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ABSTRACT: The carbon di-oxide (CO₂) emissions emanating from the consumption of fossil fuels for generation of electric power in order to sustain the smooth running of activities at the Federal University of Technology, Owerri (FUTO) has been investigated. With appropriate emission factors and the amount of fuel consumption by the generators per annum, the annual CO₂ emissions from both diesel and PMS operated electricity generators were estimated. This emission amounted to ~1460.20 tons of CO₂ per annum with the institution's diesel generators accounting for ~59%. The several gasoline generating sets scattered across the institution accounts for ~31% of the total CO₂ emission. From literature, the result of this study shows that FUTO is one of the highest carbon emitters amongst other institutions where such studies have been carried out. There is a crucial need to control pollution and diversify into renewable sources of energy so as to reduce the carbon footprint emanating from generating power for the institution's use.

KEYWORDS: CO₂ Emission, energy consumption, petrol-generators, diesel-generators, carbon footprint

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Introduction

Over the years, depletion of energy resources and changes in climatic conditions has remained a global environmental challenge.¹ As it has also been observed, the challenges and susceptibilities of these effects are not the same across various regions of the world. Some continents are more susceptible, and therefore prone to the effects of climatic variation and environmental contamination than other continents.² Africa at large, and Nigeria in particular, may have one of the highest insensitive impacts of climate change compared to other regions and countries of the world; and it is also one of the continents that is least prepared to handle the impacts of climate change.^{3,4}

Evidences abound that emission of greenhouse gases (GHG) like CO₂ (carbon IV oxide) and SO₂ (Sulphur IV oxide) are 2 criteria pollutants driving a major climatic change and their negative environmental impacts are increasing daily owing to, though not entirely, increased human activities.^{5,6} The total amount of greenhouse gases produced from any locality as a result of human activities, are usually expressed in equivalent tons of carbon dioxide CO₂ (eCO₂) and is known as Carbon footprint. A more detailed definition for carbon footprint can be found in Wiedmann and Minx.⁷ Fossil fuel energy like oil and gas are widely exploited and consumed in Africa, though oftentimes, they are crudely refined via bunkering with the consequent discharge of pollutants into water bodies and the atmosphere. The energy is lost through gas flaring, pipe

leakages, vandalism or by sea pirates⁸ with the attendant consequence of threatened increase in GHG emissions and global warming.

At the global stage, Nigeria is known to be one of the highest producers and consumers of fossil fuel. As a result, fossil fuel resources have posed hazards to the citizens of Nigeria in the past, present and imminent future.⁹ Thus, except measures for environmental sustainability and control of greenhouse gas emissions (GHGE) is adopted, the country stands to suffer a shock. Unfortunately, there are no sufficient data or studies to give pragmatic support to the concrete causes of GHGE in sub-Saharan Africa.

Carbon footprint is one of the culprits responsible for climate change in present times.^{10,11} The global community has also recognised climatic change caused by human activities as one of the greatest environmental threats of the 21st century. Human activities have been held largely responsible for the change in climatic conditions.¹² As reported by America's Climate Choices,¹³ the increase in CO₂ emission from fuel combustion started increasing in 2017 after 3 years of stability, reaching 32.8 billion tons; provisional data showed that they grew faster in 2018, with growth in the economies of nations like China and the slowdown in the penetration of renewable energy.

Africa's most populous country, produces less grid electricity than the Republic of Ireland. South Africans consume 55 times more energy per head, and Americans 100 times more. Over 50% of Nigeria's 160 million people receive no electricity at all



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Table 1. Emission factors used to calculate the carbon dioxide emissions from Different Sources.

S/N	EMISSION SOURCE	EMISSION FACTOR	SOURCE
1	Petrol	2.296 kg CO ₂ /L	http://www.ghgprotocol.org/calculation-tools/alltools
2	Diesel	2.653 kg CO ₂ /L	http://www.ghgprotocol.org/calculation-tools/alltools

Source: Malik and Srivastava.¹⁹

As observed by Omoruyi and Idiata,¹⁴ Nigeria (the most populous nation in Africa) produces less grid electricity than the Republic of Ireland and as a consequence, over 50% of Nigerians receive no electricity at all. This has led to a considerable amount of money being spent on the acquisition, repairs, and maintenance of portable and industrial electric generators since they are the major alternative source of power for homes, businesses, and industries. Much to Nigeria's disadvantage, erratic electricity and unstable power supply have remained a national challenge and dishonour. This is to the chagrin of citizens who have come to accept this failure as a norm. This failure in the power sector is a key problem to businesses and industries in Nigeria and has led to estimated spending of about \$14 billion on generators and fuels.¹⁵

