Carbon Footprinting and Mitigation Strategies for the USP Marine Campus

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Abstract

The quest for a low carbon footprint (CF) has prompted many institutions around the world, such as universities, among others, to take stock of their greenhouse gas (GHG) emissions. The CF assessment and its reporting are seen as a first step towards sustainability through planning for anthropogenic carbon emissions reduction. Carbon emissions–related activities of The University of the South Pacific (USP) Marine Campus) were investigated and then evaluated for potential reduction opportunities. A CF model for the campus's CO_2e emissions was developed. The results from the model estimated the USP Lower Campus CO_2e emissions to be 2665.8 tCO_2e. The Lower Campus per capita emissions for 2015 amount to about 1.1 tCO_2e per equivalent full-time student (EFTS) and 0.07 tCO_2e per square meter. Scope 3 emissions held the largest share of the emissions (96%). The emissions within scope 3 were largely from student and staff commuting. Besides commuting category, the largest contributor to the overall campus emission was electricity consumption and was recognized as an important source category. A 50kWp Photovoltaic (PV) rooftop system is proposed as an emission reduction strategy for the base case. This would make the campus electricity 100% renewable and entail an annual emission reduction of 12.9 tCO_2e. Other strategies that support environmental and GHG management within the campus are also proposed in this paper.

Keywords: carbon footprint; greenhouse gases; renewable energy; sustainability; The University of the South Pacific

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Introduction

Fiji along with 183 member countries of the United Nations Framework Convention on Climate Change (UNFCCC) submitted their Intended Nationally Determined Contribution (INDC) prior to the 21st Conference of Parties (COP21) in Paris, which highlighted the new universal climate change agreement. The INDC is a climate action plan submitted to the UNFCCC which is a synopsis of carbon emission–reduction targets each country is committed to (World Resource Institute, 2016). Fiji's INDC report aims for a 30% reduction in carbon dioxide emissions in contrast to a business-as-usual scenario by 2030 (IISD, 2015). Some 20% of target reduction is to be achieved through moving towards a nearly 100% renewable energy–based electricity grid and the remaining 10% through energy-efficiency measures. Meeting the INDC will be a leap towards fostering sustainable development and green growth. Carbon footprint (CF) analysis could be instrumental to this, giving a tangible figure for setting goals, implementing measures, and tracking progress. This research on CF and mitigation strategies for the University of the South Pacific (USP) Marine Campus is framed within this larger national goal.

CF is a growing field that is gaining much support in connection with climate change–mitigation efforts. Linking this to the "global stocktaking," CF at smaller scales can be seen as a building block for keeping global warming below 1.5–2 °C. Hence, such studies are important to create a knowledge base that can greatly reinforce our commitment and is imperative to reducing emissions.

This paper shows that CF reporting for the USP Marine campus is a step towards its campus greening effort and an opportunity to be on a par with other universities that are reporting greenhouse gas (GHG) emissions. An important component was developing a GHG emissions–calculation model for the campus. This model can therefore be applied to other USP campuses throughout the region as well as other academic institutions and organizations.

Carbon Footprinting

The concept of CF has been intrinsically linked to the increased levels of carbon dioxide in the atmosphere. Its importance in the public domain is to raise public awareness on climate change and global warming. Weidmann (2009) describes CF as a sustainable development indicator of the GHG emissions resulting from human activities. CF, which is a quantitative expression of GHG emissions from an activity, can help in emissions management and evaluation of mitigation measures (Williams et al., 2012). This would also mean environmental efficiencies and cost-reduction measures being emplaced to manage emissions. The term CF originated out of "ecological footprint" proposed by Wackernagel and Rees (Weidmann, 2009). Despite the term "carbon footprint" emanating from the concept of ecological footprint, it has emerged into a concept in its own right due to growing concerns of global warming and climate change. Literature in the public domain shows that a general consensus on CF is that it is "concerned with the measurement of direct and indirect GHG emissions resulting from human based consumption and production practices" (East, 2008).

A scientific definition of CF has yet to be developed; however, the methodological approach for CF determination has been classified in to two main areas—the life cycle assessment (LCA) for product CF and the corporate-based analysis for corporate CF (Alverez et al., 2016). In essence, CF determination is based on analyzing and accounting for the carbon dioxide and other GHGs emitted from processes, practices, and events. Recent development in the studies and methods of CF have acknowledged including other GHGs in the calculations and not just CO_2. This ensures that the activity being "footprinted" is consistent with standards of international agreements such as the Kyoto Protocol. Thus, a majority of the entities have expressed the CF as carbon dioxide equivalents (CO_2e).

There is a range of standards for GHG accounting published by the International Organization for Standardization. The GHG Protocol was the first standard to define CF at an organizational level (Barnett et al., 2013). The ISO14064, which is based on the GHG Protocol, includes the method for the quantification of GHGs at a product and organizational level, as well as providing methods for verifying the quality of data used to calculate emissions (Barnett et al., 2013). These standards also include the seven GHGs listed in the Kyoto Protocol (Rich, 2008). These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen triflouride (NF_3). Each of these gases have distinctive global warming potentials. This factor is used to convert non–carbon dioxide gases to CO_2 equivalents. The standards also categorize the direct and indirect emissions into three scopes, as recommended in the GHG Protocol: scope 1, scope 2 and scope 3 (GHG Protocol, 2004). Scope 1 includes direct emissions, scope 2 and scope 3 are known as indirect emissions. Scope 1 emissions refer to the direct emissions from sources owned and controlled by the reporting entity or occurring within the organizational boundary. Scope 2 includes emissions from purchased electricity, gas, or heat, whereas scope 3 includes emissions resulting from activities utilizing sources that are not owned by the reporting organization (WRI/WBCSD, 2004).

The two methodological approaches that can be utilized to undertake the task of calculating CF are Process Analysis (PA) and Environmental Input-Output (EIO) analysis (Wiedmann & Minx, 2008). PA is a bottom-up method designed to capture the environmental impacts of individual products from 'cradle to grave'. Due to its bottom-up nature, it faces a system-boundary problem and therefore the need for identification of appropriate system boundaries to minimize truncation errors (Larsen et al., 2012). This approach can become cumbersome when accounting CF for larger entities. However, it is suitable when looking at micro systems, for example a particular process, an individual product, or a relatively small group of individual products. In comparison, EIO analysis, which is a top-down approach to CF, evaluates the linkages between economic consumption activities and environmental impacts (Kitzes, 2013). This approach is superior to PA for calculating the CF in macro and meso systems, such as that of industrial sectors, individual businesses, larger product groups, households, governments, or the average citizen (Kjaer et al., 2015).

CF studies of most of the universities (Lancaster University, De Montfort University, Yale University, The Norwegian University of Technology & Science (NTNU), The University of Illinois, Chicago (UIC), University of Cape Town (UCT)), and the one applied in this work have hybridized the models to suit their institution in terms of structure, size, and organization. In general, the EIO methodological approach has been adopted, which is the recommended approach for entities such as universities and colleges. A study of the available literature on the CF of universities and organizations highlights three basic steps required for quantifying carbon dioxide and carbon equivalent emissions. The first step is to establish assessment boundaries. This involves organizational and the operational boundaries and the identification of the GHGs that will be accounted for. The second step is data collection and the final step is calculating the emissions using appropriate emission factors.

Review of University CF Assessments

The methodologies for CF vary depending on the purpose, availability of data, and measurement boundaries (Chakraborty & Roy, 2013). There are a number of tools and commercial services that have been created to support campus GHG inventory efforts. The most popular one amongst universities is the Campus Carbon Calculator (CCC) developed by the Clean Air- Cool Planet (CA-CP), a US-based organization (Klein-Banai et al., 2010). The scopes for this tool are based on the framework developed by the GHG Protocol Initiative (Hough et al., 2008). More than 200 campuses in North America have conducted their CF using the CCC (Klein-Banai et al., 2010). The CCC calculates the estimated emission from the data collected using MS Excel workbook.

Despite the ease of use of this tool, some campuses have designed their own tools based on the GHG Protocol developed by the World Resource Institute (WRI). A drawback of the CCC is that it fails to account for emissions from purchased goods and services, which is part of scope 3 emissions and which is an important source, considering the nature and activities carried out by universities (Clifford & Cooper, 2012). The environmental impacts that goods and services have during their entire life-cycle need to be accounted for in order to quantify scope 3 emissions (Thurston & Eckelman, 2011). However, studies reveal that it is fairly difficult to measure scope 3 supply-chain emissions due to limited access to detailed manufacturing information for each of the products procured by the university, as well as the lack of resources to investigate the supply chain of each product. Therefore, rationalized methods can help campus sustainability groups estimate embodied emissions so that the impacts of such GHGs can be measured and managed (Thurston & Eckelman, 2011). Table 1 shows an overview of methods employed by various universities and the results obtained for each of the scopes.

