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Assessment of entity level greenhouse gas emissions: A case in Northwestern Mindanao State College of Science and Technology, Tangub City, Misamis Occidental, Philippines

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Abstract

Institutions and universities are considered as one of the main contributors of greenhouse gas (GHG) emissions. Northwestern Mindanao State College of Science and Technology (NMSCST) is among the institutions in Northern Mindanao that is perceived to emit relevant amount of GHGs from its different sources. This study therefore aimed to quantify the GHG emissions of NMSCST by utilizing the GHG Protocol Guidelines of 2006. Results revealed a total emission of 655.35 tCO_2e covered by Scope 1 and Scope 2. Among the categories under Scope 1 emissions, cooking and heating activities got the highest emissions with the total of 102.52 tCO_2e. On the other hand, Scope 2 emissions, which are associated with power use, were found to be the largest source contributing 446.25 tCO_2e to the total, or 68% of emissions. Overall, this study highlights the significant GHG emissions at NMSCST, particularly in the areas of cooking and heating emissions and electricity consumption. The findings of the study emphasized the importance of implementing eco-friendly practices to eventually reduce emission patterns of NMSCST and promote a more sustainable future.

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Introduction

The increase in energy consumption worldwide has outpaced efficiency gains and the use of cleaner energy sources, leading to a steady rise in greenhouse gas emissions (Le Quéré *et al.,* 2013). Carbon dioxide (CO_2) is the GHG with largest release accounting for approximately 75% of total emissions and exhibiting a prolonged presence in the atmosphere (Nunez, 2019). Around 10 Pg of atmospheric carbon is released each year through the combustion of fossil fuels, resulting in historically high global background surface CO_2 concentrations of 410 ppm (Oda *et al.,* 2018). Methane (CH_4) came second as the most prevalent gas in the atmosphere accounting for about 20% of global anthropogenic emissions (United States Environmental Protection Agency, 2023). Furthermore, nitrous oxide (N_2O), as highlighted by Myhre *et al.* (2013), holds the notable distinction of being the third-most-important and long-lived greenhouse gas, emphasizing its significant contribution to environmental effects. This is further reinforced by the fact that N_2O, primarily originating from agricultural activities, contributes for approximately 6% of the total emissions (IPCC, 2014).

The Intergovernmental Panel on Climate Change (IPCC) Working Group III (WG3) categorizes global greenhouse gas (GHG) emissions sources into energy systems, industry, buildings, transportation, and AFOLU (agricultural, forestry, and other land uses) (Lamb *et al.,* 2021). Over the years, worldwide GHG emissions have shown substantial growth, reaching an alarming 48.94 Gt of carbon dioxide equivalent ($GtCO_2e$) since 1990 (WRI and WBCSD, 2004). In 2021, the transportation sector has taken the lead as the largest emitter of greenhouse gases, responsible for 28% of global releases (Skea *et al.,* 2022). Electric power production ranks second releasing a portion of 25% of all the emissions (United States Environmental Protection Agency, 2023). While, industry emissions claim the third spot on the list, producing over 23% of worldwide emissions (Skea *et al.,* 2022). These emissions were all attributed to the widespread use of fossil fuels in the transportation fleet, electricity generation, and chemical processes involved in the production of materials such as metals, chemicals, and cement (Salvi and Subramanian, 2015; Davis *et al.,* 2018). The aforementioned sectors together pose a considerable threat in terms of accumulated emissions, highlighting the dire need for concerted measures to reduce the adverse impact, which is backed by an established goal of providing support and guidance for sustainable practices (IPCC, 2014).

At the national and international levels, various organizations, institutions, governments, and groups are working to reduce emissions and achieve carbon neutrality (Ball *et al.,* 2009; Zhou *et al.,* 2022). The World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) have collaboratively established a GHG protocol and supporting website to assist organizations in measuring their carbon footprint. The protocol defines carbon footprint inventories in tiers, starting with " Scope 1" focusing on direct emissions, expanding to "Scope 2" including emissions from energy inputs, and lastly, ''Scope 3'' which is optional, accounting for other indirect activities. These tiers enable comprehensive assessment, emission reduction identification, and alignment with international standards (WRI and WBCSD, 2004; Kokoni *et al.,* 2014).

