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Greenhouse Gas Emissions Inventory of a University in the Philippines: the case of UP Cebu

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Estimating the carbon emission of a university is a key step towards carbon neutrality in the education sector and in contributing to the national greenhouse gas emission (GHG) inventory. Following the guidelines of the Philippine Climate Change Commission (CCC), this study examined the university GHG profile using the University of the Philippines Cebu (UPC) as a case study. The main goals were to create a GHG inventory that could serve as a model for other educational institutions in the Philippines and evaluate mitigation strategies that could potentially reduce emissions. Total emission of UPC in 2018 was estimated to be 1,520.6 tCO_2e, equivalent to 1.1 tCO_2e/*capita*/yr. The highest contributor to the UPC emission was student mobility, which accounted for 47.2% (717.5 tCO_2e) of the total. As the university progressed through the K-12 transition years and assuming a business-as-usual scenario, it was projected that GHG emission had increased by 9.1% (151.4 tCO_2e) in 2019 and by 13.6% (238.3 tCO_2e) in 2020. If UPC had mitigated its emission in 2018 such as reducing its purchased electricity consumption to 7.5% by shifting to solar energy, total emission could have been reduced by 1.8% or 27.4 tCO_2e. If there had been 10% less travels such as by opting to videoconferencing, UPC could have reduced its emission by 0.3% or 5.2 tCO_2e. Finally, if UPC had reduced 10% of its solid waste disposal to landfills such as by recycling, carbon emission would have been lessened by 0.3% or 4.7 tCO_2e. Through this research, UPC is the first national university in the Philippines to measure its carbon emissions using CCC guidelines. An understanding of the university carbon footprint could significantly raise awareness among stakeholders of their roles and responsibilities in creating a sustainable campus. Moving forward, it is recommended that the inventory would be continued for the succeeding years.

Keywords: academic sector, carbon footprint, carbon neutrality, climate change, emissions inventory

INTRODUCTION

The International Panel on Climate Change (IPCC) in its Global Warming Report defines global warming as the warming of the Earth's surface by 1 °C during a 30-yr period and that this warming is anthropogenically induced (Masson-Delmotte *et al*. 2019). Pursuant to the agreements under the United Nations Framework Convention on Climate Change (UNFCC), in April 2021, the Philippines submitted its nationally determined contributions or NDCs. In its submission, the Philippines set to reduce greenhouse gas (GHG) emissions by 75% below business as usual (BaU) in 2030 (Republic of the Philippines 2021), although this is conditioned under international support in terms of financing resources, technology development and transfer, and capacity building. Based on the principle that "we cannot manage what we cannot measure," countries must first perform national GHG inventories to understand GHG emission profiles. In the Philippines, a national GHG

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inventory was reported in 1996 in which the base year for the inventory was in 1990 (Francisco 1996) – almost three decades prior to the UNFCC agreement. The most recent known national inventory was that of the United States Agency for International Development (USAID), where it found a 40% increase in emissions from 1990–2012 (USAID 2016). With the renewal of the Philippine NDCs, there is an extreme need for an updated national GHG inventory. In fact, Umemiya *et al.* (2017) pointed out that the Philippines has high capacity in performing GHG inventories among developing Asian countries.

On a smaller scale, sectoral or establishment-level inventory must be performed to contribute to the national GHG emission inventory. Comparing internationally – in the education sector, for example – inspection of carbon-emitting activities in universities is not uncommon, although the main motivation of such queries was that academic institutions are considered to have great responsibilities in resolving environmental issues, including but not limited to climate change (Yañez *et al.* 2020). Exploration on university carbon footprint had been performed in many countries such as Norway (Larsen *et al.* 2013), the United Kingdom (Townsend and Barrett 2015), the United States of America (Clabeaux *et al.* 2020), Mexico (Mendoza-Flores *et al.* 2019), and South Africa (Letete *et al.* 2011). In Asia, there had also been university inventories in countries such as Indonesia (Syafrudin *et al.* 2020; Budihardjo *et al.* 2020), China (Li *et al.* 2015), Malaysia (Yazdani *et al.* 2013), and Thailand (Aroonsrimorakot *et al.* 2013).

In the case of the Philippines, there is little to no public information yet regarding a comprehensive university GHG inventory. Even in the University of the Philippines (UP) – which is one of the leading universities in the country – its constituents are yet to perform such an inventory. Thus, this paper investigated the university carbon footprint using the University of the Philippines Cebu (UPC) as a case study. The goals of the study are to [1] create a GHG inventory that could serve as a model for other universities and colleges in the Philippines; [2] generate an emission profile of UPC, which could be used as a basis for planning towards carbon neutrality; and [3] evaluate different scenarios for the possible reduction of carbon emissions. Results of the study can be beneficial in many ways, especially in contributing to the national inventory, as mentioned above. It could also be used as a reference by other higher education institutions – especially in the Philippines, where conditions are similar – in calculating for their GHG emissions. Additionally, knowledge on carbon footprint investigation could also greatly enhance awareness by students and employees on sustainability and climate action as already proven by Sippel *et al.* (2018).