Thurston and Eckelman (2011) focused on GHG emissions resulting from procurement at the Yale University. In their assessment they employed the Economic Input-Output-Life Cycle Assessment (EIO-LCA) tool developed by the Green Design Institute at Carnegie Mellon University. It works by "using the dollar value of a purchase from a specific sector in the USA to calculate the impacts created by the entire supply chain for that purchase.... results are expressed in terms of environmental impact per dollar of output" (Thurston & Eckelman, 2011, p. 228). According to Hendrickson et al. (2006), the drawback of this model is that the differences between items within a single sector are impossible to distinguish, apart from using differences in price—which means that "all goods and services within a sector are considered identical in terms of GHG emissions per dollar procured, regardless of their physical makeup or functionality of the location where they were produced" (Doyle, 2012). Another limitation is that the model is only dependent on the monetary value. For instance, if one negotiated a lower price for an item, it would mean that the environmental impact of that purchase is also lowered. Thirdly, since the EIO-LCA method is specific to a country, accounting for imported goods would be challenging: "These goods are assumed to have the same production characteristics as comparable products made in the same interest" (Doyle, 2012). The problem with this assumption is that accuracy of the model is compromised for countries with large imports.

Ozawa-Meida et al. (2013) investigated the CF for De Montfort University in a consumption-based study that included the scope 1, scope 2, and scope 3 emissions under the classification of the WRI/WBCSD GHG protocol corporate standard. The main analysis categories in this study that are relevant to most universities are: (a) building energy—direct emissions from University buildings and equipment; and (b) travel—direct and indirect emissions from the movement of people (i.e., staff and student commutes, business travel, students' trips home, and visitor travel) (Ozawa-Meida et al., 2013). The basic CF approach was used in the analysis, which comprises the following 3 fundamental steps (Ozawa-Meida et al., 2013):

Step 1: determine activity/consumption data in each sector (kWh used, km travelled/ money spent)
Step 2: derive associated GHG-emission factors (kg CO_2e/ KWh used, kg CO2e/km travelled or kg CO2e/passenger kilometer, and kg CO_2e/£spent)
Step 3: multiply activity/consumption data by the corresponding emission factors to estimate the emissions in kg CO_2e for each sector and sum up to obtain the overall carbon footprint:

$$GHG = activity/consumption\ data * emissions\ factor \quad (3)$$

The NTNU also investigated their CF using the Environmental Extended Input-Output (EEIO) modelling, which covered all aspects of the university's activities. This is part of the Input-Output Analysis that was introduced in the 1930s (Munksgaard et al., 2005). With the inclusion of environmental related information, it evolved to become the EEIO-based modeling. According to Larsen et al. (2013), CF inventories for many universities apply bottom-up data collection in conjunction with fixed CF intensities attained from online carbon calculators. The problem with these studies is that only selected indirect scope-3 emissions are accounted for (Baboulet & Lenzen, 2010). Hence, these studies are not comparable to those applying the EEIO modeling. The EEIO modeling is deemed as the most suitable in calculating CF of universities, since it includes all aspects of university activities, particularly procurement, which is part of scope-3 emissions (Pandey et al., 2010).

The EEIO is more effective than LCA on the grounds that it also accounts for services. Since universities are service-oriented organizations, EEIO is a more useful tool (Larsen et al., 2013). The EEIO modeling also utilizes a standardized format that is country-specific. It has also proven to be an efficient and reliable means of calculating the total CF relative to LCAs, which are more detailed, yet time-consuming. The downside of the EEIO model is that it is lacking in detail (Klein-Banai et al., 2010). The models are also a couple of years old and changes in the production technology have not been captured fully. The EEIO model is also not useful when in it comes to implementing mitigation actions, since it does not capture specific data, which is vital for keeping track of the effect (Letete et al., 2011). Therefore Larsen et al. (2013) in the study of CF for NTNU have hybridized the model for all scope-1 and scope-2 GHG emissions. This model is similar to that used for municipalities (Larsen et al., 2010) but has been refined for greater suitability to a university. An important aspect of the EEIO model is to match the data from financial accounts to the EEIO sectors. The compound method by Alvarez (Alvarez et al., 2004) also incorporated the EEIO model in their calculation of CF for the University of Madrid. From their findings, they claim that results are comparable to the results of the universities that used a similar approach and that the model is simple and easy to understand.

The CF results of the university CF reports analyzed reveal that scope-3 emissions dominate CFs (Table 1). This, however, is not apparent for UIC and UCT and is due to the fact that these universities employed the PA method in their analysis, whereby a number of scope-3 emission sources are excluded, thus causing a considerable cut-off error in the results.

As seen from previous works, there are a number of steps involved in deducing the CF of institutions. Studies reveal that the main purpose of universities conducting a CF study was for it to serve as a basis for their GHG-reduction plans and to uphold their commitment towards sustainability goals—for example, Lancaster University, De Montfort University, Yale University, The Norwegian University of Technology & Science, The University of Illinois, Chicago, and The University of Cape Town. In each of those studies, the boundary of measurement and the scopes of emissions were clearly categorized and defined and were generally consistent with the GHG protocol. Moreover, it can be noticed that the methodology employed is dependent on the purpose of the enquiry and the accessibility and availability of data and resources. It is also important to note that assumptions, averages, and estimates are an important part of the measurement processes. In addition to this, the models and results obtained for the different universities are dependent on the function, institutional structure, and size of the organization. Therefore, in evaluating the CF of a university, it is important to clearly specify system boundaries, identify the sources of emission, and categorize them in respective scopes and use appropriate emission factors.

Table 1. University CF assessments.

Reference	Case study	method	CF (tCO_2e)	Carbon footprint (%)		
				Scope 1	Scope 2	Scope 3
(Carbon Management Plan, 2011)	Lancaster University (LU)	HLCA	71,700	21	23	56
(Ozawa-Meida, et al 2013)	De Montfort University (DMU)		51,080	6	15	79
(Thurston and Eckelman, 2011)	Yale University (YU)		874,000	19	5	76
(Larsen, et al 2010)	The Norwegian University of Technology & Science (NTNU)	EEIOA	92,100	19		81
(Klein-Banai, et al 2010).	The University of Illinois, Chicago (UIC)	PA	275,000	64	17	19
(Letete et al., 2011)	The University of Cape Town (UCT)		84,926	81		19

Source: Authors' compilation

Case Study: USP Marine Campus (Lower Campus)

The University of the South Pacific, established in 1968, is the leading university for the Pacific region, jointly owned by the governments of 12 member countries: Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Samoa. The university has a total of 14 campuses spread throughout its member countries. Its main campus is the Laucala campus, which is situated in Fiji.

The Laucala Campus comprises the Upper Campus, Middle Campus, Marine (Lower) Campus, and Statham Campus. The University's Laucala Campus has a total of 148 buildings distributed across four locations. USP headquarters at Suva comprises the Main Campus (114 buildings), Lower Campus (19 buildings), Statham Campus (7 buildings), and Middle Campus (8 buildings).

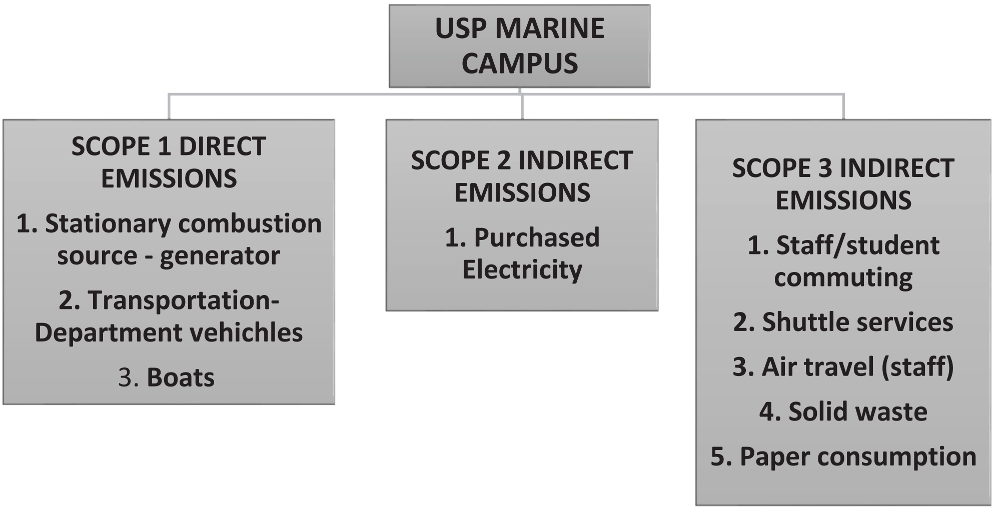
The focus of this report is the Laucala Lower Campus, which is situated along the Suva Point foreshore facing Laucala Bay (Figure 1). It is the location of USP's Marine Studies, Institute of Applied Sciences, Pacific Centre for Environment & Sustainable Development, and Institute of Marine Sciences, School of Geography as well as Marine Lodges. The campus has an area of 39659.2 m^2. This inventory was assembled by collecting and analyzing utility data, compiling university records, and conducting discussions with staff. The GHG emissions were compiled using bottom-up data acquisition, entry calculations, and management. The scope and boundary for GHG emissions analysis is presented schematically in Figure 2. This was done in accordance with industry-recognized standards for GHG emissions accounting, namely:

- 2006 IPCC Guidelines for National GHG Inventories
- *Greenhouse Gas Protocol (GHG Protocol), A Corporate Accounting and Reporting Standard*, Revised Edition, World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) (The Greenhouse Gas Protocol, 2004).
- GHG Protocol, Corporate value chain standard (WRI/WBCSD. 2004).
- EPA Simplified GHG Emissions Calculator (SGEC)

Figure 1. Google Earth image of the Marine (Lower) Campus.

