Carbon Footprint Review in Higher Learning Environment towards Campus Sustainability

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Abstract

The greenhouse gas emissions on the campus are directly or indirectly caused by activities or accumulated over the life stages of the product or services, expressed by Carbon Dioxide. The six leading gases that contribute to the carbon emissions in the atmosphere are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF). This paper aims to identify methods for evaluating the carbon footprint on the campus and its database and creates a theoretical framework for a sustainable campus in the local context of the higher learning environment of Malaysia.

Keywords: Carbon dioxide; carbon footprint; environment; sustainable campus

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1.0 Introduction

The carbon footprint is defined as a measure of human activities' impact on the environment in terms of the number of greenhouse gases produced, measured in units of carbon dioxide (CO2) (Wright et al., 2011). Many human activities place demands on the planet's capacity, including providing and processing food, constructing and maintaining housing, transportation, and the consumption of goods and services (Wackernagel & Kitzes, 2019). Global warming occurs when CO2 and other air pollutants and greenhouse gases collect in the atmosphere and absorb sunlight and solar radiation that have bounced off the Earth's surface (Filonchyk et al., 2024; Brahimi et al., 2023; Misni, 2016; MacMillan, 2016). There are a total of 18 greenhouse gases with different global warming potentials. According to UNFCCC (2011), six gasses are considered in the category of carbon accounting. It consists of Carbon dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6). One significant way of combatting climate change is by reducing greenhouse gases emitted into the atmosphere (UNEP, 2024).

In this study, the GHG Protocol Corporate Standard, provided by the World Resources Institute and World Business Council for Sustainable Development (GGP, 2004), will be used as a standard and guideline for the carbon footprint inventory. This standard is written primarily from the perspective of a business developing a GHG inventory. It also applies equally to other organizations with operations that give rise to GHG emissions, such as government agencies and universities. It also involves identifying carbon emissions associated with its services, categorizing them as direct and indirect emissions, and choosing the scope of accounting and reporting for indirect emissions.

As higher institutional learning, many universities globally are practising sustainable campuses by reducing greenhouse gas emissions, which harm the campus environment (Aghamolaei & Fallahpour, 2023). Universities can influence students' personal and professional decisions and future environmental impacts through their education and use the University as a role model (Misni et al., 2020; Clarke & Kouri, 2009). Large universities have emissions profiles similar to small cities (Knuth et al., 2007). Geng et al. (2013) determined that universities should also play an active role in society's move towards emissions reduction. Alghamdi et al. (2019) and Silva et al. (2024) added that universities should positively impact the reduction of their greenhouse gas emissions on society, as opposed to any other public sector. Universities should contribute to a sustainable campus environment.

Moreover, Versteijlen et al. (2017) also stressed that higher education institutions should be responsible for controlling carbon emissions to provide a clean, healthy, and sustainable campus environment. Generally, universities produce a carbon footprint through goods and services, transportation, and energy within the campus area envisaged to contribute significantly to its carbon footprint (Letetel et al., 2011). This study will first classify them in terms of source and significance to reduce greenhouse gas emissions and quantify carbon footprint in the campus area. Measuring the carbon footprint makes this possible. Thus, this study will determine the source of the University's carbon footprint while using these sources to quantify the carbon footprint on the campus and study the methods to build a carbon emission database.

This paper aims to review approaches to quantifying carbon footprint on campus, with the objectives of identifying suitable methods/approaches in evaluating carbon footprint on the campus and then determining the variables/attributes for the carbon footprint database. The specific sources of the carbon footprint on campus are transportation, electricity production, industry, commercial and residential, agriculture, land use and forestry (Paredes-Canencio, 2024). Finally, this study will document carbon footprint assessment strategies that will be adopted sustainably by higher education institutions in the Universiti Teknologi MARA (UiTM), Puncak Alam, Selangor, Malaysia.

