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A Study on the Carbon Footprint of a Philippine Higher Education Institution using Streamlined Life Cycle Assessment

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Higher education institutions (HEIs) have a key role in fostering sustainable development as academic organizations dedicated to research, education, and community service. As emissions rise, understanding and reducing major sources have become imperative. This study quantifies the carbon footprint of Mapúa Malayan Colleges Laguna (MMCL) for 2022 using a streamlined life cycle assessment methodology, which is a systematic framework that evaluates the environmental impacts throughout a product’s life cycle. This study aims to determine the total carbon footprint of MMCL for 2022, considering scopes that cover both indirect and direct emissions, with the objective of providing insights into HEI emissions and serving as a basis for sustainable mitigation and emission reduction efforts. Results show that the carbon footprint of MMCL in 2022 was 614,553 kg CO_2-eq, with Scope 2 (electricity consumption) contributing the most emissions at 98.49 %, followed by Scope 1 (fuel consumption) at 1.16 %, and Scope 3 (solid waste) at 0.34 %.

1. Introduction

Several nations and organizations are seeking strategies to reduce emissions, as anthropogenic greenhouse gas (GHG) emissions contribute to global climate change (Kennedy et al., 2009). The Philippines has committed to significant emissions reductions under the United Nations Development Programme (UNDP), but limited data and monitoring hinder progress assessment. Researchers have started quantifying carbon emissions because of a growing emphasis on global carbon emissions (Liu & Liang, 2017), which is crucial for understanding emissions sources and implementing reduction strategies because of the growing significance of sustainable development (Cabeza et al., 2014). Life cycle assessment (LCA) is one of the fundamental approaches for carbon emission calculation, accounting for the inputs and outputs of processes or products (Abeydeera et al., 2019). A streamlined LCA is a simplified assessment for carbon footprint evaluation that aids in identifying key emission sources and recommending mitigation measures. Universities worldwide contribute significantly to GHG emissions through activities like refrigerant use, energy consumption, and campus operations. They play a crucial role in addressing climate change, promoting, and contributing significantly to sustainable development and the effort against climate change (Cordero et al., 2020), including quantifying carbon footprints. Considering these goals, higher education institutions (HEIs) have been increasingly calculating their carbon footprint, and as a result, the sector has been able to both lessen and increase its environmental impact. Few universities globally publish and measure their carbon footprints, and practices may vary across countries in terms of methodologies, metrics, and goals considered (Helmer et al., 2021). The increase resulted from carbon footprint assessments conducted, particularly in 2020, in countries including Pakistan, the United States, Spain, Indonesia, and Chile, with more studies from India and Malaysia in 2021 (Valls-Val & Bovea, 2021). This study aims to quantify the carbon footprint of Mapúa Malayan Colleges Laguna (MMCL) using a streamlined LCA, provide insights into institution emissions, and serve as a basis for efficient mitigation measures and strategies for sustainability.

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2. Methodology

To determine the carbon footprint of MMCL in 2022 using a streamlined LCA, considering scopes that cover both direct and indirect emissions, a mixed-methods case study was conducted. The academic institution's carbon footprint adhered to the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC), following GHG Protocol and the International Organization for Standardization (ISO). The LCA methodology is in accordance with ISO 14040 and ISO 14044 standards. Figure 1 illustrates the schematic input/output diagram of the LCA study, aimed at providing insights into institution emissions and guiding sustainable mitigation and reduction plans.