Source: Google maps

Figure 2. USP Marine Campus operational boundary.



Source: Authors' compilation

Data Collection and data preparation in the model

Scope 1: Vehicle fleet, boats, and diesel generator

This scope presents two emission categories: direct transportation sources and on-campus stationary sources. The direct transportation sources are the vehicles and vessels that are at the Marine Campus and have been allocated to the departments. The IPCC methodology was used for emission calculations for this scope. Fuel-use data was available for the year 2015 and was provided by the respective departments and data from the Procurement Office was used to validate this information. For the department vehicles, fuel consumption (purchased fuel) was recorded in litres of diesel consumed for the base year. In the IPCC 2006 software, department vehicles were classified under *'Fuel Consumption Activity—Light-duty Trucks'*. For on-campus stationary sources, two diesel backup generators fell under this category. Fuel-use data in litres, model, and the amount spent per annum on the generator was available for the year 2015. This information was provided by the Properties and Facilities Department. In the IPCC 2006 software, this activity was classified under *'Fuel Consumption Activity—Stationary'*. Diesel is referred to as Gas/Diesel Oil under the IPCC guidelines.

The average density data for the fuel type was used to convert the volume (litres) to weight. This was taken from the *BP Statistical Review of World Energy* (2016). Energy from the fuel type was calculated based on the energy content values provided in the IPCC 2006 software provided in the table below (Table 2).

Scope 2: Purchased electricity

The electricity generated from the installed 45kW Solar PV system was not part of this calculation. Since electricity is purchased from the Energy Fiji Ltd. (EFL), the emission factor is 0.5095 tCO_2/MWh (CDM, 2006). This emission factor is specific to the fuel mix that FEA uses and was taken from the calcutions for Fiji Nadarivatu Hydro power project under the Clean Development Mechanism (CDM).

Scope 3: Commuting

A commuting survey for the students and staff was carried out to gather information on the distance, vehicle type, and mode of transportation for the one-way commute to the campus. Considering the large number of students, an online survey was designed through Survey Monkey and distributed via the student emails. As for the staff, survey forms were distributed to the school department secretaries, to be distributed to the staff and, where possible, staff members were personally approached with the survey forms. The data accuracy for the online survey was compromised since exact data about the number of kilometers travelled for each transportation source could not be extracted; however, estimated distances were used. The uncertainty for staff commuting can be said to be lower than that for the student commute, since the forms could easily be categorized according to mode of transportation with the distances.

Table 2. Data Table: Scope 1

Fuel consumption activity	Fuel type	Quantity (L)	Energy content (TJ/Gg)	Emission Factor (Kg CO_2/TJ
Stationary	Gas/diesel oil	12115	44.3	74100
Light-duty trucks	Gas/diesel oil	4017	43	74100
Domestic water-borne navigation	Gasoline	500	43	69300

Source: Authors' compilation, based on IPCC (2006)

Staff commuting study methodology

The motorized commuting modes, and distances for each of these modes, were considered for emissions calculation. The survey yielded a response rate of about 26%. Since some of the staff would use different modes of transportation in a typical week, the main motorized commuting modes were considered; passenger car, bus, and taxi. For those staff members who indicated that they commuted by two different modes in a typical week, emissions were accounted for the full 5 working days per week for each mode, since there was no way of knowing on which days a particular mode was used for commuting. For the commuting distance, the upper limit was considered in the calculation so as to account for under-representation of the sample size. The commuting distance was grouped with its corresponding mode of commute to find the passenger km distance for each mode.

Student commute survey study methodology

To calculate GHG emissions related to travel, information on the trip characteristics are required. Of the 612 respondents, 392 indicated the use of a motorized mode of transportation. The trip characteristics of these emitters include: mode, vehicle type, and distance traveled. Since the respondents were only asked about their commute behavior to the lower campus, it is assumed that this would be the same for the return trip. The link to the survey was distributed via email to 2,300 undergraduate students and 147 postgraduate students. The survey was left open for a period of 3 months, from January 2016 to March 2016. Irrespective of the fact that this scope 3 emissions inventory was for the calendar year 2015, the 2016 time period was deemed representative of commuter behavior at the university for 2015. A total of 2,447 email invitation links to survey monkey were distributed to students. This is also assumed to be the total student population of the USP

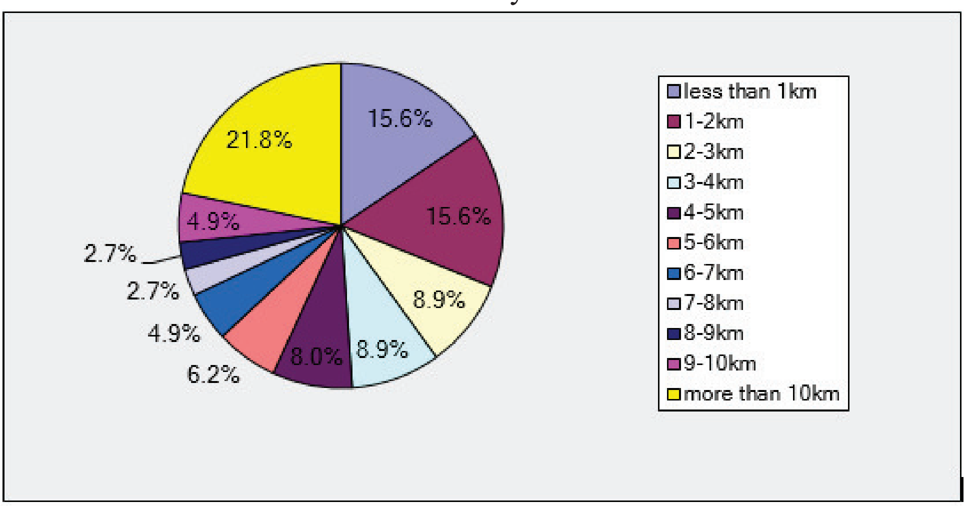
Marine Campus. Of the 2,447 surveys distributed among the student population, 612 responses were obtained by the closing date of the survey, yielding an overall response rate of 25%. This was comparable to other studies (Mathez et al., 2013; Paez & Whalen, 2010). The student responses were analyzed using Survey Monkey.

The students were categorized according to their mode of transportation. Those who commuted via motorized vehicles were further classified according to the vehicle and fuel type. Then, for each motorized transportation mode, the estimated one-way commuting distances were calculated based on the respondents' estimated distances (Figure 3). This value was recorded as "passenger-km." It can be assumed that since a majority of the respondents are face-to face students, the average number of commuting days were four. Given that a semester comprises 15 weeks, the total number of commuting days in a year were 120 days. Finally, the result was multiplied by 2, accounting for the trip to the campus and trip back home.

Student commute

The average fuel efficiency in Lge/100km for non-Organisation for Economic Cooperation and Development (OECD) countries was the used to convert total distance travelled in km for each motorized mode of vehicle type to volume (litres) (Table 3).The average density data for the fuel type was used to convert the volume (litres) to weight. This data was taken from the *BP Statistical Review of World Energy*, 2016. Energy from the fuel type was calculated based on the energy content values provided in the IPCC 2006 software.

Figure 3. Responses of estimated distances for one-way commute analyzed in Survey Monkey.



Source: Authors' compilation

Table 3. Fuel Economy for non-OECD countries

Vehicle type	Fuel efficiency (*Lge/100km)
Passenger vehicle	6.22
Light duty	6.47
Heavy duty	7.54
Bus	8.30

*Lge – Litre in gasoline equivalent terms. This energy unit is used for different fuels such as gasoline and diesel on energy equivalent basis.
Source: Authors' compilation, based on Global fuel economy initiative (GFEI, 2011)

Scope 3: Purchased Paper

Activity data on the quantity of paper purchased was obtained from the different departments. The average data approach from the GHG Protocol was used to evaluate the emissions. The mass of the total number of sheets and rolls purchased is multiplied by the Emission Factor (EF) for printing paper and toilet paper, respectively. The EF is based on published data rather than taken from onsite measurements directly. Published data on paper is sparse, therefore the data used in this report for purchased paper is based on studies from UK and thus it may not be representative of activity in Fiji. Hence, the data should be viewed with caution. Emission factor was obtained from the 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting (DEFRA, 2012).