Education is identified as a crucial catalyst for promoting environmental protection and conservation (Lozano *et al.,* 2015). Educational institutions, particularly universities, play a pivotal role as knowledge hubs, fostering scientific progress and disseminating impactful information to diverse segments of society (Purcell *et al.,* 2019). Further, institutions of higher education have the responsibility to become forerunners for climate-friendly practices and should aim at sustainable practices on their premises and in their operations (Kiehle *et al.,* 2023). These include the Northwestern Mindanao State College of Science and Technology (NMSCST), one of the higher learning institutions in the Province of Misamis Occidental. Similar to any institutions, the College's infrastructure resembles self-contained communities, with cafeterias, classrooms, library, laboratories, and healthcare facilities. Thus, these contribute to greenhouse gas emissions from multiple sources, including energy consumption, waste management, vehicle fleet, and procurement practices (Sun *et al.*, 2020; Kiehle *et al.*, 2023). These releases are anticipated to elevate as the College is required to provide an adequate number of physical facilities, laboratory equipment, and instructional resources imperative to meet the standards for University hood status.

Further, NMSCST faces challenges in addressing greenhouse gas emissions due to the absence of detailed study on particular sources of emission and a complete GHG accounting on the school premises. To bridge this knowledge gap, researchers undertook a comprehensive study aimed at quantifying the total GHG emissions of NMSCST, specifically; identifying the sources of GHG emissions resulting from the College's operations, quantifying emissions generated by each source, and determining the highest contributor to emissions within the institution. The results of this study will provide a baseline data for NMSCST to track its emissions in the following years and subsequently minimize carbon footprint. Similarly, to make valuable contributions to the broader academic and practical discourse on GHG emissions in educational institutions, fostering the adoption of eco-friendly practices, promoting a more sustainable future, and enhancing its understanding of emission patterns.

Material and methods

Locale of the study

Northwestern Mindanao State College of Science and Technology (NMSCST) is situated in Labuyo, Tangub City, Misamis Occidental, at approximately 8° 4' North longitude, 123° 43' East latitude with an elevation estimated at 17.9 meters or 58.7 feet above mean sea level and covers an area of 12 hectares (Fig. 1). To meet the different educational needs of its students, the institution provides a wide range of academic programs and courses in science, technology, engineering, mathematics, and other related areas.

In the year 2022, the institution has 201 faculty members. The campus consists of 41 buildings, including the Administration Building, Information Technology (IT) Building, School of Teacher Education (STE) Building, School of Arts and Sciences (SAS) Building, (School of Business Administration and Management) SBAM Building, School of Engineering Technology (SET) Building, School of Agriculture and Environmental Sciences (SAES) Building, two multi-purpose gymnasium, library, a student lounge, cafeteria and a canteen, providing students with a wide range of amenities. Furthermore, specialized Science Laboratories and department facilities are outfitted with modern resources to cater to the students' academic interests.

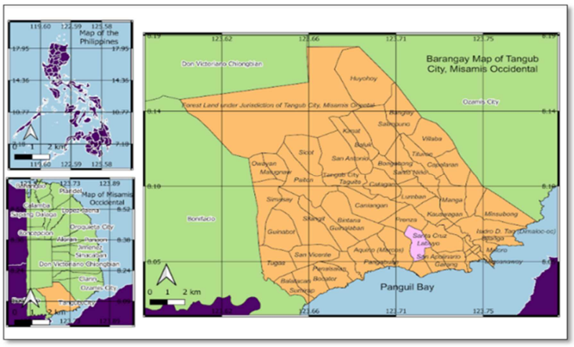

Fig. 1. The right-side map shows the City of Tangub highlighting Barangay Labuyo where NMSCST is located. Inset maps are the Philippines (upper left) and the Province of Misamis Occidental (lower left).

