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CARBON FOOTPRINTING AND MITIGATION STRATEGIES FOR THE USP MARINE CAMPUS

by

Jeanette Samantha Mani

A thesis submitted in fulfillment of the requirements for the degree
Master of Science in Physics

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February 2017
Declaration

Statement by author

I, Jeanette Samantha Mani, declare that this thesis is my own work and that, to the best of my knowledge, it contains no material previously published, or substantially overlapping with material submitted for the award of any other degree at any institution, except where due acknowledgment is made in the text.

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Abstract

Concerns over climate change and global warming are becoming increasingly important in the agenda of nations; businesses and educational institutions. The demand for low carbon footprint (CF) has prompted many institutions including universities around the world to assess and report their greenhouse gas (GHG) emissions. CF reporting is seen as a measure of long-term sustainability of the enterprise and as a planning mechanism for carbon reduction and energy efficiency. Recognizing the potential and usefulness of CF reporting, the present study attempted to quantify CF of the Marine campus of the University of the South Pacific and then evaluated various potential GHG reduction opportunities. This research involved developing a campus CF model with the aim of assessing the size and main components of the campus’s CO₂e emissions. The results from the model estimated the USP marine campus emissions to be 2666 tCO₂e. The Marine campus per capita emissions for 2015 amounted to about 1 tCO₂e emissions per student (EFTS) and 0.07 tCO₂e 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 and USP shuttle commute. Besides the commuting category, the largest contributor to the overall campus emission was electricity consumption and was recognized as an important source category due to the growing demand for electricity. A 50kWp GCPV rooftop system is proposed as an emission reduction strategy for the base case. This would make the campus electricity to be 100% renewable and entail an emission reduction of 13 tCO₂. Other strategies that support environmental and GHG management within the campus are also proposed in this thesis. Overall this CF analysis not only gives a tangible number to see the campus’s standing as compared to other university campuses carbon performance, but it also provides a platform on which future mitigation targets can be set and monitored.
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Acronyms

AFOLU – Agriculture Forestry and Other Land Use
ACUPCC – American College & University Presidents’ Climate Commitment
CEDA – Committee of Economic Development of Australia
CSIRO – Commonwealth Scientific and Industrial Research
DEFRA – Department for Environment, Food & Rural Affairs
EFTS – Equivalent Full-time students
EIO-LCA – Economic Input-Output Life Cycle Assessment
EPA – Environment Protection Agency
GCPV – Grid Connected Photovoltaic
GGI – Greenhouse Gas Inventory
GHG – Greenhouse Gas
GHGP – Greenhouse Gas Protocol
IISD – International Institute for Sustainable Development
INDC – Intended Nationally Determined Commitment
IPCC – Intergovernmental Panel on Climate Change
IPPU – Industrial Processes and Product Use
ISO – International Organization for Standardization
KOICA - Korea International Cooperation Agency
SPREP - Secretariat of the Pacific Regional Environment Programme
UNEP - United Nations Environment Programme
UNFCCC – United Nations Framework Convention on Climate change
WBCSD – World Business Council for Sustainable Development
WRI – World Resource Institute
Chapter 1 - Thesis concepts and background

1.1 Background information on the study area: USP lower campus

The University of the South Pacific (USP), 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 Laucala is situated in Fiji.

The Laucala campus comprise of the Upper campus, Middle campus, Marine (Lower) campus and Statham Campus. The focus of this report is the Laucala lower campus which is situated along the Suva Point foreshore facing Laucala Bay. It is the location of USP’s marine studies, Institute of Applied Sciences (IAS), Pacific Centre for Environment & Sustainable Development (PACE-SD) and Institute of Marine Sciences, School of Geography as well as Marine Lodges.

The Marine campus has a population of about 2447 full time equivalent students (EFTS) students and employs about 120 staff. This campus is also the key location of departments which looks into the matters of the environment and climate change. For instance it is the host to PACE-SD which caters for a post graduate diploma in climate change and climate change research and the IAS which works on environmental consultancies for various projects in the South Pacific. These centers provide an overarching research and capacity building activities for climate change, disaster risk management and sustainable development across USP and the region. The University takes a strong stance in implementing and promoting sustainable development and climate change mitigation and thus this research aims to add to the missions and goals of the university in addressing climate change.
Figure 1: Google map of USP Laucala campus

Figure 2: Google earth image of the Marine (Lower) Campus
1.2 Problem statement

University campuses globally are showing great concern for campus sustainability and campus greening efforts. In general, universities are considered as crucial drivers of sustainable development, being the hub for research and ideas vital for sustainable consumption and production and climate change mitigation (Velazquez et al., 2006; Robinson et al., 2015). Sustainability in higher education first gained its recognition through the Stockholm Declaration of 1972 (Alshuwaikhat & Abubakar, 2008). Efforts towards sustainability involve conducting a GHG inventory or more commonly referred to as **Carbon Footprinting (CF)** and planning GHG emission reduction strategies (Bailey & LaPoint, 2016). Since a GHG emissions inventory is an assessment of several types of activities, it highlights its environmental impact and become targets for sustainable initiatives (Klein-Banai & Theis, 2013). The commitment by universities to CF has been demonstrated by declarations such as the Talloires Declaration, Clean Air- Cool Planet agreement and the American College University Presidents Climate Commitment (ACUPCC). The universities guided by these declaration include; the University of Cape Town, Tufts University, the University of Winchester, and University of Newcastle among others. These Declarations, are an initiative to support the universities and colleges in their efforts to reduce GHG emissions. Moreover it prompts universities to report on their CF annually and suggest mitigation strategies to meet their long term and short term reduction goals.

The USP Marine Campus can follow these examples and be part of this global commitment. Developing a CF for the campus will be a good starting point and will act as the basis for implementing plans and policies to reduce emissions. USP is a prominent institute in the region and is capable of influencing governance at local, national and regional levels. Moreover, such an initiative is long overdue since reducing emissions is no longer an option but an imperative.
1.3 Research objectives

The overall objective of this research is to determine the carbon footprint (CF) for the USP marine campus and to develop a mitigation strategy plan to reduce emissions.

More specific objectives included:
- Analyzing international standards on GHG inventory
- Creating a CF model for the University campus
- Developing mitigation strategy
  - Establishing a mitigation goal, objective and action plan
  - Carrying out an energy audit for the campus and recommending energy efficient measures
  - Proposing campus greening measures for energy, transport and waste management

The primary goal of this research is to collect GHG activity data for the Marine Campus and acquire the relative emission factors (EF) through secondary research, leading to determination of the baseline CF for the marine campus. It aims to provide a procedure for CF reporting. Moreover other USP campuses, academic institutes and business organizations can also use this model in accounting for their GHG emissions. This research also discusses the topic of climate change and its implications. The CF results will help to guide the development of mitigation strategies which includes mitigation goals, actions and an action plan for the implementation. The marine campus is deemed as a suitable test bed for this research since it is small in size and has a range of activities and services available at the campus.
1.5.1 Fiji’s Intended Nationally Determined Contribution

In 1993 Fiji ratified the United Nations Framework Convention on Climate Change (UNFCCC) and thus became legally obligated to adopt and implement policies and measures to mitigate the effects of climate change (Second National Communication to the United Nations, 2013). Fiji along with 163 member countries of the UNFCCC submitted their Intended Nationally Determined Contribution (INDC) prior to the 21st Conference of Parties (COP21) in Paris in 2015 which highlighted the new universal climate change agreement. Fiji was among the first countries to sign the 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 (WRI, 2016). Fiji’s INDC report places greater emphasis on the energy sector whereby “it aims to achieve a 30% reduction in carbon dioxide emissions compared to a business-as-usual (BAU) scenario by 2030” (IISD, 2015). There are conditional and unconditional means to achieve the 30% target. The report states that 20% of the
reduction can be achieved through moving towards nearly 100% renewable energy. This is conditional since external funding amounting to US$500 million will be required for this 20% reduction. The remaining 10% can be achieved through the implementation of energy efficiency measures that is the Green Growth Framework which aims to make use of the country’s available resources (unconditional) (Fiji’s Intended Nationally Determined, 2015).

The energy sector which represents two-thirds of all man-made GHG emissions and CO₂ emissions has increased over the past century to ever high levels (IEA, 2015). Furthermore energy demand, as predicted by the Asian Development Bank is expected to double in the Asia and Pacific Region by 2030 (Asian Development Bank, 2015). Regional trends in the World Energy Outlook (WEO) report indicate that Non-OCED share of the total emissions is increasing as these emerging and developing countries are becoming more energy intensive in their progress towards development. There is a strong link between economic growth and emissions increase for these countries. Moreover the energy sector in Fiji, like other Pacific island countries, is highly dependent on imported petroleum products to meet its energy demands in its industrial, commercial and transportation sectors.

![Figure 3: Fiji's Total Energy Consumption (1990-2010)](image)

Source: UNSD (2011); IRENA based on UNSD

The supply of energy in Fiji is mainly dominated by petroleum (Fig. 3). Imported petroleum is also used to meet 33.2% of the country’s electricity
requirements (Second National Communication to the United Nations, 2013). Approximately 860 million litres of petroleum based fuels were imported in 2010 (IRENA, 2015). Petroleum imports make up about 10-25% of the country’s GDP (IRENA, 2015) since development and economic growth are primarily dependent on access to energy. The scarcity of energy resources and the environmental impact of extraction and conversion of energy, strongly links energy usage to sustainability, threats of global warming and climate change. The total CO\textsubscript{2} emissions in the BAU scenario for the energy sector in 2030 would be somewhat 2500 000t based on the total fossil fuel increases for energy production in relation to the population and economic growth (Fiji’s Intended Nationally Determined, 2015). The electricity sector would contribute about 20% of these emissions. The indicated reductions for the energy sector in the INDC, project an emissions level of 1800000t (IISD, 2015).

Fiji will require the aid of global, regional and bilateral based mechanisms to provide the substantial funding in order to meet the conditionality of the 20% target. Fiji is committed to do its best to mitigate, however raising the cost of living for the poor of the country to meet this target will not be an option. Thus achieving Fiji’s INDC will be largely dependent on acquiring international funding. This can be possible through the climate change initiatives such as the PSIDS-Italy Model, the UAE-Pacific Partnership Fund, and the Pacific Adaptation to Climate Change (PACC) program, which have proven to be successful in allowing Pacific Island Countries to translate their INDCs into action (PIDFS, 2016).

At the domestic level, Fiji has key policies and measures that give valuable effect to the commitment. This includes;

- *Green Growth Framework 2014*
- *Draft Energy Policy 2013*
- *Draft Energy Strategic Action Plan 2013*
- *Sustainable Energy for all (SE4All) global report*
- *Fiji Electricity Authority draft Power Development Plan*
- *Electricity Act*
- *Clean Development Mechanism Policy Guideline 2010*
In particular Fiji’s INDC commitment is well aligned with the Green Growth Framework which recognizes the need to manage emerging ‘hot spots’, taking into consideration the social and environmental consequences in the pursuit for economic prosperity. The guiding principles of this framework is based on the framework theme of “Restoring the Balance in Development that is sustainable for our future”. The framework guidelines more so include:

- Reducing CF at all levels
- Improving resource productivity
- Move away from ‘sector based’ approach to integrated approach
- Socio-cultural education of responsible environmental stewardship and civic responsibility.
- Increasing adoption of comprehensive risk management practices
- Increasing adoption of environmental auditing
- Structural reform to encourage fair competition and efficiency
- Incentivizing investment in efficient use of natural resources

This will be crucial in meeting the 10% target since green growth will be integrated into development efforts, which includes infrastructure projects and the general production and consumption. What could be of vital importance and benefit, is to monitor the impact and track progress towards this mitigation goal. This can be achieved through the CF analysis. CF can be useful in terms of giving a tangible figure for goal setting, implementing measures, tracking progress and fostering towards the set target. This will be important as highlighted in article 4 of the Paris Agreement:

“Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions”.

(UNFCCC, 2017)

1.5.2 The Paris Agreement and the Pacific

Concerns over climate change were first expressed regionally in the South Pacific forum communique in 1988. This regional approach in the subsequent years further emphasized on communicating concerns to relevant international bodies and to
develop a Framework convention on climate change. In the lead up to the Paris agreement the Pacific’s position on climate change was enforced through the following declarations:

- “Smaller Island States Leaders’ Port Moresby Declaration on Climate Change in September 2015”
- “The Suva Declaration on Climate Change in September 2015”
- “The Nuku’alofa Ministerial Declaration on Sustainable Weather and Climate Services for a Resilient Pacific in July 2015”
- “The Polynesian Leaders’ Taputapuatea Declaration on Climate Change July 2015”
- “The Lifou Ministerial Declaration on Climate Change in April 2015”
- “The SIDS Accelerated Modalities of Action (SAMOA) Pathway September 2014”
- “The Majuro Declaration on Climate Leadership in September 2013”
- “The Niue Declaration on Climate Change in August 2008”

The Suva declaration in particular voiced out support for “a goal of limiting global temperature rise to 1.5°C above pre-industrial levels; ratification and implementation of the Doha Amendment to the Kyoto Protocol; including loss and damage as a standalone element in the anticipated Paris agreement to be adopted at the 21st session of the Conference of the Parties (COP 21) to the UNFCCC” (PIDFS, 2015). The ratification to keep warming well below 2°C and limit temperature increase to 1.5°C in the Paris Agreement was a big leap for the Pacific. Article 2 of the agreement states;

1. “This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by: (a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change”(UNFCCC, 2017).
The Article 2 of the Paris agreement aims to “prompt countries response to the threat of climate change in terms of limiting the increase in the global average temperature to well below 2 °C above pre-industrial levels while making every effort to limit warming to 1.5 °C above pre-industrial levels” (Bran, 2016). The Paris agreement came into force in November 2016. Since this agreement is now into force this should mean that every effort is endowed into reaching this target. Moreover it is a milestone in the global fight against climate change. A total of 197 signatories to the Paris Agreement and 127 Parties have ratified the agreement to date. This accounts for 61% of global GHG emissions (Yeo, 2016).

Another key aspect of the Paris Agreement is the creation of the “ambition mechanism” whereby countries will take stock of the implementation of their national climate actions every five years which is to commence in 2023.

“The Conference of the Parties serving as the meeting of the Parties to this Agreement shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals (referred to as the ‘global stocktake’). It shall do so in a comprehensive and facilitative manner, considering mitigation, adaptation and the means of implementation and support, and in the light of equity and the best available science” (UNFCCC, 2017).

This is recognized to be crucial since even with the NDCs submitted prior to the COP 21, there is a shortfall to limit temperature increase to 1.5-2 °C. Hence it was agreed by the countries that in 2018 a first stock-taking exercise will take place which will help to inform and update NDCs implemented by 2020. This first stock take exercise is referred to as the “Facilitative Dialogue”. This is the text that was agreed on;

“Decides to convene a facilitative dialogue among Parties in 2018 to take stock of the collective efforts of Parties in relation to progress towards the long-term goal referred to in Article 4, paragraph 1, of the Agreement and to inform the preparation of nationally determined contributions pursuant to Article 4, paragraph 8 of the Agreement” (UNFCCC, 2017).
This will enable countries to identify opportunities for climate actions and upgrade their NDCs to meet their emission reduction targets. The Facilitative Dialogue will be one of the most important topics up for discussion since 2018 is just around the corner and countries need to discuss on how this will be implemented and its parameters. The Facilitative Dialogue can be deemed as a dry run for the 2023 stock take.

1.5.3 Notable outcomes of COP 22

In view of the Paris Agreement, the COP 22 was more so seen to be the ‘implementation’ COP. The Marrakech action proclamation reestablished the Paris Agreement affirming the countries global commitment. Countries also delivered their roadmaps to long-term de-carbonization strategies. More so the poorest countries of the world grouped together as the Climate Vulnerable Forum asserted their commitment to resorting to 100% renewable sources for energy generation as soon as possible (Yeo, 2016). Other key discussion areas were Finance and Adaptation Funds and loss and damage which reached little progress, but future discussions on the issues have been agreed on.

With regards to the Facilitative Dialogue, the decision was that the presidents of COP 22 and the upcoming COP 23 would discuss with the other countries on how this dialogue is to be organized and report on their findings over a 1 year period. Also key to COP 23 was the deliberations on creating a ‘rule book’ for the fair assessment of each other’s climate pledges. Talks on how this rule book is to be devised, that is the baselines and methodologies, is likely to be up for discussion come 2018.

A key accomplishment for the Pacific was that Fiji took up the task to preside COP 23 which will take place in Bonn, Germany. This will be crucial since it will give the Pacific a stronger stance on issues and the chance to influence the Global committee on its plea.

1.6 Climate Change

Climate change is a growing concern both globally and locally and controlling the emissions of GHGs is on the sustainable development agenda of developed and
developing nations alike. The article 1 of UNFCCC defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (IPCC, 2007). The natural and human systems worldwide have been impacted due to changes in climate in the recent decade. Moreover its impact is strongest and most widespread for natural systems (IPCC, 2013). For example observations of the climate system show how the atmosphere and the oceans have warmed, rise in sea level and increased concentrations of GHG in the atmosphere. This has most evidently led to problems such as water scarcity, extinction of species, damage to biodiversity which is beyond repair and increased frequency of extreme weather events such as El Nino; the root cause of these problems being, massive fuel consumption (Bastianoni et al., 2004). However, identifying fuel consumption as the main source of emissions is not adequate; but determining where these gases are emitted from, reasons for emissions and the economic sectors involved.