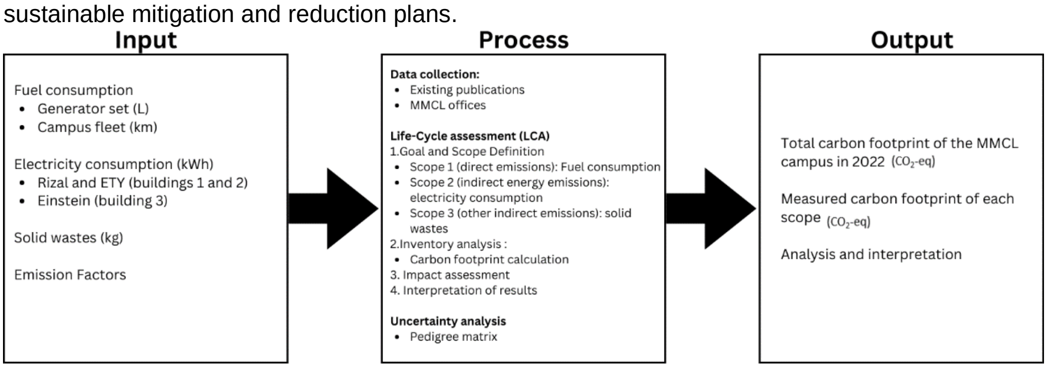

Figure 1: Schematic input/output Diagram of the Study

2.1 Goal and scope definition

This study evaluates the carbon footprint of MMCL using a streamlined LCA approach, focusing on its environmental impacts from consumption- and production-based activities within defined organizational boundaries. Emission sources are categorized into Scope 1 (fuel consumption), Scope 2 (electricity consumption), and Scope 3 (solid waste). The reference period is the COVID-19 pandemic from 2020 to 2022, with data covering operations from 2019 to 2022, considering different learning modalities: face-to-face (2018–2019), online (2021), and hybrid (2022).

2.2 Inventory analysis

The inventory data acquired in the study addressed the consumption phase of the activities that contribute to the carbon footprint of the academic institution, which is taken into consideration for the study's streamlined LCA, contributing to the carbon footprint of the academic institution, with emission sources identified in accordance with the ISO 14064 standard. Table 1 shows the academic institution's emission sources and descriptions.

Table 1: Campus consumption inventory

Scope and GHG Source	Description	Emission Factor, CO_2-eq	Dataset description
Scope 1 Fuel consumption	(Generator set) Diesel, L (D = 0.830 kg/L diesel)	0.489 kg CO_2-eq/kg diesel (SimaPro)	Burning of diesel in generator set's internal combustion engine.
	(Campus fleet) Official travels: Total distance travelled, km	0.313 kg CO_2-eq/km travelled (SimaPro)	Transportation of passengers; accounts for the internal combustion engines and electric cars from different car classes; average vehicle of the different car sizes and fuel types.
Scope 2 Electricity consumption	MMCL campus: Rizal & ETY (building 1 and 2), Einstein (building 3), kWh	0.741 kg CO_2-eq/ kWh (SimaPro)	Dataset for Philippines electricity mix.
Scope 3 Solid waste	Total solid waste, kg	Emission factor of each type of waste (US EPA)	Waste generated from operations; specific waste type treatment and disposal methods.

Due to the limited data available at the academic institution, globally valid data that falls under similar conditions and emission standards of the country shall be considered. The primary sources of information for this study, including activity and consumption data, were from several academic departments and organizational authorities of MMCL, along with literature and public databases to acquire secondary data. In addition, assessment considered the quality, reliability, completeness, and temporal scope of the data to generate a qualitative analysis of the data.

2.3 Impact assessment

MMCL's carbon footprint was calculated using the Intergovernmental Panel on Climate Change (IPCC) damage assessment approach and global warming potential (GWP) characterization. The GWP is expressed in kilograms of carbon dioxide equivalents (kg CO_2-eq) per kilogram of emissions over 100-y time horizon.

2.4 Data Collection and Carbon Footprint Calculations

The study collected data from 2018 to 2022 from various non-academic offices and relevant organization authorities, including each scope and campus population (students and staff members) data. Complete data was only obtained for Scope 2 emissions. The study obtained raw data for Scope 1 (fuel consumption) and Scope 2 (electricity consumption). Total carbon emissions were calculated based on the specified operational boundaries. Information on campus's generator sets from 2020 to 2022 contains the capacity, usage frequency, and fuel consumption (in litres) during power outages. The generator sets are subjected to weekly maintenance lasting around five minutes to ensure their quality and efficiency. The computation for the carbon emission of Scope's 1 fuel consumption of the generator set is represented by Eq(1):