In the same year, the College has a total student population of 4,540. It also has a specific Administrative Team of 59 persons, an Income Generation Program (IGP) staff of 12 persons, and a total of 26 Administrative Professionals. Additionally, the university employs and contracts personnel such as coaches (3), security guards (26), technicians (5), farm laborers (6), carpenters (9), and maintenance staff (29).

Organizational and operational limits

To establish the measurement framework, the study adopted the methodology outlined by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI), commonly known as the GHG Protocol (Varón-hoyos *et al.*, 2021).

The greenhouse gas (GHG) emissions that need to be considered were established based on specific boundary conditions. These boundary conditions include both the "organizational boundaries," which pertain to the facilities control and equity shared, and the "operational boundaries," relating to the specific sources of emissions covered by the organizational boundaries (Lau and Dowlatabadi, 2011).

In line with the definition of operational and organizational boundaries and the quantification of emission sources, the guidelines provided by the ISO 14064-1: 2018 standard was utilized to support the process (Cano *et al.*, 2023). In addition, the data collection process involved obtaining information from key offices within NMSCST as presented in Table 1.

Table 1. Organizational and operational boundary classification of NMSCST

Scope	Category	Sources/Activity	Data needed	Units	Data sources
1	Mobile combustion	Vehicles	Fuel consumption	Liters (Diesel)	Supply Office
		Grass cutter	Fuel consumption	Liters (Gasoline)	Supply Office
	Stationary Combustion	Generator	Fuel consumption	Liters (Diesel)	Supply Office
		Kitchen (Cooking/ Heating)	Liquefied Petroleum Gas (LPG) tank consumption	Kilograms	Accounting Office
2	Electricity Consumption	Power/Energy use	Monthly electricity consumption	Kilowatt per hour consumption	Accounting Office
3	Solid Waste	Waste generation	Waste composition	Kilogram per day	No data available

Table 2. Emission factors of greenhouse gas based on IPCC guidelines (2006)

Emission sources	Activity/Fuel type	CO_2 (kg/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Mobile combustion	Road transportation (Diesel)	74100	3.9	3.9
	Grasscutter (Gasoline)	69300	10	0.6
Stationary ombustion	Generator (Crude Oil)	74100	10	0.6
	LPG	69100	5	0.1

Data analysis

Emission calculations and conversion factor

The total CO_2e emission from the fuel consumption of Northwestern Mindanao State College of Science and Technology (NMSCST) in year 2022 was carried out using the calculation of Emission Factors(EF) that refer to the Intergovernmental Panel Guidelines on Climate Change (IPCC) for the 2006 National Greenhouse Gas Inventory (Table 2).

Mobile combustion

Emissions can be calculated using the amount of fuel consumed. Tier 1 for CO_2, CH_4, and N_2O computation is presented in Equation 1 by multiplying the predicted fuel consumption by a default emission factor (IPCC, 2006).

$$Emission = \sum_a [Fuel_a * EF_a] \quad (1)$$

Where:

Emission = Emissions of CO_2/ CH_4/N_2O (kg)

$Fuel_a$ = fuel consumption (TJ)

EF_a = emission factor (kg/TJ).

a = type of fuel (kg/TJ)

Stationary combustion

Equation 2 refers to the formula used when calculating estimates of emission from stationary sources. The default emission factors were established based on the expert analysis of an extensive group of inventory experts and are currently regarded as legitimate (IPCC, 2006).

$$Emissions_{GHG,\,fuel} = Fuel\ Consumption_{fuel} * Emission\ Factor_{GHG,\,fuel} \quad (2)$$

Where:

$Emission_{GHG,\,fuel}$= Emissions of CO_2/ CH_4/N_2O (kg)

Fuel Consumption= amount of fuel combusted (TJ)

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

Further, the accounting in this study focuses on the three most prevalent greenhouse gases (GHGs)- carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)- as outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. To standardize the measurement of greenhouse gases (GHGs) and express their impact in terms of carbon dioxide (CO_2) equivalence, the Global Warming Potential (GWP) is utilized (IPPC, 2014) as shown in Table 3. The GWP is a metric that scientific and regulatory communities rely upon when conducting environmental life cycle assessments and carbon footprint estimates (Andersen *et al.,* 2021) and its values are used to convert emissions of various gases into equivalent CO_2 emissions such as methane (CH_4), nitrogen oxides (N_2O).