The Intergovernmental Panel on Climate change (IPCC) which is the leading scientific body that evaluates climate change literature and the concentrations of GHGs globally suggests that GHG have increased prominently over the last decade primarily as a result of human activities. The working group 1 contribution to the IPCC’s fifth Assessment Report (AR5) suggests a rise in the globally averaged combined land and ocean temperature of 0.85°C over the period 1880 to 2012. The AR5 of the IPCC comprises of 3 working group reports and a synthesis report which hold recent information on climate science and research. Moreover a new set of coordinated climate model experiments were decided upon by 20 climate modelling groups around the world known as the Coupled Model Intercomparison Project (CMIP5) to provide estimates of future climate change. The IPCC adopted four GHG concentration trajectories for its AR5 based on the CMIP5 framework. These trajectories are termed Representative Concentration Pathways (RCPS) which describes four possible climate futures and is used for climate modeling and research. These climate futures are deemed to be likely depending on the degree of GHG emitted in the coming years.

The RCP 8.5 in figure 4 (red line) is the business as usual scenario which depicts a warming of more than four times the warming already experienced.
According to the AR5, human influence has been deemed as the likely cause of observed warming since the mid-20th century and that continued emissions of GHGs will cause further warming and changes in the climate systems. The IPCC has identified a total of 18 GHGs with varying global warming potentials (GWPs). However under the UNFCC and the Kyoto Protocol only Carbon dioxide (CO₂), Methane (CH₄), Nitrous Oxide (N₂O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF₆) are considered for the purposes of carbon accounting (Letete et al., 2011). The most important GHG produced by human activities is CO₂ (IPCC, 2013). The capacity to cause warming is not the same for all the GHGs. “The strength of warming of the GHGs depends on the radiative forcing it causes and the average time for which that gas molecule stays in the atmosphere” (IPCC, 2007). Due to the atmospheric chemistry of a gas, it tends to capture different amounts of reflected heat and therefore contributes differently to the greenhouse effect. This is referred to as its global warming potential (GWP) and is expressed in terms of CO₂ which is the reference gas with a GWP value of 1 and therefore the unit for GWP is carbon dioxide equivalent (CO₂-e) (Klein-Banai & Theis, 2013). The accumulation of CO₂ and other GHGs in the atmosphere are causing an overall increase in the earth’s surface temperature resulting in changes in the climate, loss of biodiversity and the inundation of small islands (Storlazzi et al., 2015).

Figure 4: Compatible fossil fuel emissions simulated by the CMIP5 models for the four RCP scenarios.
1.7 Implications of warming

1.7.1 Sea level rise

The principle effects of sea-level rise include coastal flooding, shoreline erosion and groundwater salinization (Nunn, 2012). A major threat of climate change for the Pacific is sea-level rise and the drowning of low level small islands since it is the location of many of the world’s low-lying atolls (Storlazzi et al., 2015). The Australian Bureau of Meteorology and CSIRO (2014) in their reports indicated that “sea levels have risen and vary across the Pacific with large scale climate processes”. Countries such as Tuvalu, Kiribati and the Republic of the Marshall Islands are likely to be submerged under water with a sea level rise of one meter (SPREP, 2015).

Rise in sea level also affects the sandy shorelines in terms of changing its equilibrium profile. That is, the sand is displaced from the back-beach to the sea floor. Nunn (2012) have reported that coastal communities in Fiji have approximately 30m of land eroded in 30 years. This is of serious concern since the eroded area could have otherwise been used for vegetation, buildings and infrastructure. Other impacts of shoreline erosion include sediments being eroded into reef-bounded lagoons increasing the turbidity of water which add to coral bleaching (Nunn, 2012). The rise in sea level also causes saline water to enter into the coastal plains. These coastal plains are permeable and maintain a freshwater lens which is the water source for the plants growing there. The salt water intrusion affects the vegetation to the extent that it threatens their survival and productivity. For example the sugarcane farms in many coastal lowlands have been reported to produce poor crops in recent years as a result of saline groundwater (Barnett, 2011). These effects can be exacerbated with further warming and sea level rise.

According to the IPCC, the RCP8.5 (red line) (Fig.5), the projected rise will be 0.52 to 0.98m by 2100 (medium confidence). Moreover if emissions persist on the “red
line”, a sea level rise of 3m is expected by 2300. This upper limit however could be misconstrued due to a recent study by NASA which suggested accelerated melting of ice sheets in Antarctic and Greenland which was once thought stable (IPCC, 2013). Hence considering this, the upper limit of the projection could now likely be 4-10m. The IPCC authors have reported with high confidence that glaciers worldwide are decreasing in size as a result of climate change which is an imminent reason for concern (Stocker et al., 2013). Amplified warming in the Arctic and Antarctic called polar amplification occur from positive feedback processes such as the ice-albedo feedback whereby warming initially melts ice and snow which exposes dark ocean and terrestrial surfaces that absorb more solar energy increasing the warming and exuberating melting.

Figure 5: Compilation of paleo sea-level data

“Tide gauge data (blue, red and green), altimeter data (light blue) and central estimates and likely ranges for projections of global mean sea level rise from the combination of CMIP5 and process-based models” (IPCC, 2013).

1.7.2 Ocean warming

Since the beginning of the 20th century a warming trend in the average global Sea Surface Temperature (SST) of ~ 0.13 °C per decade has been observed (Laffoley & Baxter, 2016). Prediction models further indicate that this trend is likely to continue in the 21st century with 1-3 °C increase in the mean global SST based on the emission
scenario used with the greatest warming occurring in the tropics and subtropics (Collins et al., 2013). Warmer oceans also affect the atmosphere above it affecting weather patterns and likely changes to the character of El Nino (Laffoley & Baxter, 2016). Considering cyclones harness its energy from the ocean, higher sea surface temperature will mean more energy for the cyclone, making it more intense and severe.

The abundance and distribution of pelagic fish species across the Pacific have also been affected as a result of ocean warming and acidification (Potts et al., 2014). This has affected the livelihood of many coastal communities and the national revenue as a whole. Some fish species in the equatorial and low latitude waters move pole wards in response to the increased ocean temperature. In fact historical catch data is evident of the decline of subtropical fish species in the tropics between the years 1970-2006 which is owed to warming (IPCC, 2013). Moreover the body size of exploited fish has also been affected due to alterations in oxygen concentrations. All future emission scenarios by the IPCC show a projected decline in tropical fisheries as a result of ocean warming by mid-century. The RCP8.5 scenario shows 65% higher shifts in abundance and distribution of fish species and a higher rate of poleward migration than the RCP2.6. For instance in the RCP2.6, the tropical finfish fisheries are expected to be at moderate risk of impacts by the end of the century (high confidence) and greater risk under the RCP8.5. Hence the pelagic fish species across the Pacific are under immense threat of being displaced if there isn’t any serious steps undertaken to mitigate the effects of climate change.

1.7.3 Coral reef ecosystems

Coral reefs are under the risk of loss of species diversity, damage to the physical structure and function from ocean warming and acidification (Spalding et al., 2015). These changes are irreversible on the time scale of centuries (IPCC, 2013). Changes in the ocean carbon chemistry results in the weakening of the reef framework and frequent coral mortality and disease out-breaks as a result of thermal bleaching. A direct consequence is the death of coral polyps which affects the production of the reef framework and thus affecting the reef ecosystem which is home to reef fish and other reef dwelling organisms (Spalding et al., 2015). The reefs also play an important role as barriers protecting shorelines from waves and storms, sustaining livelihoods and is
a tourist attraction. The threats of climate change mean that the role of coral reefs is compromised, making the Pacific more vulnerable.

The IPCC have reported that much of the decline in coral in the Pacific region is a result of ocean warming as well as factors such as pollution and harmful fishing practices. The rise in the water temperatures over the past thirty years have caused episodes of mass coral bleaching (Boyd et al., 2014). This occurs when the colourful micro-algae which reside in the coral tissues and provide it nutrients, dies depriving the coral of key food source. Extended periods of bleaching and heat stresses leaves the coral vulnerable to coral diseases and eventually results in coral mortality.

Under the medium and high emission scenarios (RCP4.5, RCP 6.0, RCP8.5), the Pacific coral reefs are at a very high risk, imposed by coral bleaching and heat stress causing long term degradation. Ocean acidification and other local issues such as nutrient pollution will further add to the risks and decrease heat tolerance. Only a third of the coral reefs are expected to be degraded by the end of the century, if the global surface temperature warming is within the limits of 1.5°C (IPCC, 2013). For the medium emissions scenario (RCP4.5), the long term degradation doubles this value. With the possibility that coral are able to adapt to warming under these scenarios, about half of corals may evade bleaching and long term degradation (Boyd et al., 2014). However the alterations in the reef structure and the loss of coral are likely to affect the reef ecosystem in terms of reduction in abundance of reef fish and invertebrate populations.

### 1.7.4 Ocean acidification

Ocean acidification is the direct result of man- made CO₂ emissions (Speers, 2016). The level of atmospheric CO₂ has risen from 280ppm to over 400 ppm since the beginning of the industrial era (Williams et al., 2015). Much of the increase is owed to fossil fuel burning, cement production and changes in land-use by humans. Scientists are capable of projecting alteration in ocean chemistry directly related to the rising of CO₂ in the atmosphere. The ocean and the atmosphere readily exchange CO₂. The alkalinity of oceans has reduced from 8.2 to 8.1 since the industrial revolution due to ocean uptake of CO₂ from human activities. This change is comparable to a 26% increase in acidity since pH is a logarithmic scale. As reported in the AR5, the ocean
pH world-wide is at its lowest now on the time scale of the last 800,000 years and the rate of decrease over the last 65 million years is exceptionally high.

The extent of CO₂ dissolved in the water can be determined by its partial pressure (PCO₂) and chemical reactions of the dissolved CO₂ with other solutes (Ford, 2015). The PCO₂ is the pressure in the air above a water of CO₂ referred to as the gas phase pressure which would be in equilibrium with the dissolved CO₂. The PCO₂ differential between the atmosphere and coastal water body (i.e. Henry’s Law) affects the dissolution of atmospheric CO₂. Hence an increase in atmospheric CO₂ concentration (due to global warming) directly leads to an increase in amount of CO₂ absorbed by the oceans (Fig 6). The increase in CO₂ in the ocean consume free protons and affect water column pH (Fig 6 (b)).

Figure 6: Multiple observed indicators of a changing global carbon cycle

(a) “atmospheric concentrations of carbon dioxide (CO₂) from Mauna Loa (19°32’N, 155°34’W – red) and South Pole (89°59’S, 24°48’W – black) since 1958; (b) partial pressure of dissolved CO₂ at the ocean surface (blue curves) and in situ pH (green curves), a measure of the acidity of ocean water. Measurements are from three stations from the Atlantic (29°10’N, 15°30’W – dark blue/dark
The ocean absorbs CO₂ from the atmosphere and will continue to do so at an alarming rate unless human derived emissions are reduced (Bijma et al., 2013). The predicted decline of the surface ocean pH is by 0.06-0.07 units in this century under the RCP2.6. This is approximately 15-17% increase in acidity. In the worst case scenario (RCP 8.5) the projected decline is as much as 0.30-0.32 units which is more than 100% in increase acidity. In general, an increase of 1°C in global temperatures will result in a decrease of ocean pH by roughly 0.1 units as predicted by climate-carbon models (IPCC, 2013).

The decline in pH means that there are now less carbonate ions hence the rate of reef production is reduced and the rate of disintegration of existing reef framework is accelerated (Doney et al., 2009). With increased ocean pH decline the net breakdown of the reef framework will occur since the rate of reef dissolution may begin to outweigh the rate of reef generation. Despite the fact that research on ocean acidification has generally focused only on limited individual reef species instead of the coral reef ecosystem as a whole, this is sufficient to suggest that there is bound to be some loss of coral reef framework in the mid-century under the medium (RCP4.5) emissions scenario (Maynard et al., 2015). Moreover most aquatic organisms and bacterial processes require specified pH range. An imbalance in the pH range can adversely affect their physiological processes. It can also alter the biological availability of metals, the speciation of nutrients and the toxicities of ammonium, aluminum and cyanide. The risk of impact is more substantial for the BAU scenario ranging from high to very high and the only efficient management option being to mitigate the risks as other management options become less efficient (Fig. 7)
These are serious environmental threats to the Pacific region that affect its culture, economy and physical survival. The implications of warming as a result of CO\textsubscript{2} emissions from human activities, is irreversible on the timescale of centuries or millennia (Stocker et al., 2013). The rate of these occurrences can be minimized by reducing the net CO\textsubscript{2} emissions. CF which is a quantitative expression of GHG emissions from an activity, can help in emission management and evaluation of mitigation measures (Williams et al., 2015). In addition to this, “keeping track of carbon emissions through CF calculations gives an indication of the environmental performance of an organization” (Alvarez et al., 2016). This can indicate progress towards achieving sustainable development and reducing GHG emissions.

1.8 Carbon Footprinting (CF)

The term carbon footprint originated out of “ecological footprint” proposed by Wackernagel and Rees (Weidmann, 2009). Despite the term “carbon footprint” arising out of the concept of ecological footprint, it has emerged into a concept of its own premise as a result of growing concerns of global warming and climate change (Mathis Wackernagel & Rees, 1998). The concept of CF has been in existence for several
decades and has been known as “life cycle impact category indicator” (Pandey et al., 2010). The present view of the concept is modified in terms of its name being derived from “ecological footprint” while conceptually having prominence as an indicator of global warming potential. What links the concepts of CF and ecological footprint together is the fact that they are both concerned with measuring the environmental effects of human production and consumption. Undoubtedly there exits wide-spread confusions on what the term CF means despite its growing popularity and favorable public reputation. A number of other terms available in the literature are also used which are associated or used synonymously to CF. These are; “embodied carbon, carbon content, embedded carbon, carbon flows, virtual carbon, GHG footprint and climate footprint” (Pandey et al., 2010). Recent development in the studies and methods of CF have also acknowledged including other GHGs in the calculations and not just CO2. Thus majority of the entities have expressed their CF as carbon dioxide equivalents (CO2e). The implications of this will be discussed further in this report.

Two apparent views exist on measurement of CF. First is that carbon emissions from human activities is measured in emission amount. The second view is in terms of ecological footprint whereby the carbon emissions from fossil fuel combustion is measured with respect to the ecological carrying capacity required in capturing the carbon emissions measured in unit area (Zhao et al., 2014). These definitions have generally been used in past studies with the former definition being applied at micro-levels such as universities and the latter at macro-levels for example municipals. A scientific definition of CF is yet to be developed. In essence, CF determination is based on analyzing and accounting for the CO2 and other GHGs emitted from processes, practices and events. In particular, 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). The range of definitions of CF shown in Table 1 illustrates that the definition is dependent on the activity or product it is applied to and on the reasons for calculating the CF.
Table 1: Definitions for CF

<table>
<thead>
<tr>
<th>Definition</th>
<th>Source</th>
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<tr>
<td>“Organizational carbon footprint is defined as the amount of greenhouse gas emissions directly and indirectly emitted by an organization, considering all relevant sources in both consumption and production within a specified spatial and temporal system boundary”</td>
<td>Wiedmann &amp; Minx, 2008</td>
</tr>
<tr>
<td>“Measure of greenhouse gas emissions associated with an activity, group of activities or a product”</td>
<td>Abbott, 2008</td>
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<tr>
<td>“The carbon footprint therefore measures the demand on bio capacity that results from burning fossil fuels in terms of the amount of forest area required to sequester these CO₂ emissions”</td>
<td>Global Footprint Network, 2007</td>
</tr>
<tr>
<td>“The term carbon footprint is commonly used to describe the total amount of CO₂ and other greenhouse gas (GHG) emissions for which an individual or organization is responsible. Footprints can also be calculated for events or products”</td>
<td>Carbon Trust, 2007</td>
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<tr>
<td>“A measure of the amount of CO₂ emitted through the combustion of fossil fuels; in the case of an organization or business, it is the CO₂ emissions due to their everyday operations; in the case of an individual or household, it is the CO₂ emissions due to their daily activities; for a product or service, it includes additional life-cycle CO₂ emissions along the supply chain; for materials, it is a measure of the embodied CO₂ emissions determined through life cycle assessment”</td>
<td>Carbon N Zero, 2015</td>
</tr>
<tr>
<td>“This term actually refers to the amount of productive land (forest) required to sequester (remove) the equivalent amount of GHGs that a company emits”</td>
<td>Triple Pundit, 2008</td>
</tr>
<tr>
<td>“The total amount of CO₂ and other greenhouse gases, emitted over the full life cycle of a product or service”</td>
<td>MCI, 2015</td>
</tr>
<tr>
<td>“The quantity of GHG emissions produced over a specific time period is defined as a carbon footprint and is commonly used to evaluate progress towards climate mitigation goals”</td>
<td>Doyle, 2012</td>
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1.8.1 Importance of CF

The importance of CF studies is apparent as the UNFCCC has prompted the development of national GHG inventories for developing and developed countries (Alvarez et al., 2016). The necessity for low carbon based development is the driving factor for this initiative. The concept of CF has been intrinsically linked to the
increased levels of CO₂ in the atmosphere and has gained popularity in the past decade in response to building 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. To control and manage emissions, a numerical representation can be useful. Since CF is the measured value of GHG emissions from activities; it can help in identifying emission hotspots, followed by implementing emissions reductions plans and then monitoring these implementations. This would help to evaluate the effectiveness of emissions reduction plans and measure progress towards reduction targets. It would also mean environmental efficiencies and cost reduction measures being emplaced to manage emissions.

