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MORALITY BEFORE KNOWLEDGE

Investigating carbon footprints of the Malawi University of Science and Technology

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ABSTRACT
Background: Increasing greenhouse gasses concentration in the atmosphere is perturbing the environment to cause grievous global warming and associated consequences. Following the rule that only measurable is manageable, mensuration of greenhouse gas intensiveness of different products, bodies, and processes is going on worldwide, expressed as their carbon footprints (CF). **Methods:** The methodologies for carbon footprint calculations are still evolving and it is emerging as an important tool for greenhouse gas management. The purpose of this paper was to determine the CF of the Malawi University of Science and Technology (MUST) campus and identify the stressors. The greenhouse gasses (GHG) protocol separates emissions into three scopes which include scope 1 of direct emissions, scope 2 which is indirect emissions, and scope 3 of other indirect emissions. **Findings:** The estimation of CF from transportation measured 930670.2 $kgCO_2e$, and from electricity measured 2824243.2 $kgCO_2e$ while from the use of charcoal fuel measured 30804 $kgCO_2e$. Results showed that emissions generated by gen-sets and transportation produced the highest contribution of 669124.8 $kgCO_2e$ and 238991.4 $kgCO_2e$ respectively to the MUST campus in the year 2018-2019 as compared to previous years (2015-2017). **Conclusion:** The study strongly suggested that for the whole 5 years period the use of gen-sets in the campus was the main stressor and this was due to frequent blackouts. Second was transport and as the university grows, the demand for transportation will also increase hence more emissions from transport. Therefore the study recommends that the university should be more considerate of these carbon dioxide sources so as it is trying to meet its needs and demand from these activities, it should also consider reducing the carbon footprint of the campus. **Novelty/Originality of this Study:** In a pioneering effort for Malawian higher education institutions, this study quantifies the carbon footprint of the Malawi University of Science and Technology campus, paving the way for targeted greenhouse gas management strategies in academic settings.

KEYWORDS: carbon footprint; climate change; energy consumption; global warming; greenhouse gas emissions.

1. Introduction

Climate change is a global as well as a national issue. The rising average temperature of the earth's climate system called global warming is the major cause of climate change. Global warming is bringing up a lot of impacts including extreme weather and changes in the timing of seasonal events (Chen et al., 2022). Global warming is a result of the emission of greenhouse gases (GHGs) into the atmosphere (Shahzad, 2017), and the future impacts of global warming depend on the extent to which nations implement prevention efforts and reduce GHG emissions. Greenhouse gases are gases that have the property of absorbing

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infrared radiation emitted from the earth's surface (Yoro & Daramola, 2020). Thus they turn like a blanket, gripping Infrared radiation and preventing it from escaping into outer space hence contributing to the greenhouse effect which is the stable heating of the earth's atmosphere and surface, thus, global warming (Kweku et al., 2018). Carbon dioxide, methane, and water vapor are the most important greenhouse gases, and this study will concentrate on carbon dioxide.

It is the national as well as global goal to reduce carbon emissions into the atmosphere. The reduction of carbon emission can be done through different means like the reduction of fossil fuels and the adoption of green technologies. However, sometimes it is difficult for industries to reduce carbon dioxide emissions, in this case, principles like the Polluter Pays Principle can be used (Khan, 2015). Those who produce pollution should bear the costs of managing it to prevent damage to human health or the environment. Global policy measures must be coordinated to improve climate change response and reduce carbon and greenhouse gas emissions, as stated in the Paris Climate Agreement, which was ratified by almost all countries in the globe (Ma et al., 2023). Malawi as a nation introduced a carbon tax as part of its initial steps to mitigate the effects of climate change. This tax is a means of reducing emissions by the transport sector and is based on the type of transport system used, as such knowing the transport systems that are used by institutions will help to reduce its costs on a carbon tax at the same time conserving the environment.

Institutions of higher learning such as MUST are among those that consume a lot of energy for different purposes including transport, electricity (generators), and food preparation (charcoal fuel) by the university's cafeteria. All these activities result in emitting carbon dioxide into the atmosphere and understanding the number of emissions from the university's activities is crucial if the management is to make long-term goals of reducing its CF. The transport department at MUST operates different types of vehicles from small to large. The university relies on generators as a backup source of energy due to electricity (hydroelectric power) problems in Malawi, and the cafeteria uses charcoal fuel for food preparation. As the university grows there is an expectation that more vehicles will be needed and there will be more energy consumption to meet the needs of the university on transport, electricity, and food preparation. Therefore, a detailed study of current and expected future carbon dioxide emissions from these activities was demanded.

1.1 Problem statement

Setting the climate goals demands that MUST understand how much carbon is emitted from different activities at the university. The transport department and energy use are among the key activities of the university that contribute more to carbon emissions. Malawi contributes 0.02% (10.85 Metric tons of carbon dioxide emissions out of global 46,906 Metric tons of carbon dioxide emissions) of world total greenhouse gas emissions, and Malawi's greenhouse gas emissions increased by 1 Metric ton from 1990 to 2011. The average annual change in total emissions during this period was 0.7%, with sector-specific average annual changes such as agriculture (3.8%), waste (2.3%), and Industrial Process (2.6%) but no data was available on the transport sector. MUST, as a higher learning institution, has no data on carbon footprint from various activities that result in carbon dioxide emission at the university thereby making it impossible to make long-term goals and track the progress made on carbon emission reduction efforts over time. The lack of information on the carbon emission at MUST has triggered this study to be conducted.

This study seeks to determine how much carbon dioxide has been emitted from the transport system at MUST during the study period, how much carbon dioxide has been emitted from energy consumption, including electricity from generators and charcoal fuel used in food preparation at MUST during the study period, and what the expected future carbon dioxide emissions for MUST are for the next five years. The main objective of this study was to investigate the carbon emission of the transport department, generators, and charcoal fuel at the Malawi University of Science and Technology. The specific objectives of this study are to estimate carbon emissions from the transport systems for the Malawi

University of Science and Technology, to estimate carbon emissions from electricity generated by generators and from charcoal fuel used in food preparation at MUST, and to make a projection on future carbon emissions in the areas of transportation, electricity (generators), and food preparation (charcoal) at MUST.

1.2 Significance of the study

Carbon footprint, being a quantitative expression of GHG emissions from an activity helps in emission management and evaluation of mitigation measures (Pandey & Agrawal, 2011). Having quantified the emissions, the important sources of emissions can be identified and areas of emission reductions and increasing efficiencies can be prioritized. This provides the opportunity for environmental efficiencies and cost reductions. The demand to decarbonize various sectors such as transport, and energy among others is growing globally including in Malawi to mitigate climate change. Nations are searching for alternative clean sources of energy (electricity) and transport systems that emit less carbon dioxide into the atmosphere. The education institutions are therefore required to play a key role in supporting the government's efforts to meet national climate goals by among others reducing their carbon footprints. Therefore, this study is crucial as it will help MUST to determine its carbon footprint from some of the sources or activities at the campus and also discover its potential carbon emission reduction opportunities. The results from this study will also help the university to make future projections on its carbon emissions hence adopting various mitigation measures to reduce the emissions. The study measured the greenhouse gas called carbon dioxide. Thus only carbon dioxide emissions were estimated from the target sources under investigation in this study. This is because carbon dioxide is the major contributor to global warming which results in climate change. Although carbon dioxide has a small global warming potential, its concentration in the atmosphere is very high as its emission into the atmosphere due to anthropogenic activities is increasing at an alarming rate hence being necessary to be investigated.