It is a well-established fact that without a reliable and affordable source of energy, governments, institutions, and individuals would find it difficult to function at their maximum social and economic capacities. Energy professionals and experts, especially those in the developed countries, have long realised the importance of energy as a veritable resource for improving human welfare and driving industrial growth.¹⁶ In a typical state in Nigeria like Imo state, a reasonable number of people generate electricity by utilising diesel-powered or petrol-powered generators for their homes and businesses. The Federal University of Technology, Owerri (FUTO), located in Imo State, Nigeria, is a typical heavy consumer of electricity. Regardless that it is the premier Federal University of Technology in the southern region of Nigeria, FUTO, with a population of over 25 000 individuals, makes use of generators as the major alternative (if not the only) source of electric power. Petrol and diesel-powered generators are the major source of power generation for businesses, faculty buildings and departments, and other offices in its environs.

The use of these electric generators poses detrimental effects to the environment from carbon emission as well as health risks affecting cognitive performances, cardiovascular, circulatory, respiratory and autonomic systems associated with short- and long-term human exposure to CO₂ ranges starting as low as ~700 ppm.¹⁷ This is expected due to the resultant deficiency in available oxygen in the same environment. Some of these effects may be reversible while some may cause severe damage or even death.

As a consequence of the near-total collapse of electric power supply from the power grid and the non-central electric power supply within the institution, there has been a proliferation of

electric power generators within the institution, all of various power generating capacities. These generators all operate in FUTO at the same period and has become a major cause for concern, more especially with the noise emitted. The noise pollution levels were reported in an earlier study¹⁸ as unpleasant and disturbing. There has also been increased air pollution associated with these generators; hence the need for the carbon footprint in FUTO from these generators to be calculated. It is therefore on this premise, that the study objective is established to estimate the fuel consumption rates and the amount of carbon footprint emitted from fuel and diesel generators in terms of carbon dioxide equivalent. This will help in the understanding and addressing the full range of environmental impact of these generators-which is very crucial for the effect of climate change to be minimised.

Materials and Methods

Emission factors

This research was carried out with relevant standards and procedures such as the Greenhouse gas (GHG) emission factors for estimating the combustion of fossil fuels.¹⁹ Table 1 shows the different emission factors used to calculate CO₂ emissions. Relevant data were obtained through surveys from private and commercial businesses, hostels and departments, the institution's senate building, library, medical and (Information and Communications Technology) ICT buildings, on the quantity of fuel used and the period it is used, in order to estimate the quantity of CO₂ emitted by these facilities. Each fuel consumption was estimated based on the exact number of hours supplied by the generator users.

Small private business operators' generators

These petrol driven-generators are owned by individuals that run businesses within the institutions. A survey on the quantity of fuel consumed and the period it is consumed was conducted and the result was used with appropriate emission factors to obtain the CO₂ emissions. A total of 48 gasoline generators were recorded and these generators consume a total of 89 338.08 L of petrol annually.

Cooperate/commercial business operators generator

This includes generators owned by cooperate/commercial businesses operating in the institution. Such businesses include

Table 2. Annual consumption of fuel by each category in the university.

CATEGORY	FUEL CONSUMPTION (IN L/YEAR)
Private/small business (gasoline)	89338.08
Cooperate/commercial business (gasoline)	7248.00
Cooperate/commercial business (diesel)	56793.00
Institution plants (gasoline)	98825.04
Institution plants (diesel)	324489.60

Table 3. Types of generator, the number recorded, and quantity of fuel consumption per annum.

TYPE OF GENERATOR	NUMBER OF ACTIVE GENERATORS RECORDED	QUANTITY OF FUEL CONSUMPTION PER ANNUM (L/YEAR)
Gasoline generator	89	195411.12
Diesel generator	13	381282.60

commercial banks, eateries, and FUTO Guesthouse which operates daily and is mainly dependent on diesel powered-generator sets.

In this category, 2 active petrol generators and 3 diesel generators were recorded that consume a total of 7248.00 L/year and 56793.00 L/year respectively.