Staff air travel (USP Business)

Each of the departments was requested to provide details of its business air travel. The necessary information was the number of persons and the trip destination. Some departments were able to provide this information; however, where gaps in data occurred the procurement office provided the necessary information.

The International Civil Aviation Organization (ICAO) carbon emissions calculator was used for estimating the volume of carbon emissions (CO2) generated by a passenger in a flight. The ICAO methodology uses a distance-based approach to estimate an individual's aviation emissions. The calculator uses a formula based on fuel combustion and employs industry averages for the various factors that lead to the determination of emissions associated with a passenger's air travel. The data required for input in the ICAO carbon emissions calculator are the airports of origin and destination. In particular the airport codes were entered. The database is then searched for all flights serving that city pair. The tool however does not compute total emissions for connecting flights. Thus, each of the journey legs were calculated separately and then added up.

USP shuttle services

The USP shuttle services are provided by the shoreline bus operators. The shuttle makes about 70 trips per week. Considering that the university has two semesters per year, each semester having 14 weeks, the total number of trips would then be 1,960 trips per year. On average, the number of passengers per trip is 10 and the approximated distance between the Main Campus and the Marine Campus is 1km. With this information, passenger km can be calculated and multiplied with the default emission factor.

SWD

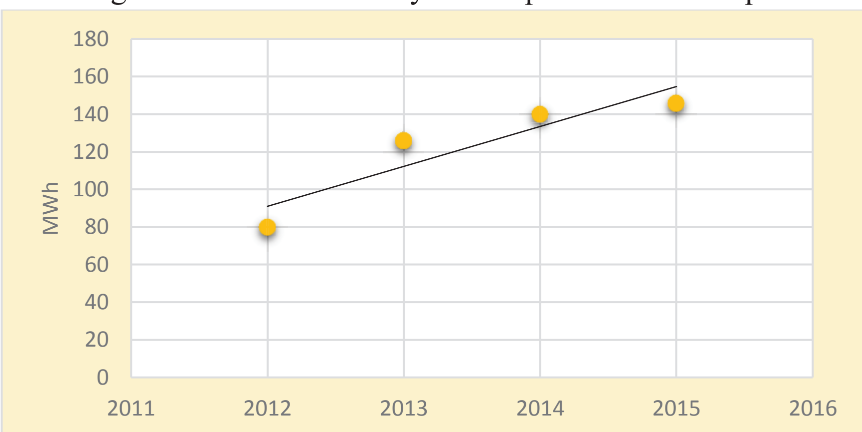
Before the collection days, garbage from the collector bin was sorted into the waste categories proposed by the IPCC. After sorting, wastes from each category were weighed. This value was then multiplied by the default value for each degradable organic compound.

Carbon Footprint Results and Discussion

Campus energy emissions

Figures 4 and 5 show the annual electricity consumption and the associated carbon emissions, respectively, for the Marine Campus from 2012 to 2015.

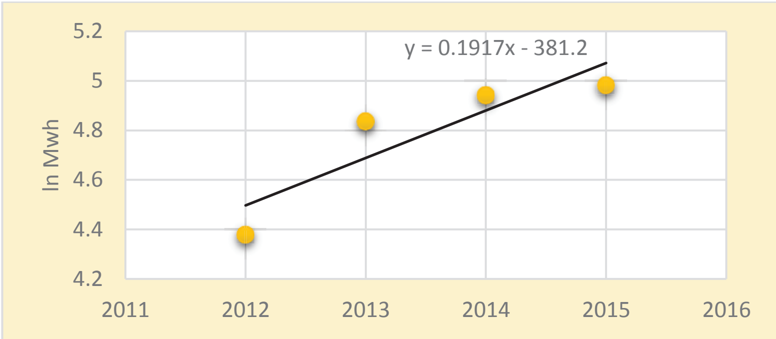
Figure 4. Trend of electricity consumption at lower campus



Source: Authors' compilation

A logarithmic graph of electricity consumption in Figure 4 shows an annual increase of 19% pa, which is relatively high. This, however, coincides with the rate of increase in the number of students. The graph also suggests that there has been only a slight increment from 2014 to 2015. Personal communication with the Properties and Facilities Maintenance manager suggested that some energy efficiency measures had been undertaken from 2014.

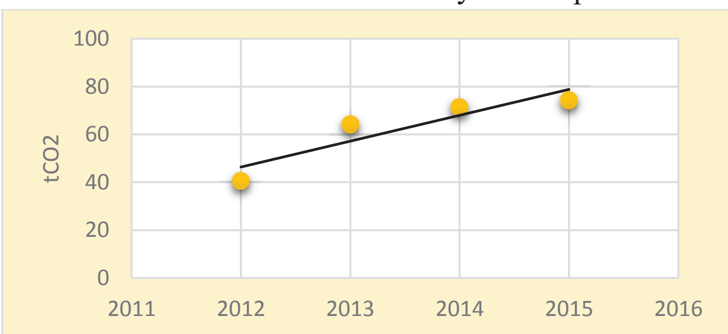
Figure 5. Logarithmic trend of electricity consumption



Source: Authors' compilation

The electricity consumption in kWh were converted to CO_2 using the emission factor of 0.5095 tCO_2/MWh obtained from the CDM Fiji Nadarivatu Hydropower project (CDM, 2006) (Figure 6). For the base year 2015 the CO_2 emissions from electricity usage was calculated to be 74 tCO_2 per annum.

Figure 6. Carbon emissions trend from electricity consumption at Lower Campus

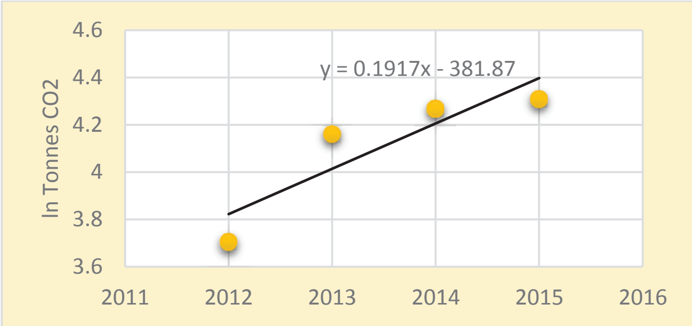


Source: Authors' compilation

The logarithmic plot of CO_2 emissions (Figure 7) suggests an annual increase of 19% pa, which is similar to kWh increase.

The emission per capita from direct energy consumption for 2015 amounts to about 0.03 tons CO_2 per student (EFTS). When compared with the different universities, this is well below the average value of 8.4.

Figure 7. Logarithmic graph of Lower Campus CO_2 emissions

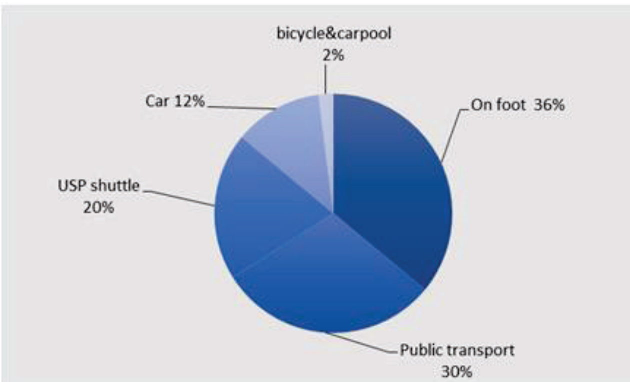


Source: Authors' compilation

Student commuting

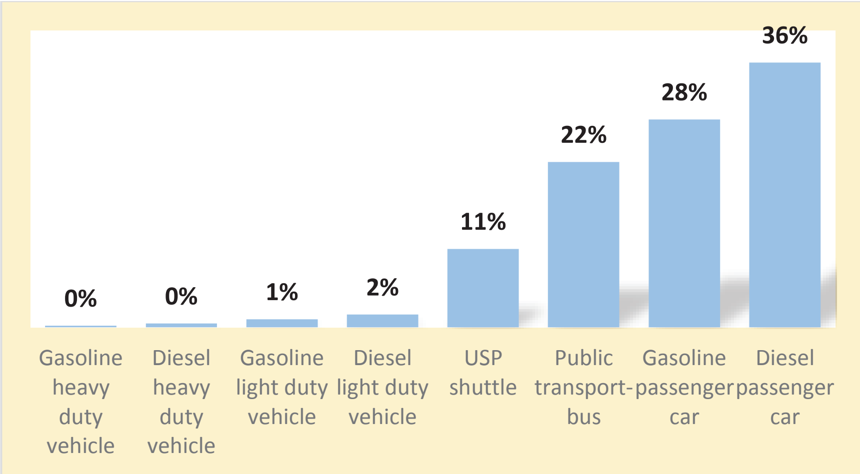
The student commute emissions for the year 2015 was about 2166.56 tCO_2e (Table 4). This is about 73% of the total inventory. From the survey sample, a summary statistic was generated for the common modes of transportation and the distance. The mode of transportation of the sample population was 36% of users commuting on foot, 30% by bus, 20% via the USP shuttle, 12% by passenger cars, and 2% by carpool or bicycle.