Institutions which have reported on their CF have done so in response to “legislative requirements, carbon trading, as part of corporate social responsibility, or for improving the brands and the organizations image” (Carbon Trust, 2007; L.E.K, consulting LLP, 2007). Legislative actions have been adopted by a number of institutions and cities that have demonstrated their commitment to reduce emissions by reporting their CF (Pandey et al., 2010). These play a vital role in policy making and implementation of mitigation strategies. In some countries it has become mandatory to keep a register of emissions, for instance in USA, under the ‘Consolidated Appropriations Act, 2008’, companies and firms are required to report on their emissions (Rich, 2008). The ultimate goal is to reduce emissions or offsetting through purchasing carbon credits or other control measure. Hence in this case CF reporting is seen as a means of demonstrating commitment to reducing emissions.

Additionally, CF is of great importance to businesses since future trajectories depict a carbon constrained economy (Gouldson et al., 2015). Thus more and more businesses are undertaking the task to calculate CF and reduce emissions so as to have a competitive advantage. It is also noteworthy that there is high preference, by consumers (mostly in developed countries) for products and services that provide details of their CF and are also willing to pay more for products with relatively low CF (L.E.K, Consulting LLP 2007). The growing awareness of climate change has also prompted individuals to take proactive roles in quantifying their emissions through online calculators and consultancies, not forgetting the growing consumer interest in CF labels (Thogersen & Nielsen, 2016). Evidently, there has been a growth in
voluntary carbon market since 1989 particularly in developed countries (Pandey et al., 2010). After quantification, individuals also offer to offset their emissions by planting trees, supporting afforestation and adapting practices that help to save energy.

UNDP (2007) and Edgar and Peters (2009) have published country wise per capita CF. This conveniently depicts countries’, cities’ and sectors’ contribution towards global warming. It is also apparent that OECD countries generate larger CF in comparison to non-OECD countries. CF has been used to indicate the impact of lifestyle of a citizen of a particular country, on that country’s carbon emissions. CF has also been used as an indicator of event management, as done for the 2006 FIFA world cup and the 2012 Olympic Games, (Bellassen & Leguet, 2007). This further emphasizes the growing popularity of CF studies in every area, from business institutions, to municipals, countries and even sporting events.

Accordingly, reducing GHG emissions can help mitigate further future changes in the climate system and subdue the effects of climate change. Keeping track of the carbon emissions from anthropogenic activities may also be useful for the purpose of comparing natural vs. anthropogenic impacts on the environment. The basis of mitigation actions can be to firstly establish a quantitative measure of the emissions, achieved through measuring the CF of a product, activity or institution. That is done by taking an inventory of GHG emissions, expressed in tons of CO$_2$e. Doyle (2012) elaborates that a CF is commonly used to evaluate progress towards climate mitigation goals and therefore Davey & Kahler (2002) also suggested the term “climate footprint”. By conducting an inventory of GHG one can identify wasteful energy use and emission hotspots and thus is the first step towards reducing energy costs (Davey & Kahler, 2002). It can also be applied to examine differences between energy sources (Klein-Banai, et al 2010). It also has the potential “to encourage a more consistent framework for environmental assessment of products and services” (Weidema et al., 2008). Such studies can also give an overview of factors affecting emissions from large institutions. Overall the intention of CF is “monitoring and keeping track of carbon performance so as to evaluate progress made towards achieving ecological sustainability” (Guereca et al., 2013). This will then lead to prioritizing mitigation efforts based on the result (Townsend & Barrett, 2013).
1.9 University CF

Institutions such as universities are significant emitters of GHGs resulting from the consumption of resources and from the services they provide. This is because educational process means high consumption of paper, student and staff commuting, usage of electricity and water and waste generation. Analyzing and reporting on the CF is an important facet of campus greening efforts and a measure of progress towards sustainability (Townsend & Barrett, 2013). University campuses also consist of specific groups of diverse buildings, for example offices, laboratories, classrooms, library etc. which makes it an excellent test bed to characterize and understand sustainability and mitigation efforts. Since education related processes have an impact on the environment, keeping track of the carbon emissions can be crucial to pursuing sustainability efforts. In fact, “sustainability efforts have prompted many Universities around the world to calculate and report on their carbon emissions” (Klein-Banai & Theis, 2013). According to Klein-Banai et al (2010) conducting a baseline GHG inventory can serve as a measure of progress towards more sustainable practices within an institution and as a tool for developing goals, strategies and policies to reduce emissions.

1.9.1 Literature Review

The impact economic activities impose on the environment has gained a promising approach through environmental footprinting (Kjaer et al., 2015). An environmental footprint can be defined as “a measure of natural resource and environmental impacts for which a company or product is responsible within the life cycle of its entire operations” (Ewing et al., 2011). CF studies look at a single indicator of environmental impact, which is the GHGs. CF assessments has been classified in two main areas - the life cycle assessment (LCA) for product CF and the corporate-based analysis for corporate CF (Alverez et al., 2016).

The two methodological approaches that can be utilized to undertake the task of calculating CF of products and organization 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 the 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, government or the average citizen (Wiedmann & Minx, 2008).

CF studies of most of the universities and the one applied in this work have hybridized these models to suit the institution in terms of structure, size and organization. In general the EIO methodological approach have 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 highlight three basic steps required for quantifying CO₂ and CO₂e emissions. The first step is to establish assessment boundaries. This involves organizational and the operational boundaries and the identification of the greenhouse gasses that will be accounted for. The second step is data collection and the final step is calculating the emissions using appropriate emission factors.

1.9.1.1 Scope of measurement

The first step in CF is to establish the boundaries of measurement. This means identifying “all facilities and emission units within the organizational and operational boundary of the inventory” (Blue & Ford, 2007). This, then leads to the issue of the inclusion of the indirect emissions (which is part of upstream production processes) or to only include the direct emissions within an organizational boundary. A direct GHG emission is defined as a “GHG emission from GHG sources owned or controlled by the company” (GHG Protocol, 2004). An energy indirect GHG emission is defined as emissions from the generation of imported electricity, heat or steam that is used by the organization. The other indirect GHG emission are the emissions apart from the energy indirect GHG emissions which results from the activities of the reporting entity (WRI/WBCSD, 2004).
Sustainable Development have categorized the emissions into three scopes of direct and indirect emissions (GHG Protocol, 2004). This serves the purpose of improving transparency and ensures that the emissions are not counted twice.

The three scopes as outlined in the GHG Protocol include; “scope 1 direct emissions, scope 2 and 3 indirect emissions (GHG Protocol, 2004). 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. This is represented diagrammatically in Figure 5. In majority of the studies, scopes 1 to 3 were well defined. The emission sources were categorized generally into; transportation, energy purchase, energy generation and solid waste generation. The acquisition of activity data are mainly attained through a bottom-up approach (Malten, 2009). Existing data is obtained through administrative, academic and technical departments whereas non-existent information is obtained through online/face to face surveys.

![Figure 5: Boundaries for CF calculation.](Greenhouse Gas Protocol, 2004)
1.9.1.2 Methodology used to establish CF boundaries

1.9.1.2.1 Equity share approach

Under this approach the GHG emissions from operations of a company are accounted for based on the company’s share in the equity (WRI/WBCSD, 2004). For instance, the USP Marine campus would only be responsible for accounting for emissions over which it has ownership.

1.9.1.2.2 Operational control approach

The company reports on those emissions from operations over which it has control, that is in terms of introducing and implementing policies. “It does not account for GHG emissions from operations in which it owns an interest but has no control” (WRI/WBCSD, 2004). This is the most commonly used boundary-setting approach.

1.9.1.2.3 Financial control approach

This approach is based on reporting for those “emissions from operations over which the organization has financial control” (WRI/WBCSD, 2004). This would mean that the organization has the right to the majority of benefits of the operation.

1.9.2 Units of measurement

The unit of measurement of a CF is established from two key questions. The first question relates to the difference between an ecological footprint and a CF. East asks the question “Should the measurement of a CF be expressed in tonnes of gaseous emissions or in area-based units tied to the natural regenerative capacity of the environment?” (East, 2008). This issue is addressed by considering the definitions of CF which draws the connection between CF and the measurement of gaseous emissions. The assumption that CF should be measured in tonnes of gaseous emissions as adopted from literature raises the second question, “should the measurement of a CF be in tonnes of CO₂ or should it be extended to include a variety of GHGs expressed in tonnes of CO₂ equivalents?” (East, 2008). A broader understanding of this issue is attained from tools and mechanisms developed to reduce GHGs, for instance the Kyoto Protocol. “This is an international legally binding agreement between signatory nations and the United Nations Framework Convention on Climate Change
(UNFCCC) to reduce GHGs and to stabilize anthropogenic GHGs” (Blobel et al., 2006). The basis for emissions accounting of the Kyoto Protocol was in measuring the global warming potential (GWP) of the different GHGs in CO$_2$e.

The Kyoto Protocol has identified six main GHGs, each with a different global warming potential (GWP). The GWP of greenhouse gases is used to convert the non-CO$_2$ gases to CO$_2$ equivalents. This suggests that a CF should take into account the greenhouse gases expressed in CO$_2$ equivalents. There is much support on this notion since this would ensure that the activity being “foot printed” is consistent with standards of international agreements such as the Kyoto Protocol.

There is a range of standards for GHG accounting published by the International Organization for Standardization (Table 2). The GHG protocol was the first standard to define CF (Barnett et al., 2013). The ISO14064 which is based on the Greenhouse gas protocol describes the quantification of GHG at a product and organizational level and also provides methods for validating the quality of data used to calculate emissions (Barnett et al., 2013). These standards also include the six GHGs listed in the Kyoto protocol and use the three scopes to categories the direct and indirect emissions. Furthermore the UK and USA (Table 3) have also developed their own GHG accounting guidelines which are primarily based on the international standards but are more specific to their country.

Table 2: Standards and guidance for GHG accounting (ANSI, 2016).

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<th>Description</th>
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<tr>
<td>“GHG protocol of World Resource Institute (WRI)/ World Business council on sustainable Development (WBCSD): there are 2 standards: (1) A Product Life Cycle Accounting and Reporting Standard, and (2) Corporate Accounting and Reporting Standard: Guidelines for Value chain (tier111) Accounting and Reporting” (WRI/WBCSD, 2004).</td>
</tr>
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</table>
- Publicly Available Specifications-2050 (PAS 2050) of British Standard Institution (BSI). It specifies the requirements for assessing the life cycle GHG emissions of goods and services

- 2006 IPCC guidelines for National Greenhouse Gas inventories

- ISO 14025: a standard for carrying out LCA

- ISO 14067: a standard on carbon footprinting of products (under development).

Table 3: The United Kingdom and The United States of America GHG accounting guidelines

| United Kingdom | • Department of Food and Rural Affair (DEFRA)  
|                | • Carbon Trust |
| USA            | • Environmental Protection Agency (EPA)  
|                | • Registries and consultancies e.g. World Wildlife Fund Climate Servers  
|                | • California Climate Registry  
|                | • The Climate Registry  
|                | • Campus Carbon Calculator |
1.9.3 Emission Factor

GHG emissions associated with an organization’s activities are calculated by converting the ‘activity data’ such as distance travelled, liter of fuel used or tonnes of waste disposed into carbon emissions. The conversion factor is referred to as the emission factor which is “a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant” (Anderson, 2008). The unit of expression of these factors is in terms of “the weight of pollutant divided by a unit weight, volume, distance or duration of the activity emitting the pollutant” (Anderson, 2008). These factors are usually averages of all data of acceptable quality and are considered to be representative of long-term averages for all facilities in the source category. Hence the emission factor is the input for the emission inventory used to calculate the total emission.

1.9.3.1 Sources of emission factor

Emission factors in this CF analysis were used from the following sources:

- 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- IPCC Emission Factor Database
- United Kingdom's emission factor database (DEFRA)
- Environment Protection Agency (EPA)

The reliability of a CF is “not only dependent on data accuracy but also on the emission factors” (Abbott, 2008). These standards however may carry a high level of uncertainty since in many cases it’s not country specific. To cater for this, the IPCC provides a methodology for assessing uncertainty (Abbott, 2008). The 2006 IPCC Guidelines for National Greenhouse Gas Inventories have also calculated the levels of uncertainty.
1.9.4 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 as identified in tables 2 and 3. The most popular for 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 Campus Carbon Calculator (Klein-Banai et al., 2010). The carbon calculator calculates the estimated emission from the data collected using MS Excel workbook. The calculations are based on the following equation:

\[ A \times F_g = E_g \]  

(1)

Where: - A is the quantification of an activity in units that can be combined with emission factor of GHG \((F_g)\) to obtain the resulting emissions for that gas \((E_g)\). For example, activity units include kilowatt-hours of electricity or the miles traveled. The sum total of all the gases can be expressed as the sum of the emissions for each gas multiplied by its GWP (equation 2). The unit of measurement used is metric tons of carbon dioxide equivalents (metric tons CO\(_2\)e).

\[ GHG = \sum_g E_g \times GW P_g \]  

(2)

Despite the ease of use of this tool some campuses have designed their own tools based on the GHG Protocol developed by the WRI (Clifford & Cooper, 2012). For example Tufts University developed a methodology and spreadsheet in accordance with the WRI protocol (Townsend & Barrett, 2013). The emission calculators also use different source categories e.g. EPA GHG emission calculator (Fig 4). These have been analyzed to suit which sources are relevant. 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 an important source considering the nature and activities carried out by universities. The “environmental impacts that goods and services impose 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 and also the lack of resources to investigate the supply chain of each product. “Therefore, rationalized methods can help campuses to estimate embodied emissions so that the impacts of such GHGs can be measured and managed” (Thurston & Eckelman, 2011). Table 5 shows an overview of methods employed by various universities and the results obtained for each of the scopes.

Table 4: Comparison of major emission sources of the CCC and EPA GHG emission calculator

<table>
<thead>
<tr>
<th>Major Emission sources</th>
<th>Campus Carbon Calculator</th>
<th>EPA simplified GHG emission calculator</th>
</tr>
</thead>
<tbody>
<tr>
<td>On campus energy production</td>
<td></td>
<td>Mobile sources</td>
</tr>
<tr>
<td>Purchased electricity</td>
<td></td>
<td>Stationary combustion</td>
</tr>
<tr>
<td>Natural gas service to buildings for laboratories and cooking</td>
<td></td>
<td>Refrigeration and AC</td>
</tr>
<tr>
<td>Transportation (including air travel and commuting)</td>
<td></td>
<td>Purchased gases</td>
</tr>
<tr>
<td>Waste</td>
<td></td>
<td>Waste gases</td>
</tr>
<tr>
<td>Paper</td>
<td></td>
<td>Electricity</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td>Business travel</td>
</tr>
<tr>
<td>Refrigerants</td>
<td></td>
<td>Commuting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Product transport</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fire suppression</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steam</td>
</tr>
</tbody>
</table>
Table 5: Some examples of University CF assessments

<table>
<thead>
<tr>
<th>Case study</th>
<th>method</th>
<th>Carbon footprint (tCO₂e)</th>
<th>Carbon footprint (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lancaster University (LU)</td>
<td>HLCA</td>
<td>71,700</td>
<td>21 23 56</td>
<td>Thurston and Eckelman, (2011)</td>
</tr>
<tr>
<td>De Montfort University (DMU)</td>
<td></td>
<td>51,080</td>
<td>6 15 79</td>
<td>Ozawa-Meida et al., (2013)</td>
</tr>
<tr>
<td>Yale University (YU)</td>
<td></td>
<td>874,000</td>
<td>19 5 76</td>
<td>Thurston and Eckelman, (2011)</td>
</tr>
<tr>
<td>The Norwegian University of Technology &amp; Science (NTNU)</td>
<td>EEIOA</td>
<td>92,100</td>
<td>19 81</td>
<td>Larsen et al., (2010)</td>
</tr>
<tr>
<td>The University of Illinois, Chicago (UIC)</td>
<td>PA</td>
<td>275,000</td>
<td>64 17 19</td>
<td>Klein-Banai et al., (2010).</td>
</tr>
<tr>
<td>The University of Cape Town (UCT)</td>
<td></td>
<td>84,926</td>
<td>81 19</td>
<td>Letete et al., (2011)</td>
</tr>
</tbody>
</table>

Thurston and Eckelman (2011) focused on GHG emissions resulting from procurement at the Yale University. In their work they utilized the 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). According to Hendrickson et.al (2006), the drawback of this model is “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 the university 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.

The CF of UC Berkeley was conducted by means of “a top-down hybrid life cycle assessment using the Comprehensive Environmental Data Archive (CEDA) emission factor database, annual procurement reports and vendor location data” (Doyle, 2012). This analysis also focused only on scope 3 emissions. The study revealed that the “top-down LCA component was not time intensive and proved to be very effective for the ‘hot-spot’ analysis. The bottom up LCA component of this methodology would be improved if more specific procurement data was available” (Doyle, 2012). The data set contained only the account, vendor and total spend data. What was lacking was that it did not specify what goods and services were being purchased from vendors. Moreover transactions were sent through accounts that don’t accurately depict what is being purchased.

Ozawa-Meida et al. (2013) investigated the CF for De Montfort University through a consumption based study which included the scope 1, 2 and 3 emissions under the classification of the WRI/WBCSD Greenhouse gas protocol corporate standard. The main analysis categories in this study which is relevant to most universities are; “building energy: direct emissions from University buildings and equipment, travel: direct and indirect emissions from the movement of people, that is the 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 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 CO₂e/ KWh used, kg CO₂e/km travelled or kg CO₂e/passenger kilometer, and kg CO₂e/ £spent)
- Step 3: multiply activity/consumption data by the corresponding emission factors to estimate the emissions in kg CO₂e for each sector and sum up to obtain the overall CF.
\[ GHG = activity/consumption\ data \ast\ emissions\ factor \quad (3) \]

The emissions factor for this analysis is derived from top-down environmentally extended input-output analyses which refer to economic sectors. For instance the emission factors were based on the guidelines to Defra/DECC’s Greenhouse Gas Conversion Factors for Company Reporting which included 75 Defra sectors (Larsen, et al 2013). The limitation of this methodology as recognized by the authors was that since it was national “sector average” emission factors and not specific to the product or process, it did not fully capture ‘local’ differences in consumption. The authors thus recommended a more specific methodology for product CF of goods and services and life cycle analysis of waste streams (Larsen et al., 2013).

