ASSESSMENT OF GREENHOUSE GASES EMISSION SOURCES IN A TYPICAL NIGERIAN UNIVERSITY CAMPUS: CASE STUDY OF BAYERO UNIVERSITY, KANO NEW CAMPUS

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ABSTRACT

Identification and reduction of the major sources of GHG emissions is key to the reduction in the average world temperature. This research assessed the quantity and pattern of GHG emissions in a typical Nigerian University campus using Bayero University Kano new campus as a case study. Emissions from electricity usage, transportation, solid waste management and cooking fuels were assessed using IPCC’s guideline for assessment and reporting GHG emissions because these sources have been noted to be the major emissions sources in university campuses. It was found that the estimated annual GHGs emission of the Campus is 7,914tCO$_2$e. Sixty-one percent of the campus’ emission was noted to be from electricity usage, while 30%, 7% and 1% of the campuses emissions were from transportation, solid wastes and burning of cooking fuels respectively. It was concluded that the campus’ per capita GHG emissions is lower than what is recommended by the Kyoto Protocol. Nevertheless, it can still be reduced by using electricity more efficiently, recovering energy from solid waste, provision and incentivising the use of mass transits.

Keywords: Greenhouse Gases; Carbon footprint; Municipal Solid Waste; Global Warming; Emission factor.

1 INTRODUCTION

Since the beginning of the industrial revolution at the beginning of the 20th century, global average temperatures have been steadily increasing. The peak of this steady increase in global temperatures was reached in the year 2016 which on record is the warmest year ever thus far (Boykoff, Katzung, & Nacu-Schmidt, 2019). Other changes in the climate being observed in recent times globally include generalised melting of glaciers which leads to rise in sea levels and submerging of coastal towns and islands, multiplicity of heat waves, droughts, cyclones and torrential rains (Ayanlade et al., 2010; Dodman, 2009; Roeckner et al., 2007).

Increase in the emission of anthropogenic greenhouse gases as a result of increased usage of fossil fuels has been identified as the major reason for rise in the average global temperature and the accelerated change in the world’s climate (Dodman, 2009; Duan et al., 2006; Hiller, 2011; Weitzman, 2012). With greenhouse gas (GHG) emissions being projected to increase by up to 150% by the year 2050 in modest scenarios (IPCC, 2014), the first step to avoiding this prediction which is likely to have catastrophic consequences is by planning how to reduce one’s carbon footprints. For that to be done, firstly the amount of GHG emissions and their major sources have to be known.

University Campuses and other institutions of higher learning are usually clusters where high energy consumption and emission of GHGs exist. For example, in the United States, college campuses account for approximately 3% of the
country’s GHGs emission despite these campuses having less than 1% of the population in the country (Sinha et al., 2012). In other places like Korea and Japan, this value is up to 5% of the Nation’s GHGs emission (Seo et al., 2018; Tear et al., 2019). Higher institutions of learning having higher per capita emission of GHGs means there is need to reduce these emissions, reduction in the emissions first entails understanding the sources and patterns of emissions. In other countries, particularly western nations, the carbon footprints of institutions of higher learning have been assessed and are known. Unfortunately, most Nigerian Universities despite being citadels of learning and an example to the wider society do not have a record of their GHGs emission. Responding to climate change by the reduction of GHGs emission on an individual and institutional level requires a strategic approach from policy, regulatory and institutional frameworks to facilitate the identification of priority emission sources and the appropriate reduction measures that can be taken. Bayero University, Kano (BUK), like most other university campuses in Nigeria and other developing countries does not have a record of its GHG emissions. Therefore, for it to be able to monitor and reduce its carbon footprint, it first has to have a record of the sources and pattern of emission on the campus. This research intends to provide the Campus’ stakeholders with data which can serve as a baseline for studying and monitoring the campus’ emissions and a basis for policy formulation to reduce GHGs emissions on campuses and for further research.