2.0 Literature Review

In order to understand the importance of a sustainable campus environment, it is necessary first to understand the actual events related to it. It includes greenhouse gases, their relationship to climate change, and the role of the carbon footprint in the goal of the future neutrality of a campus. One must first investigate the basic concepts of campus sustainability through the following important events:

2.1 Greenhouse gas effect

The greenhouse effect is how heat is trapped close to the surface of the Earth by greenhouse gases (Misni, 2015). These heat-trapping gases can be considered a blanket wrapped around the Earth, which keeps it toastier than without them (NASA, 2021). Greenhouse gases include carbon dioxide, methane and nitrous oxides (Morris et al., 2024). Carbon dioxide is a gas formed by carbon combustion and in the respiration of living organisms and is considered a greenhouse gas (GHG). Release means the emission of greenhouse gases into the atmosphere over an area and within a specified period (McGrath, 2023). Causes of carbon release include natural resources, including decomposition, ocean release, and respiration. Human resources come from factory production, deforestation, and fossil fuel combustion, such as coal, oil, and natural gas (Shahbazi & Nasab, 2016). The amount of greenhouse gases produced to support human activity is usually expressed in carbon dioxide equivalent (CO2) in carbon footprint (Selin, 2024). Fossil fuel combustion releases carbon dioxide and other greenhouse gases. This carbon production raises global temperatures by capturing more solar energy in the atmosphere.

2.2 Global warming effect

Other GHG emissions will cause continued global warming and climate change. Carbon dioxide is the primary contributor to global warming. Carbon dioxide is generated from fuel combustion, such as oil, natural gas, diesel, petrol, organic gasoline, and ethanol. This global warming has increased the average temperature on Earth (Misni, 2016; Misni, 2015). As more greenhouse gases are produced, they capture more heat in the sun, and the

Earth's surface is getting hotter (Misni et al., 2020; Misni et al., 2015). It is mainly transparent to incoming solar radiation but can still absorb longwave radiation from the Earth's surface. Earth's temperatures have warmed about 0.7 degrees Celsius in the last hundred years. Even small temperature changes can drastically affect the ecosystem, vegetation, wildlife and other aspects of ecology (Melendez-Rivera, 2013). Lechner (2000) added that the average global air temperature near the ground is expected to increase by about 1.5 to 4.5°C by 2100. An increase of 1°C will make the Earth warmer now than at least a thousand years. Global warming and climate change are expected to impact the Earth severely. Therefore, this carbon outlay contributes to global warming, which can severely affect the quality of human life and the environment.

2.3 Carbon footprint

The carbon footprint is defined as a certain amount of gaseous emissions relevant to climate change and associated with human production activities (Pandey et al., 2011). According to Larsen et al. (2013), carbon footprinting has proven to be a valid measure of direct and indirect GHG emissions. Carbon footprinting stems from "ecological footprinting," a test of the biologically productive land area required to sustain human activity (Wiedmann & Barrett, 2010). Peters et al. (2016) justified that other terms associated with carbon footprint are embodied carbon, carbon content, embedded carbon, carbon flows, virtual carbon, GHG footprint, and climate footprint.

A carbon footprint is usually expressed in several ways, including carbon emissions measured in tons or tons of CO2 equivalents. There are several definitions of a carbon footprint. However, the common denominator is that it is a form of measurement of gaseous emissions produced through the effects of greenhouse gases or emitted through daily activities (Melendez-Rivera, 2013). Although there has yet to be a consensus on measuring or quantifying a carbon footprint, leading organizations have developed tools to quantify it effectively. The carbon footprint is simply the sum of GHGs emitted that can be attributed to an activity, process, and organization/university.

2.4 Campus sustainability

Universities play a vital role in the education system by educating future leaders and contributing to sustainable campus development. Environmental issues are direct consequences of human activities. The University campus is a beehive of human activities ranging from high energy consumption, high traffic volume, intensive waste generation, infrastructural usage and many more (Ng et al., 2019). The University conducts numerous activities and operations which significantly impact the environment. Subsequently, Disterheft and Ramos (2012) also highlighted that a sustainability campus considers the operational aspects based on environmental impacts and educational aspects based on stability education.