MATERIALS AND METHODS

Case Study

UPC is a national university and is part of the UP system. It has two campuses – the Lahug campus and the South Road Properties (SRP) campus, both of which are located in the province of Cebu (Figure 1). In the UP system, one academic year (AY) is commonly composed of two semesters – the first semester is from August–December, whereas the second semester is from January–May. The regular semester break occurs from June–July. In this study, calendar year 2018 was chosen as the inventory base year for calculations, which means that this covered the second semester of AY 2017–2018 and the first semester of AY 2018–2019. Additionally, 2018 was within the five-year transition period between 2016–2021 as a result of the nationwide shift from 10-yr to 12-yr basic education program (PCDSPO 2012). Thus, in 2018, UPC had 1161 students (no sophomores) plus 226 staff with academic and administrative functions.

Emission calculations were grouped according to scope, following the specifications set in the Philippine GHG Inventory and Reporting Protocol: Manual for Business (CCC 2017). Table 1 shows the different GHG emission sources in UPC and the corresponding scope.

Estimating GHG Emissions

By adapting the calculation method specified in the Philippine GHG Inventory and Reporting Protocol: Manual for Business (CCC 2017) – which is also based on the IPCC guidelines – the basic equation followed was:

$$CE = \sum A \times EF \times GWP_{100} \tag{1}$$

in which CE is the carbon emission equivalent in tons (tCO_2e), A is the activity, EF is the emission factor, and GWP_{100} (CO_2e) is the global warming potential of a specific gas using a 100-yr averaging time. Based on IPCC's Fifth Assessment Report, GWP values of 28 and 265 were used to convert CH_4 and N_2O into CO_2-equivalents, respectively (Pachauri and Mayer 2014).

Scope 1

Direct emissions of UPC came from fuel consumption of university vehicles often used to transport students, faculties, researchers, and other staff to and from the two university campuses. Carbon emission was determined by considering the type of fuel consumed per vehicle for the entire year such that:

$$CE = \sum A_{FC} \times EF_{FT} \times GWP_{100} \tag{2}$$

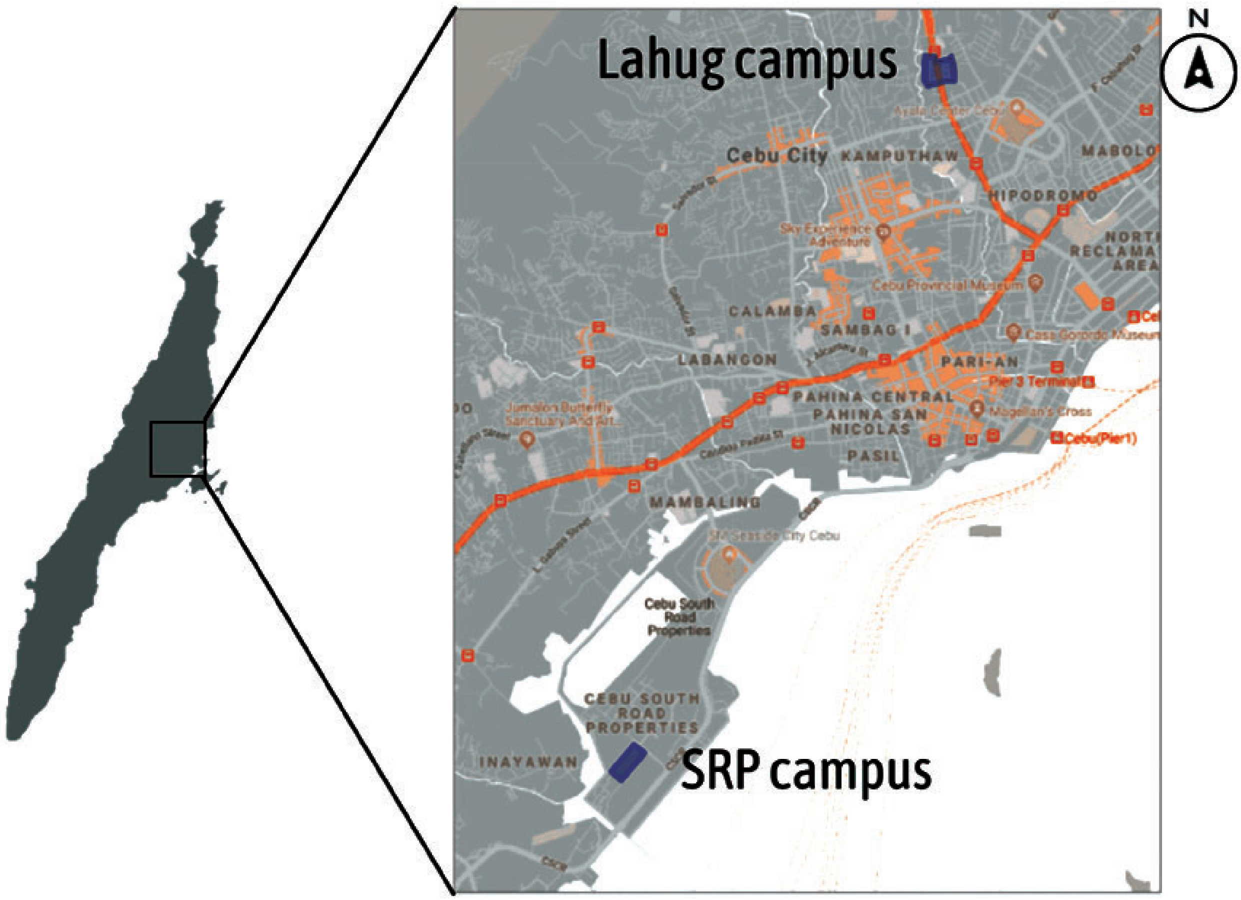

Figure 1. Location of the two campuses of UPC in Cebu, Philippines.