Institution energy emissions

These are the emissions from fuel consumption by the institution to generate energy. These emissions are as a result of the use of petrol generators by the departments and the use of diesel generators by the university hostels, senate building, ICT building, a microfinance bank (owned by the Institution), and other generators/plants that power the institution. The operators of these generators provided the quantity of fuel these generators consume and for how long it is consumed during our survey. Then using the Greenhouse Gas emission factor according to GHG Protocol, the quantity of CO₂ emitted is calculated. For this category, a total of 10 diesel generators were recorded and a total of 39 gasoline generators were also recorded. A total of 324489.60 L of diesel was consumed by the diesel generators in this category annually and a total of 98825.04 L of petrol was consumed by the gasoline generators in this category annually.

Petrol/gasoline. The quantity of petrol/gasoline consumed in litres in a month was recorded from relevant data gotten from the distributed questionnaire. The annual consumption of petrol/gasoline was calculated accordingly. The value for the annual consumption of petrol/gasoline is then multiplied by the emission factor to get the quantity of CO₂ emission. A total of 89 active gasoline generators were recorded which consume a total of 195411.12 L/year.

Diesel. The quantity of diesel consumed in a month was also recorded from relevant data gotten from the distributed questionnaire. The annual consumption of diesel was calculated accordingly. The value for the annual consumption of diesel is then multiplied by the emission factor to get the quantity of CO₂ emission. A total of 13 diesel generators were recorded which consume a total of 381282.60 L/year.

Carbon footprint calculation

The CO₂ emissions were calculated after the acquisition of substantial data. There are various formulas for calculating GHG emissions but in this research, we considered the quantity of fuel burnt in litres per year and the emission factor of the corresponding fuel, and used same to estimate the amount of CO₂ emission. Table 2 shows the annual consumption of fuel by each category in the university while Table 3 shows the types of generators, the number recorded, and quantity of fuel consumption per annum.

Carbon Emission Calculations

$$\text{Quantity of CO}_2 \text{ emission per year} = QF \times EF \quad (1)$$

Where QF is the Quantity of Fuel Consumed (in litres per year) and EF is the Emission Factor

For gasoline generators

$$CO_2EM_p = QP \times 2.296 \text{ kgCO}_2 \text{ per litre} \quad (2)$$

Where CO₂EM_p is the Quantity of CO₂ Emission per year of Petrol (in tonnes of CO₂) and QP is the Quantity of petrol (in litres per year). The Emission Factor for Petrol is 2.296 kg CO₂/L (see Malik and Srivastava¹⁹).

Table 4. Category of consumer, type of generator, number of active generators, quantity of fuel consumed per annum and quantity of CO₂ emission.

CATEGORY	TYPE OF GENERATOR	NUMBER OF ACTIVE GENERATORS RECORDED	QUANTITY OF FUEL CONSUMED PER ANNUM	QUANTITY OF CO ₂ EMISSION (TONNES OF CO ₂)
Private/small business	Gasoline	48	89 338.08	205.12
Cooperate/commercial business	Gasoline	2	7248.00	16.64
Cooperate/commercial business	Diesel	3	56 793.60	150.67
Institution generators/plants	Gasoline	39	98 825.04	226.90
Institution generators/plants	Diesel	10	324 489.60	860.87
Total		102	576 694.32	1460.20

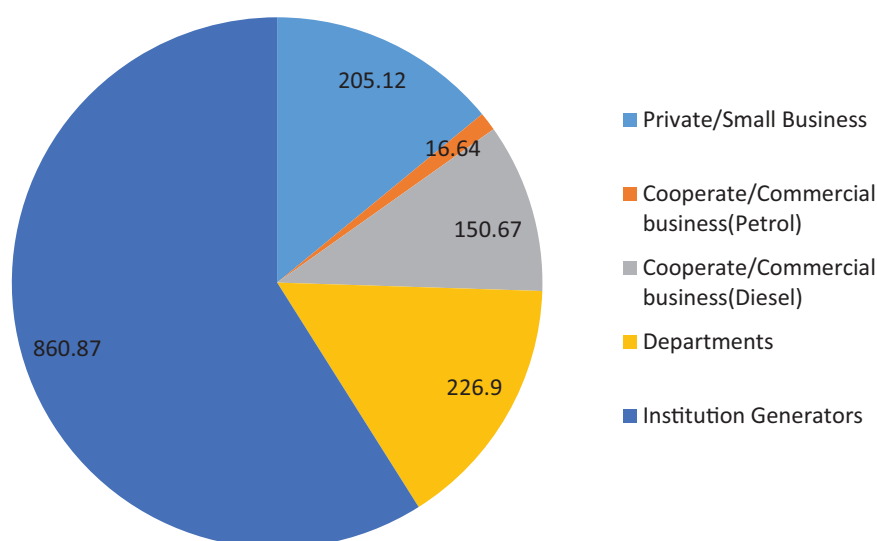


Figure 1. Quantity of CO₂ in tonnes as emitted in the university environment in 1 year.