$$C_{S1(genset)} = \sum(F_{genset} \times EF) \quad (1)$$

Where $C_{S1(genset)}$ is the carbon emission of *Scope's* 1 fuel consumption of the generator set (kg CO_2-eq*),* F_{genset} is the fuel consumption of the generator set (kg diesel), and *EF* is the emission factor (kg CO_2-eq/kg diesel).
The campus has seven service vehicles that operate on either gasoline or diesel and are used to transport students and campus personnel. The study collected data for official travel for the year 2022, including records of destinations and vehicle types. The study used Google Maps to determine the total distances, including their return travels. The carbon footprint for Scope's 1 fuel consumption from official travels was determined using Eq(2):

$$C_{S1(OT)} = \sum(d \times 2 \times EF) \quad (2)$$

Where $C_{S1(OT)}$ *is* the car*bon emission of fuel consumption from official travels* (kg CO_2-eq*), d* is the distance from MMCL campus to the specified destination (km) multiplied by 2 to account for the return trip, and *EF* is the emission factor (kg CO_2-eq/km).
Electricity emissions correspond to indirect GHG emissions brought on by purchased electricity, steam heat, or cooling. These emissions are accounted for in an organization's GHG inventory as a by-product of energy consumption, even though they occur at the generation source. MMCL's operations rely on electricity for lighting, equipment, electronics, water distribution, and generator sets. An electric service provider supplies electricity for the academic institution's facilities, with data provided in kilowatt-hours (kWh) per month from 2018 to 2022. Eq(3) represents the computation for *S*cope 2, electricity consumption:

$$C_{S2} = \sum(e \times EF) \quad (3)$$

Where C_{S2} is the carbon emission of Scope's 2 electricity consumption (in kg CO_2-eq), *e* is the electricity consumption (in kWh), and *EF* is the emission factor (in kg CO_2-eq /kWh).
Scope 3 emissions are generated by operations not owned or controlled by the reporting institution, which indirectly influence its value chain, contributing to the institution's carbon footprint. The study considered solid waste as part of Scope 3 emissions. The raw data collected included the weight and composition of solid wastes but lacked the percentage composition of the wastes. The studies used surrogate data from Elayan et al. (2019), who proposed a study on the characterization of solid wastes at the University of Science and Technology of the Southern Philippines in Cagayan de Oro Campus, and it includes the composition and percentages needed for complete calculations and accurate results. The calculation for the carbon emissions of Scope's 3 solid wastes is represented by Eq(4):

$$C_{S3} = \sum(m \times \%C \times EF) \quad (4)$$

Where C_{S3} *is* the carbon emissions of Scope's 3 solid waste (in kg CO_2-eq), *m* is the mass of solid waste generated (kg), *%C* is the percent composition of the specific waste, and *EF* is the emission factor (in kg CO_2-eq/kg solid waste).

3. Results and discussion

The study developed a consumption-based carbon footprint of MMCL during the pandemic, resulting to a total carbon footprint of 614,553 kg CO_2-eq, with 98.49 % of emissions from Scope 2, 1.16 % from Scope 1, and 0.34 % from Scope 3. The findings show that due to pandemic restrictions, hybrid learning became the primary learning modality, resulting in adjustments in campus activities from 2020 to 2021. MMCL's carbon footprint showed a comparable trend in Scope 2 emissions to a UK university's during the lockdown. The findings suggest a potential reduction in MMCL's total carbon footprint during online learning throughout the pandemic.
The study assessed Scope 1 emissions from fuel consumption in official travel and campus generator sets, resulting to a total carbon footprint of 7,154.99 kg CO_2-eq. Official travels primarily contributes to transportation-related emissions, with other activities like food and accommodations are considered negligible. Seven service vehicles fueled by gasoline or diesel generate emissions, influenced by fuel types and distances travelled for academic or administrative purposes. A report from the non-academic office for 2022 includes campus fleet use, with a total distance travelled of 20,958.26 km, resulting in a total carbon footprint of 6,559.93 kg CO_2-eq. Recommendations to mitigate emissions include prioritizing accessible locations, reconsidering travel methods, and promoting virtual participation in meetings. Diesel emissions from generator sets accounted for around 8.32 % of Scope 1 emissions. Differences in fuel consumption and emissions depend on power outage frequency in a specific year, with fewer outages in 2021 and none in 2022, which resulted to reduced emissions from generator sets. Despite no electricity loss in 2022, regular weekly maintenance still consumes no less than a thousand Liters of diesel, contributing to emissions.
For Scope 2 emissions, focusing on electricity consumption of the campus from 2018 to 2022, the total campus electricity consumption during the specified period was was 6,009,200 kWh, with an average of 890,563.44 kg CO_2-eq of GHG emissions produced annually. Buildings 1 and 2 accounted for 82.41 % of the campus's net consumption. The carbon footprint of Scope 2 emissions was higher pre-pandemic, slightly decreasing during the pandemic due to online and hybrid learning modes. Figure 2 shows that the carbon footprint of Scope 2 emissions and electricity consumption was significantly higher before the pandemic, with a slight decrease during the pandemic period due to the adoption of online and hybrid learning modalities. Operations at MMCL revolve around electricity, particularly in administrative buildings such as buildings 1 and 2. Variations in energy use are attributed to differences in infrastructure efficiency, with older buildings like buildings 1 and 2, requiring more electricity. Expansion of campus buildings also contributes to increased emissions. Factors such as high CO_2 emissions from the Philippines electricity mix and high share of coal-based electricity further contributes to emissions. Implementing energy management systems and transitioning to renewable energy sources are suggested for emission reduction strategies.