Table 1. Sources of emissions in UPC and accumulated total for the entire 2018.

Scope and activity	Description	Intensity	Units
Scope 1: direct emissions			
Fuel consumption	Gasoline	286.2	L
	Diesel	1,022.6	L
Scope 2: indirect emissions			
Electricity consumption	Lahug campus	683,949.0	kWh
	SRP campus	36,684.0	kWh
Scope 3: other indirect emissions			
Official travel	Distance traveled	534,064.9	km
Student mobility	Distance travelled	2,651.6	km
Employee mobility	Distance traveled	3,778.6	km
Solid waste disposal	Solid waste	25.31	ton
Waste water generation	Biological oxygen demand	20,250.2	kg BOD

where A_{FC} is the volume of fuel consumed (L) and EF_{FT} is the emission factor according to the type of fuel (Table 2).

Scope 2

Indirect emissions of UPC came from purchased electricity supplied by a regional electric company, which used coal and geothermal sources for its energy production. Carbon emission was calculated using the emission factor set by the Department of Environment and Natural Resources for the Visayas grid, where the electricity provider belongs to, such that:

$$CE = \sum A_{EC} \times EF_{VG} \times GWP_{100} \tag{3}$$

where A_{EC} is the total electricity consumed by UPC in 2018 (kwh) and EF_{VG} is the emission factor for the Visayas grid (Table 2). Electricity consumption was extracted from the monthly electricity bill starting January–December 2018.

Scope 3

In this category, total carbon emission was calculated as the sum of emissions from all activities considered under scope 3:

$$CE = \sum CE_T + CE_M + CE_{SW} + CE_{WW} \tag{4}$$

in which CE_T is emission from official travels, CE_M is emission from student and employee mobility, CE_{SW} is emission from solid waste disposal, and CE_{WW} is emission from the disposal of untreated wastewater.

Emissions from official travels accounted for the academic travels by employees – including the faculties, staff, researchers, and administrators. For this category, the activity was measured in terms of total distance traveled in 2018 such that:

$$CE = \sum A_{DT} \times EF_V \times GWP_{100} \tag{5}$$

where A_{DT} is the distance traveled (km) and EF_V is the emission factor according to the type of vehicle used during the travel (Table 2). The university did not calculate the distance traveled by each employee per trip, but the human resource office kept track of travel destination, date, and purpose. Using this information, distance

Table 2. Emission factors used in the estimation of GHG emissions.

Category	Source	Value			Unit	Ref.
		kg CO_2/unit	kg CH_4/unit	kg N_2O/unit		
Fuel consumption	Gasoline	2.1750000	0.0002400	0.0005800	kg GHG/L	US EPA (2021)
	Diesel	2.5560000	0.0001100	0.0001510	kg GHG/L	
Electricity consumption	Visayas grid	0.5070000			kg GHG/kWh	DENR-EMB (n/d)
Official business travels and mobility	Motorcycle	0.1174424	0.0001127	0.0000113	kg GHG/km	US EPA (2021)
	Tricycle	0.1174424	0.0001127	0.0000113	kg GHG/km	
	Jeepney	0.2883241	0.0000075	0.0000062	kg GHG/km	
	Taxi/Grab	0.2118934	0.0000145	0.0000050	kg GHG/km	
	Car – hatchback	0.2118934	0.0000145	0.0000050	kg GHG/km	
	Car – sedan	0.2118934	0.0000145	0.0000050	kg GHG/km	
	Car – SUV	0.2118934	0.0000145	0.0000050	kg GHG/km	
	Pick-up	0.2883241	0.0000075	0.0000062	kg GHG/km	
	Bus	0.2883241	0.0000075	0.0000062	kg GHG/km	
	Waterborne	0.0260977	0.0001330	0.0004000	kg GHG/km	
	Van	0.2883241	0.0000075	0.0000062	kg GHG/km	
	Airplane – short haul[a]	0.1280060	0.0000044	0.0000040	kg GHG/km	
	Airplane – medium haul[b]	0.0814019	0.0000004	0.0000026	kg GHG/km	
	Airplane – long haul[c]	0.1000435	0.0000004	0.0000026	kg GHG/km	

[a]Short haul (< 482.8 km)
[b]Medium haul (≥ 482.8 km, < 3701.5 km),
[c]Long haul (≥ 3701.5 km)

traveled (A_{DT}) was calculated following the method of Santos *et al.* (2015):

$$A_{DT} = \textit{Distance from origin to destination} \times 2 \quad (6)$$

in which distance traveled from origin to destination (km) was determined using Google Maps and × 2 to account for the return trip. Assumptions were that for each travel, only a single type of vehicle was used, and only a single type of fuel was used. When origin and destination were set in Google Maps, search results may provide several routes; in this case, the longest route was chosen. All travels made *via* air, water, and land transportation were included. Air transport was further categorized into short, medium, and long haul flights as each category had different emission factors (US EPA 2021). Short haul flights were those that traversed < 482.8 km, medium haul flights traversed ≥ 482.8 km but < 3701.5 km, and long haul flights traversed ≥ 3701.5 km.