It is expected that at the end of this assessment of GHGs emissions on BUK new campus that: the total amount of GHGs emitted on the campus and the amount emitted by each of the major sources on the campus will be determined; GHGs emission level of BUK will be compared to those on other campuses so as to ascertain how eco-friendly the campus is; suitable measures of reducing the GHG emissions of the campus will be suggested.

2 MATERIAL AND METHODS

2.1 Data Collection

Four main emission sources as identified by IPCC (2014) were considered, these are electricity; transportation; solid waste and cooking fuels. Data for each of the four sources was collected differently.

For grid electricity usage, a record for the monthly electricity consumption for a period of one calendar year was obtained from the Electrical Department of the Works and Services Division of the University. For electricity generated on the campus, questionnaires were used to obtain the required information from the University’s power generator operators, businesses and households. A structured interview was carried out with the head of the Sanitation Unit of the University’s Health Services Division to obtain information about the campus’ solid waste management. A process of randomly selecting 4 kilogrammes of waste from 4 different waste collection points on the campus was engaged, this was done within the months of March and August so as to account for seasonal variation. The collected waste was then hand sorted into the following components and weighed with a digital weighing scale: food wastes; papers; textiles; plastics; metals; glasses; wood; agricultural and garden wastes; inert materials (sand and stones).

Since different categories of vehicles have their separate emission factors, vehicles were grouped into five groups and their data collected and analysed in that manner. The five categories are: Sedans; Sports Utility Vehicles (SUVs)/minibuses; Motorcycles; Tricycles; Trucks. For ease of analysis, emissions from vehicles were obtained in two formats. Firstly, vehicles resident on the campus. Information on the number and types of vehicles resident on the campus was obtained using a questionnaire which was issued to the residents of the campus. The second group of vehicles were vehicles daily entering the campus, the numbers and categories in which these vehicles fell into was determined by observing the volume of traffic between 06:00 hours and 23:59 hours for three weekdays and a weekend during school sessions and academic break. The school’s academic calendar was then used to calculate the vehicular traffic during school breaks and when school was in session. For this section, the following assumptions were made:

1. No vehicle resident on the campus is polled as part of the vehicles entering the campus.
2. All vehicles entering the campus use the main entrance.
3. The average distance covered by each vehicle is 2.4 kilometres: this is the measured to and fro distance between the main gate to the Administrative Block.
A questionnaire was issued to all the 182 houses on the Campus so as to obtain the various types of cooking fuels used and the average consumption rate. Restaurants were not considered because it was observed that 98% of them use fuelwood for cooking and according to IPCC’s guideline, biogenic CO$_2$ is not accounted for (IPCC, 2006). In the same vein, students’ cooking footprints were not considered because it was observed that most of them use electric stoves for cooking.

2.2 Data Analysis

Formulae and steps as provided and outlined by IPCC (2006) as guidelines for assessment of GHG emissions were used to calculate the emissions in each of the categories being studied. For grid electricity, consumption data and Electricity Emission Factor were used to determine the amount of GHG emissions from this category. Equation 1 was used to determine the emission from grid electricity.

\[
E'_{\text{grid}} = \text{AME} \times \text{EEF} \times n \quad (1)
\]

Where,

- **AME** = Average Monthly Grid Electricity Consumption (kWh)
- **EEF** = Electricity Emission Factor for Nigeria = 0.4157342 kgCO$_2$/kWh (Brander et al., 2011)
- **n** = Number of months being evaluated

Fuel consumption data obtained were used with emission factors for stationary combustion engines and were used to calculate the amount of GHGs emitted into the atmosphere due to power generation. The general formula used to determine the emission from power generators on the campus is thus:

\[
E'_{\text{g}} = \text{AMF} \times \text{FEF} \times \text{d/p} \times n \quad (2)
\]

Where,

- **AMF** = Average Monthly Fuel Consumption (litres)
- **FEF** = Fuel Emission Factor

Petrol = 2.2862kgCO$_2$/l; diesel = 2.6924kgCO$_2$/l (IPCC, 2006)

\[n = \text{Number of months being evaluated}\]