Moreover, Alshuwaikhat and Abubakar (2008) revealed that these campus activities generate tonnes of waste, water usage and material consumption, and electricity and fuel consumption as they have many users and daily activities. Velazquez et al. (2006)

mentioned that a sustainable higher educational institution should promote the minimization of adverse environmental, economic, societal, and health effects generated by using their resources on a regional or a global level. In order to fulfil its functions of teaching, research, outreach, partnership, and stewardship to help society transition to sustainable lifestyles. The definition might differ from institution to institution, which makes campus sustainability a challenge to achieve.

3.0 Methodology

The method used is for collecting secondary data/reviewing previous research studies and current standards and guidelines. This method produces a framework or systematic research method to deal with actual data in the following research progress. The secondary collection review data are divided into two phases, as follows:

3.1 Determine organizational boundaries

According to the GHG Protocol Project Quantification Standard (GGP, 2004), the University has to determine its organizational boundaries regarding the operations that it owns or controls, such as faculties, hotels, administration offices, and cafeterias, as shown in Figure 1. After its operational boundaries are set, it then involves identifying emissions associated with its operations, categorizing them as direct and indirect emissions, and choosing the scope of accounting and reporting for indirect emissions.

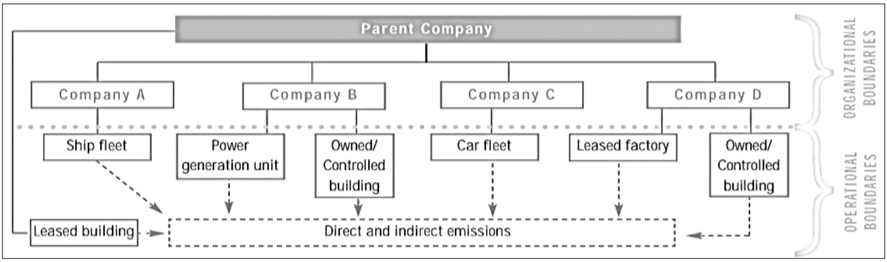

Figure 1: Organizational and operational boundaries of a company/university
(Source: GHG Protocol Project Quantification Standard (GGP, 2004))

3.2 Introduce the concept of "Scope"

The concept of Scope should be introduced to help delineate direct and indirect emission sources, improve transparency, and provide utility for different types of organizations and different kinds of climate policies and university goals. The total carbon emissions, such as a university, can be split according to three scopes. Each Scope can be subdivided into different categories. Scope 1, Scope 2, and Scope 3 are defined for GHG accounting and reporting purposes, as shown in Figure 2 (Letete et al., 2011). Scope 1 is direct GHG emissions from sources the university owns, such as emissions from combustion in controlled boilers, furnaces, vehicles, and chemical production. Next is Scope 2, which is indirect GHG emissions in electricity.

The accounts for GHG emissions are from the generation of electricity purchased by the university. Purchasing power is energy purchased, physically occurring at the facility where electricity is used—finally, Scope 3 is the indirect GHG emissions. The emissions result from the university's activities but occur from sources not owned or controlled by the university. Some examples of Scope Three events are extracting and producing purchased materials, transporting purchased fuels, and using sold products and services.

Activity data and emission factors are needed for the carbon calculation for each emission category. According to Sprangers (2011), activity data related to the activity produces an emission (i.e., the amount of electricity used in terms of kWh), while emission factors express the amount of CO2 consumed for each unit of activity data. For example, an emission factor for electricity is expressed in kg CO2 / kWh. Sometimes, emission categories contain subcategories, such as employee commuting, split into gasoline, train, and tram.