Emission from student and employee mobility were also calculated using Equation 5. In order to approximate the average distance traveled per student and employee for the entire year, an online survey was conducted following the method of Varón-Hoyos *et al.* (2021). In the survey, respondents were asked to describe their usual route during their daily commute to and from UPC. Questions such as the origin of travel, frequency of travel on a daily and weekly basis, and type of vehicle used were asked. If the respondent used a private vehicle, information on whether the vehicle was shared with other people was also obtained. For the student survey, the movement from their hometown to Cebu at the start of the semester was also considered as part of the GHG emissions. Similar to the method of Varón-Hoyos *et al.* (2021), the distance traveled by students at the start of the semester was also doubled to account for the trips taken as they went back to their provinces at the end of the semester. For people who transported to the university on foot or by bicycle, zero-emission was set. The survey was disseminated through official emails and social media posts and was made available online for 2 mo. In total, 81 students and 68 employees answered the survey, which was equivalent to a response rate of 6.9 and 30.1% respectively. From this sample size, the average emission per student and per employee in 2018 was calculated. The average emission was then multiplied to the total population to estimate the emission of the entire university.

In 2018, UPC was not able to quantify its solid waste disposed to landfills. Due to the unavailability of data, Equation 7 was used to calculate the total volume of solid waste (MSW_T, in tons) with the population (P, total of 1387 in 2018) and the average volume of waste produced *per capita* in a university setting (MSW_{PC}) equivalent to 0.05 kg/d/person (Ridhosari and Rahman 2020) as parameters. The emission factor for solid waste disposal in the Philippines was also not set; thus, the basic equation (Equation 1) could not be used. Instead, the IPCC equation – (Jensen and Pipatti 2000) shown below as Equation 8 – was followed.

$$MSW_T = MSW_{PC} \times P \quad (7)$$

$$CE = MSW \times MSW_F \times MCF \times DOC \times DOC_F \times F \times \frac{16}{12 - R} \times (1 - OX) \quad (8)$$

In Equation 8, MSW_F is the fraction of solid waste sent to disposal sites; in this study, $MSW_F = 1$, i.e. 100% of waste; MCF is the methane correction factor set 0.8 in this study (IPCC default for unmanaged, deep sites); DOC is the degradable organic carbon set at 0.25 tons C/ton MSW in this study; DOC_F is set at 0.5 (IPCC default value), which is a fraction of DOC; F is the fraction of CH4 in landfill gas set at 0.5 in this study; R is set at 0, which is recovered CH4; and OX is set at 0 (IPCC default value), which is the oxidation factor.

Carbon emission from the disposal of untreated wastewater to the municipal sewer was also calculated using the IPCC equation (Doorn et al. 2006), shown below as Equation 9.

$$CE = MSW \times MSW_F \times MCF \times DOC \times DOC_F \times F \times \frac{16}{12 - R} \times (1 - OX) \quad (8)$$

$$CE = \left[\sum_{i,j}\left(U_i \times T_{i,j} \times EF\right)\right](TOW - S) - R \quad (9)$$

$$TOW = P \times BOD \times 0.001 \times I \times 365 \quad (10)$$

In Equation 9, U_i is the fraction of population in income group i in inventory year set at 1 in this study, *i.e.* 100% of UPC population; $T_{i,j}$ is set at 1, which is the degree of utilization treatment; TOW is the total organics in wastewater calculated using Equation 10 (kg BOD/year); and S is the organic component removed as sludge, assumed to be 0 kg BOD/yr for UPC. In Equation 10, BOD is the *per capita* biological oxygen demand equivalent to 0.04 kg/per person/d for the Philippines (IPCC default value), and I is set at 1 (IPCC default value), which is the correction factor for additional industrial BOD discharged into sewers.

Predicting Future Emissions and Potential Reductions

Assuming a BaU scenario, the population of UPC was projected using the rate of annual population increase obtained from enrollment data. As such, the population of UPC was expected to have reached 1520 and 1599 in years 2019 and 2020, respectively. Carbon emission was then calculated by multiplying the population of said years and the 2018 *per capita* emission ($\frac{\sum CE}{P}$). On the other hand, potential emission reductions were also predicted if the university had mitigated its carbon emissions in 2018. Conditions were as follows: Scenario 1 – if the university had installed 971 m^2 solar photovoltaic (PV) system, which could have reduced electricity consumption by 7.5% (Varón-Hoyos *et al.* 2021); Scenario 2 – if the university had reduced its travels by 10%; and Scenario 3 – if the university had reduced the volume of solid waste sent to landfills by 10%.

Boundaries and Assumptions

Several organizational boundaries and assumptions were set in the estimation of carbon emission. In terms of exclusions, fugitive emissions (Scope 1), emission from hazardous waste such as those from the laboratories (Scope 3), and emission removal from carbon sinks were not included in the inventory. Also, in the case of official travel, trips made from airports outside the Philippines to the final destination were not accounted for due to the unavailability of data. With regards to accounting student and employee mobility, the data from the online survey was assumed to represent the pattern for the entire student and employee population respectively. Specific to the student mobility, it was also assumed that the students followed the same route to UPC to start the semester and to return to their provinces at the end of the semester.