1.3 Literature review

Human activity produces greenhouse gases daily. The term "carbon footprint" refers to the overall amount of greenhouse gas emissions and is measured in carbon dioxide equivalent (CO_2e) units (Naderipour et al., 2021). Transport accounts for 23% of global carbon dioxide emissions and is one of the few industrial sectors where emissions are still growing (Streimikiene et al., 2013). Car use, road freight, and aviation are the main contributors to greenhouse gas emissions from transport (Hu et al., 2019; Abbood & Meszaros, 2023). As the standards of living have increased over the previous four decades, the consumption of electricity also increased. As a result of this high electricity generation, some countries like Pakistan are meeting electricity demands by using fossil fuels (Ali et al., 2018). These fossil fuels emit carbon dioxide in large amounts. Approximately 40% of global emissions are emitted from electricity generation through the combustion of fossil fuels to generate heat needed to power steam turbines (Abdallah & El-Shennawy, 2013). Understanding the transport systems as well as energy consumption in electricity (generators) and charcoal fuel used at various scales is crucial in investigating the carbon footprint of an institution.

1.3.1 Estimating carbon emissions from the transport systems

The road transport system is mainly used all over the world, and the world of transport is changing rapidly, its future path is uncertain (Pojani & Stead, 2015). Mobility will increase as more people and goods move across towns and the globe and by 2030, annual passenger traffic will exceed 80 trillion passengers per kilometer, a 50 percent increase compared to 2015. The global freight volumes will grow by 70 percent compared to 2015 and an additional 1.2 billion cars will be on the road double today's total (Abbood & Meszaros, 2023; Hu et al., 2020; Hu et al., 2019).

Between 1994 and 2005, India's greenhouse gas emissions were estimated to have risen by approximately 50 percent ranking fourth globally in overall terms (behind the US, China, and the EU) and contributing around 5.5 percent of global emissions (Bhandari et al., 2013). In 1994 energy accounted for about 61 percent of total carbon dioxide emissions of which almost half came from electricity supply, 20 percent from industrial fuel combustion, and around 11 percent from transport. Road transport accounted for nearly 90 percent of transport emissions (the remaining 10 percent coming from rail, aviation, and shipping). In the United States, transportation is the second largest source of greenhouse gas emissions Within transportation, light-duty vehicles represent almost 60% of greenhouse gases. Transportation emissions have been increasing, with freight transportation greenhouse gases expected to grow three times as fast as greenhouse gases from passenger vehicles from 2009 to 2035 (Abbood & Meszaros, 2023).

In Kenya, the transport sector is rapidly growing and it is dominated by road transport (Nkem & Gicheru, 2016; Ministry of Transport and Highways, 2009). The total vehicle population (excluding motorcycles) is estimated to have doubled from 600,000 vehicles in 2000 to 1,200,000 vehicles in 2010. Its public transport is dominated by minibuses and the vast majority of freight transport, including transit freight headed to other countries, is served by trucks. Transport sector greenhouse gas emissions are growing rapidly in Kenya (Nkem & Gicheru, 2016). The emissions from the sector were equivalent to six million tonnes of carbon dioxide equivalent in 2010, or 10 percent of national emissions. These emissions are expected to rise to an estimated 19 percent of total emissions by 2030. These studies show that the transport department is contributing a lot to atmospheric carbon dioxide emissions and there will be a tremendous increase in these emissions globally, especially from well-developed countries.

A study done by Yañez et al. (2020), shows that The University of Talca of the Republic of Chile, since 2012, has been annually tracking the carbon footprint based on the greenhouse gas protocol for all its five campuses. All the university's activities such as transportation, refrigeration, printing, and waste among others resulted in approximately 0.72 tons of carbon dioxide emissions per person. Results from the study showed that emissions generated by activities like transportation of people produced the highest contribution of 0.41 tons of carbon dioxide emission per person to the university's carbon footprint in 2016 hence strongly suggesting that transportation of students and faculty to and from the campus is one of the main stressors (Yañez et al., 2020).

1.3.2 Estimating carbon emission from electricity (generators)

The number of backup generators in the developing world has grown over recent decades due to the electricity demand. Over the past century, diesel engines and generator sets have been widely employed for standby and remote power generation (Wheeler et al., 2017). Diesel generators are the most widely used as small electrical power-generating units in off-grid locations in the world due to their low capital costs (Jakhrani et al., 2012). However, diesel engines release many hazardous air contaminants and greenhouse gases (GHG) including particulate matter (diesel soot and aerosols), carbon monoxide, carbon dioxide, and oxides of nitrogen (Hwang et al., 2023).

Studies done on the emissions of generators revealed that each year, backup generators emit more than one hundred megatons into the atmosphere, and In Sub-Saharan Africa, the emitted from generators is equal to about 20% of the total emissions from vehicles. While backup generators are widespread, there are a handful of countries with particularly large and frequently operated fleets. The top six countries generating energy by backup generators are Nigeria, India, Iraq, Pakistan, Venezuela, and Bangladesh (Heinemann et al., 2022; Hasanuzzaman et al., 2017; Hwang et al., 2023; Ericson & Olis, 2019; Sharma, 2007).

1.3.3 Estimating carbon emission from charcoal fuel

Charcoal is a fuel commonly used for household and institutional cooking and heating in certain parts of the developing world, especially Africa and Southeast Asia. Over 80% of urban families and small- to medium-sized commercial enterprises in sub-Saharan Africa (SSA) use charcoal (Sumba et al., 2020). In Brazil, charcoal is produced on a large scale for use in the steel and pig iron industries (Bailis et al., 2013). Charcoal is essentially produced by heating fuel or any other raw biomass in some type of kiln with limited access to air, a process called carbonization (Da Silva et al., 2024).

About half the wood extracted worldwide from forests is used to produce energy, mostly for cooking and heating, and of all the wood used as fuel worldwide, about 17 percent is converted to charcoal. Global charcoal production is expected to continue increasing in coming decades. An estimated 1 – 2.4 Giga tones of greenhouse gases are emitted annually in the production and use of fuel wood and charcoal, which is 2 – 7 percent of global anthropogenic emissions (Bailis et al., 2013). These emissions are due largely to unsustainable forest management and inefficient charcoal manufacture and wood fuel combustion. Projections indicate that demand for charcoal use will continue to increase, especially in Africa. Charcoal produced using sustainably managed resources and improved technologies, on the other hand, can be a low net emitter of greenhouse gases, with the potential to reduce emissions by more than 80 percent along the charcoal value chain, thereby helping to mitigate climate change. A greener charcoal value chain can also increase access to cleaner energy, reduce health risks associated with rudimentary stoves and generate sustainable income for poor rural people. The use of efficient cook stoves means that less fuel is required than for traditional cook stoves when used correctly (Bhattacharya et al., 2018). Improved charcoal-burning stoves vary considerably in size, shape and design, depending on their intended use. Compared with traditional stoves, improved charcoal stoves have higher heating efficiencies and use less fuel, thereby emitting less carbon monoxide (CO).