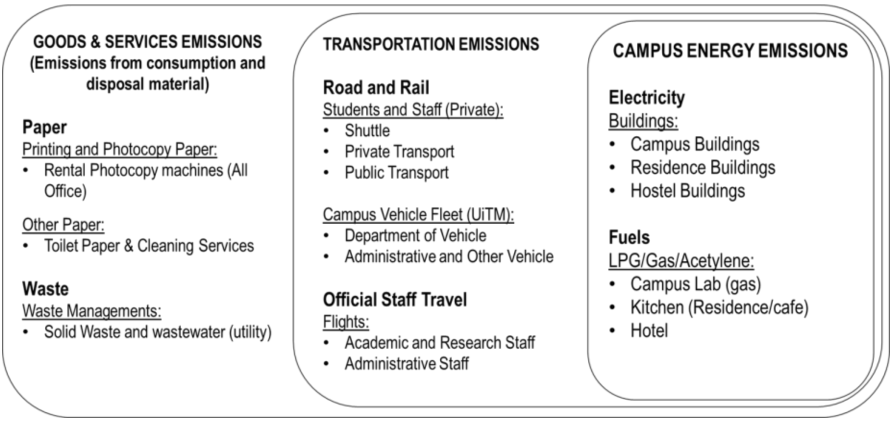

Figure 2: University carbon footprint methodological framework in three Scopes: goods and services, transportation and energy used

(Sources: Letete et al., 2011)

4.0 Results

4.1 Basis and emission factors

The university's initial carbon footprint estimation will be carried out over three years, using a university's organisational/faculties/administration and operational boundaries. Three years' data will be analysed to see the general pattern of a carbon footprint on the campus, especially during every peak month of the running semester. Furthermore, the specific area data collection categories will use a university carbon footprint methodological framework in three Scopes: goods and services, transportation, and energy consumption.

4.2 Calculation procedure

The first step of the calculation is the collection of necessary data from the University's related offices. Among them are administration, transportation, central cooling and water support, electrical and gas works, solid waste and forestation and landscape planning. Then, an emission factor for each data category will be studied and selected. At the same time, unit conversions will be applied and multiplied with consumption data to find the total carbon footprint of the UiTM Campus. All data will be registered and manipulated in the spreadsheet system. The analysis will show the relationships between time and variables and each other's scope of data. Regression models will be used to estimate any missing data. All carbon footprints will be calculated, and the shares of each footprint source will be analyzed. The carbon emission formula and calculations are shown in Table 1.

4.2.1 Campus energy emissions

Campus energy gas emissions are directly or indirectly caused by activity or accumulated over the life stages of the product or services, expressed by Carbon Dioxide (Wiedman & Minx, 2008). The overall process can be divided into four stages. Phase 1: Identify the areas and characterize the activities. Phase 2: Determine the components of energy gas emission on the respective activities in Phase 1. Phase 3: Improve resolution of the specific group of all elements; and Phase 4: Analysis of the findings for each component of carbon footprint: the carbon emission calculation and indicators of each scope component (Table 1).

4.2.2 Transport emissions

Transport emission covers commuting to and from UiTM and vehicles owned by the University. Emissions from the university-rented Shuttle, which provides commuting services for UiTM students and staff between campuses and within areas close to the main campus, are also included. All emissions from medium and long-distance staff/student flights (e.g., travel to conferences, seminars, and workshops outside the city of Puncak Alam) (Table 1).

4.2.3 Goods and services emissions

This section captures GHG emissions associated with goods and services consumed by the UiTM. The category included emissions from various products and services delivered to the University (e.g., paper products, chemicals, equipment, waste disposal services, fertilizer plants/landscape) (Table 1).