RESULTS AND DISCUSSION

Total CO_2 Emissions of UPC in 2018

The total emission of UPC in 2018 was estimated to be 1,520.6 tCO_2e, both coming from direct and indirect emission sources (Table 3). Total emission of 3.3 tCO_2e was emitted from direct sources (Scope 1), whereas a total of 365.4 tCO_2e was emitted from indirect sources (Scope 2). A total of 1,151.9 tCO_2e was emitted from other indirect sources (Scope 3), which accounted for the largest fraction of the total emissions. Similar studies which examined university carbon footprint have also reported indirect sources under Scope 3 to be the highest contributing factor, *e.g.* Varón-Hoyos *et al.* (2021), Iskandar *et al.* (2020), Townsend and Barrett (2015), and Yañez *et al.* (2020). Considering the total carbon footprint of UPC and its population, results imply that 1.1 tCO_2e/*capita* was emitted in 2018. This *per capita* emission of UPC is comparable with the national average for the Philippines, reported to be 1.23 tCO_2e/*capita* in 2018 (Ritchie and Roser 2020). Also, the *per capita* emission of UPC falls within the range of *per capita* emission of universities located in South America and Asia. The Autonomous Metropolitan University (Cuajimalpa campus) in Mexico reported 1.1 tCO_2e/*capita*/yr; the University of Talca (Curico campus) and University of Talca (Talca campus), both in Chile, reported 0.9 tCO_2e/*capita*/yr and 0.7 tCO_2e/*capita*/yr, respectively; the University of Technology Malaysia in Malaysia reported 2.0 tCO_2e/*capita*/yr; and the University of Pertamina reported 0.5 tCO_2e/*capita*/yr.

Emission from Mobile Sources

Scope 1 emissions of UPC solely came from mobile sources and is very small compared to Scopes 2 and 3. This is similar to the case of Trisakti University, where Scope 1 emission was only 0.4% of the total (Iskandar *et al.* 2020). Both Trisakti University and UPC did not emit CO_2 from stationary sources such as a university-owned energy generating facility. In UPC, the fuel consumption of five university vehicles constituted the mobile source of CO_2 emission. The vehicles were used mainly to transport students and employees between the two campuses or between one campus and to other locations within Cebu. Only one of the five vehicles was used for the entire year, three were acquired and used starting mid-2018, and one vehicle was used only for the first quarter of the year. As emphasized by Yazdani *et al.* (2013), the fuel type greatly affects CO_2 emission. Considering that UPC vehicles consumed mostly diesel (Table 1), CO_2 emission from diesel accounted for 79.9% or 2.7 tCO_2e, whereas gasoline accounted for 20.1% or 0.7 tCO_2e.

Emission from Electricity Consumption

Scope 2 emission from consumption of purchased electricity accounted for 24.0% of the total emission, the second most carbon-intensive activity in UPC. In this category, 94.9% was emitted by the Lahug campus and 5.1% was emitted by the SRP campus, which is equivalent to 346.8 and 18.6 tCO_2e, respectively. The large difference between the two campuses is attributed to the fact that most academic and non-academic activities were held in the Lahug campus daily. All university offices were also situated in the said campus, whereas only a few classes were held in the SRP campus, usually on Wednesdays and Saturdays.

If temporal variation is examined, Figure 2 shows that for both campuses, the highest electricity consumption and, hence, emission occurred from April (37.6 tCO_2e) to May (37.2 tCO_2e). The high activity during these months was expected since this duration coincides with the warmest period in Cebu. Naturally, the weather affects the demand for air conditioning, such that the highest demand for cooling happens during the warmest months (Ohashi *et al.* 2007). It was also during this time that class-related activities were peaking as the students prepared for final examinations and final course requirements. Emissions were lowest when no classes were held such as during semester break in July (24.9 tCO_2e) and during Christmas break in December (22.5 tCO_2e).

Table 3. Summary of emission sources in UPC.

Scope and activity	Emission (tonCO_2e)	Contribution to scope	Contribution to total
Scope 1	**3.3**		**0.2%**
Fuel consumption	3.3	100.0%	0.2%
Diesel	2.7	79.9%	0.2%
Gasoline	0.7	20.1%	0.0%
Scope 2	**365.4**		**24.0%**
Electricity consumption	365.4	100.0%	24.0%
Lahug campus	346.8	94.9%	22.8%
SRP campus	18.6	5.1%	1.2%
Scope 3	**1,151.9**		**75.8%**
Employee mobility	166.0	14.4%	10.9%
Public	90.7	54.7%	6.0%
Private	75.3	45.3%	5.0%
On foot/bicycle	0.0	0.0%	0.0%
Official travels	51.7	4.5%	3.4%
Airplane – medium haul	22.9	44.2%	1.5%
Airplane – long haul	21.7	41.9%	1.4%
Taxi/Grab	3.5	6.7%	0.2%
Airplane – short haul	2.2	4.3%	0.1%
Bus	0.8	1.6%	0.1%
Waterborne	0.6	1.2%	0.0%
Student mobility	717.5	62.3%	47.2%
Public	625.9	87.2%	41.2%
Private	91.6	12.8%	6.0%
On foot/bicycle	0.0	0.0%	0.0%
Solid waste disposal	46.6	4.0%	3.1%
Untreated wastewater disposal	170.0	14.8%	11.2%
Grand total	**1,520.6**	**100.0%**	**100.0%**

