (LPFO) in their heating furnaces which results in emission of greenhouse gases into the atmosphere. The study estimate the greenhouse gas emission from one of the steel industry in Nigeria in keeping with the principle of UNFCC GHG protocol of estimating country specific GHG, also reporting GHG estimate is a key issue in achieving industrial energy efficiency.

2. Methodology

The fuel used in the heating furnaces of the rolling mill is low pour fuel oil (LPFO). The main greenhouse gas associated with combustion of the fuel is carbon dioxide and smaller amounts of methane (CH_4) and nitrous oxide (N_2O). This paper adopts the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [6] Tier 1 approach for the estimation of green house gases from combustion of LPFO in the steel rolling mill.

The Tier 1 estimation of GHG emissions from combustion of a fuel is given as follows [6]:

$$Emissions_{GHG,fuel} = Fuel\ consumption_{fuel} \times Emission\ Factor_{GHG,fuel} \quad (1)$$

Where

$Emissions_{GHG,fuel}$ = Emissions of a given GHG by type of fuel (kg GHG)

$Fuel\ consumption_{fuel}$ = Amount of fuel combusted (TJ)

$Emission\ Factor_{GHG,fuel}$ = Default emission factor of a given GHG by type of fuel (kg/TJ).

The equation for estimating the CO_2 emissions is given as [7]:

$$E = A \times HV_f \times F_{c,h} \times F_{ox} \times \frac{44}{12} \quad (2)$$

Where:

E = Amount of CO_2 emitted (metric tonnes)

A = Mass of fuel consumed (metric tonnes)

HV_f = Lower Heating value of fuel (MJ/Kg)

$F_{c,h}$ = Carbon content of fuel on a lower heating value basis (kg/GJ)

F_{OX} = Fraction oxidation factor = 1 [6]

44/12 = The ratio of the molecular weight of carbon to that of CO_2

For the estimation of CH_4 or N_2O the equation is expressed as:

$$E = A_f \text{ x } HV_f \text{ x } EF \text{ x } GWP \quad (3)$$

Where:

E = Amount of either N_2O or CH_4 emitted (metric tonnes CO_2-equivalent)

A_f = Amount of fuel combusted on a mass or volume basis.

EF = Tier 1 fuel-specific emission factor.

GWP = Global warming potential, 21 for CH_4 or 310 for N_2O.

3. Results and Discussions

Annual production and fuel oil consumption data from the year 2012 to 2015 were obtained from the rolling mill and shown in Table 3.1.

Table 3.1: Annual production and fuel oil consumption (tonnes)

Year	Steel Production (tonne)	Fuel oil consumption (tonne)	Fuel oil consumption per tonne of product (tonne/tonne)
2012	31,257.97	1,016.05	0.0325
2013	19,110.39	591.01	0.0309
2014	6,554.75	177.39	0.0271
2015	14,182.95	693.13	0.0489

Source: Dana Steel rolling mill Katsina, (2016).

Using the default values of carbon content of 21.1 kg/GJ and lower heating value of 40.4 MJ/kg for fuel oil (IPCC, 2006), the annual carbon dioxide emissions from combustion of fuel oil in the rolling mill are computed using equation (2) and shown in Table 3.2.

Table 3.2: Annual Carbon dioxide emissions from combustion of fuel oil

Year	Steel Production (tonne)	CO_2 Emissions (tonne/year)
2012	31,257.97	3,175.78
2013	19,110.39	1,847.27
2014	6,554.75	554.45
2015	14,182.95	2,166.46

The default emission factors for stationary combustion of fuel oil for CH_4 and N_2O emissions are given as 3 kg/TJ and 0.6 kg/TJ respectively (IPCC, 2006). Therefore the annual emissions of CH_4 and N_2O, and their carbon dioxide equivalent emissions from combustion of fuel oil in the rolling mill are computed using equation (3) and shown in Table 3.3.

Table 3.3: Annual CH_4 and N_2O emissions from combustion of fuel oil

Year	**CH_4 Emissions (tonne/year)**	**CO_{2e} equivalent emission of CH_4 (tonne/year)**	**N_2O Emissions (tonne/year)**	**CO_{2e} equivalent emission of N_2O (tonne/year)**
2012	0.123	2.583	0.024	7.440
2013	0.071	1.491	0.014	4.340
2014	0.021	0.441	0.0043	1.333
2015	0.089	1.869	0.017	5.270

Table 3.4: Total annual CO_2 emissions

Year	**Steel Products (tonne/year)**	**Total CO_{2e} emissions (tonne/year)**	**Total CO_{2e} emissions per tonne of product (tonne/tonne)**
2012	31,257.97	3,185.803	0.1019
2013	19,110.39	1,853.101	0.0970
2014	6,554.75	556.224	0.0849
2015	14,182.95	2,173.599	0.1533

The total carbon dioxide equivalent emission from combustion of the fuel oil for the year 2012 was 3,185.803 tonne at the rate of 0.1019 tonne of carbon dioxide per tonne of steel product (tC/t). In the years 2013 and 2014 the CO_{2e} emissions were 1,853.101 tonne and 556.224 tonne at rate of 0.0970 tC/t and 0.0849 tC/t respectively, while in the year 2015 the carbon dioxide emissions was 2,173.599 tonne at rate of 0.1533 tC/t of product as shown in table 3.4. The results show that there was decrease in CO_{2e} emissions per tonne of product between 2012 to 2014 but there was an increase in the emission per tonne of product in the year 2015. The trend follows the fuel oil consumption per tonne of steel product as shown in table 3.1, which shows a decrease in fuel oil consumption per tonne of product from 0.0325 tonne/tonne in 2012 to 0.0309 tonne/tonne and 0.0271 tonne/tonne in 2013 and 2014 respectively. But in the year 2015 the fuel oil consumption per tonne increases to 0.0489 tonne/tonne which result in subsequent increase in the GHG emissions. Also Lynn et, al. [8] reported that carbon intensity trends are closely related to energy intensity tends. The South East Asia Iron and Steel Institute [9] reported that the bench mark for GHGs intensity in iron and steel industry in the South East Asian (ASEAN) nations is 0.2 tC/t with fuel responsible for 53% of the emissions, while electricity accounts for 47%. Therefore the GHG intensity due to fuel in the iron and steel industry in ASEAN is about 0.106 tC/t which can be compared with the result obtained.

4. Conclusion

The total GHGs emissions from combustion of low pour fuel oil in Dana steel rolling mill Katsina for the years 2012 to 2015 had been computed. The results show that the total annual carbon dioxide emissions for the years 2012 t0 2015 ranges between 0.0849 tonne of carbon dioxide equivalent per tonne of steel product to 0.1533 tC/t. The lowest figure obtained in 2014 while the highest was obtained in 2015 and this can be attributed to the fuel oil consumption per tonne of product as shown in table 3.1. The result has also shown that intensity of GHGs emissions per tonne of steel product can be compared with what is obtained in ASEAN countries.

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