Figure 8. Distribution of daily commuting modes by students



Source: Authors' compilation

Figure 9. Distribution of GHG emissions of students commuting by motorized vehicles to Lower Campus

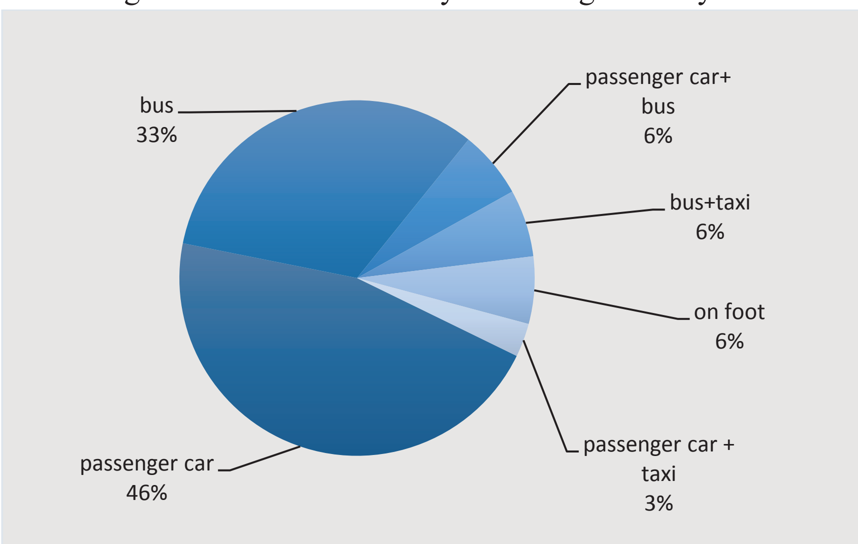


Source: Authors' compilation

Staff commuting

GHG emissions from staff commuting represented about 13% of the overall emissions. Total emissions was estimated to be 332.94 tCO_2e. The distribution of daily commuting modes by staff is given below in Figure 10.

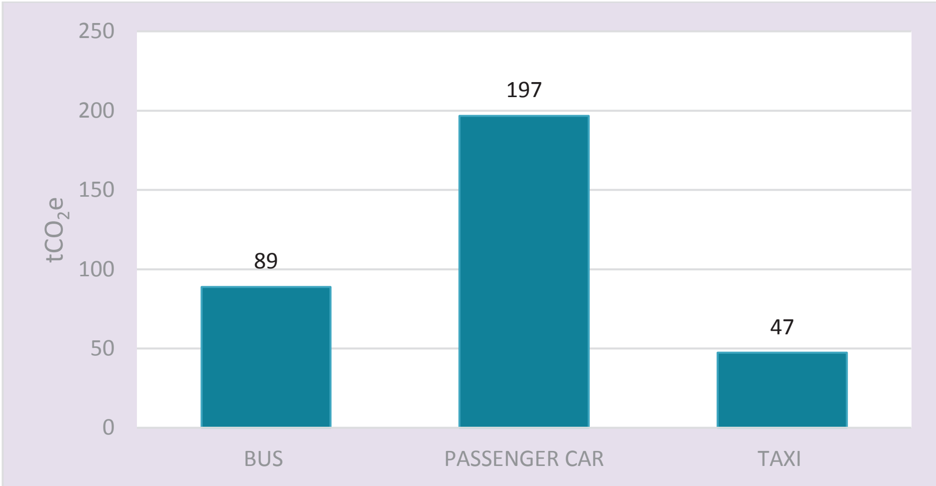
Figure 10. Distribution of daily commuting modes by staff



Source: Authors' compilation

The number of staff commuting by passenger vehicle and bus are about 46% and 33%, respectively, yet the emissions for these modes vary largely, passenger vehicles having a very large share of emissions in contrast to emissions by bus commute (Figure 11). Thus, commuting daily by bus is a greener and also a more economical option.

Figure 11. Staff commuting emissions for different transport modes.

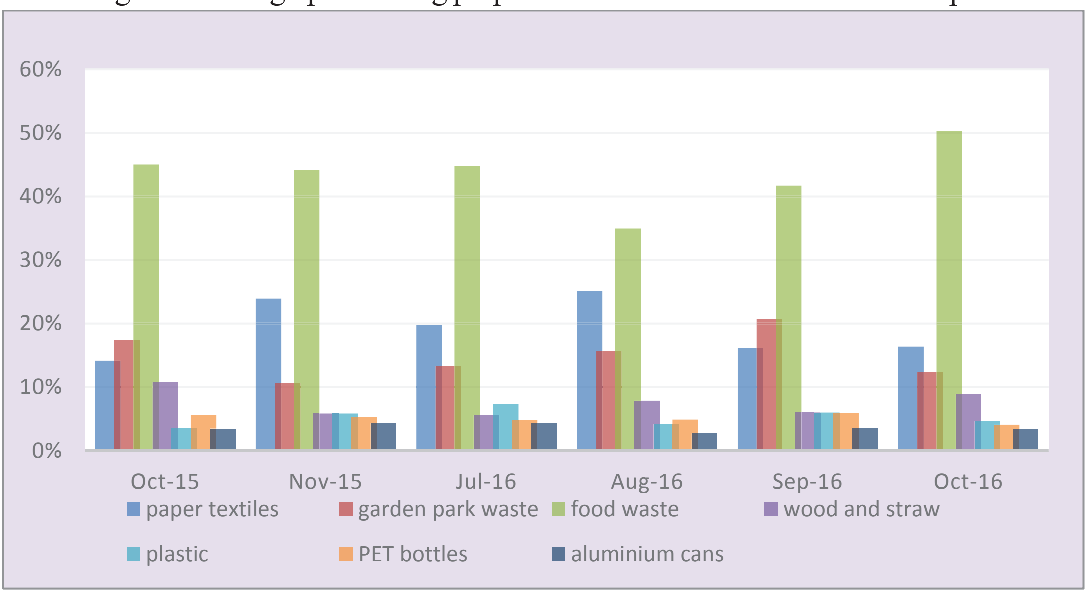


Source: Authors' compilation

Scope 3 emissions: Municipal Solid Waste (MSW)

Data was collected on the percentage weight for the main waste streams as specified by the IPCC default method for 6 different months (Figure 12). The degradable organic wastes were used for methane emissions calculations based the IPCC default method and the default values used in the GHG Inventory for Waste for Fiji's Second National Communication.

Figure 12. Bar graph showing proportions of solid waste at Marine Campus

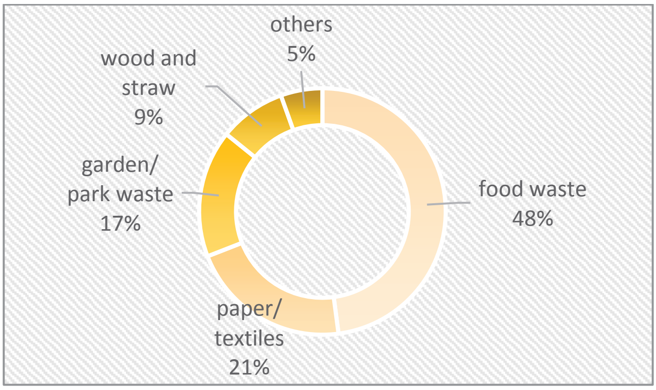


Source: Authors' compilation

Figure 13 (below) shows that a majority of Lower Campus degradable organic waste comprising food waste (48%) followed by paper/textiles and garden park waste.

Using the IPCC default method, methane emissions from MSW for the USP Lower Campus was estimated to be 0.036 tCH_4/yr for the base year 2015. Fiji's average methane emissions from Solid Waste Disposals (SWDs) is about 3.12 Gg (Fiji Second National Communication, 2013). The USP Marine Campus accounts for about 0.001% of the country's CH_4 emissions. Using the global warming potentials value of methane, which is taken as 28, the MSW emissions in carbon-dioxide equivalent is calculated to be 1 tCO_2e/yr.