Table 3. Global warming potential of the greenhouse gases (IPCC, 2014)

Common name	Chemical formula	Global warming potential (CO_2e)
Carbon dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265

Power consumption

There are several aspects to consider when calculating Scope 2 emissions, which relate to indirect greenhouse gas (GHG) emissions caused by the use of purchased power, heat, or vapor. In this case, necessary data were provided by the institutions' accounting department, while the 2017 grid emission factor for Mindanao was obtained from the Department of Energy (DOE, 2020).

$$\text{Emission (tons}CO_2\text{)} = \text{Activity Data} * \text{Grid Emission Factor} \quad (3)$$

Results and discussion

NMSCST's scope 1 emissions

The study primarily focused on Northwestern Mindanao State College of Science and Technology (NMSCST). As it prepares to become a university, the number of students is anticipated to escalate subsequently contributing to the increased usage of vehicles for administrative transactions, educational tours, community outreach, extension programs, and other academic-related activities.

Table 4. NMSCST emissions from mobile, stationary, and cooking and heating sources

Scope 1	Activity Data	Annual Consumption	tCO_2e	Total tCO_2e
Mobile	Vehicles fuel consumption	7,611.5 liters (Diesel)	91.75	97.61
	Grass cutter	520 liters (Gasoline)	5.86	
Stationary	Generator	746 liters (Diesel)	8.98	111.50
	Cooking/Heating activities	10,009 kg	102.52	
Total				209.11

As reflected in Table 4, it was estimated that in the year 2022, the mobile category accounts for the larger share with an annual fuel consumption of 7,611.5 liters of diesel, accumulating a total tCO_2e of 91.75. These emissions come from the six vehicles acquired by the College for more than five years. According to Hao *et al.* (2000), older vehicles or those equipped with outdated emission control technologies tend to have higher emissions. Similarly, Wang *et al.* (2015) stated that vehicles with lower fuel efficiency tend to consume more fuel, resulting in higher accumulation of emissions. Meanwhile, the emissions associated with the grass cutter utilizing 520 liters of gasoline contribute to approximately 5.86 tCO_2e. According to Kareem, 2015, a lawn mower or known as a grass cutter machine is the most common machine that found in market due to its availability and low cost too. It was highlighted by the study of Banks and McConnell (2015), that gasoline-powered lawnmowers are significant contributors of GHG (particularly carbon dioxide, methane, and nitrous oxide), as well as air pollutant emissions (such as volatile organic compounds, carbon monoxide, nitrogen oxide, airborne particulate matter, and sulfur oxides).

Within the stationary category, the data provided indicates emissions from two sources: one generator and 11 tanks of LPG for cooking and heating. The generator's annual diesel fuel consumption of 746 liters results in approximately 8.980 tCO_2e. According to the study conducted by Varon-Hoyos *et al.* (2021), carbon emissions from this section are mainly explained by the consumption of fossil fuels from stationary sources (such as diesel in emergency electricity generation plants and natural gas in restaurants and laboratory equipment). Furthermore, according to Ologun and Wara (2014), fuel consumption by generators contributes an estimated 145.8 tons of CO_2 emissions to the University's carbon footprint, assuming a daily consumption of 7 liters of petrol during the specified working hours. Further, the highest numbers of students are enrolled in Hospitality Management under the School of Business and Administration Management (SBAM) with the addition of Food Technology students under the School of Engineering and Industrial Technology (SEIT). These programs both utilized the functional areas of the College such as the kitchen, food court, and coffee lounge that contributed to the increased consumption of LPG (Liquefied Petroleum Gas). LPG, a versatile fuel consisting of propane and butane began to be used in the early 1900's for cooking, heating, power generation, and transportation, LPG to fuel stationary torches (Unnasch and Goyal, 2017). Compared to gasoline and diesel fuel, LPG emits significantly lower levels of carbon dioxide (CO_2) upon combustion, with propane emitting about 12.61 pounds and butane emitting about 14.7 pounds of CO_2 per gallon, making LPG a more environmentally friendly option (Smoot, 2023). However, emissions from cooking and heating activities have the highest amount of emissions with 102.52 tCO_2e. This is attributed to a greater fuel consumption considering the number of students enrolled under the SBAM plus Food Technology students which utilize LPG for their laboratory activities accounting to 10, 000 kg of LPG used in year 2022. Overall, the direct emission from Scope 1 is 209.11 tCO_2e.