BUK landfills all its solid wastes, according to the information obtained from the Sanitation Unit of the Health Services Division, the Campus generates 2.67 tonnes of municipal solid wastes on a daily basis which is equivalent to 975 tonnes annually. The emission from landfillsing of Solid Waste is calculated using the following series of formulae (IPCC, 2006):

\[
E'_{\text{SWL}} = \text{CH}_4 \text{Emissions} \times \text{GWP of } \text{CH}_4 \quad (3)
\]

Global Warming Potential (GWP) of CH$_4$ = 28 (IPPC, 2014)

\[
\text{CH}_4 \text{Emissions} = \text{MSW}_X \times L_o \times (1 - f_{rec}) \times (1 - OX) \quad ... \quad (4)
\]

Where:

- **CH$_4$ Emission** = Total CH$_4$ emission (tonnes of methane)
- **MSW$_X$** = Mass of solid waste sent to landfill in inventory year (metric tonnes)
- **L$_o$** = Methane generation potential (m$^3$/tonne)
- **f$_{rec}$** = Fraction of methane recovered at the landfill (flared or energy recovery)
- **OX** = Oxidation factor (0.1 for managed sites, 0 for unmanaged sites)

\[
L_o = \text{MCF} \times \text{DOC} \times \frac{16}{12} \quad ... \quad (5)
\]

Where,

- **MCF** = Methane correction factor which is based on type of landfill (0.4)
- **DOC** = Degradable organic carbon, fraction (tonnes C/tonnes waste)
- **DOC$_F$** = Fraction of DOC that ultimately degrades (0.6).

\[\frac{16}{12} = \text{Stoichiometric ratio between methane and carbon}\]

\[
\text{DOC} = (0.15 \times A) + (0.2 \times B) + (0.4 \times C) + (0.43 \times D) + (0.24 \times E) + (0.15 \times F) \quad ... \quad (6)
\]

- **A** = Fraction of solid waste that is food
- **B** = Fraction of solid waste that is garden waste and other plant debris
- **C** = Fraction of solid waste that is paper
- **D** = Fraction of solid waste that is wood
- **E** = Fraction of solid waste that is textiles

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F = Fraction of solid waste that is industrial waste

For vehicles entering the campus and those resident on the campus, the general formula in equation 7 was used to determine the emission of each category of vehicle.

\[ \text{Emission} = \text{Number of vehicles} \times \text{Average Travel Distance} \times \text{Emission Factor for Vehicle type} \ldots (7) \]

Table 1 shows the emission factor for each type of vehicle and the corresponding data source.

<table>
<thead>
<tr>
<th>Emission Source</th>
<th>Emission Factor</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedans</td>
<td>0.23398 kg CO₂ e/km</td>
<td>(IPCC, 2006)</td>
</tr>
<tr>
<td>SUVs</td>
<td>0.88634 kg CO₂ e/km</td>
<td>(IPCC, 2006)</td>
</tr>
<tr>
<td>Trucks</td>
<td>0.99976 kg CO₂ e/km</td>
<td>(IPCC, 2006)</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>0.12761 kg CO₂ e/km</td>
<td>(WRI, 2008)</td>
</tr>
<tr>
<td>Tricycles</td>
<td>0.1860 kg CO₂ e/km</td>
<td>(IES, 2004)</td>
</tr>
</tbody>
</table>

For cooking fuels, the average monthly quantity of each fuel type used and its emission factor was used for the estimation. Note that quite a number of households reported using firewood for cooking, however, since emissions from firewood are considered biogenic emissions therefore they are not accounted for in GHGs estimation (IPCC, 2006). The general equation below was used for the estimation of emissions from cooking fuels.

\[ \text{Emission} = \text{Average Monthly Quantity used} \times \text{Emission Factor} \ldots (8) \]

- \( LPG \) Emission Factor = 1.6159 kg CO₂ e/l
- \( Kerosene \) Emission Factor = 2.5344 kg CO₂ e/l