Figure 13. Distribution of different degradable organic compounds

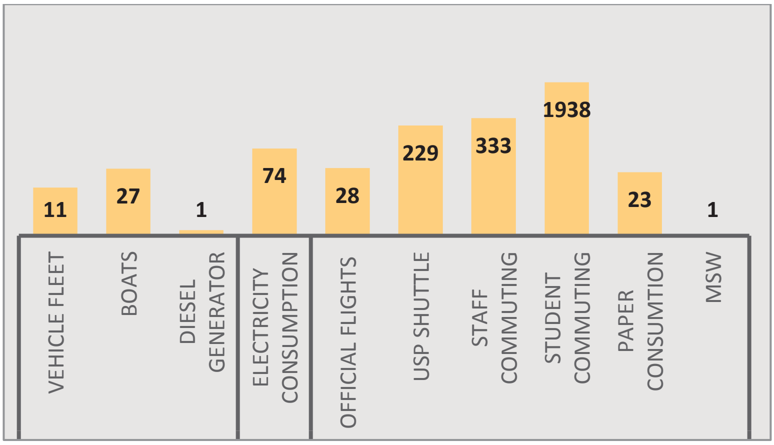


Source: Authors' compilation

Net Emissions for the Campus

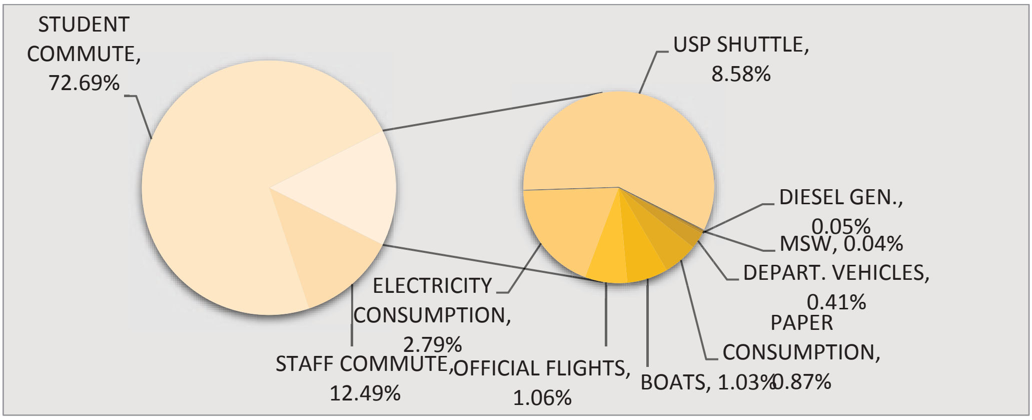
The USP Marine Campus GHG emissions for the year 2015 were estimated to be 2665.8 tCO_2e. The campus's activities that were assessed and the percentage emissions released are shown in Figure 15. The results of the model indicate that the greatest source of emissions is from student commute. This accounts for approximately 73% of all emissions. Staff commute constituted about 13%, whereas other emission categories made up the remaining 14%. Figure 14 is an overview of the USP Lower Campus CF contribution by tons of CO_2e of the different emission source categories. Emission categories that are greater than 0.5% are considered significant contributors (Letete et al., 2011).

Figure 14. Tons of carbon dioxide equivalent for the USP Lower Campus for the base year 2015.



Source: Authors' compilation

Figure 15. Contribution (%) of the different emission sources to the overall GHG emissions

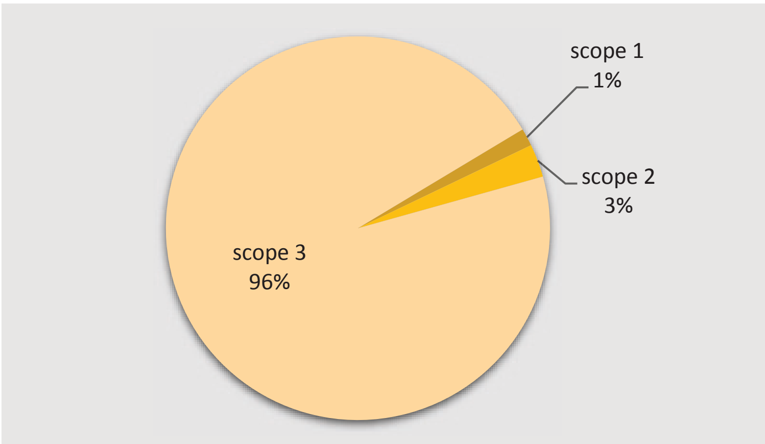


Source: Authors' compilation

Emissions under scope 1 were around 39.59 tCO_2e. This is about 1% of the overall emissions. Scope-2 emissions at 74.27 tCO_2e represented 3% of the total emissions. Scope-3 emissions were the largest contributor, with emissions of approximately 2550.95 tCO_2e, making up 96% of total emissions (Figure 16). Compared with other universities, the magnitude of scope-3 emissions are generally high, for instance: De Montfort University (79%), University of York (61%), and Erasmus University Rotterdam (80%). For Erasmus University Rotterdam (EUR), student and staff commuting are the main sources of scope-3 emissions, which was also the case for the USP Marine Campus. The average student commuting emissions for EUR was 0.42 tons of CO_2/student/year as compared with 0.27 for the Marine Campus. A factor which can influence this difference is the number of commuting days; for instance, students at EUR spend 40 weeks per year as compared with 30 weeks for

USP Marine Campus students. The smaller magnitude of scope-1 and scope-2 emissions obtained for the Lower Campus is due to the small size of the campus and the climate. With only a few buildings, which means less energy use and climate-control system(s) whereby heaters and air conditioners are not so common as at De Montfort and University of York, which have a colder climate. This was also revealed in the study by Klein-Banai, who inferred that "scope 1 and 2 emissions are primarily influenced by the physical size of the institution and secondarily by climate" (Klein-Banai et al., 2013). EUR also depicted smaller scope-1 and scope-2 emissions, 0.12% and 7% (electricity emissions), respectively. This is because heat and electricity are produced in an environmentally-friendly way at EUR.

Figure 16. Emissions distribution by scope



Source: Authors' compilation

A desktop CF study was also recently commissioned by the university for the entire Laucala Campus (Lloyd, 2016 [unpublished]). The study, however, did not look into all the scopes and therefore was inconclusive for a complete CF assessment. Comparison, however, can be made for the categories that are similar to this study. The Lower Campus emission contributes about 20% of the overall emissions. Since the CF for the whole of Laucala Campus included similar scope-1 and scope-2 emissions categories, but only business air travel for scope-3 emissions, the student and staff commute, paper consumption, and MSW emission categories were omitted for this comparison. CF results for the entire Laucala Campus was estimated to be 0.5 tCO_2e per student (FTES), the lower campus contributing 0.1 tCO_2e per student (FTES), (not including student/staff commute, paper consumption, and MSW). Also, emissions from energy consumption depicted the highest emissions (excluding student/staff commute). This is particularly important since trends in electricity consumption show a rapid increase.

Uncertainties

The figures in this report should be viewed as a best estimate rather than an exact measure due to uncertainties. This is inevitable and may arise in the data-collection process, resulting from infrequent reporting across the departments, data gaps, lack of standards, and human error. The emission factors determined by the IPCC take national scenarios into account wherever possible and present uncertainty calculations (Bastianoni et al., 2004). Emissions for scope 1 were calculated for fuel consumption using the IPCC 2006. For scope-2 emissions, from purchased electricity since the emission factor is country-specific and with high confidence in the quality of activity data, the results is likely to be accurate to within 2%. There is low confidence for scope-3 emissions, since assumptions had to be made for some of the categories. For instance, for the staff and student commuting, assumptions based on the travel distance relative to the vehicle type were made. The average global fuel economy of 8L/100km (UNEP, 2016) was used to convert distances traveled for the motorized vehicle to fuel consumed. The IPCC 2006 was then used to estimate the CO_2e emissions. Hence the uncertainty in the results is likely to be 10%. For business air travel there were gaps in data and thus there might be some trips not accounted for. Default emission factors published by the Environment Protection Agency were used and thus the accuracy of the results are within the range of 5%. For paper consumption, default emission factor was used; the level of uncertainty was within 5%. In totality, the estimated emissions are considered to be accurate to within 22%.

Mitigation Strategies

Renewable energy–based electricity generation—USP/KOICA 45kWp GCPV system

The Lower Campus has a 45kWp Grid Connected PV (GCPV) system, which was established in 2012. This is connected to one of the main load-distribution boards so that the PV power produced is first consumed for energy use at the campus and the excess is exported to the Energy Fiji Limited (EFL) grid. On average, the PV system yields about 48.7 MWh of electricity per annum (Sunny Portal, 2016). This constitutes about 25% of the total electricity consumed at the Lower Campus.

Motorized vehicle GHG emissions and % contribution

Table 5. Total electricity consumption for the lower campus in 2015

EFL Grid electricity used	PV system production	Total electricity consumption (2015)
145.8 MWh	48.7MWh	194.47 MWh

Source: Authors' compilation

The electricity provided by the grid is generated by the FEA. The producers utilize a mix of both renewable and non-renewable resources to generate electricity. The average power generation mix for 2013 was 60% hydro, 37% diesel and heavy fuel oil, 1% wind, with the remaining 2% provided by the Independent Power Producers, namely Tropik Wood Industries Limited, and Fiji Sugar Corporation (FEA, 2016).