2. Methods

2.1 Research design

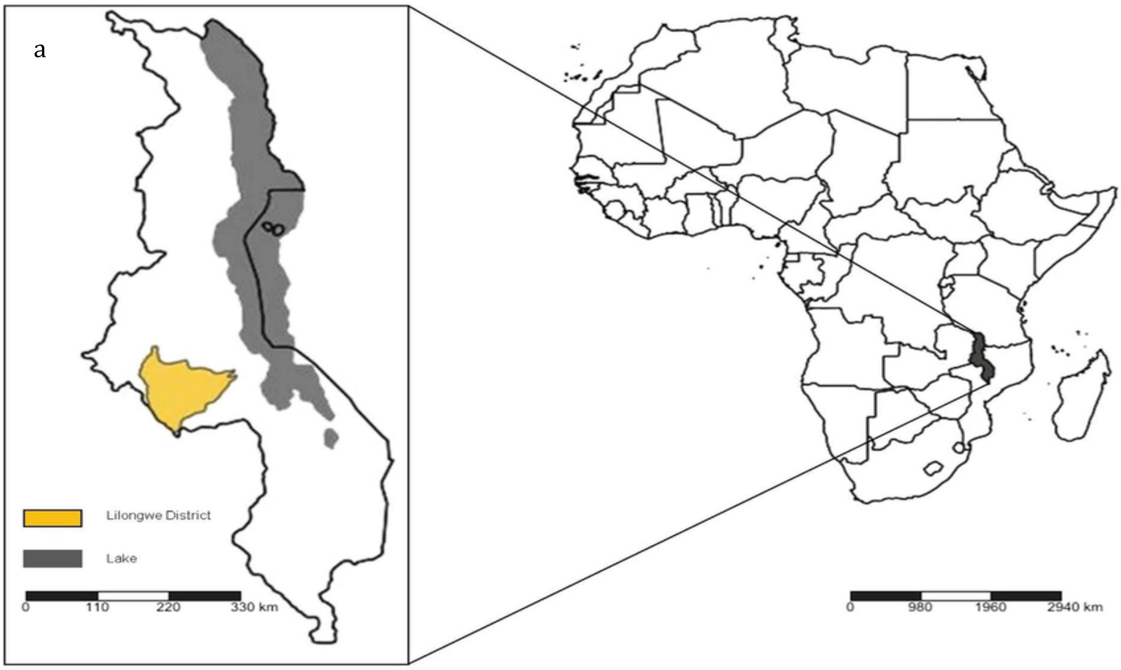
The research study was based on both quantitative and qualitative methods of data collection and analysis. This method was adopted as the study aimed at investigating the carbon footprints of MUST by quantifying the carbon emitted from some of the key energy consuming activities at the university, namely the transport, electricity (diesel generators) and the cafeteria (cooking using charcoal fuel). Based on the amount of fuel consumed and operating hours (i.e. diesel generators) or (mileage i.e. vehicles) the carbon footprint was determined. Using the necessary formulas the carbon footprint from each identified activity was calculated. Lastly, the data on the characteristics of vehicles, the mileage and fuel consumption of the vehicles; the type and fuel consumption of each generator; and the amount of charcoal used monthly was presented in a tabular form. Data showing the carbon emissions from each activity as well as the total carbon footprint of MUST was also presented in tables. Excel was used in plotting bar graphs showing the emissions trend from each activity from the year of 2015 up to 2019 and pie chat was used to demonstrate the emission contribution from each source.

2.2 Data type and sources

This study used data on the vehicles used by the transport department and top officials of the university, the data on electricity usage (generators) as well as on the use of charcoal fuel by the university's cafeteria. Data on vehicles include the characteristics of the vehicles i.e. the type of vehicles used by the university, their models and sizes, their sizes of engines as well as the type of fuel they use and fuel consumption per month, and also a number of vehicles used by the university per day and their millage was collected from the university's transport department. A total number of 18 cars were assigned for general purposes such as transporting both staff members and students as well as goods and services such as food, tissues among others, and those cars that were used by top officials from the management (i.e. the vice-chancellor, deputy vice-chancellor, university registrar, deans, and director of finance) were analyzed. Two electric gen-sets are used as backup electricity on the campus and the data on the type of generators the type of fuel used and fuel consumption of each generator per month was collected from the estate's manager offices, and service providers at the cafeteria provided the data on the amount of charcoal used per month. Data collected was for a period of 5 years from 2015 to 2019 and where there was missing data estimations were made.

2.3 Study area

The study was conducted at the Malawi University of Science and Technology (MUST) campus which is a public university located in Thyolo, off Mugabe road, near Ndata farm, in South Malawi. Figures below are the maps of Malawi showing the location of the capital city of Malawi, Lilongwe and the study area Thyolo district.



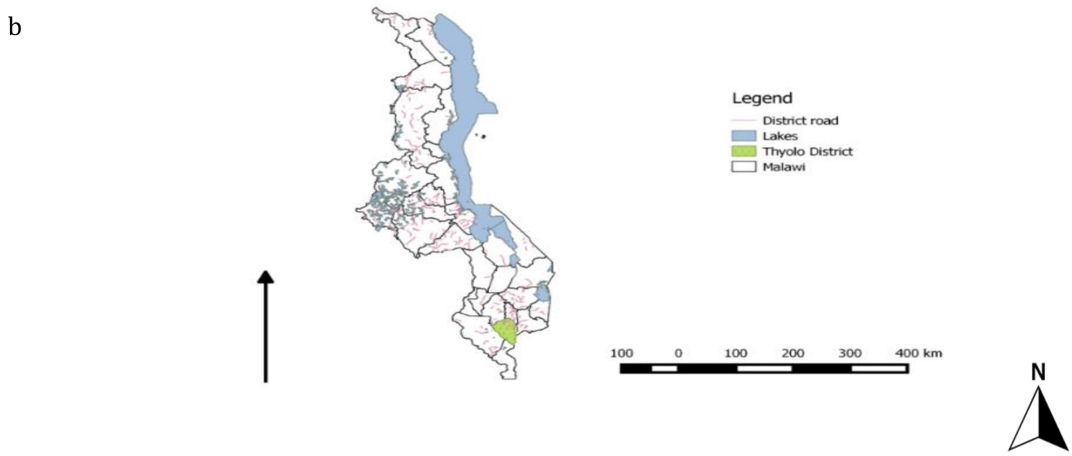


Fig. 1 (a) is a map of Malawi showing the capital city of Malawi Lilongwe in yellow colour;
(b) is a map showing Thyolo District in green colour