NMSCST's scope 2 emissions

As the institution's population grows, infrastructure development such as the construction of new buildings results in elevated electricity consumption. The provided data in Table 5 presents the monthly electricity consumption and corresponding greenhouse gas (GHG) emissions of NMSCST in year 2022. It is evident that electricity consumption fluctuates throughout the year. Electricity usage has risen steadily, from 39,122 kWh in January to 47,931 kWh in December.

The range of consumption from highest to lowest encompasses over 22 megawatts, which might be attributed to several trends. The cumulative GHG emissions for the year is 446.24 tCO2e providing an overall measure of NMSCST's carbon footprint from electricity consumption. In particular, the highest consumption is observed in June with 58,127 kWh yielding to 46.04 tCO_2e of emissions. While the lowest power consumption was on the month of March with 36,180 kWh noting the lowest emissions of 28.66 tCO_2e. The peak consumption in June is attributed to the transition of the delivery of instruction from online to face-to-face classes. Activities such as mid-year classes, enrolment period and other academic events likely contributed to increased electricity usage. As these would entail the use of different learning facilities and resources such as computer unit, projector, smart TV, electric fan, air conditioner, and lights. Likewise, the construction of the new library building and student center has started. This is supported by the study of Hatlelid and Aass (2016) stating that power supply in schools allows the use of multimedia tools and better preparation underscoring that electricity access is an important measure for attracting highly skilled teachers to work in rural schools. Other reasons for electrification at school were modern communication skills with computer classes for students, easier preparation and revision of homework and exams, improved security (guard lights), use of electronic teaching materials, and phone and radio charging at school for teachers (Lenz *et al.*, 2017).

Table 5. NMSCST emissions from monthly purchase of electricity.

Month (2022)	Electricity Consumption (kWh)	Megawatt	Total GHG Emission (tCO_2e)
January	39,122	39.12	30.99
February	41,166	41.17	32.61
March	36,180	36.18	28.66
April	43,865	43.87	34.75
May	43,267	43.27	34.27
June	58,127	58.13	46.04
July	50,842	50.84	40.27
August	50,228	50.23	39.79
September	52,885	52.89	41.89
October	52,291	52.29	41.42
November	47,452	47.45	37.59
December	47,931	47.93	37.97
Total	563,361	563.37	446.25

On the contrary, the most notable trend is the decline in power use in the month of March. This power reduction is ascribed to the work-from-home arrangement and absence of face-to-face learning. This finding aligns with the study conducted by Cortes *et al.* (2020), which observed a significant drop in CO_2 emissions during the pandemic, indicating the influence of changes in educational activities on energy consumption. Similarly, Yin *et al.* (2022) reported decreased electricity consumption and emissions in Chinese universities due to the shift toward online education. While, Gaspar *et al.* (2022) emphasized the significant environmental impact of building energy consumption, whether occupied or unoccupied, is particularly relevant during lockdown periods. Despite this, emissions from the electricity consumption category remain a major contributor to carbon releases in NMSCST since the full implementation of the in-person class started on the month of August 2022.