Considering this generation mix, 54 MWh of energy consumed by the USP Lower Campus per year is non-renewable. Establishing a 50kWp PV rooftop system for the campus can offer the campus a 100% reliance on renewable sources for its energy needs and a net annual GHG reduction of 12.9 tCO_2. The CF calculated for electricity consumption for the base year is 74 tCO_2. Although the initial investment costs would be high, the system will offer a 17.4% reduction in emissions from electricity consumption for the campus and will do away with that expense from electricity bills. The cost analysis and emission reduction analysis are summarized below in Tables 6 and 7, respectively.

Table 6. Cost analysis

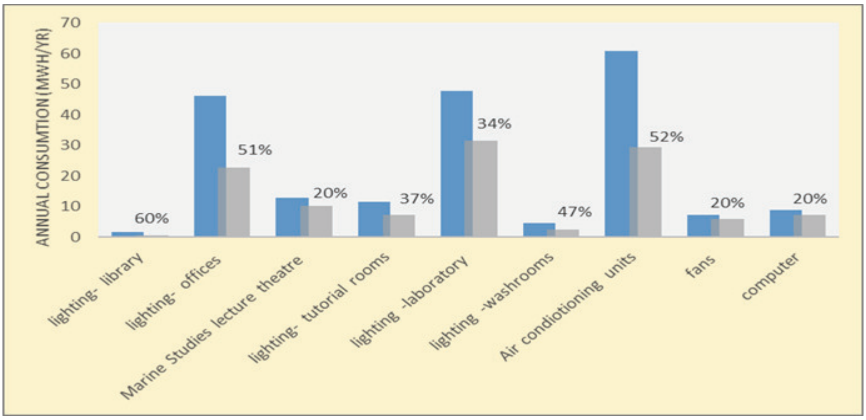
Measure	**Install 50kWp photovoltaics**
Annual emissions savings	12.9 tCO_2
Annual financial cost saving	FJD $26,866
Initial costs	FJD $150,000
Pay back	5.8 years

Source: Authors' compilation

Energy Audit and Energy Efficiency Measures

Before establishing any new renewable energy (RE) based generation system, energy efficiency measures are a must. The energy use at Lower Campus can be greatly minimized by the implementation of the proposed cases for the facility.

Figure 17. Post-measures reduction opportunity breakdown



Source: Authors' compilation

Table 7. Emission reduction analysis

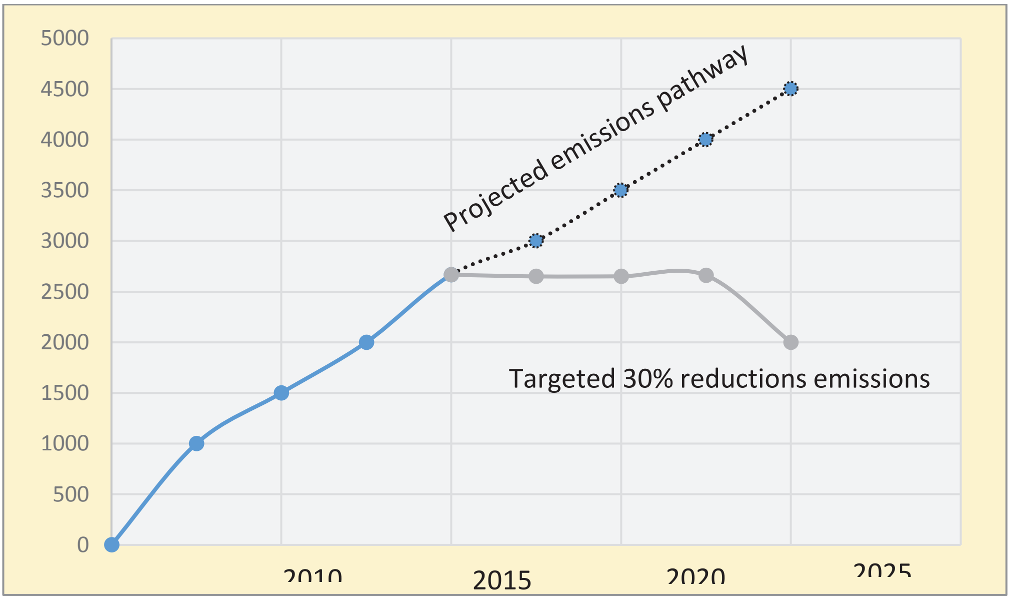
Base case system GHG summary (baseline)									
Fuel type	Fuel mix (%)	CO_2 EF (Kg/GJ)	CH_4 EF (Kg/GJ)	N_2O EF (Kg/GJ)	Fuel consumption (MWh)	Elect. Gen Efficiency	T&D losses	GHG EF (tCO_2/MWh)	GHG emission (tCO_2)
Diesel	40	36	0.0019	0.0019	65	24.8%	10%	0.5095	13.4
Proposed case system (GHG summary)									
Solar	100	0	0	0	65	0	4%	0.310	0.5
GHG emission reduction summary									
Power Project	Base case GHG emission		Proposed case GHG emission (tCO_2)		Gross annual GHG emission reduction (tCO_2)		Net annual GHG emission reduction (tCO_2)		
	13.4		0.5		12.9		12.9		

Source: Authors' compilation

About 23.9 MWh of energy can be saved. This is approximately 13% of the total amount of energy that was consumed at the campus for the base year. This also offers an opportunity for an emissions reduction of 12.2 tCO2. The proposed cases for the main building spaces include using energy efficient luminaires for lighting, end-of-life replacement of AC units and use of LED monitors for computer equipment. Energy-use reduction potential of these measures is depicted in Figure 17 (above).

This part of the study involved proposing mitigation strategies and "internal reductions," which is part of the mitigation action plan—for example, opting for energy efficient lighting. WRI suggests that organizations should give priority to internal reductions and consider offsets options as a supplementary effort in order to achieve reduction goals. The mitigation goal for the campus can be to reduce 30% of its emissions by 2019 (Figure 18, and Table 8).

Figure 18. Suggested mitigation pathway for the campus.



Source: Authors' compilation

Conclusion

The CF for the Lower Campus was estimated to be 2665.8 tCO2e. The purpose of this study is to act as a baseline, monitor trends, and measure future progress. Emissions from transport held the largest share of emissions for the Lower Campus, which comprised mainly staff and student commuting. The total CF for the Lower Campus was estimated to be about 1.1 tCO2e per student (EFTS) and 0.07 tCO2e per square meter. This value is quite low as compared with other universities around the world.

However, energy consumption is relatively high considering the energy demand with the growing population of the university; thus, among the carbon emission–reduction strategies, there is a suggestion to install an additional 50 kWp PV rooftop system, which will make the Lower Campus 100% renewable in terms of electricity consumption. Other internal reduction strategies are recommended that involve following simple energy-efficiency practices by the staff and students to make a difference and contribute to the campus greening efforts of the university. Hence, this CF analysis not only gives a tangible number, so as to see the campus's standing relative to other university campuses' carbon performance, but it also provides a platform on which future mitigation targets can be set and monitored.

Future Work and Recommendations

This CF study has potential to be implemented in entities with larger organizational and operational boundaries. Business organizations, government ministries, non-governmental organizations, and municipalities can have CF analysis carried out to account for their emissions, to help plan their mitigation strategies. Since the GHG Protocol guide also includes sector-specific guidance, CF study of various industries can also be conducted. The Marine Campus CF analysis is a small dot relative to the many more dots that need to be connected to make progress towards the long-term mitigation goal under the Paris Agreement, which is to reach net-zero GHG emissions by the second half of the century.

With the regional and domestic focus in mind, this CF report can be used by campus stakeholders to revisit and refine strategies in achieving campus greening and sustainability efforts. Using this report, an emissions-reduction plan can also be devised and the effectiveness of the strategies and the progress towards achieving these goals can be measured and tracked. This report can also be used to educate students, faculty, and staff about campus CF and encourage participation in sustainability efforts of the campus. This report can also set a trend in the community for the other educational institutions and business organizations to follow and establish their own carbon-reduction plans, which will not only benefit the environment but also contribute to Fiji's target of achieving 30% reduction in CO2 emissions. This GHG- emissions inventory lays a foundation for documenting an institution's emission sources that is quick and inexpensive.