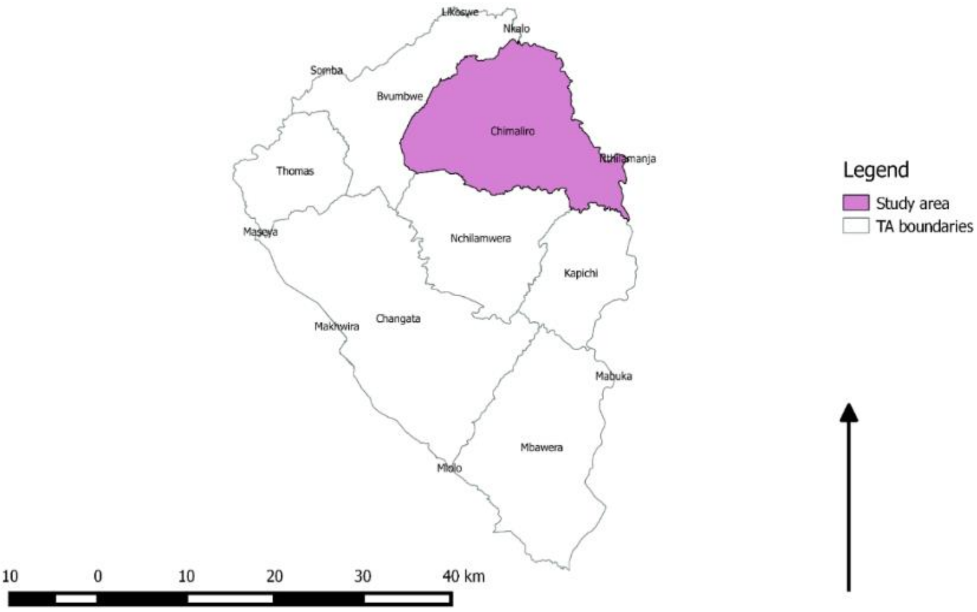


Fig. 2. Study area map showing Chimaliro area where there is MUST campus

The MUST campus is under Traditional Authority (TA) Chimaliro and it occupies a total plot area of 215,000m^2 and has a total building area of 46,000m^2. The University enrolled its first cohort of students in April 2014 but was officially opened on October 24, 2014, by His Excellency the President, Professor Arthur Peter Mutharika. During the study, MUST had four operational schools: the Malawi Institute of Technology (MIT), the Ndata School of Climate and Earth Sciences (NSCES), the Academy of Medical Sciences (AMS), and the Bingu School of Culture and Heritage (BISCH). The school's student capacity was 5,000, and the student population grew to around 2,000 from 120 in 2014, with a total number of 200 permanent staff and 20 part-time staff.

2.4 Methods and techniques (Procedures)

This paper has adopted an approach used by Yañez et al. (2020), in Carbon Footprint Estimation in a University Campus of Talca in Chile. Total carbon dioxide emissions and the carbon footprint of MUST from the transport department was computed as a product of the following components; the characteristics of the vehicle, distance covered by each vehicle, the type and level of fuel use of each vehicle and the carbon content of the fuel used. Carbon emission estimations from MUST transport systems were made as the product of fuel consumption and the standard emission conversion factors of the fuel used in every car. The carbon footprint was quantified in terms of a single measure: kilogrammes of carbon dioxide equivalent (kgCO_2e).

2.4.1 Selection of conversion factors

Conversion factors facilitate the calculation of emissions by multiplying activity data, expressed in their respective international units, and converted into kilograms of carbon dioxide equivalent (kgCO_2e). CO_2e is the universal unit of measurement to indicate the global warming potential (GWP) of GHGs, expressed in terms of the GWP of one unit of carbon dioxide. Numerous reference sources were consulted to select the most appropriate conversion factors, considering certain selection criteria such as accessibility, consistency, and transparency in revisions and updates since every year, during the first months of the year, conversion factors are reviewed and updated (Loyarte-López et al., 2020). The conversion factors were used directly as defined in the chosen source and generally the emissions from each source were calculated as.

$$GHG\ (kgC\ QUOTE\ \ e) = \ aspect\ quantity\ data\ x\ conversion\ factor$$

2.4.2 Conceptual framework

The research framework was designed to be carried out in four phases as shown in Figure 3 below with a view to achieving the above stated objectives.

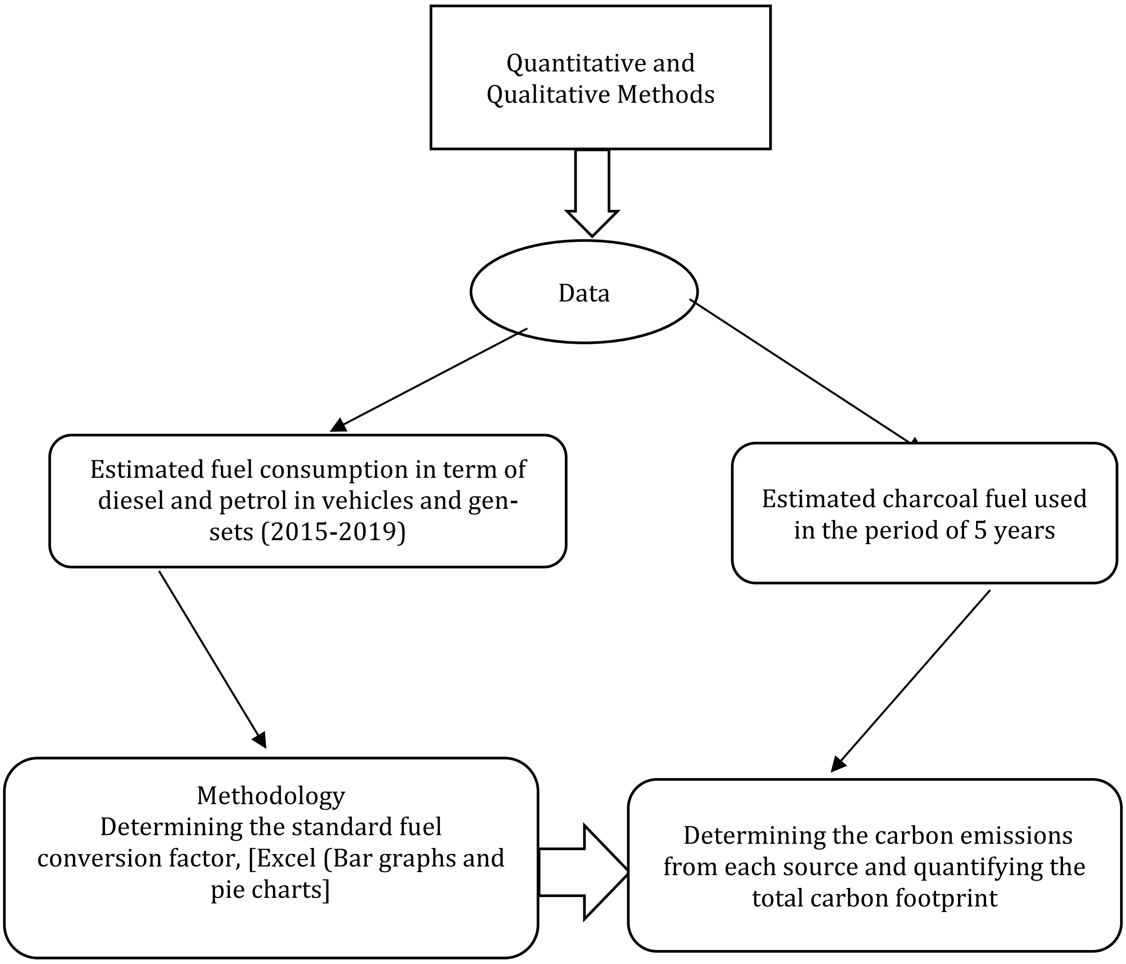


Fig. 3. Research conceptual framework

3. Results and Discussion

3.1 Emissions from transport

The Carbon Footprint (CF) from transportation was calculated using the following formula:

$$CF\ (kgCO\ QUOTE\ \ 2e)\ =\ QUOTE\ \ \times\ \ QUOTE$$

Where, Xi is the amount of energy (petro, diesel,) and Fi is the GHG emission factor per type of energy. Thus the summation of carbon dioxide emitted by every car in the department gave us the total carbon footprint of the transport department.