The Norwegian University of Technology and Science (NTNU) also investigated their CF using the Environmental Extended Input-output (EEIO) modelling which included all the aspects of the university’s activities. This is part of the Input-Output Analysis which was introduced in the 1930s (Munksgaard et al., 2005). With the inclusion of environmental related information, it evolved to become the Environmental Extended Input-Output (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 cannot be compared 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 in comparison to LCA is more effective on the basis 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 a reliable mean in calculating the total CF compared to LCAs which are more detailed yet time consuming, however the EEIO model is lacking in detail” (Klein-Banai et al., 2010). The models are also couple of years old and changes in the production
technology have not been captured fully. The EEIO model is also not useful when 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 the suitability of a university. An important aspect of the EEIO model is to match the data from financial account to the EEIO sectors. The compound method by Alvarez (Alvarez et al., 2016), also incorporates the EEIO model in their calculation of CF for University of Madrid. From their findings they claim that results are comparable to the results of the universities which used a similar approach and that the model is simple and easy to understand.

The CF results of most of the Universities depict that scope 3 emissions dominate CFs (Table 5). This however is not apparent for UIC and UCT 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 these works there are 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 act as a basis for their GHG reduction plans and to uphold their commitment towards sustainability goals, for example (Lancaster University (LU) De Montfort University (DMU) Yale University (YU), The Norwegian University of Technology & Science (NTNU), The University of Illinois, Chicago (UIC), The University of Cape Town (UCT)). In each of the studies the boundary of measurement and the scopes of emissions were clearly categorized and defined and was generally consistent with the greenhouse gas 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 it in respective scopes and use appropriate emission factors.

1.9.5 Challenges in estimating CF

Knowledge gaps in CF studies are mainly due to the lack of availability of detailed data. Attempts in estimating CF are oriented by researchers’ efforts in acquiring data primarily through consultations with management divisions/departments. Other challenges based on the methodologies are the inclusion of only CO₂ by some entities despite the fact that international standards and guidance require the inclusion of all Kyoto gases. Also reporting scope 3 emissions is optional under the standards since it is vaguely defined but most importantly due to the data gaps in developing countries circumstance. For instance for the scope 3 emissions, detailed data of distance travelled and fuel consumed by the staff/faculty and the student is not known by the university nor is regarded of much relevance to its overall purpose (Chakraborty & Roy, 2013). However in most of the CF studies of universities, scope 3 emissions contribute significantly to the total CF. Another challenge is that most of the CF studies do not account for the GHG removal and sequestration (Peters, 2010). “GHG inventories are also limited by the fact that not all environmental impacts are accounted for, for example hazardous waste disposal, air pollutants, water usage, or waste water and storm water generation” (Klein-Banai & Theis, 2013). Also the issue of methodological inconsistency with regards to accounting of scope 3 emissions makes comparing results of CF studies of universities implausible (Townsend & Barrett, 2013). What is plausible however is the analysis to identify the sources of these inconsistencies (Townsend & Barrett, 2013). Therefore when reporting it is important that universities clearly define the emission sources they are accounting for and the reasons for inclusion or exclusion of the common source categories relevant to universities.
1.9.6 Chapter summary

Institutions such as universities are significant emitters of GHGs resulting from the consumption of resources and from the services they provide. This is because educational processes require a high consumption of paper, student and staff commuting, usage of electricity and water and the production of waste. In order to reduce energy consumption and hence the carbon emissions, the first step is to develop a CF inventory followed by mitigation strategies based on the inventory. Analyzing and reporting on the CF is an important facet of campus greening efforts and a measure of the progress towards sustainability initiatives. Since education related processes have an impact on the environment, it is important that the universities keep track of their carbon emissions and work to reduce it. In fact, sustainability efforts have prompted many Universities to calculate and report on their carbon emissions. Universities around the world are committed to sustainability efforts and the basis of these efforts is estimating the GHG emissions of the university. GHG inventories however are limited by the fact that not all environmental impacts are accounted for. Despite this, CF is an excellent indicator of environmental performance and the basis for climate change mitigation action and sustainable development.
Chapter 2- Existing tools and Methodology

This chapter introduces the methodologies used in CF estimations for the USP marine campus. In particular it discusses the IPCC and the GHG Protocol Guidelines methodology which is the main reference point of this project. The calculation methods for emission causing sectors that are relevant to institutional activities are described. Since the IPCC Guidelines are specifically for national GHG inventories, alternative methodologies from the GHG Protocol are described for emission categories that are unique to lower level single organization.

2.1 The IPCC Guidelines methodology

The Intergovernmental Panel on Climate Change (IPCC) is the main scientific body that appraises climate change, which was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) with the purpose of disseminating scientific views and information on the present state of climate change and its potential environmental and socio-economic threat (UNFCCC, 2014). “The United Nations Framework Convention on Climate Change” (UNFCCC) established the “2006 IPCC Guidelines for National GHG Inventories” which is the updated version of the Revised 1996 Guidelines and associated good practice guidance. These guidelines which are internationally approved provide methodologies deliberated for countries to produce GHG Inventories to be reported to the UNFCCC under article 4 of the convention (UNFCCC, 2014). The 2006 guidelines is one of the main methodical approach adopted for this project since it provides a standard method which can also be used to benchmark project level inventories. There are five main categories of the 2006 IPCC which represent sectors at national level related to processes, sources and sinks. These are:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste
- Other (e.g., indirect emissions from nitrogen deposition from non-agriculture sources)
Each sector is then further divided into individual categories, for example the energy sector has a category e.g. transport and sub categories e.g. cars. For single organization inventory which is less complex as compared to national inventory, has certain categories which may not be applicable; for example energy consumption category for an organization would be different for the 2006 IPCC which considers the generation of electricity.

2.2 Estimation method

A simple approach is to multiply the activity data with emission factors per unit activity. Activity data is defined as the extent to which a human activity takes place and the emission factor is the coefficient which quantifies the emissions or removals per unit activity (Vaccari et al., 2011). For example in the energy sector the activity data would be the amount of fuel consumed and emission factor would be the mass of carbon dioxide emitted per unit of fuel consumed.

\[
Emission = activity\ data \times emission\ factor
\] (4)

This is the basic equation for the estimation of emission. Other estimation parameters may also be included in circumstances whereby time lags are involved. For example for solid waste disposal whereby materials take time to decompose in a landfill or refrigerant leaks from cooling system. Hence other methods are provided for these scenarios and is described in the IPCC reference manual.

2.3 Key elements of IPCC method

**Tiers:** the level of complexity of the methods is represented by a tier. Three tiers are provided: tier 1 (basic method), Tier 2 (intermediate) and Tier 3 which is more complex and requires much more specific data. The tier levels also coincide with the level of accuracy and thus tiers 2 and 3 are considered to be more accurate.

**Default data:** this is a key element of tier 1 methods which are designed to use data that are readily available (e.g. national or international statistics) in addition with the given default emissions factors and other parameters. Since the data set is country or region specific this method should be feasible for all countries (Vaccari et al., 2011).
**Key Categories:** this identifies with the categories that have a significant influence on a country's total inventory of GHG emissions. These are the priority categories for which countries during inventory assessments allocate resources for data collection, compilation, quality assurance/quality control and reporting.

### 2.4 General Inventory Guidelines

USP marine campus inventory was developed in accordance with industry standards and the GHG Protocol. GHG Accounting and reporting are based on five principles to ensure that the GHG inventory is true and is a just account of a company’s GHG emissions. The principles which form the basis of reporting are; “relevance, completeness, consistency, transparency and accuracy” (GHG Protocol, 2004). The principles are discussed in detail on page 23 of The Corporate Value chain Accounting and Reporting Standard.

### 2.5 Organizational CF and assessment standards

#### 2.5.1 CF at organizational level

The CF of an organization alludes to accounting for direct and indirect GHG emissions given off within the scopes defined by the reporting organization (Gao et al., 2013). A widely accepted GHG accounting standard for corporations and organizations is the GHG Protocol (Gao et al., 2013). The GHG Protocol provides the steps in calculating an organizational CF which include:

- Defining organizational boundary
- Establishing operational boundary
- Calculating CF
- Reporting and verifying

Primarily defining and establishing the organizational and operational boundaries forms the basis of CF assessment. An overview of the elements of the assessment is given in Figure 8. The protocol also emphasizes on GHG accounting and reporting principles which forms the basis of organizational CF (Chapter 1). The GHG protocol systematically classifies and defines emission sources that is comprehensive and sets a benchmark for all corporations and organizations.
2.6 The GHG Protocol

The World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) developed the Greenhouse Gas Protocol (GHGP) which is a tool for measuring, managing, and reporting GHG emissions at organization level (Green, 2010). It was developed as an environment instrument, targeting corporations in light of evolving climate change policies which placed greater emphasis on corporations to regulate emissions in order to address climate change. The Greenhouse Gas Protocol: Corporate Standard was first published in 2001 and has since been the basis for nearly all GHG standards and programs in the world (Gao et al., 2013). For instance the corporate standard was adopted by the International Organization for Standardization (ISO) as the foundation for its “ISO 14064-1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals” (WRI/WBCSD, 2004). This reinforced the GHG Protocol’s Corporate Standard as the international standard for GHG accounting and reporting at corporate and organization level.
2.6.1 Overview of The GHG Protocol’s Scope and emission standard

The GHG Protocol framework for quantification of GHG emissions is centered on categorizing the emission sources into ‘scope’ as mentioned earlier in chapter 1 (Fig 5). The three specified scopes are: “Scope 1 Emissions from sources directly controlled by the company (e.g. vehicles and manufacturing facilities), Scope 2 emissions associated with the generation of electricity and other utilities consumed by the company and Scope 3 emissions from all other activities that are an indirect consequence of the company’s activities, such as employee commuting and disposal of company waste” (Matisoff et al., 2013). This categorization provides a comprehensive view of sources of GHG emissions for businesses or any office based organization (Fig 9). The GHG Protocol corporate accounting and reporting standard provides businesses a framework on how to perform a GHG inventory which focuses on scopes 1 and 2. The corporate value chain standard covers scope 3 emission sources. These standards are described in detail together with calculation tools, excel worksheets and guidance for each scope are provided on the GHG Protocol website. Moreover sector specific calculation tools and emission sources are clearly defined for the associated industry or sector. This is because emission sources and categories would differ for different sectors. For instance the service sector which is mostly office based organizations would have emission sources that would be different for an industry sector and therefore specific sector toolsets are available under the GHG Protocol tools.
2.6.2 Users of the GHG Protocol Standards

These standards are primarily targeted for quantifying GHG emissions for businesses; however, it is applicable to other types of organizations, for example government agencies, NGO’s and universities (GHG Protocol, 2004). Therefore, the protocol categorizes users into Corporate Users and Non Corporate users.

2.7 Overview of Calculation methods

The calculation guide provides multiple calculation methods for each of the categories. These are dependent on the extent of data available, the time factor and effort to collect data. The method with the quality output will require a more extensive data collection process. The choice of the calculation method by companies as provided in the GHG Protocol is reliant on;

- Goals of the business and the purpose for calculating the emissions
- The significance of a scope category to the overall emissions (scope 1 and 2 are compulsory).
- The categories which are relevant for the business

Figure 9: Overview of scopes and emissions
(Source: The GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard)
• Availability of data

2.7.1 Sampling

Categories which have large quantity of data will require the need to use appropriate sampling techniques since it is impractical to collect data from each individual activity (Thompson, 2012). The sample data collected will then be extrapolated to give a general picture. Some instances in which sampling is required include, collecting data on employee and student commuting for an organization with large student and staff population and also collecting data on waste produced (WRI/WBCSD, 2011).

The Guidance for calculating scope 3 emissions describes factors that will influence the choice of sampling method. These factors include but not limited to:

- Available resources
- Number of data points
- Expected level of homogeneity between samples
- Geographical spread of data points
- Ease of data collection
- Timeframe available

The choice of sampling method aims to offer a balance between cost and accurate representation of scope 3 emission sources (Guidance for calculating scope 3 emissions, 2011). The sampling methods discussed in the guide include: simple random sampling, systematic sampling and stratified sampling. Sampling methods are not limited to these method and alternative methods for sampling may be used where appropriate. Other aspects of sampling that need to be discussed as identified in the IPCC guide are level of precision, confidence level and variability.

2.7.2 Sample size

The GHG Protocol Guide highlights the factors that influence sample size relative to GHG inventory of an organization. These factors are; the likely significance of GHG emissions from the sources in question, the size of the population, the variability of the emission sources, and the necessary degree of precision. To
determine the sample size the GHG Protocol guidance for Calculating scope 3 emissions discusses four alternative approaches which may prove useful for companies. These are:

- Using the sample size of a similar project (justify the similarity and appropriateness for the comparison)
- Using online calculators (quick easy way to assess sample size)
- Using published tables (should match their specific sampling criteria)
- Using formulas

### 2.8 Meaningful categories for Organizational based GHG inventory

Organizational CF is defined as “the amount of GHG emissions directly and indirectly emitted by an organization, considering all relevant sources in both consumption and production within a specified spatial and temporal system boundary”(Wiedmann & Minx, 2008). The CF of a single organization is an inventory list of CO₂e emission sources and their quantities. Previous studies have highlighted on possible sources of emissions linkable to higher educational institutions (Baboulet & Lenzen, 2010; Clifford & Cooper, 2012; Davey & Kahler, 2002; Doyle, 2012; Klein-Banai & Theis, 2013; Klein-Banai et al., 2010; Larsen et al., 2013; Letete et al., 2011). The emission scopes are defined and the categories relevant to University campus level GHG inventory are presented below.

#### 2.8.1 Scope 1: Direct GHG emissions

This scope covers all direct GHG emissions incurred from sources that are owned or under the control of the reporting company. For instance emissions that result from combustion of company owned boilers, furnaces, vehicles etc. The USP marine campus scope 1 direct emissions, which have been categorized to align with the 2006 IPCC guidelines, are:

- Stationary combustion sources - backup generator
- Transportation vehicle - University vehicle fleet and boats
- Fuel for sea transport
2.8.2 Scope 2: Electricity indirect GHG emissions

Scope 2 includes purchased electricity by the reporting company who is the end user. Emissions result when electricity is produced and thus is accounted under scope 2 since the reporting company purchases this and therefore falls within the organizational boundary of the company. The only scope 2 indirect emission source for USP marine campus is purchased electricity. The campus uses grid electricity from FEA to power air conditioning, lighting, computers, laboratory equipment, etc. GHG emissions associated with purchased electricity are calculated using the GHG protocol methodology using the following equation:

\[
GHG (\text{Metric tons } CO_2e) = Purchased Elect. (kWh) \times EF (\text{Metric ton} \frac{CO_2e}{kWh})
\]

2.8.3 Scope 3 categories

Reporting of scope 3 emissions is optional under the GHG Protocol. However, the Corporate value chain Accounting Reporting standard was developed specifically to account for the scope 3 emissions. The standard distinguishes scope 3 emissions into 15 different categories. It provides guidance and all requirements related to accounting and reporting of Scope 3 emissions. A separate document, “GHG Protocol Guidance for Calculating Scope 3 emissions” contains calculation guidance for the 15 different categories. However, it may be practically impossible for companies to achieve a complete scope 3 inventory for all the different categories. Achieving a complete scope 3 inventory may mean using less accurate data for the activities. Thus in some instances where the data accuracy is low, the activities are excluded from the inventory. The relevance of the categories to an organization is based on; the goals, function, and structure of the organization and the availability of data as stated in the guide. The goal is to adopt a practical approach that is cost effective and simple without compromising the quality of the overall inventory. This involves using the most accurate data and calculation methods for large contributors as opposed to small contributors, combining similar activity data and selecting samples which are representative of the whole and extrapolating the results. Exclusion of any of the categories should be disclosed and reason for exclusion should be justified.
The USP marine campus Scope 3 indirect emissions consist primarily of the following and are quantified in this GHG inventory to the extent practical. The emission categories are aligned with the 2006 IPCC Guidelines and The GHG Protocol.