Table 8: Emissions and cost analysis of proposed energy efficient measures

Facility characteristics—lighting	**Measure**	**Annual energy consumption saving (MWh)**	**Annual emissions saving (tCO_2)**	**Annual energy cost saving (FJD)**	**Total initial cost (FJD)**	**Payback period (yrs.)**
Marine Studies library	De-lamp and ballast upgrade	0.5	0.26	195	150	0.8
Marine Campus offices	De-lamp and ballast upgrade	6.5	3.31	2535	6350	2.5
Tutorial rooms	Luminaire upgrade	2.3	1.17	897	1775	2.0
Laboratories	De-lamp and ballast upgrade	1.2	0.61	468	2575	5.5
Washrooms	De-lamp and ballast upgrade	0.9	0.46	351	425	1.2
Facility characteristics: Air-conditioning units	End-of-life replacement for AC units	10.1	5.16	3946.8	20000	5.1
Facility characteristics: Circulation fans	Upgrade to energy-efficient fans	0.6	0.31	234	3,125	13.4
Facility characteristics: Computer equipment	Replace CRT monitors with LED monitors	1.78	0.91	694.2	6498	9.4

Source: Authors' compilation

References

Alvarez, S., Carballo-Penela, A., Mateo-Mantecón, I., & Rubio, A. (2016). Strengths-Weaknesses-Opportunities-Threats analysis of carbon footprint indicator and derived recommendations. *Journal of Cleaner Production, 121*, 238-247.

Baboulet, O., & Lenzen, M. (2010). Evaluating the environmental performance of a university. *Journal of Cleaner Production*, *18*(12), 1134-1141.

Barnett, A., Barraclough, R. W., Becerra, V., & Nasuto, S. (2013). *A history of product carbon footprinting*. UK: University of Reading.

Bastianoni, S., Pulselli, F. M., & Tiezzi, E. (2004). The problem of assigning responsibility for greenhouse gas emissions. *Ecological Economics*, *49*(3), 253-257.

Bran, F. (2016). Paris climate agreement: Responsibilities and commitments for a sustainable future. *Quality—Access to Success*, *17*, 298-303.

Clean Development Mechanism(CDM). (2006). Fiji Nadarivatu Hydropower Project. Retrieved from https://cdm.unfccc.int/filestorage/c/k/KZTL134O976SUE5QVFAPXJHDCWR0MY.pdf/PDD.pdf?t=WVN8b2djb3cxfDAEWDpqjDbmjWD2CghHOX8I

Department of Environment, Food and Rural Affairs (DEFRA). (2012). *2012 Greenhouse gas conversion factors for company reporting*. Retrieved from Gov.UK: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69554/pb13773-ghg-conversion-factors-2012.pdf

Doyle, K. (2012). Converting university spending to greenhouse gas emissions: A supply chain carbon footprint analysis of UC Berkeley. (Undergraduate), UC Berkeley, California. Retrieved from https://sustainability.berkeley.edu/sites/default/files/DoyleK_Thesis_UCB2009SupplyChainCarbonFootprint.pdf

East, A. J. (2008). What is carbon footprint? An overview of definitions and methodologies. Vegetable industry carbon footprint scoping study—discussion papers and workshops, 26 September 2008. Horticulture Australia Limited, Sydney.

Fiji Electricity Authority (FEA). (2016). Annual Report 2015. Suva

Gao, T., Liu, Q., & Wang, J. (2013). A comparative study of carbon footprint and assessment standards. *International Journal of Low-Carbon Technologies, 9*(3), 237-243.

GFEI (2011). International comparison of light-duty vehicle fuel economy and related characteristics. Retrieved from https://www.globalfueleconomy.org/media/44069/wp5-iea-fuel-economy-report.pdf

Government of the Republic of Fiji, in consultation with the National Climate Change Coordination Committee and National Stakeholders, (2013). *Republic of Fiji: Second national communication to the United Nations*. Retrieved from http://unfccc.int/resource/docs/natc/fjinc2.pdf.

The Greenhouse Gas Protocol. (2006). *Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*. ISO 14064-1:2006. Retrieved from http://www.iso.org/iso/catalogue_detail.htm?csnumber=39883

Hendrickson, C. T., Lave, L. B., & Matthews, H. S. (2006). Environmental life cycle assessment of goods and services: an input-output approach: Resources for the future, Washington, DC, USA

Hough, I., Kowalski, J., Roby, C., Taft, T. Y., & Weil, L. (2008). Clean air—cool planet. In: *Campus carbon calculator user's guide, version 6.2* (pp. 43): UNH Sustainability Institute, Portsmouth, NH.

International Institute for Sustainable Development (IISD) (2015). Climate Change Policy and Practice, Fiji submits INDC. Retrieved from http://climate-l.iisd.org/news/fiji-submits-indc/

Kjaer, L., Høst-Madsen, N., Schmidt, J., & McAloone, T. (2015). Application of environmental input-output analysis for corporate and product environmental footprints—Learnings from three cases. *Sustainability, 7*(9), 11438.

Kitzes, J. (2013). An introduction to environmentally-extended input-output analysis. *Resources*, *2*(4), 489.

Klein-Banai, C., & Theis, T. L. (2013a). Quantitative analysis of factors affecting greenhouse gas emissions at institutions of higher education. *Journal of Cleaner Production*, *48*(0), 29-38.

Klein-Banai, C., Theis, T. L., Brecheisen, T. A., & Banai, A. (2010). A greenhouse gas inventory as a measure of sustainability for an urban public research university. *Environmental Practice*, *12*(1), 35-47.

Larsen, H. N., Pettersen, J., Solli, C., & Hertwich, E. G. (2013). Investigating the carbon footprint of a university—The case of NTNU. *Journal of Cleaner Production*, *48*(0), 39-47.

Letete, T. C. M., Mungwe, N. W., Guma, M., & Marquard, A. (2011). Carbon footprint of the University of Cape Town. *Journal of Energy in Southern Africa*, *22*(2), 2-12.

Lloyd, B. (2016). Carbon footprint report for USP Laucala Campus June 2016 (unpublished).

Munksgaard, J., Wier, M., Lenzen, M., & Dey, C. (2005). Using Input-Output Analysis to measure the environmental pressure of consumption at different spatial levels. *Journal of Industrial Ecology*, *9*(1-2), 169-185.

Ozawa-Meida, L., Brockway, P., Letten, K., Davies, J., & Fleming, P. (2013). Measuring carbon performance in a UK university through a consumption-based carbon footprint: De Montfort University case study. *Journal of Cleaner Production, 56*, 185-198.

Pandey, D., Agrawal, M., & Pandey, J. S. (2011). Carbon footprint: Current methods of estimation. *Environmental Monitoring and Assessment*. 178(1-4),135-160.

Páez, A., & Whalen, K. (2010). Enjoyment of commute: A comparison of different transportation modes. *Transportation Research Part A: Policy and Practice, 44*(7), 537-549.

Rich, D. (2008). Designing a U.S greenhouse gas emissions registry. Climate and energy. World Resource Institute.

Sunny Portal. (2016). Retrieved from SMA Solar Technology AG: Retrieved from https://www.sunnyportal.com/Templates/PublicPageOverview.aspx?page=912

622c3-8981-4e4b-88f6-4209ebb89501&plant=f46fa170-f258-4618-bde4-63d53a65b45d&splang=en-GB

The British Petroleum Company plc (2016), *BP Statistical Review of World Energy*, 65th edition, Retrieved from http://oilproduction.net/files/especial-BP/bp-statistical-review-of-world-energy-2016-full-report.pdf

Thurston, M., & Eckelman, M. (2011). Assessing greenhouse gas emissions from university purchases. *International Journal of Sustainability in Higher Education*, *12*(3), 225-235.

Townsend, J., & Barrett, J. (2015). Exploring the applications of carbon footprinting towards sustainability at a UK university: reporting and decision making. *Journal of Cleaner Production, 107*, 164-176.

University of Lancaster. (2011). *Carbon Management Plan 2009–2012*. Retrieved from https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/sustainability/CarbonManagementPlan.pdf

Wackernagel, M. & Rees, W. (1998). *Our ecological footprint: Reducing human impact on the Earth*. Canada: New Society Publishers.

Weidema, B. P., Thrane, M., Christensen, P., Schmidt, J., & Løkke, S. (2008). Carbon footprint. *Journal of Industrial Ecology*, *12*(1), 3-6.

Wiedmann, T., 2009. Editorial: Carbon footprint and input-output analysis—an introduction. *Economics System Research, 21*, 175-186.

Wiedmann, T., & Minx, J. (2008). A definition of 'carbon footprint'. In C. C. Pertsova (ed.), *Ecological Economics Research Trends* (pp. 1-11). Hauppauge, NY: Nova Science Publishers.

World Resource Institute (WRI). (2016). *What is an INDC?* Retrieved from World Resource Institute: http://www.wri.org/indc-definition

World Resource Institute/World Business Council for Sustainable Development WRI/WBCSD. (2004). A corporate accounting and reporting standard. The Greenhouse Gas Protocol. Retrieved from http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf

World Resource Institute/World Business Council for Sustainable Development WRI/WBCSD. (2013). Corporate value chain (scope 3) accounting and reporting standard. The Greenhouse Gas Protocol. Retrieved from http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf

World Resource Institute/World Business Council for Sustainable Development WRI/WBCSD. (2011). Guidance for calculating scope 3 emissions. The Greenhouse Gas Protocol. Retrieved from http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revise