Table 1. Carbon footprint from transport for the year 2015

Car model	Fuel consumption in liters/month(Xi)	Type of fuel	Emission factor (Fi)	CF (Xi*Fi) (kgCO_2e.)
Nissan hardbody	400	Diesel	2.6	12715.2
Hyundai truck	350	Diesel	2.6	11125.8
Nissan X-Trail	300	Petrol	2.3	8445.6
TATA bus (Big)	80	Diesel	2.6	25430.4
TATA bus (Small)	200	Diesel	2.6	6357.6
Toyota fortuner	500	Diesel	2.6	15894
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
			Total	96859.8

The above table 1 shows the monthly fuel consumption of each car that was available in 2015. In estimating the emissions from transport for the year 2015, the monthly fuel consumption was multiplied by 12 months and the product was the fuel consumption for the whole year. This was then multiplied by the emission factor of the fuel used by the car (petro or diesel) hence determining the carbon footprint for the year 2015. MUST emit a total of 96,859.8KgCO_2e from transport in the year 2015 as shown in table 1 above.

Table 2. Carbon footprint emissions from transport for the year 2016

Car model	Fuel consumption in liters/month(Xi)	Type of fuel	Emission factor (Fi)	CF (Xi*Fi) (kgCO_2e.)
Nissan hardbody	400	Diesel	2.6	12715.2
Hyundai truck	350	Diesel	2.6	11125.8
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
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Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
TATA bus (Big)	800	Diesel	2.6	25430.4
TATA bus (Small)	200	Diesel	2.6	6357.6
Toyota coaster	500	Diesel	2.6	15894
Toyota fortuner	500	Diesel	2.6	15894
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
			Total	154981.8

The table 2 above shows the monthly fuel consumption of each car that was available in 2016. In estimating the emissions from transport for the year 2016, the monthly fuel consumption was multiplied by 12 months and the product was the fuel consumption for the whole year. This was then multiplied by the emission factor of the fuel used by the car (petro or diesel) hence determining the carbon footprint for the year 2016. MUST emitted a total of 154,981.8 kgCO_2e from transport in the year 2016 as shown in the table 2 above.

Table 3. Carbon footprint from transport for the year 2017

Car model	Fuel consumption in liters/month(Xi)	Type of fuel	Emission factor (Fi)	CF (Xi*Fi) (kgCO_2e.)
Nissan hardbody	400	Diesel	2.6	12715.2
Hyundai truck	350	Diesel	2.6	11125.8
Nissan patrol	500	Petrol	2.3	14076
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6

Nissan X-Trail	300	Petrol	2.3	8445.6
Scania torino bus	1000	Diesel	2.6	31788
TATA bus (Big)	800	Diesel	2.6	25430.4
TATA bus (Small)	200	Diesel	2.6	6357.6
Toyota coaster	500	Diesel	2.6	15894
Toyota fortuner	500	Diesel	2.6	15894
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
Toyota Corolla	300	Petrol	2.3	8445.6
			Total	200845.8

MUST emitted a total of 200,845.8 kgCO_2e from transport in the year 2017 as shown in the table 3 above. The above also shows the monthly fuel consumption of each car that was available in 2017. In estimating the emissions from transport for the year 2017, the monthly fuel consumption was multiplied by 12 months and the product was the fuel consumption for the whole year. This was then multiplied by the emission factor of the fuel used by the car (petro or diesel) hence determining the carbon footprint for the year 2017.

Table 4. Carbon footprint from transport for the year 2018

Car model	Fuel consumption in liters/month (Xi)	Type of fuel	Emission factor (Fi)	CF (Xi*Fi) (KgCO_2e.)
Nissan hardbody	400	Diesel	2.6	12715.2
Hyundai truck	350	Diesel	2.6	11125.8
Nissan patrol	500	Petrol	2.3	14076
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Scania torino bus	1000	Diesel	2.6	31788
TATA bus (Big)	800	Diesel	2.6	25430.4
TATA bus (Small)	200	Diesel	2.6	6357.6
Toyota coaster	500	Diesel	2.6	15894
Toyota fortuner	500	Diesel	2.6	15894
Toyota fortuner	500	Diesel	2.6	15894
Toyota land cruiser	700	Diesel	2.6	22251.6
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
			Total	238991.4

Table 4 above shows the emissions from the transport department for the year 2018. The total emissions were approximated to be 238,991.4kgCO_2e.

Table 5. Carbon footprint from transport for the year 2019

Car model	Fuel consumption in liters/month(Xi)	Type of fuel	Emission factor (Fi)	CF (Xi*Fi) (kgCO_2e.)
Nissan hardbody	400	Diesel	2.6	12715.2
Hyundai truck	350	Diesel	2.6	11125.8
Nissan patrol	500	Petrol	2.3	14076
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Nissan X-Trail	300	Petrol	2.3	8445.6
Scania torino bus	1000	Diesel	2.6	31788
TATA bus (Big)	800	Diesel	2.6	25430.4

TATA bus (Small)	200	Diesel	2.6	6357.6
Toyota coaster	500	Diesel	2.6	15894.0
Toyota fortuner	500	Diesel	2.6	15894.0
Toyota fortuner	500	Diesel	2.6	15894.0
Toyota land cruiser	700	Diesel	2.6	22251.6
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
Toyota corolla	300	Petrol	2.3	8445.6
			Total	238991.4

Table 5 above shows the emissions from transport department for the year 2019. The total emissions were approximated to be 238,991.4 kgCO_2e. Different sources contributed to the must carbon footprint differently during the study period due to several factors. Figure 4 below shows the emissions from the transport department from the year 2015 to 2019. 2015 has the less amount of emissions and the emissions increased highly in the year of 2018 and 2019. This is because in 2015 there was less number of cars and as the car population grew, the amount of carbon dioxide produced by the cars also increased.

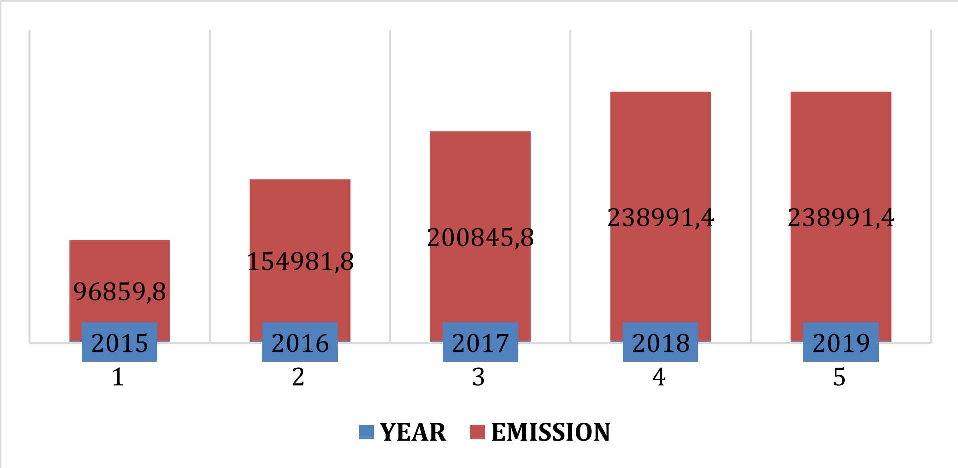

Fig. 4. Carbon footprint from transport

This implies that as the demand of transportation will be increasing due to an increase of both staff and student population, the number of cars procured will also increase hence an increase in fuel consumption and thus more carbon dioxide emissions. Such being a case, several factors should be put in place to reduce these emissions at the same time meeting the university's transportation demands. This can be done by considering the characteristics of cars being procured such as their engine size as well as the fuel type they use.