Table 1: The carbon emission calculation and indicators of each scope components

No	Components	Data Sources	Criteria	Carbon Calculation

1	Campus Energy Emission: (Electricity, Fuels and Gases).	Buildings: Campus Buildings Residence Buildings Hostel PG/Gas/ Acetylene: Campus Lab Kitchen (Residence/ Cafeteria).	An energy-indirect greenhouse gas emission is a GHG emission from the generation of imported electricity, heat or steam consumed by the organisation (Sprangers, 2011).	o Electricity CFP (kWh) x CO2 emission factor (EPA eGRID, 2019). o Total consumption from gas/LPG used from canteen/lab/etc. o IPCC guideline emissions factor in calculating. (There are 0.00548 metric tonnes of CO2 per 1 therm of natural gas. (IPCC, 2019).
2	Transportation Emissions (Road, parking, etc.).	Students and Staff (Private): Shuttle Private Transport Public Transport Campus Vehicle Fleet (UiTM): Department of Vehicle Administrative and Other Vehicle Flights: Academic and Research Staff Administrative Staff.	The transportation activities are a vital source of CO2 emissions for universities. This directs the emission of CO2 related to the transportation of purchased materials or goods, transportation of purchased fuels, employee business travel, employees/students commuting to and from universities, shuttle transportation and transportation of waste (Sprangers, 2011).	o Bus trips emit 0.055kgs CO_2e per passenger mile (EPA, 2019). o Add 10% to the total mileage to account for potential traffic jams, detours, and pit stops that may arise during the trip. o Emissions per commercial air passenger mile = 0.00041 tons of CO2 (Kimberly, 2013). o Emissions per person per hotel night = 0.0136 tons of CO2 (Kimberly, 2013).
3	Goods & Services Emissions (Emissions from consumption	Printing and Photocopy Paper: Rental Photocopy machines (All Office).	The waste and disposal components are also relevant to universities. It can include the usage of papers (disposal material), waste of operations, waste of production of purchased goods, and waste	o The life-cycle emission factor is 1200 kg CO2-eq per tonne of paper. o The generation potential of CH4 emissions from solid waste was used and converted to CO2 emissions using a global

	and disposal material) e.g., Paper and Waste, Fertilizer.	Other Paper: Toilet Paper & Cleaning Services Waste Management: Solid Waste and wastewater (utility).	of disposal of reliable products. This component directly emits CO2 to the universities because of the natural activities in universities (Sprangers, 2011).	warming potential of 25 for methane (IPCC, 2019). ○ Amount of waste recycled: below average, average, above average.

4.3 Carbon footprint in sustainable campus

Reducing carbon emissions by a small fraction is no longer enough to achieve a long-term stable climate worldwide. The term zero emissions, however, needs to be defined: carbon neutrality, for example, requires (net) zero carbon emissions in the global economy, and technically (IPCC (2019). In contrast, net-zero carbon emissions can be achieved by balancing residual carbon emissions with carbon removal in equal amounts (Rogelj et al., 2015). Risbeck et al. (2024) supported that to achieve zero carbon emissions on campus and produce a long-term sustainable environment can be a plan/made by implementing zero energy buildings, creating renewable power plants, and reducing energy consumption.

5.0 Discussion

Higher education, such as UiTM, has a critical role in local society by addressing climate change and finding solutions to mitigate global phenomena. This study documents carbon footprint assessment strategies adopted by higher education institutions in UiTM Malaysia. The carbon footprint assessment of the UiTM is categorised into two scopes: direct and indirect GHG emissions. Universities produce carbon footprint through goods and services, transportation, and energy within the campus area, using the GHG Protocol Corporate Standard, provided by the World Resources Institute and World Business Council for Sustainable Development as a standard and guideline to inventory campus carbon footprint.

In Malaysia, carbon dioxide emissions will continue to increase, parallel with the country's economic growth (Begum et al., 2015). Since 2005, greenhouse gas emissions in Malaysia have roughly increased by about 3.09% per annum (Knoema, 2018). Carbon dioxide emissions are derived mainly from fossil fuel combustion for the transport and industry sectors (Ritchie et al., 2022). They also include carbon dioxide generated using solids, liquids, gas fuels and gas combustion (Hunt et al., 2010). Therefore, in line with higher education environments such as university campuses, each year, carbon emissions are continually increasing in tandem with the increase in student and staff population and the university's standard of infrastructure and technology used for teaching and learning. The emission of greenhouse gases from the university is calculated using carbon footprint as the environmental indicator to measure the global warming potential UiTM adds to the environment. It can also measure the health of the campus environment while leading the surrounding society in knowledge and technology. The society also can make a profit while the university produces a model of a sustainable/green environment.