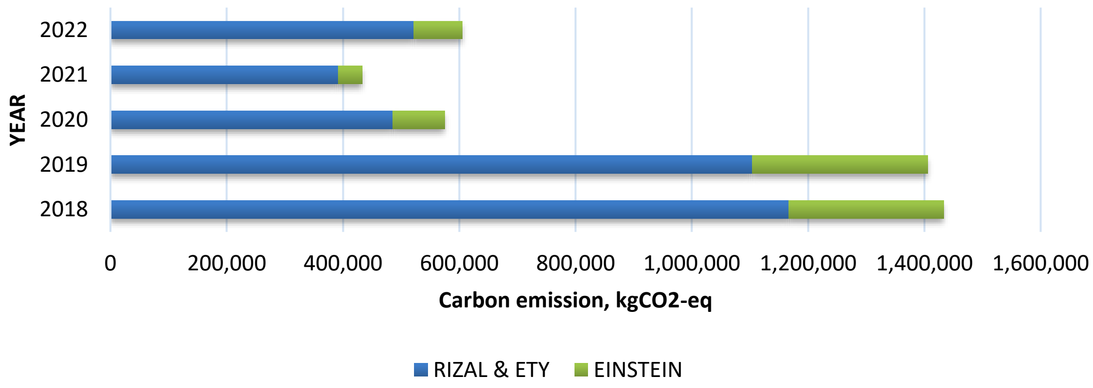

Figure 2: Carbon footprint of Scope 2 (Electricity consumption)

In 2022, the total carbon footprint of indirect emissions due to solid waste was 2,119.68 kg CO_2-eq, with a total mass of 4,224.9 kg. The pandemic resulted to minimal waste production due to the campus typically unoccupied. Prior to the pandemic, MMCL lacked solid waste production data, with records only available for 2022. Surrogate data from Elayan et al. (2019) was used due to insufficient weight percentage data for solid waste types. Organizational events on campus can influence waste generation, with factors such as population size and food consumption patterns impacting emissions. Trends suggest a decrease in paper waste due to the reliance on digital devices, while home-cooked meals reduce packaging waste. Figure 3 illustrates the carbon footprint of specific solid wastes. The study applied the landfill disposal approach for emissions and emission factors, adhering to the IPCC method for solid waste disposal.