Emission from Mobility

Total Scope 3 emissions accounted for 75.8% of the total UPC carbon footprint. Among the activities under this scope, student mobility emitted the highest, which is equivalent to 717.5 tCO_2e. This is higher when compared to emission from employee mobility, which is 166.0 tCO_2e. Higher emission from student mobility can be attributed to the movement of students during the start and end of each semester. In 2018, > 60% of the students moved in and out of Cebu and stayed in the city, whereas the semester was ongoing. For activities related to mobility, it is also useful to examine *per capita* emission to take into account the population in each group. In the case of UPC, the average emission per student is lower compared to the average emission per employee. In terms of mobility alone, carbon emission was 0.62 tCO_2e/student/yr and 0.74 tCO_2e/employee/yr. This is due to the difference in vehicle types used to commute to UPC. Figure 3 depicts the distribution of emissions according to the type of transportation used. The use of private vehicles was more common among employees than among students; on the other hand, walking or cycling to and from the university is more common among students. The majority of the students who were originally from other places or islands lived in the university dorm or nearby areas and, thus, did not use any vehicle for transportation. Still, the fact remains that student mobility is the most carbon-intensive among all activities included in the inventory. This is also the case of other universities – in Technological University of Pereira, the student commute contributed to 74.5% of the total emission (Varón-Hoyos *et al.* 2021), University of Talca Curico campus reported 62% (Vásquez *et al.* 2015), and Trisakti University reported 37.5% (Iskandar *et al.* 2020).

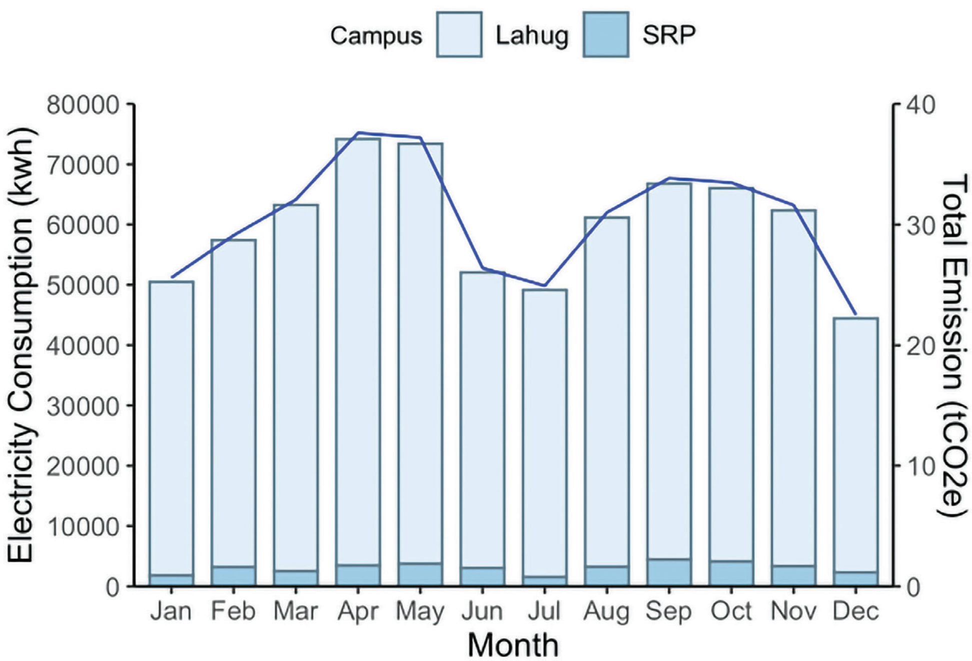

Figure 2. Monthly GHG emissions from 2018 electricity consumption.