- Faculty/staff/student commuting to the marine campus
- Staff airline travel (USP business)
- Personal Automobile use/ Reimbursed mileage (USP business)
- Student Airline travel (study Abroad and other)
- Decomposition of solid waste generated at USP marine campus
- Contracted transportation namely by the bus company
- Transportation of solid waste from and delivery of supplies and material to lower campus.
- Contractor owned and operated construction vehicles, construction equipment and landscaping.
- Fuel for sea transport

These represent the emission categories which a university should typically address in a GHG inventory for scope 3 emissions.
Table 4: Justification for inclusion/exclusion of scope 3 categories

<table>
<thead>
<tr>
<th>Scope 3 categories</th>
<th>Inclusion</th>
<th>Reason for Inclusion/Exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased goods and services</td>
<td>✓</td>
<td>The activity that is accounted for in this category is paper consumption. Since the reporting entity is an academic institute, emission from paper use is an important contributor to the overall emissions of the campus. Other purchased goods and services are not included due to time constraints and availability of data.</td>
</tr>
<tr>
<td>Capital goods</td>
<td>✗</td>
<td>No capital good was purchased for the reporting year.</td>
</tr>
<tr>
<td>Fuel &amp; energy related activities not included in scope 1 &amp; 2</td>
<td>✗</td>
<td>No activity fell under this category and therefore was not relevant for the USP campus GHG inventory.</td>
</tr>
<tr>
<td>Upstream transportation &amp; distribution</td>
<td>✓</td>
<td>This category includes the USP shuttle service which is used to transport students between the campuses.</td>
</tr>
<tr>
<td>Waste generated in operations</td>
<td>✓</td>
<td>The activity of solid waste disposal was included under this category. The IPCC guideline was used to collect activity data for the waste streams and to quantify methane emissions. Emissions from incineration were not relevant since burning of waste does not occur at the campus site.</td>
</tr>
<tr>
<td>Business travel</td>
<td>✓</td>
<td>A major activity that could be an important contributor to the overall emissions is air travel for business related activities of the University and therefore effort and time was dedicated in gathering data on this activity for its inclusion in the inventory of the Marine Campus.</td>
</tr>
<tr>
<td>Employee commuting</td>
<td>✓</td>
<td>This is a relevant emissions category for an organization such a University. Other relevant studies also show the inclusion of this category in their GHG inventories and CF initiatives.</td>
</tr>
<tr>
<td>Upstream leased assets</td>
<td>✗</td>
<td>Not applicable to the Campus inventory.</td>
</tr>
<tr>
<td>Downstream transportation &amp; distribution</td>
<td>✗</td>
<td>The university is a service based institute and is not engaged in selling goods thus this category is not relevant.</td>
</tr>
<tr>
<td>Processing of sold products</td>
<td>✗</td>
<td>Category not relevant</td>
</tr>
<tr>
<td>Use of sold products</td>
<td>✗</td>
<td>Category not relevant</td>
</tr>
<tr>
<td>End of life-cycle treatment of sold products</td>
<td>✗</td>
<td>Category not relevant</td>
</tr>
<tr>
<td>Downstream leased assets</td>
<td>✗</td>
<td>Category not relevant</td>
</tr>
<tr>
<td>Franchises</td>
<td>✗</td>
<td>Category not relevant</td>
</tr>
<tr>
<td>Investments</td>
<td>✗</td>
<td>Category not relevant</td>
</tr>
</tbody>
</table>
2.8.4 Category 1: Purchased goods and services

The GHG Protocol guidance for calculating scope 3 emissions provides calculation guidance for implementing the GHG Corporate Value Chain (Scope 3) Accounting and Reporting standard. For this category guidance is provided on calculation methods to calculate emissions from purchased goods and purchased services. This category accounts for emissions that result from the production of a product that is purchased by the reporting company in the reporting year. This is the upstream emissions (cradle-to-gate) that occur in the life cycle of the purchased product. Its life cycle includes extraction of raw material, the agricultural activities, use of land, manufacturing process, electricity consumption, waste generated, transportation and any other activities that would result in emissions from its starting point to the point it is purchased or acquired by the reporting company (Rebitzer et al., 2004). There are three calculation methods provided in The GHG Protocol guidance for calculating scope 3 emissions for this category and a decision tree (Fig 10) is also provided for selecting the relevant method. The methods are:

- Product level Method- provided tier 1 supplier can provide product level cradle-to-gate GHG data for the purchased product following the GHG Protocol Standard.
- Supplier Specific Method- provided tier 1 supplier can provide scope 1 and 2 emissions data
- Material or spend based approach- average data method.

Figure 10: Decision tree for selecting a calculation method
(Source: The GHG Protocol guidance for calculating scope 3 emissions)
Worked examples are provided in the “Guidance for calculating scope 3 emissions’. Description of the three methods, the activity data needed, and emission factor required and the calculation formula is provided below adapted from the “Guidance for calculating scope 3 emissions’ of the GHG Protocol.

2.8.5 Method 1: product level method
Activity data:
- Quantities or units of goods and services purchased.
Emission factor (EF): supplier specific EF

Calculation formula
Sum across purchased goods and services:

\[ \sum \text{quantities of goods purchased (eg. kg)} \times \]  
\[ \text{supplier specific emission factor of purchased good or service (e.g. } kg\text{CO}_2\text{e/kg) } \]  
(6)

2.8.6 Method 2: supplier specific method
Activity data:
- allocated scope 1 and 2 data by tier 1 supplier relating to purchased good  
- Mass of material input  
- Distance of transport  
- Quantities of waste output  
- Other emissions emitted in provision of the purchased goods as applicable.

Calculation formula
\[ \sum \text{scope 1 & 2 emissions of tier 1 supplier relating to purchased good} + \]  
\[ \sum \text{mass or value of material inputs used by tier 1 supplier relating to purchased good (kg or $)} \times \]  
\[ \text{EF for the material (kgCO}_2\text{e/kg or kgCO}_2\text{e/}$) + \]  
\[ \sum \text{distance of transport of material inputs to tier 1 supplier (km) } \times \]  
\[ \text{mass of material input (tonnes) } \times \text{EF for the vehicle type } kg\text{CO}_2\text{e/tonne/km} + \]  
\[ \sum \text{mass of waste from tier 1 supplier relating to the purchased good } \times \]
EF for waste activity \((kgCO_2e/kg)\) + other emissions emitted in provision of the good is applicable \hspace{1cm} (7)

2.8.7 Method 3: average data method

Activity data:
- mass or number of purchased goods or services

If EEIO data is used: cradle to gate emission factors of the purchased goods and services per unit of economic value (e.g. \(kgCO_2e/\$\)).

Calculation formula

\[
\sum \text{Mass of purchased good or service (kg)} \times \text{emission factor of purchased good or service per unit of mass } 9kg \text{ } CO_2e/kg
\]
\hspace{1cm} (8)

OR

\[
\sum \text{Unit of purchased good or service (e.g. piece)} \times \\
\text{EF of purchased good or service per unit of economic value } \left( \frac{kgCO_2e}{\text{piece}} \right)
\]
\hspace{1cm} (9)

OR

\[
\sum \text{Value of purchased good or service (\$)} \times \\
\text{EF of purchased good or service per unit of economic value } \left( \frac{kgCO_2e}{\$} \right)
\]
\hspace{1cm} (10)

2.8.5 Category 6: business travel

The emissions incurred under this category arise from travel by employees for company business in vehicles that are not company operated or owned. For example employee travel for business purposes by taxi, aircraft, busses or passenger cars. Emissions from vehicles under the control of the reporting company are reported separately under scope 1 (for fuel use).

Activity data:
- The total distance travelled by each mode of transport for employees in the reporting year.
- Countries of travel
- Specific types of vehicles used for travel.
Emission factor:
- Emission factors that represent kilograms of CO₂e emissions emitted per kilometre or passenger-kilometre for each mode of transport (e.g. aircraft, rail, metro, bus, taxi, bus, etc.)

Calculation formula

\[ \sum \text{Distance traveled by vehicle type (vehicle – km or passenger – km)} \times \text{vehicle specific EF (kgCO₂e /vehicle – km or CO₂e/passenger – km)} + \text{(optional) } \sum \text{annual number of hotel nights (nights) } \times \text{hotel emission factors (kgCO₂e /night)} \]  

(11)

2.8.6 Category 7: Employee commuting
This category deals with emissions resulting from employees commuting to work from home. Its categorization as an upstream emission is owed to the fact that employees commute to work so that businesses can operate. Since it contributes to the functioning of the business, the emissions incurred are reported under the businesses’ scope 3 emissions.

2.8.8.1 Method 1: Company specific method
Activity data required:
- total distance travelled by employees in the reporting year
- transport mode used for commuting

Emission factor
- Emission factors for each mode of transport (usually expressed as kg GHG emitted per passenger-kilometre travelled)

Calculation formula

1. Sum across all employees to determine total distance travelled using each vehicle type.
Total distance traveled by vehicle type \((vehicle - km or passenger - km) = ∑(daily one way distance between home and work (km) \times 2 \times number of commuting days per year)\)  \hspace{1cm} (12)

2. Then sum across vehicle types to determine total emissions

\[\sum \text{Total distance travelled by vehicle type (vehicle – km or passenger – km)} \times \text{vehicle specific EF (kgCO}_2\text{e /vehicle – km or kgCO}_2\text{e/passenger – km)} + \text{(optionally) for each energy source used in teleworking} \hspace{1cm} (13)\]

2.8.8.2 Method 2: Average data method

Activity data required:
- Average daily commuting distances of employees
- modes of transport
- average number of commuting days per week average number of weeks worked per year

Emission factor: Emission factors for each mode of transport (usually expressed as kg GHG emitted per passenger-kilometre travelled)

Calculation formula

\[\sum \text{Total number of employee} \times \% \text{ of employees using mode of transport} \times \text{one way commuting distance (vehicle – km or passenger – km)} \times 2 \times \text{working days per year} \times \text{EF of transport mode (kgCO}_2\text{e /vehicle – km or kgCO}_2\text{e /passenger – km)} \hspace{1cm} (14)\]
2.8.7 Category 5: Waste generated in operations

2.8.7.1 CH₄ Emissions from Solid Waste Disposal Sites (SWDs)

There are two methodologies outlined in the IPCC Guidelines for the estimation of CH₄ emissions from SWDs. These are; Default method (Tier 1) (Table 6) and the First Order Decay (FOD) method (Tier 2) (Table 5). A decision tree is also provided to opt for the method of most relevance and suitability (Fig 11). The FOD method is based on depicting the emissions over time as a result of the degradation process which involves time lag. This reflects a more accurate emissions trend and thus is classed under Tier 2. The default method on the other hand assumes that all the CH₄ that would be released over some period of time is released in the year the waste is disposed of. This gives a reasonable estimate of the annual emissions provided that the amount and composition of waste disposed at SWDs have been constant or varies slowly over a timescale of several decades.

Figure 11: Decision tree for CH₄ emissions from solid waste disposal sites
(Source: IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories, Chapter 5)
First order decay method (FOD) - tier 2

Equations 15 and 16 are used to evaluate CH$_4$ generated in year $t$. The FOD method is represented by these two equations which are adopted from chapter 5 of the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. This method involves acquiring historic data on waste generation and management practices. More detail on the method can also be obtained from IPCC Guidelines Reference manual, p 6-10.

\[ CH_4 \text{ generated in year } t \left(\frac{Gg}{yr}\right) = \sum \left[ (A \cdot k \cdot MSW_T(x) \cdot MSW_F(x) \cdot L_0(x)) \cdot e^{-k(t-x)} \right] \]

(15)

for $x =$ initial year $t$

Where:

$t = \text{year of inventory}$

$x =$ years for which input data should be added

$A = \frac{1 - e^{-k}}{k};$ normalization factor which corrects the summation

$k = \text{Methane generation rate constant (1/yr.)}$

$MSW_T(x) = \text{Total municipal solid waste (MSW) generated in year } x \ (Gg/yr)$

$MSW_F(x) = \text{Fraction of MSW disposed at SWDs in year } x$

$L_0(x) = \text{Methane generation potential} \left[ MCF(x) \cdot DOC(x) \cdot DOC_F \cdot F \right.$

\[ \frac{16}{12} \left( Gg \frac{CH_4}{Gg \text{ waste}} \right) \]

$MCF(x) = \text{Methane correction factor in year } x \ (\text{fraction})$

$DOC(x) = \text{degradable organic carbon (DOC) in year } x \ (\text{fraction}) \ (Gg \ C/Gg \text{ waste})$

$DOC_F = \text{Fraction of DOC dissimilated}$

$F = \text{Fraction by volume of CH}_4 \text{ in landfill gas}$

$16/12 = \text{Conversion from C to CH}_4$

\[ CH_4 \text{ emitted in year } t \left(\frac{Gg}{yr}\right) = \left[ CH_4 \text{ generated in year } t - R(t) \right] \cdot (1 - OX) \]

(16)

Where:

$R (t) = \text{Recovered } CH_4 \text{ in inventory year } t \ (Gg/yr.)$

$OX = \text{Oxidation factor (fraction)}$
Table 5: Category 5 default method (Source: IPCC Good Practice guidance and Uncertainty)

Default Method- Tier 1
The parameters in the equation are bound to change over time as a result of changes in waste disposal trends and waste management practices. Good practice for all the parameters will be deliberated on in the following chapter in accordance with the IPCC guidelines.

\[
CH_4 \text{ emissions} \left(\frac{Gg}{yr}\right) = \left[ (MSW_T \cdot MSWF \cdot L_0) - R \right] \cdot (1 - OX) \quad (17)
\]

Where:
- MSWT = Total MSW generated (Gg/yr.)
- MSWF = Fraction of MSW disposed at SWDs
- \(L_0\) = Methane generation potential \(\left[ MCF \cdot DOC \cdot DOCF \cdot F \cdot \frac{16}{12} (Gg \frac{CH_4}{Gg \text{ waste}}) \right]\)
- MCF = Methane correction factor (fraction)
- DOC = Degradable organic carbon [fraction (Gg C/Gg MSW)]
- DOCF = Fraction DOC dissimilated
- \(F\) = Fraction by volume of \(CH_4\) in landfill gas
- \(R\) = Recovered \(CH_4\) (Gg/yr.) (no recovery of methane from any of the SWDs)
- \(OX\) = Oxidation factor

\[
DOC = (0.4 \cdot A) + (0.17 \cdot B) + (0.15 \cdot C) + (0.3 \cdot D) \quad (18)
\]

Where:
- \(A\) = Fraction of MSW that is paper and textiles
- \(B\) = Fraction of MSW that is garden waste, park waste or other non-food organic putrescible
- \(C\) = Fraction of MSW that is food waste
- \(D\) = Fraction of MSW that is wood or straw
2.9 Chapter summary

The 2006 IPCC guidelines for National Greenhouse gas Inventories and the GHG Protocol was analyzed in this chapter to help develop a CF model for the marine campus. Aspects of these guidelines were adapted for the emission source categories that are relevant to universities as suggested from previous studies. Scope 1 and 2 source categories are relatively simple and straightforward. The 2006 IPCC was used in modelling the scope 1 emissions for the campus which included vehicle and boat fleet. Scope 2 emissions had only 1 source category; purchased electricity. This was relatively straightforward and time series data was also readily available and the emission factor was also specific to Fiji. As for scope 3 emissions, the GHG Protocol Guidance for Calculating Scope 3 provides guidance for 15 different source categories. The categories which was most relevant to the campus are identified. The inclusion/exclusion of the source categories are justified. Five categories were included in the model and the GHG protocol standard was used to evaluate these categories as described above. These calculation methodologies were used to create excel databases for each source categories and the emissions were evaluated by the input of activity data and the relative emission factors.
Chapter 3 - Case Study: USP Marine Campus (lower campus)

This study will enable the university to measure, assess, report on and establish strategies for the reduction of GHG emissions. It represents the baseline marine campus GHG inventory. This can be recognized as a voluntary action to manage GHG risks and identify reduction opportunities. The marine campus GHG inventory followed the operational control approach to define its boundary. In this chapter the case study of USP marine campus is examined. A model was created by which the CO$_2$e emissions of the campus can be calculated.

The University’s Laucala Campus has a total of 148 buildings that is distributed across four locations. USP headquarters at Suva comprises the Main Campus (114 buildings), Marine (Lower) Campus (19 buildings), Statham Campus (7 buildings) and Middle Campus (8 buildings). The scope of this GHG inventory is the Marine campus (also referred to as the Lower Campus) shown in Figure 12. This campus is located along the Suva point foreshore facing Laucala Bay and has an area of 39659.2 m$^2$. It has a population of about 2447 full time equivalent students (EFTS) students and employs about 120 staff. The GHG inventory for the campus was assembled by collecting and analyzing utility data, compiling university records and conducting discussions with staff. It was compiled using a bottom up data acquisition, entry calculations and management. This was done in accordance with industry recognized standards for GHG emissions accounting namely:

- 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- GHG Protocol, Corporate value chain standard
- EPA Simplified GHG Emissions Calculator (SGEC)
3.1 Organizational boundaries

The organizational boundary of the inventory is defined in relation to the sources of GHG emissions to include or not to include in the inventory. Moreover, this is determined to help establish the emissions for which an organization is responsible for. The GHG protocol and other inventory reporting guidelines recognize two approaches which are used to define these boundaries and consolidate GHG emissions:

- Equity share: accounts for an organization’s GHG emissions based on its percentage ownership
- Control: Accounts for an organization’s GHG emissions based on its financial or operational control.

The control approach was used to develop the GHG inventory for USP marine campus since USP has operational control over the campus.

Figure 12: USP Marine Campus boundary
Figure 13 shows the FTES for the campus. This is the student population for the faculty of Science and Technology. Majority of the students undertaking courses at the Lower campus fall under this faculty hence student population data for this faculty was acquired. This may slightly over represent the population of the lower campus since the number of students enrolled in the courses offered at the campus in 2015 was about 2447. However in general the FTES population increases by 5% per annum.

![FTES for the Faculty of Science & Technology](image)

**Figure 13: FTES for the Faculty of Science & Technology**

The boundary of measurement included all the building, facilities and assets that are within the operational control of the campus. For example the GHG emissions associated with USP owned vehicles are classified under Scope 1 sources whereas GHG emissions associated with the student bus service (operated by an independent contractor) are accounted for under scope 3.

The operational boundary encloses five departments, these are:

- Marine studies, (MS)
- Institute of Applied Sciences (IAS),
- Pacific Centre for Environment and Sustainable Development (PACE-SD),
- Institute of Marine Science (IMS)
- School of Geography & Earth Science (SGES)
Data was collected for the following categories for each of the departments for the 2015 fiscal year:

- Business air travel
- Paper consumption
- Vehicles (fuel usage data)
- Boats (fuel usage data)
- Staff commuting.