3.2 Emissions from electricity (generators)

Must operates two diesel electrical gen-sets which are Perkins-cat gen-sets and the carbon dioxide emissions of the generators was calculated based on the amount of fuel consumption by each generator. The first generator (named as GR1) is a 500 KVA (Kilovolt-Ampere) which is located near the administration block of the university. This generator supplies electricity to the administration block, classes, teaching hospital, auditorium, mechanical engineering, Chinese camp as well as the plant of water treatment for southern water board at the campus. The second generator (named GR2) is a 225 KVA which is located near the cafeteria, and it supplies power to the hostels, library, cafeteria and the sewer treatment. The carbon content of fuels slightly varies, but typically the average carbon content values to estimate emissions was adapted. The consumption of one-litre diesel normally emits around 2.7kg of carbon dioxide (Jakhrani et al., 2012). However, the number of kg of carbon dioxide produced per litre of fuel consumed by the diesel generator depends upon the characteristics of the diesel generator and the characteristics of the fuel, and it usually falls in the range of 2.4 – 2.8 kgCO_2/l. Depending on the characteristics of the generator and fuel, the carbon footprint was estimated as.

$$The\ carbon\ content\ of\ the\ fuel\ (kg) \times\ the\ amount\ of\ fuel\ used$$

3.3 Fuel consumption of the gen-sets

Consumption, liters/hour, largely depends on power load demand. From the year 2018-2019, at full load GR1 operates using 120litres per hour. But due to the diversity factor, that is to say all electric appliances cannot be used at the same time, the three-quarter load which is 90.0 liters per hour was adopted. These operations were during school periods when the students were on campus. During the holidays, this generator was operating at quarter load which is on average 43 liters/hour. The generator was operating on half load which was 62.4 liters/hour during the school period in the year 2015/2017, and a quarter load of 36.0 liters per hour during holidays. Generally, GR1 uses 36 liters per hour at zero load. Table 6 below is a summary of the emissions from the 500KVA generator for the year 2015/2019.

Table 6. Carbon footprint from 500KVA generator

Year	Fuel consumption (liters/hour) (Xi)	Emission factor (Fi) (kgCO2/l)	CF (XI*Fi) (kgCO_2e)
2015	115776	2.7	312595.2
2016	115776	2.7	312595.2
2017	115776	2.7	312595.2
2018	160560	2.7	433512.0
2019	160560	2.7	433512.0
		Total	1804809.6

GR2 at full load uses 60litres per hour but due to diversity factors for the years 2017-2019 during school periods, the three-quarter load which is 45.0litres per hour was used. During holidays the generator was using 31.2 liters/hour and generally, when operating at zero load it uses 18.0 liters/hour. From the year 2015 to 2016 during the school period this generator was operating on half load and was using 31.2litres/hour and half load during which was consuming 18.0liters/hour during the holidays. The generator consumes 18.0liters/hour when operating on zero load. Table 7 below shows the total emission from a 225KVA generator for the entire study period.

Table 7. Carbon footprint from a 225KVA generator

Year	Fuel consumption (liters/hour) (Xi)	Emission factor (Fi) (kgCO2/l)	CF (XI*Fi) (kgCO_2e)
2015	57888	2.7	156297.6
2016	57888	2.7	156297.6
2017	87264	2.7	235612.8
2018	87264	2.7	235612.8
2019	87264	2.7	235612.8
		Total	1019433.6

Table 8. Total carbon footprint from generators

Year	Fuel consumption (liters/hour) (Xi)	Emission factor (Fi) (kgCO2/l)	CF (XI*Fi) (kgCO_2e)
2015	173664	2.7	468892.8
2016	173664	2.7	468892.8
2017	203040	2.7	548208.0
2018	247824	2.7	669124.8
2019	247824	2.7	669124.8
		Total	2824243.2

Table 8 above shows the total amount of carbon dioxide emitted from using generators on the campus for the entire study period. MUST emitted a total of 2,824,243 KgCO_2e in the year 2015/2019.

3.4 Emissions from charcoal fuel

On estimate the University's cafeteria was using 40 kilograms (kgs) every four days for food preparation for food preparation during school period and no charcoal during holidays. During holidays the cafeteria used electrical appliances only since the demand for food was low. On average the academic year lasts for 8 months. The amount of charcoal that was used for the period of 5 years (2015-2019) during the school periods was estimated and using proper conversion factors, the emissions were estimated. Charcoal combustion carbon dioxide emission ranges from 2155-2567g/kg of charcoal depending on the type of stove used. This study adopted 2567g of carbon dioxide/kg as conversion factor that was used in Bhattacharya et al. (2018) as the stoves used by the MUST cafeteria are not modern and improved ones hence high emissions. The carbon footprint was calculated as follows.

$$The\ amount\ of\ charcoal\ used\ monthly \times\ the\ emission\ factor$$

Table 9. Emissions from charcoal combustion

Year	Charcoal fuel consumption (Kgs)(Xi)	Conversion factor (g) (Fi)	CF (Xi*Fi) g
2015	2400	2567	6160800
2016	2400	2567	6160800
2017	2400	2567	6160800
2018	2400	2567	6160800
2019	2400	2567	6160800
		Total	30804000

Table 9 above shows the approximated carbon dioxide emissions from the use of charcoal fuel. The university's cafeteria emitted a total sum of 30804 kgCO_2e in the year 2015/2019. The amount of carbon dioxide released using charcoal fuel in the university's cafeteria was estimated to be constant during the entire study period. Figure below shows the amount of carbon dioxide released form the combustion of charcoal fuel in the year 2015/2019 at MUST.

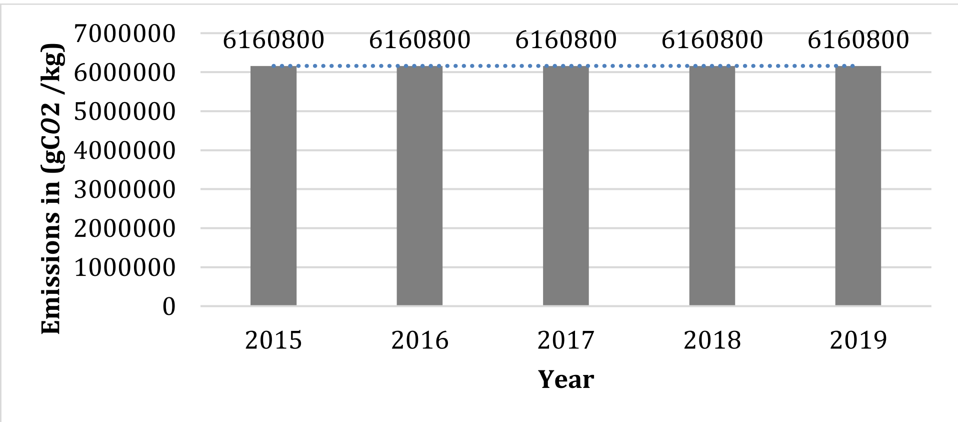

Fig. 5. Carbon footprint from the use of charcoal fuel

3.5 Emissions from gen-sets

During the years 2015 and 2016, the emissions from generators were less as compared to 2018 and 2019. The emissions from generators depend on the load at which the generators are operating as well as the duration (operation hours). During these first two years, the generators were not operating at full load since the campus was not fully occupied. Thus, the reason of few emissions in the year 2015 and 2016.