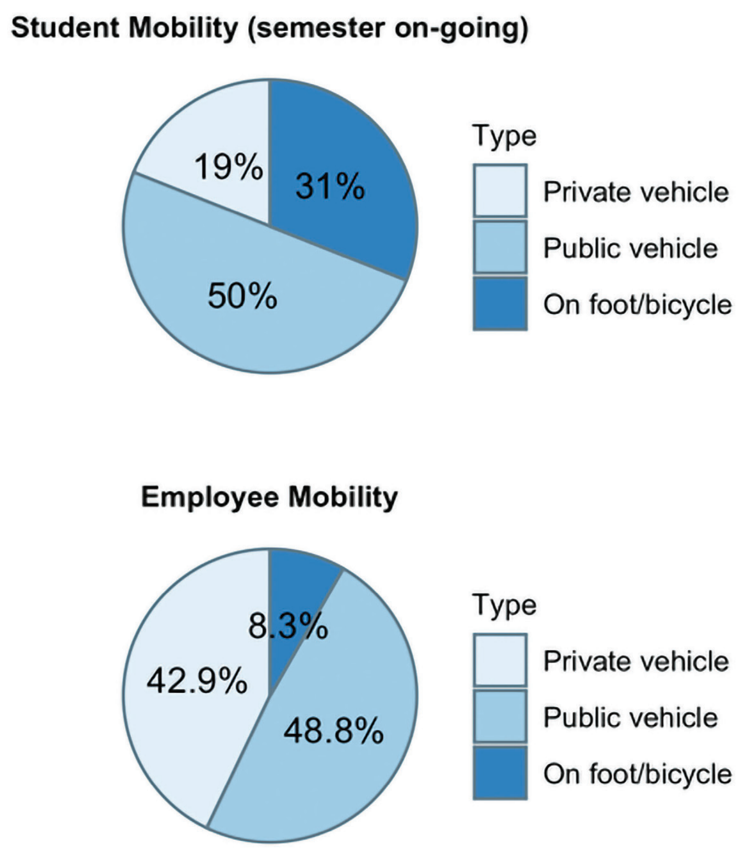

Figure 3. Type of transportation used by UPC students and employees during the daily commute.

Emission from Official Travels

The total distance accumulated by UPC academic personnel *via* air travel (Table 1) is comparable to the findings of Vásquez *et al.* (2015), wherein the academic personnel of the University of Talca (Curico campus) accumulated a total distance of 568,880 km. Both universities share a similar population size of < 2000. The inventory estimated 51.7 tCO_2e from travels within and outside the Philippines, which accounted for 3.4% of the total emission. Figure 4 indicates that the highest emissions came from airplane use for medium haul flights with a total emission of 22.9 tCO_2e. The majority of these medium haul flights were travels to mainland Luzon, including to cities like Manila and Quezon. A total of 21.7 tCO_2e was emitted from long haul flights, 3.5 tCO_2e from cars, 2.2 tCO_2e from short haul flights, 0.8 tCO_2e from buses, and 0.6 tCO_2e from waterborne vessels. Long haul flights were taken by personnel to attend to international conferences, workshops, or symposia. These types of activities are common in universities as in the case of Birla Institute of Technology and Science Pilani (Sangwan *et al.* 2018), University of Cape Town (Letete *et al.* 2011), and University of Montreal (Arsenault *et al.* 2019).

Emission Solid Waste Disposal

A total of 46.6 tCO_2e was emitted by UPC from its solid waste disposal, which contributed to 3.1% of the total emission. Among all activities under Scope 3, solid waste was the least carbon-intensive. When compared with other universities, which have similar population size; the 3.1% contribution to total emission is high. Autonomous Metropolitan University (Cuajimalpa campus) had a population of 2751, and solid waste contributed only 0.001% (Mendoza-Flores *et al.* 2019). The University of Pertamina had a population of 2621, and solid waste contributed only 0.01%. This study does not discount an overestimation of total emission from solid waste since actual waste generated in 2018 was not measured. However, even very large universities such as Sakarya University, which had a population of 81,737, solid waste only accounted for only 0.07% of the total. The case of UPC can be traced to the lack of a material recovery facility, which could have potentially reduced waste volume for landfill disposal. In 2018, all solid wastes were disposed of in landfills through the municipal waste collection system. Mendoza-Flores *et al.* (2019) found that university recycling and separation of waste reduced emissions significantly, such that it only represented < 1.0% of the total emissions, whereas had the university not performed such mitigation, emissions from waste could potentially reach 85.0%.

Emission from Disposal of Untreated Wastewater

Regarding wastewater generation and disposal, UPC emitted 170.0 tCO_2e, which is 11.2% of the total emission. In 2018, UPC did not treat its wastewater, such that the majority were disposed into the municipal sewage system. Only the water used for flushing the toilet – which was a very small fraction – went to the septic tanks. For this reason, when compared to other universities such as those in Asia, 11.2% contribution is significantly higher. In the case of Mahidol University, wastewater contributed to 0.3% of the total (Aroonsrimorakot *et al.* 2013); in Sakarya University Esentepa campus, wastewater contributed to 2.8% of the total (Sreng and Yiğit 2017); and in Diponegoro University, wastewater contributed to 4.5% of the total emission (Syafrudin *et al.* 2020).

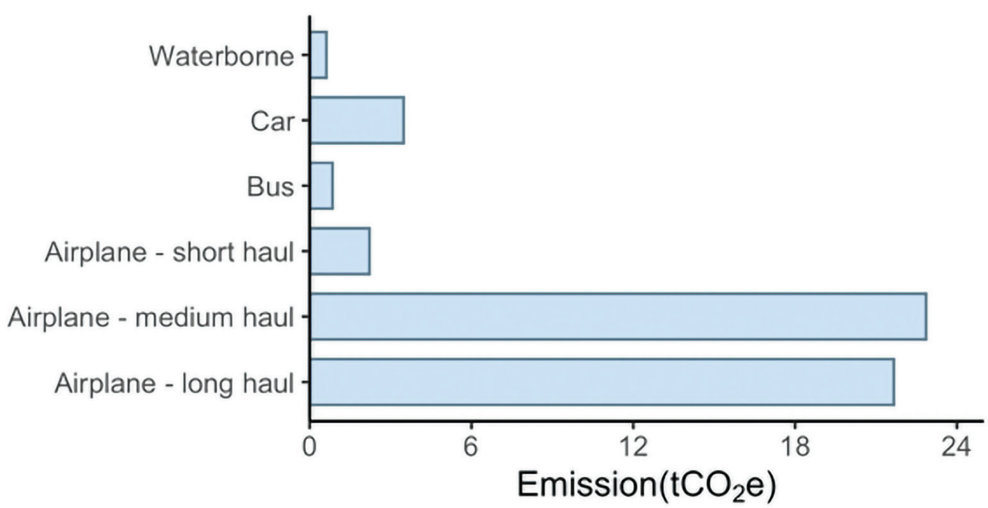

Figure 4. Emission from official travels according to transportation used.