The university needs accurate information to calculate its carbon footprint based on the time and source of the gas emissions generated in its academic school/faculty, administration/office, cafeteria/hotel, and residential/hostel. This study has four primary sources of carbon dioxide emission: electricity, natural gas, transportation, and food consumption. It is assumed that natural gas, electricity, transportation, and waste of the total carbon dioxide emissions and comparison percentages will be calculated. The global carbon dioxide emission factor from IPCC (2007) is used in the calculation, and it has not changed and remained the same for years. In the analysis, energy-saving activities play an essential role and significantly affect carbon footprint. Those activities directly affect carbon dioxide emission amounts. The difference between the three years in carbon footprint amounts will also be calculated. At a minimum, energy will be produced, and minimum carbon dioxide emission was prevented with the energy-saving precautions taken.

Many previous studies have emerged on this topic, especially at the university level. Inventory effectively can help identify the sectors and activities of the highest GHG transmitter to address mitigation efforts and facilitate low carbon policies. After the inventory, all the data collected will be saved in a systematic database. GIS-based accounting is one of the databases that can generate a map of the current prevalent carbon footprint. This approach outlines the use of GIS to build carbon footprint databases, perform spatial analysis, and map economic values. The ability to categorise carbon footprint in a GIS is the added value of the calculation tool that was developed. All the carbon footprint sources have been geo-referenced, and the results are turned in a graphical format using a Raster Data approach, a well-known model in which a grid is laid over the land. For each grid cell, assigning a variable's value (Goodchild et al., 1992, cited in Asdrubali et al., 2013; Buyadi et al., 2014). Thus, the total carbon footprint value (tons) resulting from the emissions will be generated using a mesh of one-hectare square cells to obtain the total carbon emission in the hectare rate. The calculation tool creates the sum of all the layers representing a layer for each sector considered and the overall carbon footprint value for each cell. Therefore, more studies on the carbon footprint in the university campus environment need to be conducted using this database. These databases will effortlessly highlight the areas of the carbon footprint on the campus while planning future sustainable development.

A vital mindset to adopt at the sustainable campus is understanding that pursuing carbon neutrality will be a long-term journey. Thus, plans must be flexible to allow for the new technologies, energy developments, and world realities that will emerge (APPA, 2008). Today, a strategy has value as a transitional strategy. Furthermore, it can make more dramatic opportunities emerge or legislative requirements force changes. At the same time, higher learning institutions' ultimate carbon reduction goals for sustainable use may be restorative. That surpasses climate neutrality by making the institution a carbon sink using existing natural elements such as forest and mature landscaping (Misni et al., 2015; Misni, 2015; Lazim & Misni, 2015) rather than a carbon source (APPA, 2008). Initial strategic planning for a sustainable campus should precede financial planning to achieve overall campus sustainability.

6.0 Conclusion

Higher education, such as UiTM, has a critical role in local society by addressing climate change and finding solutions to mitigate global phenomena. This study documents carbon footprint assessment strategies adopted by higher education institutions in UiTM Malaysia. The carbon footprint assessment of the UiTM is categorised into two scopes: direct and indirect GHG emissions. Universities produce carbon footprint through goods and services, transportation, and energy within the campus area, using the GHG Protocol Corporate Standard, provided by the World Resources Institute and World Business Council for Sustainable Development as a standard and guideline to inventory campus carbon footprint.

The data inventory will be collected within three years of operation to see the trends of the carbon footprint on the campus. The carbon emission database for the campus will be built using mapping methods such as CO2 emission/carbon footprint dispersion modelling with GIS. This study will collect data accurately and transfer it directly to the database. Moreover, the University will use it as a primary database to produce any mitigating program to reduce global warming and save their running cost and energy consumption. Finally, this study will help local universities in Malaysia, especially UiTM campuses, handle their carbon footprint in their urban campus areas sustainably every year. Furthermore, it saves the campus's yearly overall running and maintenance costs.

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