For diesel generators

$$CO_2EM_D = QD \times 2.653 \text{ kgCO}_2 \text{ per litre} \quad (3)$$

Where CO_2EM_D is the Quantity of CO₂ Emission per year of Diesel (in tonnes of CO₂) and QD is the Quantity of Diesel (in litres per year). The Emission Factor for Diesel is 2.653 kg CO₂/L (see Malik and Srivastava¹⁹).

Carbon footprint

$$\text{carbon footprint} = CO_2EM_P + CO_2EM_D \quad (4)$$

Where CO_2EM_P is the Total Quantity of CO₂ Emission per year for Petrol (in tonnes of CO₂) and CO_2EM_D is the Total Quantity of CO₂ Emission per year for Diesel (in tonnes of CO₂).

Results and discussion

The annual emission of CO₂ as a result of generator usage in the Federal University of Technology, Owerri has been estimated. This emission amounted to 1460.20 tons of CO₂ per annum, with the institution's diesel generators accounting for

the highest amount of this emission ~58.95%. The results showed that diesel generators account for more CO₂ emissions than petrol generators. Table 4 summarily presents each category of energy consumption with the type of generator, the number of active generators, the quantity of fuel consumed per annum, and the quantity of CO₂ emission. The quantity of CO₂ in tonnes as emitted in the university environment is shown in Figure 1 while the percentage contribution by the various consumption categories is shown in Figure 2.

Emissions from the small business sources amounted to 205.12 tons of CO₂ per annum, and this accounts for 14.05% of the total emissions.

There is only one commercial bank on the university premises, and 3 corporate businesses which are 2 eateries and a guest house. The bank operates a 135 KVA diesel generator which serves as their main power supply. The generator consumes an average of 150 L of diesel per day and it operates weekly from Monday to Friday except for public holidays. The 2 eateries on the other hand use a 200 KVA diesel generator and a 3 KVA petrol generator as their main power supply. The diesel generator consumes an average of 70 L of diesel per day and the

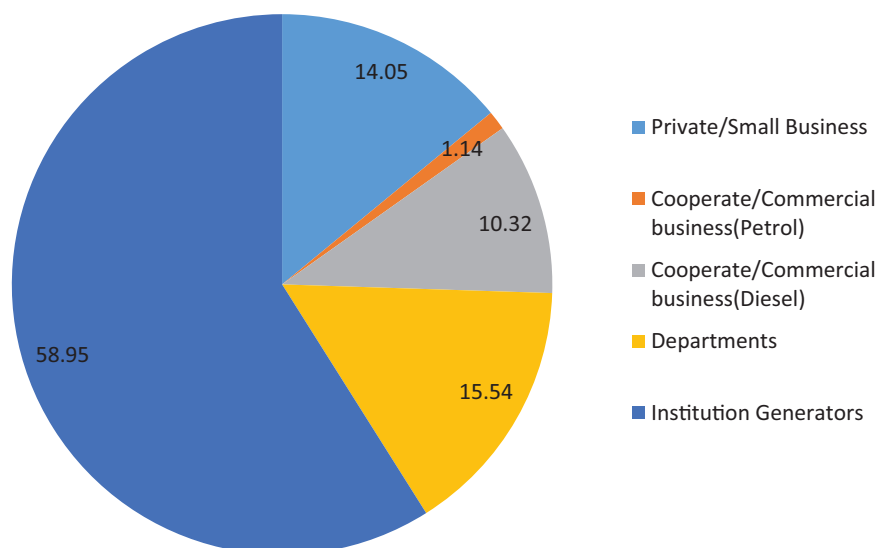


Figure 2. Percentage distribution of GHG emissions.

business operates weekly from Monday to Friday, while the petrol generator consumes 5 L of petrol per day and operates weekly as well from Monday to Friday. The guest house uses a 8.8KVA petrol generator and a 110 KVA diesel generator alternately, the petrol generator consumes 18L of petrol for 12hours daily, while the diesel generator consumes 100L of diesel for 12hours daily. The corporate businesses emitted a total of 150.67 tons of CO₂ per year through diesel consumption, which amounts to 10.32% of the total emissions, and 16.64 tons of CO₂ per year through petrol consumption, which amounts to 1.14% of total emissions.