### 3.2 Operational boundaries

This defines and identifies the emission sources that will and will not be included in the inventory. Under the operational boundaries the GHG emission sources are categorized into direct (Scope 1), energy indirect (scope 2) and other (Scope 3) indirect emissions (GHG Protocol, chapter 4). The USP lower campus operational boundaries are shown schematically below.

**Figure 14: USP Marine campus operational boundary**

The operational boundaries are the corner stone of a GHG inventory since it serves to verify that all GHG emission sources are accounted for accordingly and ensures that double counting is avoided.
3.3 Data Collection and data preparation in the model

3.3.1 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 was 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 Institute of Marine Resources (IMR) has four boats that are used by the staff. The fuel data for the base year 2015 was provided by the Director of IMR. This was recorded as outboard unleaded petrol quantity in liters. This is the average quantity purchased for the year. In the IPCC 2006 software this was classified under ‘Fuel Consumption Activity- Domestic Water-borne Navigation’. The unleaded petrol is referred to as gasoline 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 (see Appendix A-2). Energy from the fuel type was calculated based on the energy content values provided in the IPCC 2006 software. All factors and values used are summarized in Table 7.
Table 6: Data Table - Scope 1

<table>
<thead>
<tr>
<th>Fuel consumption activity</th>
<th>Fuel type</th>
<th>Quantity (L)</th>
<th>Energy content (TJ/Gg)</th>
<th>Emission Factor (Kg CO₂/TJ)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary</td>
<td>Gas/diesel oil</td>
<td>12115</td>
<td>44.3</td>
<td>74100</td>
<td>2006 IPCC Guidelines</td>
</tr>
<tr>
<td>Light-duty trucks</td>
<td>Gas/diesel oil</td>
<td>4017</td>
<td>43</td>
<td>74100</td>
<td></td>
</tr>
<tr>
<td>Domestic water-borne navigation</td>
<td>Gasoline</td>
<td>500</td>
<td>43</td>
<td>69300</td>
<td></td>
</tr>
</tbody>
</table>

3.3.2 Scope 2: Energy Indirect

This scope involves only one emission category which is purchased electricity. The records for electricity use in kWh was available for the base year (Fig 15). The electricity generated from the installed 45 kW Solar PV system was not part of this calculation. Since electricity is purchased from FEA, the emission factor is 0.5095 tCO₂/MWh (CDM, 2006). This emission factor is specific to the fuel mix that FEA use and was taken from the calculations for Fiji Nadarivatu Hydro power project under the Clean Development Mechanism (CDM). The emission factor is specific to Fiji hence is classified under the tier 2 approach.

3.3.3 Scope 3: Commuting

A student and staff commuting survey was carried out to obtain information on the travelling behavior of the staff and students (see Appendix C 1-2). Different approaches were used for student and staff surveys. 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 were personally approached to fill the forms. The data accuracy for the online survey was compromised since exact data on the amount of kilometers travelled for each transportation source could not be extracted. However estimated distances were used in determining the CF.
3.3.4 Staff commuting

3.3.4.1 Study methodology

The motorized commuting modes and distances for each of these modes were considered for emissions calculation. The survey conducted 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. The staff 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. The daily commuting modes of staff are represented in Figure 17. 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 distance for each mode. The model (Table 9) was then used to calculate the staff commuting emissions for different transport modes (Fig 18).

3.3.5 Student commute survey

3.3.5.1 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 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 2300 undergrad 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 of 2015, the 2016 time period was deemed representative of commuter behavior at the university for 2015. A total of 2447 email invitations were distributed to students. This is also assumed to be the total student population of the USP marine campus. Of the 2447 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 (Paez & Whalen 2010, Mathez et al., 2013).

The students were categorized according to their mode of transportation (Fig 19). Those who commuted via motorized vehicles were further classified under vehicle type and fuel type. For car commute, the common vehicle types are depicted in Figure 21. Then for each motorized transportation modes the estimated one way commuting distances were calculated based on the respondents estimated distances (Fig 20). This value was recorded has passenger-km. It can be assumed that since majority of the respondents are face to face students, the average number of commuting days are four. Given that a semester comprises of 14 weeks, the total number of commuting days in a year are 112 days. Finally the result is multiplied by 2 accounting for the trip to the campus and trip back home. The emissions are calculated based on the model (Table 9). The emissions for each commuting mode and its’ percent contribution is represented in Table 13.

3.3.6 Emissions calculation and data preparation

The average fuel efficiency in Lge/100km (Appendix A-3) was the used to convert total distance travelled in km of each motorized mode vehicle type to volume (litres) (Table 8). 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 (see Appendix A-2). Energy from the fuel type was calculated based on the energy content values provided in the IPCC 2006 software. All calculations were carried based on the data model shown in Table 9.

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Fuel efficiency (*Lge/100km)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger vehicle</td>
<td>6.22</td>
<td>Global fuel economy initiative (GFEI)</td>
</tr>
<tr>
<td>Light duty</td>
<td>6.47</td>
<td><a href="https://www.globalfueleconomy.org/medi">https://www.globalfueleconomy.org/medi</a>...</td>
</tr>
<tr>
<td>Heavy duty</td>
<td>7.54</td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>8.30</td>
<td></td>
</tr>
</tbody>
</table>

* Lge – Litre in gasoline equivalent terms. This energy unit is used for different fuels such as gasoline and diesel on energy equivalent basis.
Table 8: Data Preparation in the Model

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average commuting distance/yr (Km)</td>
<td>fuel economy (L)</td>
<td>kl to t</td>
<td>Mass (Gg)</td>
<td>NCV (TJ/Gg)</td>
<td>Consumption (TJ)</td>
<td>EF (kg CO₂/TJ)</td>
<td>CO₂ Emissions (tCO₂)</td>
<td>EF (kg CH₄/TJ)</td>
<td>CH₄ emissions* GWP</td>
<td>EF (kg N₂O/TJ)</td>
<td>N₂O Emissions* GWP</td>
</tr>
<tr>
<td>Diesel</td>
<td>43</td>
<td>0</td>
<td>74100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td>44.3</td>
<td>69300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Column A** – contains the activity data analyzed from the survey forms that is the total commuting distance. This data is input separately for the different motorized transportation modes and vehicle types.

**Column B** – the fuel economy is multiplied by the distance traveled for the different vehicle types. The fuel economy is the ratio of fuel consumption per travel distance. The fuel economy varies for different vehicle types and is provided in table 8. These values are specific to non-OECD countries which Fiji is a part of. These standards were classified under the Global fuel economy initiative.
**Column C** – this conversion factor converts volume consumed to mass unit in tonnes. This factor is retrieved from the BP Statistical Review of World Energy, 2016. This value varies for the different fuel types; (diesel - 0.798, motor gasoline – 0.753).

**Column D** – the mass in the preceding column is converted to Giga grams (Gg)

**Column E** – the net calorific value (NCV) input for the different fuel types; (diesel – 43 TJ/Gg, motor gasoline – 44.3 TJ/Gg). This is the default value as indicated in the IPCC guidelines.

**Column F** – the total energy consumption is calculated in Terra joules by multiplying the total mass (Gg) by the NCV.

**Column G** – this is the default EF for CO₂ adopted from the IPCC guidelines. The EF is dependent on the fuel type; (diesel – 74100 Kg/CO₂, motor gasoline – 69300 kg/CO₂). The EF is also based on the type of fuel consumption activity. For instance the EF for *Fuel Consumption Activity- stationary’ will be different for *Fuel Consumption Activity- Light-duty trucks’.

**Column H** – the CO₂ emissions is expressed in tonnes.

**Column I, J, K & L** – the emission factor for methane (CH₄) and nitrous oxide (N₂O) are indicated in columns I and K respectively. To calculate CH₄ emissions in carbon-dioxide equivalent the value in column J is multiplied by the GWP of CH₄ which is 28, (Greenhouse gas protocol, 2016). Similarly for nitrous oxide, the value in column L is multiplied by N₂O GWP of 265 (see Appendix A-1). CH₄ and N₂O emissions from combustion of Diesel may be ignored since they are minor emission sources.
3.3.7 Scope 3: Purchased Paper

The inventory data was collected for each of the five departments. The school secretaries and finance officers were helpful in providing the number of boxes of paper that are purchased for the department. This activity falls under category 1 of the GHG value chain protocol. Moreover the average data approach was used to evaluate the emissions from paper purchases for the year 2015. The total emissions from the use of printing paper and toilet paper is depicted in Figure 22. This is then further broken down for the different departments (Fig. 23).

The mass of the total number of sheets and rolls purchased is multiplied by the EF for printing paper and toilet paper respectively. The EF is based on published data rather than 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. The EF from Defra GHG emission factors under material use and waste is used (Table 10). The EF represents the mass (kg) of CO$_2$e emission released as a result of producing one ton of paper. It accounts for the cradle-to-gate emission of the product. Based on the mass of 1 A4 printing paper the total mass of the paper purchased by the departments were calculated. This was then multiplied by the EF provided by Defra (see Appendix A-6 for calculations).

\[
\text{Carbon emission from paper} = \text{emission factor} \times \text{mass of paper}
\]

\[(19)\]

Table 9: EF for printing paper and toilet paper

<table>
<thead>
<tr>
<th>Emission factor</th>
<th>Kg CO$_2$e /ton</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing paper</td>
<td>939</td>
<td>2012 Guidelines to Defra / DECC’s GHG Conversion Factors for Company Reporting (DEFRA, 2012)</td>
</tr>
<tr>
<td>Toilet paper</td>
<td>1284</td>
<td></td>
</tr>
</tbody>
</table>
3.3.8 Scope 3: Staff air travel (USP Business)

Each of the departments were requested to provide details of the business air travel. The information required was the number of persons and the trip destination. Some departments were able to provide this information however where gaps in data occurred the USP procurement office provided the necessary information. This activity falls under category 6 of the GHG value chain protocol.

The International Civil Aviation organization (ICAO) carbon emissions calculator was used for estimating the amount 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. It uses a formula based on the fuel combustion and employs industry averages for the various factors which lead to the determination of emissions associated with a passenger’s air travel. The data required for input in the ICAO carbon emissions calculator is the airports of origin and destination. The airport codes are entered and the database then searches 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.

The ICAO carbon emission calculator works by comparing the airports of origin and destination for a direct flight with the published scheduled flights that matches the aircraft types that is used for travel between the two airports concerned and the number of departures per aircraft. There are 312 equivalent aircraft types to which each aircraft is then mapped to. This is to calculate the fuel consumption for the trip based on the great circle distance between the airports under consideration. The application of the passenger load factors and passenger to cargo ratios to the system then calculates the proportion of total fuel used which can be attributed to the passengers carried. These factors are part of the traffic and operational data collected by ICAO. The average fuel consumption for the journey weighted by the frequency of departure of each similar aircraft type is calculated and is divided by the overall economy class passengers which then results in the average fuel burn per economy class passenger. This is then multiplied by 3.16 which gives the amount of CO₂ footprint each passenger emits while travelling between the two airports.
3.3.9 Scope 3: USP shuttle services

The USP inter-campus shuttle services is provided by the Shoreline bus operators. The shuttle makes about 70 trips in a week. Considering that the University has two semesters in a year, each semester having 14 weeks, a total of 1,960 trips would be made in a 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.

3.3.10 Scope 3: SWD

The properties and facilities department was approached for information on waste management at the campus site. The site has a compacter bin where all the campus garbage is disposed for collection by the municipal garbage trucks two times in a week. In order to determine SWD related CF, garbage from the collector bin was sorted in various waste categories in accordance with the IPCC default method classifications.

These categories are paper and textiles, food waste, garden and park waste and wood and straw. This separation was done just before the collection days. The percentage contribution of these categories to the total waste generated for the months was also worked out (Fig 24 & Table 14). After sorting, wastes from each category were weighed. This value was then multiplied by the default values for the degradable organic compounds (DOC) (Table 11).

The total waste generated (MSWT) for the campus was estimated from the waste records collected by the properties and facilities department. The estimated tonnage of MSW generated however, was only available for the year 2016 from January to June. Hence the average value was used to calculate the total waste generated for the year. This value is deemed to be a representative for the base year 2015. Other parameters and constants of the IPCC default method (equation 17) to determine CH₄ are described below.
Table 10: IPCC default method equation parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Constants used</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSWT</td>
<td>0.07 Total MSW generated (Gg/yr)</td>
</tr>
<tr>
<td>MSWF</td>
<td>1 Fraction of MSW disposed to solid waste disposal sites.</td>
</tr>
<tr>
<td>MCF</td>
<td>0.6 methane correction factor</td>
</tr>
<tr>
<td>DOC</td>
<td>0.049 degradable organic carbon</td>
</tr>
<tr>
<td>DOCF</td>
<td>0.77 fraction DOC dissimilated</td>
</tr>
<tr>
<td>F</td>
<td>0.5 fraction of CH₄ in landfill gas (default is 0.5)</td>
</tr>
<tr>
<td>R</td>
<td>0 recovered CH₄ (Gg/yr)</td>
</tr>
<tr>
<td>ox</td>
<td>0 oxidation factor (default is 0)</td>
</tr>
</tbody>
</table>

- *The fraction of MSW disposed to SWDs* - This value is 1 which means that all MSW generated is disposed to the SWDs. All MSW generated at the Marine campus is disposed at Naboro landfill.
- *Methane correction factor* – a factor of 0.6 was assigned based on the categorization of the dump site. This value was taken from the Second National Communication (SNC) report.
- *Degradable organic carbon*– the percent DOC (by weight) was calculated using default DOC values for the main waste streams (Table 12) and the DOC (% by weight) equation. The waste data for the waste streams indicated in Table 12 was collected for the Marine campus.

Table 11: DOC % in different waste streams

<table>
<thead>
<tr>
<th>Waste Stream</th>
<th>% DOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and Textiles (A)</td>
<td>40</td>
</tr>
<tr>
<td>Food waste (C)</td>
<td>15</td>
</tr>
<tr>
<td>Garden and park waste and other (non-food) putrescibles (B)</td>
<td>17</td>
</tr>
<tr>
<td>Wood and straw waste (D)</td>
<td>30</td>
</tr>
</tbody>
</table>

Percent DOC (by weight) = 0.4(A) + 0.17(B) + 0.15(C) + 0.30(D)  \hspace{1cm} (20)
• *Fraction DOC dissimilated* – a default value of 0.77 is used based on the assumption that the temperature in the zone is constant at about 35°C
• *Fraction of CH₄ in landfill gas* – default value of 0.5 is used in the calculation.
• *Recovered CH₄* – there is no recovery of methane from any SWDs thus R=0
• *Oxidation factor* – the default value of 0 is used.

These constants are used in equation 17 to estimate methane emissions from SWDs;

### 3.4 Carbon footprint Result

#### 3.4.1 Campus energy emissions

The annual Electricity consumption shows an increasing trend of 19% pa. The electricity consumption in kWh were converted to CO₂ using the emission factor of 0.5095 tCO₂/MWh obtained from the CDM Fiji Nadarivatu Hydropower project (CDM, 2006). The CO₂ emissions also shows a mean increase of 19% pa.

![Figure 15: Trend of electricity consumption and carbon emissions at lower campus](image)

It is also depicted (Fig 15) 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 practiced which explains this trend.

For the base year 2015 the CO$_2$ emissions from electricity usage was calculated to be 74 tCO$_2$ per annum. The emission per capita from direct energy consumption for 2015 amounts to about 0.03 tons CO$_2$ per student (EFTS). When compared to the different universities this is well below the average value of 8.4 tons CO$_2$ per student.

### 3.4.2 Transport emissions

#### 3.4.2.1 University fleet

The USP lower campus fleet was made up of department vehicles which were diesel vehicles and boats with motor gasoline as the fuel type. Emissions from university transportation fleet are direct emissions and fall under scope 1 emissions. The generation of emissions from the consumption of fuel was approximated to be 39 tCO$_{2e}$ for 2015. The IPCC emission factors were used in the calculations.

The Institute of Marine Resources (IMR) has four boats that are used by the staff and students. The fuel data for the base year 2015 was provided by the Director of IMR. This was given as outboard unleaded petrol quantity in liters. The IPCC method was used to approximate emissions from fuel combusted from the outboard motor engines of the boats. The fuel use and the carbon emissions for the department vehicles and the boats is shown in Figure 16.
3.4.2.2 Commuting

The commuting survey which is part of scope 3 emissions was conducted to gather data on travel behavior, distances and frequencies of trips to the lower campus. The participants were asked to describe their commuting behavior to marine campus in a typical week. A total of 644 students and staff members responded to USP lower campus commuting survey.

3.4.2.3 Staff commuting

GHG emissions from staff commuting represented about 13% of the overall emissions. The total emissions was estimated to be 333 tCO$_2$e.
Figure 18: Staff commuting emissions for different transport modes

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 as compared to emissions by bus commute. Thus commuting daily by bus is a greener and also an economical option.

3.4.2.4 Student commuting

The student commute emissions for the year 2015 was about 1938 tCO\textsubscript{2e}. This is about 73% of the total inventory. From the survey sample a summary statistics was generated for the common modes of transportation and the distance. The mode of transportation of the sample population resulted in 36% of user commuting on foot, 30% by bus, 20% via the USP shuttle, 12% by passenger cars and the 2% by carpool or bicycle. For the distance, respondents indicated estimated distance for one way commute to the Marine campus.