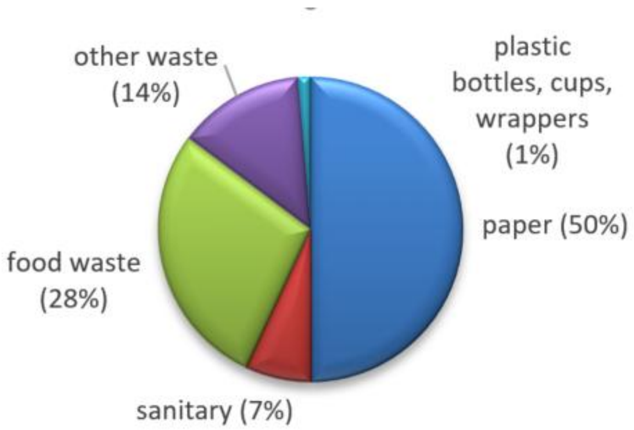

Figure 3: Carbon footprint of Scope 3 by types of solid waste

4. Uncertainty

This study used a streamlined LCA, omitting stages and focusing only on the consumption of each emissions source, which could generate uncertainties. The qualitative analysis approach described in studies by Clabeaux (2017) and Cortes et al. (2022) was carried out to evaluate data quality and analyse the reliability of the results, minimizing data uncertainty (Table 2). The data sources were evaluated using a pedigree matrix approach by Weidema and Wesnaes (1996), with varying degrees of uncertainty assessed through data quality indicators (DQIs), ranging from 1 to 5, representing categories from low to high uncertainty. Low uncertainty is attributed to direct measurements that is readily available and collected from statistics; medium uncertainty to data collected from alternative statistics; and high uncertainty to projections, estimates, and assumptions based on factual data. Scopes 1 and 3 for years prior to 2022 were not entirely representative, as only data and information were accessible from the academic institution and for the year 2022, showing limitations in data availability. A comparative analysis of the carbon footprints of the three learning modalities was only conducted for Scope 2 and annual trends are needed for future studies because year-to-year patterns may fluctuate. Some activities were based on assumptions, and the basis for specific wastes in solid wastes was derived from surrogate data. Obtaining LCA data for individual activities and processes of MMCL may provide a deeper insight into GHG emissions.

Table 2: Uncertainty analysis

Scope	Indicator Element	DQI	Explanation
Scope 1 Fuel consumption	Reliability	2	Data partially based on assumptions for official travel.
	Temporal correlation	1	Data collected are from 2020 to 2022.
	Geographical correlation	1	Data are from area under study.
	Technological correlation	1	Data is specific to the processes under study.
	Completeness	1	Data was collected over an adequate period to balance fluctuations
Scope 2 Electricity consumption	Reliability	1	Calculated data based on recorded electricity bills.
	Temporal correlation	1	Data are from 2018 to 2022.
	Geographical correlation	1	Data are from area under study.
	Technological correlation	1	Data are from processes under study.
	Completeness	1	Data collected covers an entire year; sufficient time to balance fluctuations.
Scope 3 Solid waste	Reliability	2	Data collected on amount of solid waste from the office.
	Temporal correlation	2	Less than 6-year difference for waste characterization.
	Geographical correlation	3	Data from area with similar conditions.
	Technological correlation	2	Data from processes under study but from different enterprise.
	Completeness	1	Representative data from varied sites and period.

5. Conclusions

This study conducted a streamlined LCA to determine the carbon footprint of MMCL, focusing on apparent GHG emissions from fuel consumption, electricity consumption, and solid waste. Higher education institutions like

MMCL are required to develop a GHG emissions inventory, identify carbon emission reduction plans, and assess GHG emissions in terms of CO_2 equivalents in response to the rising GHG emissions that contribute to global warming. The total carbon in 2022 was 614,553 kg CO_2-eq, with Scope 2 emissions (electricity consumption) having the largest contribution, followed by Scopes 1 and 3. The study identified the campus's electricity use as the primary emissions source, as air conditioning and lighting systems consume a significant amount of electricity. The pandemic and shift to online learning reduced emissions per activity, particularly in Scope 2. With face-to-face classes resuming, MMCL must investigate mitigation strategies to reduce its emissions. The study suggests strategies for reducing carbon footprints, focusing on electricity consumption and solid waste. The environmental impacts of organizational processes and activities are assessed using LCA methodologies and standards. These effects are caused by GHG emissions from consumption-based activities and processes which have an adverse effect on human health, ecosystems, and resource scarcity. The findings from this study provide insights for GHG reduction efforts and can serve as a basis for Philippine and global universities. Despite data limitations, GHG inventories are feasible through data sets from the US EPA, IPCC, and other sources that offer default emission factors. This study highlights carbon-intensive activities and how they are influenced due to changes brought by the pandemic, emphasizing the importance of quantifying emissions for sustainable goals and practices among HEIs and organizations.

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