Highest contributor relative to the college's total emissions

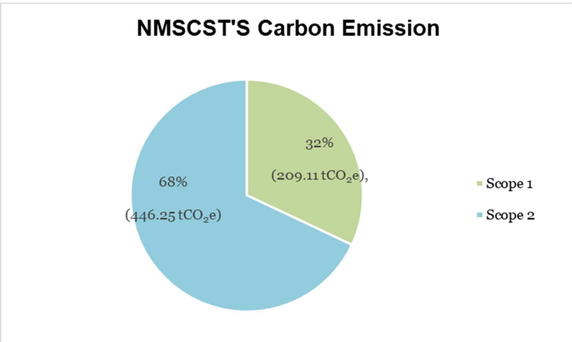

Fig. 2. Percent distribution of carbon emission in NMSCST from different sources

As seen in Fig. 2, the total emissions were 655.35 tCO_2e, with Scope 1 emissions accounting for 32% (209.11 tCO_2e). These emissions primarily originated from direct sources including mobile combustions, stationary sources, and emissions generated from food service areas such as the kitchen and coffee lounge. On the other hand, Scope 2 emissions were the highest contributor, accounting for 446.25 tCO_2e or 68% of the total emissions. This can be linked to the number of structures in NMSCST, especially considering the presence of electronic device appliances including air conditioners, televisions, fans, and laboratory equipment. Furthermore, the act of keeping the light on at night for security purposes, as well as the behavior of individuals in terms of consumption, contributes to the situation, as does the use of inefficient energy input in place. The findings of Aroonsrimorakot *et al.*, 2013 study revealed a similar finding, having electricity identified as the primary source of emissions attributed to activities such as teaching and learning, as well as the use of electrical equipment in offices attaining about 869.62 tCO2e. Roa (2022) further expands on this, highlighting Scope 2 emissions as the largest contributor, obtaining a total GHG emission of 24.7135 tCO2e or 99.086% which may be influenced by the institution's numerous buildings. As is true for most campuses, electricity constitutes the single largest source of GHG emissions (Yasukochi, 2007). Energy costs are significant because they are directly tied to the institution's basic operations (Moerschbaecher and Day, 2010).

Overall, total emissions for the year 2022 were calculated to be 655.36 tCO2e, which included Scope 1 and 2 emissions. The findings emphasize the importance of addressing direct and indirect emissions, particularly Scope 2, while also recognizing the importance of evaluating and managing Scope 3 emissions. UP Cebu, on the other hand, showed a substantial reduction in emissions during the COVID-19 pandemic where in the year 2019 it is estimated to be 1420.7 tCO2e, and in 2020, UP Cebu reduced emissions by 60.9% to 555.8 tCO2e (Cortes *et al.,* 2022). These findings highlight the need to continuously track and control emissions while also being ready to adapt to fluctuating conditions.

Conclusion

In conclusion, this study conducted at NMSCST provides a comprehensive assessment of greenhouse gas emissions, focusing on identifying sources, quantifying emissions, and determining the major contributors within the institution. These emissions were categorized into Scope 1, 2, and 3, representing direct emissions (mobile and stationary combustions, and cooking and heating activities), indirect emissions from electricity consumption, and other indirect emissions, respectively. The study revealed that the total emission of tCO_2e was 655.36 which covered by Scope 1 and 2. Furthermore, among the Scope 1 emission sources, cooking and heating activities got the highest contribution to greenhouse gas emissions with an annual consumption of 10,009 kg, accounting for a total emission of 102.52 tCO_2e than mobile combustion. It is also indicated that Scope 2 emissions accounted for the largest share of greenhouse gas emissions, totaling 446.25 tCO_2e, representing approximately 68% of the total emissions. These findings provide valuable insights for NMSCST to develop targeted strategies aimed at reducing greenhouse gas emissions to create a more environmentally friendly campus.

To address this, it is recommended that NMSCST undertake a Waste Analysis and Characterization Study to account for Scope 3 sources that could provide a more accurate carbon footprint analysis of the institution. Additionally, the NMSCST should enhance procurement practices by choosing more efficient facilities and equipment, such as vehicles with improved fuel economy. Lastly, sustainable practices must be implemented to reduce the fuel and energy consumption of the campus. This could include actions such as installing solar panels, using alternative fuel, and planting trees within the campus. By implementing these recommendations, the NMSCST can make a significant improvement in reducing its emissions and transitioning into a sustainable and environmentally conscious institution. These efforts not only help the environment but also reinforce the institution's vision of fostering a culture of innovation and sustainability in the quality of lives in the community it serves.

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