3.4.2.4.1 Distances

The distribution of daily commuting modes by students is shown in Figure 19. For the 36% of respondents who commuted on foot, it is assumed that they travelled less than 1km. This is also the portion of the population that commutes to campus carbon free. For the consideration of calculation of emission, 20% of the total student population was considered for USP shuttle commute and the route distance from the
main campus to marine campus was considered. There are a total of 70 trips in a
typical week from Monday to Friday. For the 42% motorized trips included in the
total emissions calculations, there was no sure way of knowing the distances covered
by the different modes of transport except for the USP shuttle. Therefore for the
different modes that is the car and public transport- bus; passenger -km was calculated
from 1-20km radius and correspondingly the emissions for each of the scenarios. The
upper limit for the distance interval was considered in the emissions calculation.

![Pie chart: Distribution of daily commuting modes by students]

**Figure 19: Distribution of daily commuting modes by students**

![Circle chart: Responses of estimated distances for one way commute]

**Figure 20: Responses of estimated distances for one way commute**

A large share of emissions come from passenger vehicles. Despite the fact
only 12% commute via passenger vehicles the emissions are still large. For the 30%
who commute by bus, the emissions are relatively small as compared to emissions from passenger vehicle commutes. Hence commuting by passenger vehicles is energy intensive.

![Figure 21: Common vehicle types used for commuting](image)

### 3.4.2.4.1 Car commute

The 12% student commuters who travel via cars were further categorized according the types of vehicles and fuel types used for commuting. The common vehicle types were passenger vehicles, light duty vehicles, heavy duty vehicles and hybrids. The common fuel types were diesel and gasoline. The emissions from the heavy duty and hybrid vehicles were insignificant and thus not represented graphically.

### 3.4.2.5 USP shuttle services

Of the total students commuting to the Lower campus, 20% of students commute by the shuttle. The shuttle service is provided by a local company ‘Shoreline buses’ and thus is considered as scope 3 emissions. Emission calculations was based on the number of trips the shuttle makes in a week. According to the shuttle timetable, the number of trips in a typical week is 70. Considering the fact that there are 14 weeks per semesters and 2 semesters in a year, the total number of trips in a year can be calculated. The distance considered for the calculation was between the main campus and the lower campus. About 1 tCO$_2$e are emitted from student commuting by shuttle. This is about only 8.58% of the overall campus emissions.
Table 12: Motorized vehicle GHG emissions

<table>
<thead>
<tr>
<th>Motorized vehicle</th>
<th>tCO₂e</th>
<th>% contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>USP shuttle</td>
<td>228.73</td>
<td>10.56%</td>
</tr>
<tr>
<td>Public transport- bus</td>
<td>482.75</td>
<td>22%</td>
</tr>
<tr>
<td>Diesel passenger car</td>
<td>773.03</td>
<td>36%</td>
</tr>
<tr>
<td>Diesel light duty vehicle</td>
<td>36.92</td>
<td>2%</td>
</tr>
<tr>
<td>Diesel heavy duty vehicle</td>
<td>10.76</td>
<td>0.5%</td>
</tr>
<tr>
<td>Gasoline passenger car</td>
<td>606.68</td>
<td>28.0%</td>
</tr>
<tr>
<td>Gasoline light duty vehicle</td>
<td>23.34</td>
<td>1.1%</td>
</tr>
<tr>
<td>Gasoline heavy duty vehicle</td>
<td>4.35</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2166.56</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

3.4.3 Scope 3 emissions: Paper

The emission contribution of paper to the university’s CF for the year 2015 is depicted in Figure 22. The total emissions from paper use is approximately 23 tCO₂e.

![Figure 22: Emissions from the use of paper on lower campus in 2015](image)

Paper use by the departments at lower campus is depicted in Figure 23. Toilet paper is also used in lab work, therefore higher consumption is depicted for IAS. Other factors which contributed to greater consumption of paper were staff/student numbers.
and the number of courses offered by the departments. Departments which offered a larger number of courses obviously had greater use of printing paper.

![Figure 23: Paper and toilet paper consumption for the different departments at lower campus in 2015](image)

**3.4.4 Scope 3 emissions: MSW**

Data was collected on the percentage weight for the main waste streams as specified by the IPCC default method (Fig 24). Data was collected for 6 different months. The Degradable organic wastes used for methane emissions calculations is based on the IPCC default method and the default values used in the GHG Inventory for Waste for Fiji’s Second National Communication.

![Figure 24: Proportion of solid waste at Marine Campus](image)
The average sample size of waste collected for each of the months was about 384kg. The percentage generation of each of the waste categories based on its weight over the total sample weight was calculated for each month. Looking at the monthly data, inference can be made on the average proportion of the different waste categories of the total waste generated.

Table 13: Monthly breakdown of proportion of Solid waste disposed at Marine Campus

<table>
<thead>
<tr>
<th>Month</th>
<th>paper textiles</th>
<th>garden park waste</th>
<th>food waste</th>
<th>wood and straw</th>
<th>plastic</th>
<th>PET bottles</th>
<th>aluminum cans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct-15</td>
<td>14%</td>
<td>17%</td>
<td>45%</td>
<td>11%</td>
<td>3%</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>Nov-15</td>
<td>24%</td>
<td>11%</td>
<td>44%</td>
<td>6%</td>
<td>6%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>Jul-16</td>
<td>20%</td>
<td>13%</td>
<td>45%</td>
<td>6%</td>
<td>7%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>Aug-16</td>
<td>25%</td>
<td>16%</td>
<td>35%</td>
<td>8%</td>
<td>4%</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>Sep-16</td>
<td>16%</td>
<td>21%</td>
<td>42%</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Oct-16</td>
<td>16%</td>
<td>12%</td>
<td>50%</td>
<td>9%</td>
<td>5%</td>
<td>4%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Figure 25: Proportion contribution of solid waste per annum at Marine Campus
Majority of Marine campus degradable organic waste comprised of food waste (44%) followed by paper/textiles and garden park waste as shown in Figure 26.

![Figure 26: Distribution of different degradable organic carbon (DOC)](image)

Using the IPCC default method, CH$_4$ emissions from MSW for the USP Marine campus was estimated to be 0.036 tCH$_4$/yr for the base year 2015. Fiji’s average methane emissions from SWDs is about 3.12 Gg (Fiji Second National Communication to the United Nations, 2013). The USP Marine campus accounts for about 0.001% of the country’s CH$_4$ emissions. Using the GWP value of methane (28) the MSW emissions in carbon-dioxide equivalent is calculated to be 1 tCO$_2$e/yr.

### 3.5 Net emissions for the campus

The USP Marine campus GHG emissions for the year 2015 were estimated to be 2666 tCO$_2$e. The campus’s activities that were assessed and the emissions released are shown in Figure 27. 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 28 shows an overview of the USP lower campus CF contribution by percentage of the different emission source categories, whereas Figure 29 shows USP lower campus emissions by scope. Emission categories that are greater than 0.5% are considered significant contributors (Letete et al., 2011).
Figure 27: Tons of CO$_2$e for the USP Lower campus for the base year 2015

Figure 28: Different emission sources by % contribution
Emissions under scope 1 were around 40 tCO₂e. This is about 1% of the overall emissions. Scope 2 emissions at 74 tCO₂e represented 3% of the total emissions. Scope 3 emissions were the largest contributor with emissions of approximately 2551 tCO₂e making up 96% of the total emissions. With regards to other universities around the world, the magnitude of their scope 3 emissions is high compared to De Montfort University (79%), University of York (61%) and Erasmus University Rotterdam (EUR) (80%). For 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 CO₂/student/year as compared to 0.27 for the USP Marine campus. A factor which can influence this difference are the number of commuting days. For instance students at EUR spend 40 weeks per year as compared to 30 weeks for USP marine campus students.

Also the smaller magnitude of scope 1 and 2 emissions obtained for the lower campus is due to the small size of the campus and the local climate coupled with only a few buildings which means lesser energy use. Building heaters and air conditioners are not so common as compared to the 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). The scope 1 and 2 emissions of EUR were also not as significant as compared to the scope 3 emissions,
0.12% and 7% (electricity emissions) respectively. This is because heat and electricity are produced in an environmentally friendly way at EUR.

Excluding the staff and student commuting, since this activity is not directly under the control of the University, the highest emissions category is electricity consumption (74 tCO$_2$e). This is an important source category to track and monitor due to the ever growing demand for electrical energy.

### 3.5.1 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 where possible and present uncertainty calculations (Bastianoni et al., 2004). Emission for scope 1 were calculated for fuel consumption using the IPCC 2006. For the scope 2 emissions from purchased electricity, the emission factor is country specific and there is 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. In addition to that, 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$_2$e emissions. Hence the uncertainty in the results is likely to be within 10%. For business air travel there were gaps in data and thus there might be some trips which are not accounted for and thus the accuracy of the results are within the range of 5%. For paper consumption default emission factor was used and record keeping of the paper consumption could be improved. This emission factor may also not be specific to this product. This category also presented a level of accuracy to within 5%. In totality the estimated emissions are considered to be accurate to within 22%.
3.6 Chapter summary

This type of CF study is first for the USP Marine campus. Hence 2015 is the baseline year for the marine campus GHG emissions inventory. General information about the campus is important in this type of analysis. This includes the campus area, population size, hierarchy system and other functions. Hence the first step in developing the GHG inventory model was establishing the organizational and operational boundary for the campus. The total carbon emissions for USP lower campus for the year 2015 were estimated at 2666 tCO$_2$. This value is likely to be an underestimate because of unavailability of some of the activity data for example activity data for scope 1 fugitive emissions wasn’t sufficient to determine its CF. Thus this was excluded from the calculations. Despite this, it is the best estimation that was possible with the available data and is a good indicator of the magnitude of campus’s annual CF. A major challenge in determining a complete and comprehensive CF for the campus was the unavailability of data.
Chapter 4- Mitigation strategies for emission reduction

The mitigation strategy is to firstly establish a mitigation goal, objective and an action plan. A crucial response to climate change is to lessen the output of GHG emissions. Reducing on-campus emissions is a strong demonstration of sustainability policy, which can be achieved through energy efficiency and conservation, switching to Renewable sources of energy and sequesting or offsetting any remaining emissions (Carbon Management & Greenhouse gas Mitigation, 2016). This chapter deals with proposing mitigation strategies and campus greening efforts for the USP Marine campus. It suggests some measures that reduce GHG emissions relative to the baseline scenarios. A mitigation assessment is carried out with measures recommended that will help to reduce future GHG emissions for the campus.

A mitigation assessment is an analysis of the various technologies and practices that have the capacity to mitigate climate change (Heaps & Kollumuss, 2008). This assessment comes in two parts; first of all a baseline scenario is developed, which was the GHG inventory for the campus for 2015; and then developing scenarios which project how future GHG emissions can be mitigated relative to the baseline scenario. This part of the study involves 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 considering 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 (Fig. 30).
4.1 Renewable Energy based electricity generation- USP/KOICA

45kWp GCPV system

The lower campus has a 45kWp GCPV system which was established in 2012 (Fig.31). This is connected to one of the main load distribution boards so that the PV power produced is first consumed at the campus and any excess is exported to the grid. On average, the PV system yields about 48.7 MWh of electricity per annum (Raturi et al., 2016) (Fig 32). This constitutes about 25% of the total electricity consumed at the lower campus. For the base year 2015 the total electricity consumption for the Marine campus was 194.47 MWh. A breakdown of the electricity consumption is given in Table 15.
The electricity provided by the grid is generated by the Fiji Electricity Authority (FEA). The producers utilize a mix of both renewable and non-renewable resources to generate electricity and to distribute among its customers. The average
Power generation mix for 2015 was 60% hydro, 37% diesel and heavy fuel oil, 1% wind with the remaining 2% provided by the Independent Power Producers (IPPs), namely Tropik Wood Industries Limited (TWIL) and FSC (FEA, 2016).

4.1.1 Proposed Case for making the lower campus electricity 100% renewable

Considering the above generation mix, about 54 MWh of electricity annually consumed by the USP lower campus comes from non-renewable resources. Establishment of an additional 50kWp PV rooftop system for the campus will offer a 100% renewable source base for all its energy needs and a net annual GHG reduction of 13 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 17% reduction in emissions from electricity consumption for the campus and will do away with the expenses from electricity bills.

Emissions savings have been calculated based on the FEA fuel mix emission factor - 0.5095 tCO$_2$/MWh. The initial costs for the implementation of the project include cost for the feasibility study, purchasing and installing the equipment, performing the project development functions and other miscellaneous costs.

**Table 15: Project costs and savings summary**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Install 50kW Grid connected PV Roof top System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual emissions savings</td>
<td>12.9 tCO$_2$</td>
</tr>
<tr>
<td>Annual financial cost saving</td>
<td>FJD $26,860</td>
</tr>
<tr>
<td>Initial costs</td>
<td>FJD $150,000</td>
</tr>
<tr>
<td>Pay back</td>
<td>5.8 years</td>
</tr>
</tbody>
</table>
Before establishing any new RE based generation system, energy efficiency measures are a must. An energy audit of the campus was conducted to analyze energy use and identify energy saving opportunities. The basic step involved was identifying the fuel flow which is done by considering how a fuel is being converted to something useful and how this useful output is being used. This, then leads to minimizing usage, maximizing efficiency and optimizing supply. The RET Screen energy model was employed to analyze characteristics of the building facility at the campus. The main buildings of the campus are the Marine Studies Centre, Marine Studies Annex, Marine Studies Lecture Theatre and the IMR building. The audit has been carried out based on the space types of these building, i.e. offices, laboratories, teaching spaces, library and washrooms. This formed the base case in the RET Screen analysis. The proposed cases are the measures that will offer energy savings and emission reduction opportunities. The financial saving calculations have been based on the average tariff of $0.39/kWh. Calculations were also performed for the initial costs which included the cost for replacing inefficient equipment. Labor costs are not included since it is assumed that the task will be carried out by the existing staff. Duties and taxes are also not included in the calculations as energy efficient technologies can be imported into Fiji without fiscal duties.

### Table 16: GHG Emission Reduction Analysis

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel mix %</th>
<th>CO₂ EF Kg/GJ</th>
<th>CH₄ EF Kg/GJ</th>
<th>N₂O EF Kg/GJ</th>
<th>Fuel consumption MWh</th>
<th>Elect. Gen Efficiency</th>
<th>T&amp;D losses</th>
<th>GHG EF (tCO₂/MWh)</th>
<th>GHG emission (tCO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>40</td>
<td>36</td>
<td>0.0019</td>
<td>0.0019</td>
<td>65</td>
<td>24.8%</td>
<td>10%</td>
<td>0.5095</td>
<td>13.4</td>
</tr>
<tr>
<td>Solar</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>65</td>
<td>0</td>
<td>4%</td>
<td>0.965</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### GHG emission reduction summary

<table>
<thead>
<tr>
<th>Power Project</th>
<th>Base case GHG emission</th>
<th>Proposed case GHG emission (tCO₂)</th>
<th>Gross annual GHG emission reduction (tCO₂)</th>
<th>Net annual GHG emission reduction (tCO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.4</td>
<td>0.5</td>
<td>12.9</td>
<td>12.9</td>
</tr>
</tbody>
</table>
4.2.1 Facility characteristics- lighting

The fluorescent lamp is the most common discharge lamp type used universally to provide office lighting. The basic linear tubular fluorescent lamp have undergone 3 generations, T12, T8 and T5. The third generation T5 lamp has the greatest luminous efficiency output (100 lm/W) (IEA International Energy Agency, 2012). Since the fluorescent lamp cannot be connected directly to the mains, special devices called ballasts are used which limit the current flowing through it. The ballasts can be electromagnetic with a starter or electronic. The electronic ballast offers a better lighting system efficacy as compared to the electromagnetic ballast since circuit power losses are reduced (Kwok-tin, 2013). Also since it is capable of operating high frequency, the lamp is operated at a lower input power than at 50 Hz mains power frequency (IEA International Energy Agency, 2012).

4.2.1.1 Marine studies library

Lighting at the marine studies library is provided by the 2×36W T8 fluorescent lamps with magnetic ballast. The lighting level provided by these luminaries are well above the levels recommended in the AS/NZS1680. Also observations of the library suggested that the book shelves are arranged perpendicular to the luminaries.

4.2.1.1.1 Proposed case

Lighting upgrade hardware is suggested whereby the 2×36W T8 luminaries with magnetic ballast are replaced with 2×28 T5 luminaries with electric ballast. Also re-arranging the bookshelves parallel to the luminaries will also ensure the best availability of light.

4.2.1.1.2 Savings calculation

The proposed case will offer a 60% reduction in electrical energy usage during the operating hours of the library.

<table>
<thead>
<tr>
<th>Measure</th>
<th>De-lamp and ballast upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>0.5 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>0.26 tCO₂</td>
</tr>
</tbody>
</table>
### 4.2.1.2 Marine campus offices

The offices are mainly illuminated by the 2×36W T8 fluorescent luminaries, the 1×36W T8 fluorescent and the 1×18W T8 fluorescent lights with magnetic ballasts. The office lighting is manually switched and is normally permanently on during the working hours. Typically the lights are on 8 hours per day. This number is assumed to be the operating hours.

#### 4.2.1.2.1 Proposed case

It is recommended that the 2×36W T8 fluorescent lights with magnetic ballast be replaced with single lamp 1×36W T5 lamps with electronic ballasts. In general it is proposed that all T8 lamps with magnetic ballasts be replaced with T5 lamps with electronic ballasts.

#### 4.2.1.2.2 Savings calculation

Energy saving achieved through the implementation of the proposed case is about 50%.