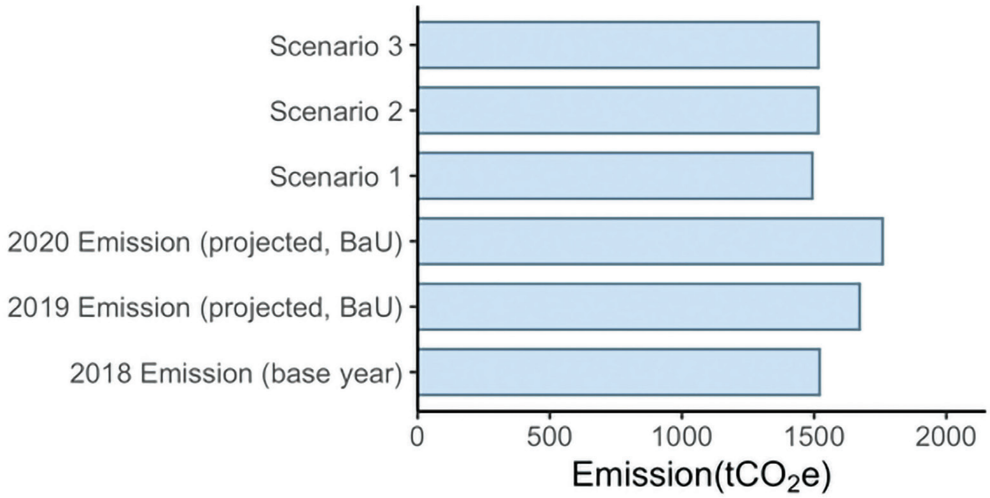

Figure 5. Emissions under business-as-usual (BaU) scenario and reduction potential when mitigation strategies are imposed.

Future Projections and Reduction Potential

Moving forward through the K-12 transition years, an increase in enrollment will have increased the population of UPC in 2019 and 2020 to 1520 and 1599, respectively. Figure 5 illustrates that in a BaU scenario and, considering the *per capita* emission in 2018, carbon emission in 2019 was predicted to have risen by 9.1% or 151.4 tCO_2e. Carbon emission in 2020 was predicted to have risen by 13.6% or 238.3 tCO_2e. If UPC had mitigated its emission in 2018 such as reducing its purchased electricity consumption to 7.5% by installing solar PV as in Scenario 1, total emission could be have been reduced by 1.8% or 27.4 tCO_2e. Solar PV could be installed on top of building roofs and is ideal for warm countries such as the Philippines (Ridhosari and Rahman 2020). Although Scenario 1 only considered solar PV for reducing electricity consumption, UPC could also consider other strategies such as shifting to LED lighting (Vásquez *et al.* 2015). In Scenario 2, if there had been 10% less travels, UPC could have reduced its emission by 0.3% or 5.2 tCO_2e. Arsenault *et al.* (2019) suggested that in a research university, an alternative to travel would be videoconferencing. In Scenario 3, if UPC had reduced its solid waste disposal to landfill by 10%, carbon emission would have been lessened by 0.3% or 4.7 tCO_2e. According to Ridhosari and Rahman (2020), university waste could be managed through sorting and recycling, which may not only reduce carbon emissions but may also be income-generating.

CONCLUSION

Estimating the carbon emission of a university is a key step towards carbon neutrality in the education sector and in contributing to the national GHG emission inventory. Following the guidelines of the CCC – on the basis of the Intergovernmental Panel on Climate Change – this study determined that UPC emitted a total of 1,520.6 tCO_2e in 2018. It was also shown that student mobility, followed by electricity consumption, is the most carbon-intensive activity. In this regard, the emission profile of UPC is similar to that of other universities, especially in Asia and South America. In the inventory year, the carbon footprint *per capita* in UPC was 1.1 tCO_2e, which is comparable with the national average. If UPC proceeds with its activities as normal, as in the BaU scenario, its carbon emission would increase due to an increase in population. However, if mitigation strategies are in place, there is potential to lower the impact of carbon emissions. Through this research, UPC is the first national university in the Philippines to measure its carbon emissions using the CCC guidelines. An understanding of the carbon footprint – not only in UPC but also among other higher educational institutions in the Philippines – could significantly raise awareness among stakeholders of their roles and responsibilities in creating a sustainable campus. Moving forward, it is recommended that the emissions inventory would be continued for 2019 and 2020, such that actual emissions for these years can be compared with the base year. Accounting for the year 2020 would also give light to the effects of the pandemic on the carbon emissions of UPC.

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