3 RESULTS AND DISCUSSIONS

It was found that the Campus’ average monthly grid electricity consumption is 141,805 kWh. While for power generated on the campus, it was noted that there are 131 petrol generators and 12 diesel generators whose collective average monthly fuel consumption are 5,700 litres and 123,700 litres respectively. It was found that the campus’ GHG emissions due to electricity usage amounted to 4,860 t CO₂ e. That is about 61% of the total GHGs emissions of the campus. A closer examination of the campus’ GHG emissions from electricity usage shows that power generated on campus is responsible for 4,153 t CO₂ e (85%), while electricity from grid is responsible for the remaining 15% of the campus’ total GHGs emission from electricity usage. For electricity generated on campus, it was noted that diesel generators are responsible for 96% of GHGs emission, while petrol generators are responsible for the remaining paltry 4%. A closer look at the emission from generators in its entirety showed that 45% of the emissions from generators were from the school owned generators; 50% from generators owned by businesses and 5% from generators owned by households.

The percentage by weight composition of the solid waste on the campus was determined according to ASTM D5231-92 standards (ASTM, 2004), the composition by weight found is presented in Table 2 below.

<table>
<thead>
<tr>
<th>Category</th>
<th>Weight Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>13</td>
</tr>
<tr>
<td>Paper</td>
<td>15</td>
</tr>
<tr>
<td>Textiles</td>
<td>4</td>
</tr>
<tr>
<td>Plastics</td>
<td>23</td>
</tr>
<tr>
<td>Metals</td>
<td>12</td>
</tr>
<tr>
<td>Glass</td>
<td>5</td>
</tr>
<tr>
<td>Fines (Ash, dust &amp; Sand)</td>
<td>8</td>
</tr>
<tr>
<td>Wood</td>
<td>1</td>
</tr>
<tr>
<td>Agriculture/garden waste</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

It was estimated and found that the emission from landfilling of BUK’s municipal solid waste (MSW) was responsible for the emission of 584 t CO₂ e annually, this is just about 7% of the total GHG emission of the campus.
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From the manual polling of vehicles done at the campus’ main entrance and the data obtained from questionnaires issued to residents of the campus, it was discovered that a total of 3,927,513 trips are made on the campus’ roads annually. The vehicles resident on the campus make an estimated 105,485 trips annually while those who commute daily in and out of the campus make an estimated 3,822,028 trips annually. The breakdown of the trips made by each category of vehicle is presented in Table 3 below.

Table 3: Annual Vehicular Traffic on the Campus

<table>
<thead>
<tr>
<th>Type of Vehicle</th>
<th>Number</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resident on Campus</td>
<td>Daily Commute</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>28,470</td>
<td>1,605,012</td>
</tr>
<tr>
<td>Sedans</td>
<td>46,720</td>
<td>1,770,414</td>
</tr>
<tr>
<td>SUVs &amp; Buses</td>
<td>13,870</td>
<td>324,923</td>
</tr>
<tr>
<td>Tricycles</td>
<td>16,425</td>
<td>92,135</td>
</tr>
<tr>
<td>Trucks</td>
<td>0</td>
<td>29,544</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>105,485</strong></td>
<td><strong>3,822,028</strong></td>
</tr>
</tbody>
</table>

GHG emissions estimation done revealed that commuting within the campus was responsible for 2,361tCO$_2$e, this represents 20% of all GHG emissions and making vehicles the second highest sources of GHGs emission on the campus. When this is picked apart to look at the emission from each category of vehicle, it was found that the highest emission per number of vehicles was from the SUVs/buses category, while the least was from motorcycles. This however does not reflect the fact that buses carry more people than the other vehicles, as such if the emission is going to be calculated per passenger, buses will be the vehicles of choice. The estimated annual GHGs emission determined for sedans, SUVs/buses, motorcycles, trucks and tricycles were 1,020tCO$_2$e, 721tCO$_2$e, 500tCO$_2$e, 62tCO$_2$e and 57tCO$_2$e respectively. Figure 1 graphically presents the annual GHGs emission accrued to each category of vehicle juxtaposed to their annual traffic volume.