The institution's energy emissions were grouped into 2 categories, which are emissions from departments resulting from petrol generators used as an alternative to the power supply and emissions from faculty plants/generators which use diesel as fuel. These plants/generators supply electricity to the university hostels, senate buildings, faculty buildings, library, etc. These plants/generators are of different capacities ranging from 15 KVA to 800 KVA. The fuel consumption ranges from about 10 to 400 L of diesel per day. The petrol generators contributed about 226.90 tons of CO₂ per annum, which is about 15.54% of total emissions in the institution, while the diesel generators contribute about 860.87 tons of CO₂ per annum, which is about 58.95% of total emissions – making institutional diesel generators/plants the largest CO₂ emitter in the institutional environment.

Given that this study is for an institution of learning, and taking cognisance of the health hazard of exposure to CO₂ for a prolonged period, there should be, as a matter of utmost importance, a run towards the use of renewable energy. Poor cognitive performances, by students especially, will stem from learning disabilities occasioned by GHG concentration in the environment,¹⁷ and so measures should be adopted to reduce the GHG concentration, thereby ensuring that students' performances and achievements are not negatively impacted.

A similar study (see Ologun and Wara²⁰) showed that the annual emission from the usage of generating sets to produce electricity at the Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria, is about 1365 tons of CO₂. This is close to what was calculated in this research for FUTO and further depicts the near collapse of national electricity grid the country. The total CO₂ emissions due to gasoline and diesel generating set usage at the Abia State Polytechnic, Aba (ASPA) also in Nigeria, was estimated to be 773 tons of CO₂,²¹ which is less than that of this research, while in a semi-urban region in India, the quantity of CO₂ emission as a result of different forms of energy consumption was estimated to be 6.54 tons of CO₂ per household.¹⁹ In a separate study carried out by Omoruyi and Idiata¹⁴ in the city of Benin, Nigeria, shows that the impacts of generator on health and the environment is very high with impaired hearing, choking sensation and deafness ranking 96%, 94% and 92.7% respectively from their survey, while impaired visibility ranked 49%.

Conclusion

This research work set out to calculate the annual carbon footprint from electricity generation at the Federal University of Technology Owerri (FUTO), Imo state, Nigeria. The electricity generation from gasoline and diesel generators was the focal point. The fuel users in FUTO were broadly grouped into 3: Private/Small businesses, Cooperate/Commercial businesses and the Institution. Primary data was collected from these fuel users in FUTO via face-to-face interviews and this was presented in Tables 2 and 3. Greenhouse gas (GHG) emission factors for estimating the combustion of fossil fuels is displayed in Table 1, and this was used to calculate the annual CO₂ emission in FUTO. The values obtained from this calculation are illustrated in Table 4 and Figure 1 depicts a pie chart of these values. The Percentage distribution of GHG emissions is presented in Figure 2.

The institution, Federal University of Technology Owerri (FUTO), is a large consumer of fossil fuel for petrol-powered and diesel-powered generators. The major fuel consumption was by the institution's generators (423314.64L per annum). It is therefore recommended to the institution that focused effort be made to develop renewable sources of energy so as to reduce reliance on fossil fuels. The institution is blessed to have a river, the Otamiri river, flowing/passing through it. Effort should be geared towards generating electricity from this Otamiri river, as this option is yet to be explored. The large amount of waste generated by offices and residential apartments in the institution can also be a source of energy generation if well harnessed. With the situating of this institution in the tropical region comes the option also of implementing solar energy systems as a good power supply alternative, because the sun is available for a greater part of the year. Planting of more trees to absorb this CO₂ is also recommended and encouraged. Moreover, the development of noise filters, emission filters, and absorbers as well as setting emission standards by institution management will reduce the emission level in the foreseeable future. The government is heretofore implored to make steady electric power supply available to its citizenry so that policies can be put in place thereafter to mitigate the GHG emissions. If the government does this bit, then the university is encouraged to connect to this national/central energy supply system. Reduction in the carbon footprint and the general GHGE will also ultimately spell better quality of life for the university community as their susceptibility to the associated diseases is greatly decreased.

Author Contributions

All the authors contributed equally to ensure the completion of the research.

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