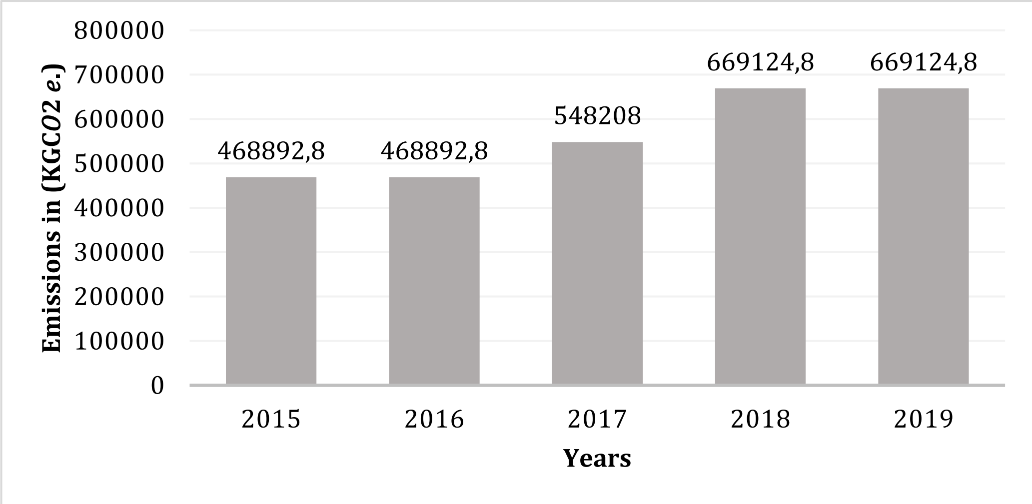

Fig. 6. Carbon footprint from generato

Starting from the year 2017, the campus was fully occupied and there was an additional of extensional camp and mechanical engineering at which the generators supplied energy and as a result the generators were operating at full load hence more fuel consumption and thus more carbon dioxide emissions as shown in the figure 5 above. The generators were running for at least six hours daily during the entire study period as the campus was experiencing electricity challenges during this reign and thus a reason to more carbon emissions as the generators were operating every day and for many hours.

3.6 MUST carbon footprint contribution from each source

It was revealed from the analysis that the use of generators as back up electricity contributed a lot to the MUST carbon footprint. Thus gen-sets were the main carbon dioxide stressor on the campus seconded by transport. This was because during the study period, the school was experiencing a lot of blackouts hence generators were operating almost everyday. The use of charcoal fuel contributed less to the campus' carbon footprint. This is because the cafeteria also uses electrical appliances and it mostly use charcoal when there is no electricity and it is projected that when there are few problems of electricity, the emissions from charcoal use will be very little.

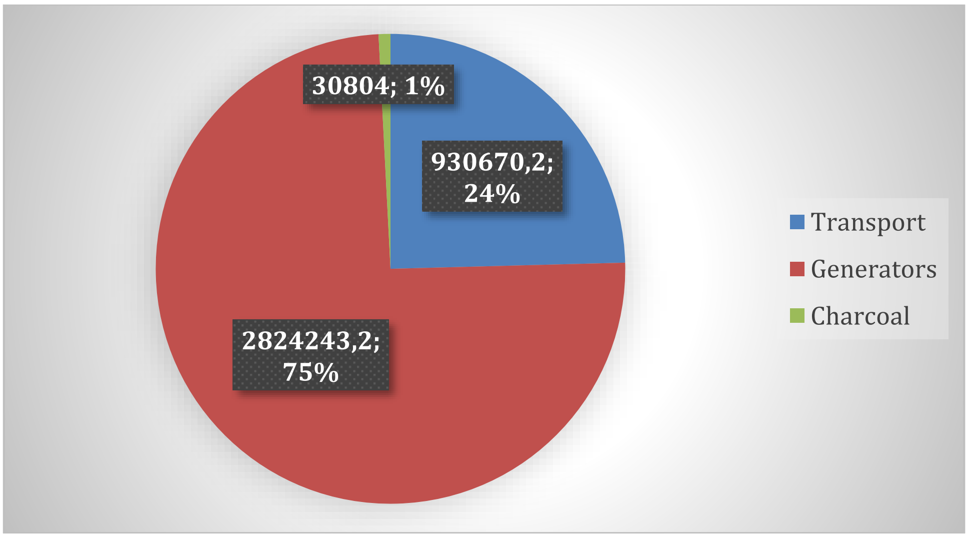

Fig. 7. Carbon footprint contribution per source

From the above figure 6, it was estimated that generators are contributed 75% to the MUST carbon footprint while the transportation and the use of charcoal fuel contributed 24% and 1% to the MUST carbon footprint respectively during the entire study period.

3.7 Projections on future carbon emissions at MUST from transport, generators charcoal fuel

The future Must Carbon Footprint is uncertain as it depends on several factors, however projections on the emission from the targeted sources in the coming five years can be estimated. The charcoal combustion projections showed that the carbon emissions will decrease by almost 80% as compared to the emissions that were there during the study period. This is so because during the study period, some of the electrical appliances used for cooking were not in good state and the school was experiencing frequent blackouts hence charcoal fuel consumption was high. Mean time these electrical appliances are being maintained and will be in use very soon and the electricity problems have reduced hence charcoal use will decrease. Estimation shows that a 20kgs bag of charcoal will be used for a period of 5days and thus as lower as compared to 40kgs which was used for a period of 4days during the study period. During the holidays, estimations show that no charcoal fuel will be used on the campus, hence on average, the emission from charcoal fuel use will be reduced by at least 80% and thus contributing less to the MUST carbon footprint.

The contribution of backup generators to the MUST Carbon Footprint depends on its working hours since its fuel consumption is dependent on time factor. Thus the longer the operational hours the higher the fuel consumption and thus more emission. During the study period the campus was in electricity crisis hence generators were used daily. As for the year 2020 the situation was different. The campus was mostly using the hydro-electric power and the gen-sets were operating on an average of 3 hours per day. This implies that if the situation in the next coming five years remains the same as of the year 2020, the emissions from gen-sets will be reduced by 50% as compared to the emissions during the study period. The more the electricity challenge reduces, the less the operational hours of the gen-sets and thus less fuel consumptions hence less carbon emissions. The study strongly believe that the country will experience less blackouts as compared to those experienced during the study period hence the emissions from gen-sets may reduce by almost 65% in the coming 5 years. In case the campus experiences the similar electricity scenarios like those experienced during the study period, the gen-sets are expected to contribute the same amount of carbon dioxide emissions emitted during the study period to the MUST carbon footprint in the next coming 5 years.

The study strongly believe that if there will be no electricity problems, transport department will be a major contributor to the MUST carbon footprint if not taken into careful consideration. Projections show that the carbon dioxide emissions from transport will double the amount of that was released during the study period in the coming five years. This is because the staff and students population on the campus is growing and there will be an increase on transport demand hence more cars will be procured. A part from the type of fuel that cars use, the size of engine and the model of car determines the fuel consumption and hence determining the amount of carbon dioxide a car emits. Table 10 below is a table showing the model and size of engine of cars under study.