Data obtained from questionnaires issued out to campus residents showed that 1,923.77kg of LPG is being used monthly by 96 households while for kerosene, an average of 1,175 litres is being burnt by 109 households monthly. The GHG emissions from burning of cooking fuels on the campus amounted to 109tCO$_2$e, that is approximately just about 1% of the campus’ total carbon footprint. Table 4 shows the different cooking fuels used on the campus and their corresponding carbon footprint.
The study revealed that the highest emission on the campus comes from the usage of electricity, then vehicular traffic. Solid wastes and cooking fuels are the third and fourth largest sources of emissions on campus respectively.

Table 5 below presents a summary of the GHG emission of BUK New Campus.

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount (tCO₂e)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>4,860</td>
<td>61</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>584</td>
<td>7</td>
</tr>
<tr>
<td>Transportation</td>
<td>2,361</td>
<td>30</td>
</tr>
<tr>
<td>Cooking Fuels</td>
<td>109</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7,914</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

When the total GHGs emission of the campus was compared to that of other campuses outside the country, it was found that the emission of the campus is significantly low. For example, a study done in MIT found the campus’ estimated annual GHG emission to be 200,000tCO₂e (Groode & Heywood, 2004). In South Africa it was noted by Letete, Mungwe, Guma, & Marquard (2011) that the carbon footprint of The University of Cape Town (UCT) was about 83,400tCO₂e annually. While in India, the carbon footprint of Rajiv Gandhi South Campus Banaras Hindu University (RGSU) was estimated to be 69,727tCO₂e (Sadhana, Vijai, Juli, Gandhi, & Gramodaya, 2012). While juxtaposing the blanket gross carbon footprint of these campuses might not be a fair comparison, the per capita footprint is a better index for comparison. It was estimated that the New Campus of BUK has a per capita emission of 0.3668tCO₂e (366.82kgCO₂e), while that of MIT, UCT and RGSCU were 17.7tCO₂e, 4tCO₂e and 53.7tCO₂e respectively. Figure 2 is a graphical comparison of the carbon footprint of the campuses.

The higher GHG emissions recorded by these campuses outside Nigeria cannot be unconnected to the fact that these campuses are situated in technological more advanced and more affluent nations than Nigeria as such their per capita energy consumptions and consequent GHG emissions are naturally higher than that of BUK.
4 CONCLUSION

An assessment of the GHGs emission sources of a typical Nigerian University was done, the new campus of Bayero University Kano being the case study. It was found that the campus emits an estimated 7,914tCO₂e annually from electricity usage, solid waste management, commuting and cooking fuels. It was found that emission from electricity usage is responsible for more than half (61%) of the campus’ carbon footprint, the next highest emitter was found to be the transportation sector which was found to contribute 30% of the campus’ emissions. Emissions from solid waste management and cooking fuels were responsible for only 7% and 1% of the campus’ GHGs emission.

It was observed that the high GHGs emission due to the generation of power on campus can be reduced by gradually replacing inefficient gadgets being used on the campus with energy efficient ones, this has the potential of reducing the campus’ energy consumption by about 40%, consequently its carbon footprint too. Likewise, the campus can consider supplementing its energy needs with renewable energy sources, particularly solar energy since Kano has abundant sunshine all year round.

Also, instead of landfilling the MSW generated by the campus, a properly designed and managed sanitary landfill can be set up on the campus with the sole aim of harvesting methane and using it, to reduce the amount of GHG emission from MSW and also offset that from other sources as have been proven by studies (Finlay & Massey, 2012; Jain et al., 2017; Qdais, Saadeh, Al-Widyan, Al-tal, & Abu-Dalo, 2019). To clamp down on the emissions of GHGs due to commuting, efficient public mass transit should be made available by the school and its use should be encouraged by incentivising it so as to reduce the number of personal vehicles.

Lastly, the Campus can sequester the amount of CO₂ it emits into the atmosphere by planting more trees on the vast amount of unutilised land it has.
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