Table 10. The size engines of the cars and their models

Car model	Vehicle type	Engine size (volume) (liters)	Year of make (Model)
Hardbody nissan	Diesel car	2	2013
Hyundai truck	Diesel car	3	2012
Nissan patrol	Petrol car	5.6	2018
Nissan X-Trail	Petrol car	2	2016
Nissan X-Trail	Petrol car	2	2016
Nissan X-Trail	Petrol car	2	2016
Nissan X-Trail	Petrol car	2	2016
Nissan X-Trail	Petrol car	2	2016

Scania torino bus	Diesel car	3	2013
TATA bus (Big)	Diesel car	4	2013
TATA bus (Small)	Diesel car	3	2013
Toyota coaster	Diesel car	3	2015
Toyota fortuner	Diesel car	3	2017
Toyota fortuner	Diesel car	3	2015
Toyota land cruiser	Diesel car	3	2013
Toyota corolla	Petrol car	1.8	2013
Toyota corolla	Petrol car	1.8	2015
Toyota corolla	Petrol car	1.6	2015

A car's engine size, also known as the engine capacity, is the size of the volume swept by each of the cylinders, which inside combine and burn air and fuel to generate energy. The larger the engine size, the more the fuel the vehicle consumes, the more power it produces, and the more the car accelerates. Bigger engines have more space to burn fuel, which means that these engines consume more fuel than smaller ones. An engine that has less than 1.5 litres is generally regarded as a smaller engine. The fuel characteristics also differs as diesel is heavier than petrol. This means that a petrol engine and a diesel engine of the same size will consume different amounts for the same distance. Overall, a diesel engine will consume less than a petrol engine**.** Larger engines will use more fuel for town driving that requires constant braking. Therefore, the study recommends the use of smaller engine if you constantly travel small distances, like going to work. Larger engines are ideal for long distances, towing heavy loads, and if one prefer faster acceleration. However, with turbo charge, smaller engines can wield more power and accelerate just as well as some bigger engines in some cases. Thus depending on fuel and also the bigger the engine the more fuel it consumes and burns and thus higher carbon dioxide emissions as shown in the table 11 below.

Table 11. Carbon dioxide emission per kilometer depending on fuel type and size of engine

Vehicle type	Engine size	Size label	Emission factor (gCO2/km)
	< 1.41	Small	125.5
Petrol car	1.41-2.01	Medium	163.8
	>2.01	Large	147.7
Averaged petrol car		All	151.8
	< 1.71	Small	110.6
Diesel car	1.71-2.01	Medium	138.3
	> 2.01	Large	169.2
Averaged diesel car		All	139

The above table 11 was adopted in Department for Business, Energy & Industrial Strategy (2019), where the carbon footprint was also calculated using the distance based approach. Based on this approach the carbon footprint or carbon dioxide emitted by each car is estimated as a product of the emission factors as shown in the above table and the distance travelled.

$$\textit{Emission conversion factor * distance; expressed } (kgCO_{2eq})$$

Adopting this procedure results shows that the petrol and big car engines release more carbon dioxide as compared to the diesel and small car engines. From these estimations, it shows that there are high possibilities of more carbon dioxide emissions from transport department at the university campus.

4. Conclusions

4.1 Conclusion

Climate change is becoming a global concern due to its impacts on human health and the environment. Human activities that has resulted to emission of greenhouse gases into the atmosphere such as transportation, the use generators as well as charcoal combustion among others have contributed a lot to the effects of this climate change. It is therefore important to reduce these emissions so as to mitigate some of the changing climate impacts. In order to achieve this, firstly the possible sources that result to these emissions must be identified and quantified. Thus calculating carbon footprint. This helps an individual, organization as well as a nation at large to trace and discover all available sources and estimate the amount of greenhouse gases they contribute into the atmosphere and hence being able to come up with reducing strategies.

This study has estimated the MUST carbon footprint from targeted sources which includes the transport, electricity from generators and also the use of charcoal fuel. It has also provided relevant information on how to estimate the carbon footprint from the above mentioned sources. Therefore the measurement of the CF in this study during 2015–2019 provides a methodological terms and identification of the GHG emission inventory, a clear and concise vision on the way in which to perform the measurement of CF in the next years. The study found out that during the study period the use of generators was the major contributor to the MUST CF but it strongly suggests and projects that transportation will be a main stressor of carbon emissions on the campus in the next coming five years if there will be no frequent blackouts on the campus.

4.2 Study limitations

The empiric evidence about methodologies to calculate CF in institutions of higher education shows that there is more than one way to calculate it. However, the method that was adopted in this study is a widely recognized and well-known methodology to calculate CF. In order for other ways to be adopted, enough data must be available. This study met a challenge of missing data for example the data on charcoal use from the past years since the service providers at the cafeteria changes each and every academic year, hence estimations were used. Time factor was also another challenge for this study. The study was conducted for three months and thus a limited time to collect enough data for the large sample size for example in transport department, hence a manageable sample size was used. Other methods of calculating CF were just explained like estimating CF from transport through distance based approach. This was due to gaps in data for making the calculation.

4.3 Study recommendations

This study only cannot be inferred to as the total amount of CF of MUST. This is because the study was based on some targeted scope 1 emissions. There are other several sources that contribute to the MUST carbon footprint such as emissions from scopes 2 and 3 which are indirect and other indirect sources. These emission include emissions from the electric appliances used at the campus such as heaters and projectors, emissions from waste disposal and the burning of the wates, emissions from the sewage tank, water consumption among others, and also emissions from transport including the cars from lectures and other personal cars that visits the campus as well as motorcycles. Therefore since there are several other emissions sources that contributes to MUST CF but were not quantified in this study, the study recommends and encourages other scholars to do a further research on the same and estimate the emissions from these sources. Additionally, it is important to develop emissions inventory based on case studies and departments that their operations result to significant carbon dioxide emissions. In this study of CF at the MUST University, Scope 1 emission sources like transport, use of gen-sets and charcoal combustion consumption were deemed important because of its institutional relevance and contribution to the total emissions and, therefore, must be quantified. The university should also be considering of other clean alternative source of electricity such as solar since in case the campus continues to experience electricity challenges, the gen-sets will be operating more frequently and thus more fuel consumption hence more carbon dioxide emissions and also more costs. Lastly the university should take into consideration the characteristics of vehicles that it will be purchasing in the near future. The study recommends that the university should be buying more cars that use diesel than petrol, and also cars of latest model with small sizes of engine but with the same capacity like those with big engines. This will help the university to meet its demands on transport at the same time reducing the carbon dioxide emissions.

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Author Contribution

Conceptualization, P.D.M and H.B.N.C.; Methodology, P.D.M; Software, P.D.M.; Validation, P.D.M., H.B.N.C. and M.M; Formal Analysis, P.D.M.; Investigation, P.D.M.; Resources, M.M, M.F.C.; Data Curation, P.D.M.; Writing – Original Draft Preparation, P.D.M.; Writing – Review & Editing, P.D.M, M.M, M.F.C, H.H.; Visualization, H.B.N.C and P.D.M.; Supervision, M.M, M.F.C, H.B.N.C.; Project Administration, M.M, M.F.C.; and Funding Acquisition, M.M.

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Conflicts of Interest

The authors declare no conflict of interest.

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