<table>
<thead>
<tr>
<th>Measure</th>
<th>De-lamp and ballast upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>6.5 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>3.31 tCO₂</td>
</tr>
<tr>
<td>Annual energy cost saving</td>
<td>FJD $2535</td>
</tr>
<tr>
<td>Total initial cost</td>
<td>FJD $6350</td>
</tr>
<tr>
<td>Payback</td>
<td>2.5 years</td>
</tr>
</tbody>
</table>

### 4.2.1.3 Marine studies lecture theatre

The lecture theatre is illuminated by the 44W LED luminaries which provide a high luminance level of 1000 lux which is well above the average recommended lux of 320. The recent energy audit carried out by Exergy (Foo & Jolley-Rogers, 2014)
for the whole of Laucala campus suggested that it will be wasteful to replace these luminaires since they are new and efficient. As an alternative it was suggested the number of luminaires are reduced which would reduce the power usage and luminance to the recommended level. The extra luminaires could then be used to provide lighting elsewhere in the campus.

**4.2.1.4 Teaching space (tutorial rooms)**

Most tutorial room lighting is manually switched and is generally left on even when the space is not occupied. The teaching spaces are illuminated by the of 2×36W T8 lamps with magnetic ballast. These rooms have limited natural lighting however the twin lamps provide higher levels of lighting than is necessary.

**4.2.1.4.1 Proposed case**

It is suggested that these luminaires be replaced with the 1×36W T5 lamps with electronic ballasts which provide the recommended lighting level of 400 lux.

**4.2.1.4.2 Savings calculation**

Energy saving of 37% is feasible through the recommended measure.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Luminaire upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>2.3 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>1.17 tCO₂</td>
</tr>
<tr>
<td>Annual energy cost saving</td>
<td>FJD $897</td>
</tr>
<tr>
<td>Total initial cost</td>
<td>FJD $1775</td>
</tr>
<tr>
<td>Pay back</td>
<td>2 years</td>
</tr>
</tbody>
</table>

**4.2.1.5 Laboratories**

The laboratories are illuminated by the 2×36W T8 lamps with magnetic ballast luminaires which provide lighting levels of 600 lux.
4.2.1.5.1 Proposed case

It is proposed that these lighting fixtures be replaced with the 1×36W T5 luminaries with electronic ballast which will provide lighting levels of 500 lux which is the recommended level for laboratories.

4.2.1.5.2 Savings calculation

Energy saving reduction of 34% is feasible through the recommended measure.

<table>
<thead>
<tr>
<th>Measure</th>
<th>De-lamp and ballast upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>1.2 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>0.61 tCO₂</td>
</tr>
<tr>
<td>Annual energy cost saving</td>
<td>FJD $468</td>
</tr>
<tr>
<td>Total initial cost</td>
<td>FJD $2575</td>
</tr>
<tr>
<td>Pay back</td>
<td>5.5 years</td>
</tr>
</tbody>
</table>

4.2.1.6 Washrooms (internal)

An audit of lighting for the washrooms in the main buildings was conducted. There are a total of 16 washrooms for the main buildings. The washrooms are illuminated by 1×18W T8, 1×36W T8 and 2×36W T8 lamps with magnetic ballasts.

4.2.1.6.1 Proposed case

It is proposed that the 1×18W T8 lamp with magnetic ballasts be replaced with 1×14W T5 lamp with electronic ballasts. The 1×36W T8 lamp with magnetic ballasts be replaced with 1×36W T5 lamp with electronic ballasts and the 2×36W T8 lamp with magnetic ballasts be replaced with 1×36W T5 lamp with electronic ballasts.

4.2.1.6.2 Savings calculation

Energy saving of 47.4% is feasible through the recommended measure.

<table>
<thead>
<tr>
<th>Measure</th>
<th>De-lamp and ballast upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>0.9 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>0.46 tCO₂</td>
</tr>
</tbody>
</table>
### 4.2.2 Facility characteristics- Air conditioning units

Majority of the air conditioning units and split systems in the campus are old and inefficient. These units operate on R22 refrigerant which is being phased out under the Montreal Protocol and the complete phase out will occur in 2020. This will mean an increase in maintenance costs for these units which will have to rely solely on recycled or reclaimed refrigerants.

Laboratories and computer labs are the common spaces where split units are installed. The Marine Studies analytical lab has 6 units with each unit having a cooling capacity of 5.5-8 kWhr. The laboratories which make up half of the Marine Studies building have split units installed that generally run 24/7 to maintain temperatures of 23-25°C. Also the GIS block with computer labs has about 10 split units installed that operate 24/7 to maintain the optimum temperatures for the computers.

<table>
<thead>
<tr>
<th>Building</th>
<th>AC units</th>
<th>Annual MWh consumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine studies annex</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Marine studies Centre</td>
<td>31</td>
<td>217</td>
</tr>
</tbody>
</table>

### 4.2.2.1 Proposed case

It is suggested that new locally controlled split systems replace the old split systems. This will offer a higher coefficient of performance (COP) and therefore will be energy efficient. For instance in the RET-Screen analysis the base case COP for the units is stated to be 1.5 and in the proposed case for the new units, the COP is 3.36 for a 7.1KW unit. It is also proposed that the R-22 refrigerant is replaced with R 410 refrigerant. Both the refrigerants have a high GWP of 1,760 (IPCC, 2013). However
R-410 contains only fluorine which does not contribute to ozone depletion and is therefore more widely used as the R-22 are being phased out. Moreover R-410 has a higher seasonal energy efficiency ratio rating which lowers power consumption (Jadhav & Mali, 2009)

### 4.2.2.2 Savings calculation

Energy saving of 52% is feasible through the recommended measure

<table>
<thead>
<tr>
<th>Measure</th>
<th>End of life replacement for AC units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>10.12 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>5.16 tCO₂</td>
</tr>
<tr>
<td>Annual energy cost saving</td>
<td>FJD $3946.8</td>
</tr>
<tr>
<td>Total initial cost</td>
<td>FJD $20000</td>
</tr>
<tr>
<td>Pay back</td>
<td>5.1 years</td>
</tr>
</tbody>
</table>

### 4.2.3 Facility characteristics- circulation fans

Inventory of the circulation fans was taken for the Marine Studies Centre, Marine Studies Annex and IMR. The fan types are forward curved fans with standard efficiency which use 65W of electricity. The normal operating hours is assumed to be 6. An important observation was that fans were left on even for unoccupied rooms of the buildings. Circulation fans used a total of 7.2 MWh of energy for the base year for the campus.

<table>
<thead>
<tr>
<th>Building</th>
<th>Circulation fans (Quantity)</th>
<th>Total kW (fans)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Studies Centre</td>
<td>63</td>
<td>4.1</td>
</tr>
<tr>
<td>Marine Studies Annex</td>
<td>19</td>
<td>1.2</td>
</tr>
<tr>
<td>IMR</td>
<td>6</td>
<td>0.4</td>
</tr>
</tbody>
</table>
4.2.3.1 Proposed case

It is proposed that these circulation fans be replaced with energy efficient fans. It is also important that the fans are turned on only when necessary. The fans must also be turned off when the spaces are not occupied.

4.2.3.2 Savings calculation

Energy saving reduction of 20% is feasible through the recommended measure.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Upgrade to Energy Efficient fans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>0.6 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>0.31 tCO₂</td>
</tr>
<tr>
<td>Annual energy cost saving</td>
<td>FJD $234</td>
</tr>
<tr>
<td>Total initial cost</td>
<td>FJD $3125</td>
</tr>
<tr>
<td>Pay back</td>
<td>13.4 years</td>
</tr>
</tbody>
</table>

4.2.4 Facility characteristics- computer equipment

The FSTE undergraduate computer lab in the Marine studies have computer monitors that use Cathode Ray Tube (CRT) technology. It was also observed that the computers go into standby mode when not in use.

4.2.4.1 Proposed case

The CRT monitors draw between 90-150W of power which is quite significant. It is recommended that these monitors be replaced with LED monitors which draw 25-40W of power.

4.2.4.2 Savings calculation

Energy saving of 20% is feasible through the recommended measure.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Replace CRT monitors with LED monitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy consumption saving</td>
<td>1.78 MWh</td>
</tr>
<tr>
<td>Annual emissions saving</td>
<td>0.91 tCO₂</td>
</tr>
</tbody>
</table>
Before establishing any new RE based generation system, energy efficiency measures are a must. The energy use at lower campus can be significantly minimized by the implementation of the proposed cases for the facility. About 24 MWh of energy can be saved through energy efficiency measures. This is approximately 13% of the total amount of energy that was consumed at the campus for the base year. This also offers opportunity for emissions reduction of 12 tCO₂. The proposed cases for the main building spaces include using energy efficient luminaires for lighting, end-of-life replacement of AC units, installing energy efficient fans and using LED monitors for computer equipment.

There are other opportunities available for the campus that will help to reduce emissions. These actions are deemed to provide emissions reduction at the lowest cost. This can be achieved through reducing energy consumption by;

- Switching off equipment when not in use or put the equipment in energy save mode. Timers can also be purchased for equipment so that they turn off
automatically when not in use. Using notices like “switch me off” as reminders. Also using the electric kettle to heat only the amount of water needed and encouraging the staff to switch their computers off when they are away for long periods of time.

- Where possible Energy Star rated equipment/appliances should be purchased.
- Employing power management features on computers. This feature enables the computer’s monitor to shut down automatically when inactive for a specified period of time. This can be useful for the student computer labs.
- ACs, lights and fans in offices and meeting rooms should be turned off when empty. It would be useful to install motion sensors which turn off when not occupied for some time.

These energy saving practices can offer reduction in campus energy use by up to 30%. Awareness campaigns can also play a key role in encouraging students and staff to practice energy saving.

4.3 Strategies to reduce travel related emissions

The use of energy in the transport sector is a major concern because of the reliance on petroleum and the resulting increase in carbon emissions. These emissions are primarily from fuel burning in the engines. Higher rates of emissions from the transport sector is pronounced in developing countries as compared to other regions of the world (UNFCCC, 2017). This is evident from the increasing number of vehicles on road and an ever growing demand for mobility. For Fiji the number of motor vehicles increase is at 5% pa since the 1970s (Fiji’s Intended Nationally Determined, 2015) as the modern society is drawn to individual transport options. The engine size distributions is also moving away from energy and emissions savings. Moreover this has put a strain on national resources to meet the infrastructure requirements to accommodate vehicle increase. To reduce emissions, mitigation in this area at a national scale is a challenge whereby fuel switching options are sought (for example biofuel or electricity) rather than mode changing for example improved public transport systems.
For the USP marine campus itself about 1409 tCO$_{2e}$ were emitted as a result of travel related activities, making up 93% of the overall emissions. 94% of these emissions were from staff and student commuting. In order to reduce these emissions, changes in travel behavior must be encouraged in terms of considering more sustainable transport options e.g.; carpooling, public transit, walking and biking. The case study on the campus showed that none of the staff engaged in carpooling. This could be due to people living on different routes or it may be due to personal choices. There are cases in the world whereby local car sharing websites are developed to find people to car share with. This could be a good carbon and money saving option for our community and could also help to solve the issue of traffic congestions and save time. A website itself could be setup at the campus whereby student and staff could be encouraged to participate and find people to car share with, within the campus community and thus help in reducing the large emissions resulting from commuting.

Other strategies for reducing commuting GHG impact include;

- Establishing a bicycle-friendly campus by building campus bike paths especially on upper campus to the marine campus route. This will make bicycle commuting more practical. Offering incentives for bicycle commuting will also actively encourage more bicycle commuters. Having bicycle programs and organizing biking contests can also draw students’ interest in biking.

- Implementing on-campus parking charges to discourage vehicle commuting.

- Carpooling can also be encouraged by offering incentives.

- Raising awareness on transportation options with less environmental impact. Encourage staff and students to utilize public transit, avoid single-occupancy vehicles and use high efficiency vehicles if the use of cars is necessary.

Another important travel related emissions is the emissions resulting from business air travel. The aviation industry is accountable for four to nine percent of the total climate change impact of human activity (Budd et al., 2013). Moreover, there has been 83% increase in CO$_2$ emissions from international aviation since 1990 (IPCC, 1999). Burning jet fuel releases CO$_2$, water vapour, nitrous oxides, sulphates
and soot which are produced at high altitudes in the atmosphere. This is more harmful to the climate since a net warming effect occurs due to the chemical reactions triggered by the presence of these gases. Estimations by the IPCC also suggest that the impact of aircraft on the climate is two to four times greater than just the effect of their CO₂ emissions (IPCC, 1999).

The USP marine campus air travel emission constituted about 3% of the total travel emissions. This category includes emissions for trips paid by the University for Staff and visitor travel. The purpose of travel mainly included; attending conferences, meetings, trainings and workshops. The university should consider avoiding its air travel by using alternatives to long- distance travel for example video and web conferencing and virtual training sessions. Where air travel cannot be avoided the following strategies can help to reduce the impacts of business air travel;

- Opting for direct fights since take-offs and landings use the most fuel,
- Fly economy, because more people per plane means fewer emissions per person,
- Fly during the day because night flights have the strongest warming impact from the contrails since heat accumulated on the ground are prevented from escaping. In the day the contrails actually reflect some sunlight away from the earth (Bråthen and Williams 2016).
- Having a light luggage since lighter planes burn less fuel.
- Combining trips, which is by booking more than one meetings in your destination city so there is no need to fly there several times. This will minimize on the number of flights.

Additionally about 1% of the overall campus emissions are owed to the four boats at campus which are mainly used for fieldwork by the marine students. 28 tCO₂e emissions resulted from the boating activities for the base year. Time series data was not available for this category. Despite the fact that emissions from boats only make up 1% of the total campus emissions, a value of 28 tCO₂e emissions for the four boats is still large. There is potential to reduce CO₂e emissions for these marine boats by for example replacing the motor gasoline engines with electric outboard (direct current)
coupled with bank of electrochemical batteries and Photovoltaic system on board to recharge the batteries (Florez-Escobar et al., 2015).

### 4.3.1 Electric outboard motors

There is potential to reduce CO₂ emissions for the marine boats as suggested through personal communication with the Research Associate for Sustainable Sea Transport Research Programme at Lower campus. Electric motors are suggested for the boats to reduce the need for fossil fuels. Solar energy can be used to generate electrical energy which can partially power the boats. The initial cost for the implementation of this project maybe quite substantial. This is due to the extra costs for photovoltaic plant and replacing the outboard motors with electric motors. These costs are compensated by lower maintenance costs, no fuel consumption and reduction in operation costs. Additionally implementing the use of electric motors will offer a net annual GHG emission reduction. Other emission reduction strategy could also be to organize training and awareness with research vessel maintenance and operations staff.

### 4.4 Strategies to reduce MSW emissions

Waste data was collected for the marine campus. This was then further grouped into wastes that can be recycled and organic wastes (Fig 34). The recyclables group included paper, PET bottles and aluminum cans. Despite the fact that there is a USP recycling program whereby bins are allocated throughout the campus for different wastes, in particular paper, Pet bottles, cans and organic food item, this rubbish still end up in the common solid wastes compactor bins. These wastes which can be recycled makeup on average 28% of the total waste generated at the campus and end up in the landfills.
To prevent these recyclable wastes ending up in the landfills it is recommended that USP expand its recycling efforts. A renewed commitment to the current USP recycling program is needed for minimizing waste. Some key actions could include:

- More recycling locations be established throughout the campus. Having recycling bins more conveniently available can encourage positive recycling behavior.
- Create more awareness on recycling, and special events such as orientation week can be used to introduce the recycling program.
- Implement penalty system to encourage recycling behavior.
- Initiate collaboration with local reuse/recycling entities
- Environmental science students can take a more proactive role in promoting the recycling program among their peers. This initiative can be inter linked with their courses, helping to build greater awareness in protecting our environment.

The Properties and facilities have taken a positive step to collect data on waste/garbage disposal which commenced in January 2016 (Fig. 35). They have collected data on the estimated tonnage generated and waste recovered for the whole of Laucala campus. A waste reduction profile has also been simulated from this data.
To initiate programs and policies to minimize and manage waste, it is crucial that a more comprehensive waste audit be carried out. This is the process of quantifying the amount and type of waste being generated by an organization (Appalachian State University, 2012). This also includes assessing the effectiveness of the waste management and recycling habits of the campus community. Strategic action plans can then be formulated to enhance waste minimization on campus.

Another waste minimization strategy is composting. Organic waste make up a large share of the total waste generated. Emissions can also be reduced if food waste and plant waste from landscaping is composted. By doing so the release of methane is prevented that would occur otherwise if this organic waste was sent to a landfill.

A pilot composting organic waste project was implemented in 2005-2007 at the campus with the primary aim of scientifically testing composting, using readily available green and putrescible wastes in the absence of animal waste. This project also aimed to build awareness about composting and a knowledge base on composting. The scientific testing of the end product of the compost proved to meet the Australian guidelines for compost quality and therefore the project was deemed to be a success (PACE-SD, 2012). In addition to this a ‘Waste Wise USP’ project was also set up by IAS and PACE-SD. This project was part of the broader ‘Greening the
University of the South Pacific initiative’ with the aim of incorporating sustainable waste management system which includes reducing, re-using and recycling waste (PACE-SD, 2012).

A composting program should again be initiated with the aim of minimizing organic waste and methane emissions at the campus. There is already strong basis for this program based on the past composting project and hence can prove to be a successful endeavor. The “Waste Wise USP’ project and campus greening efforts can be more strongly enforced in light of the CF reporting for the campus. Staff and students can be encouraged to take a more proactive role in ensuring that these initiatives thrive for the betterment of the environment with the aim of achieving sustainability. It will also be a good idea to incorporate sustainability in the courses offered by the university. This will help to encourage and promote the need for sustainable growth for the campus and also the community.

4.5 Chapter summary

The key areas for which campus greening efforts are recommended were energy, transport and waste. The mitigation efforts include switching to Renewable sources of energy, energy efficient measures and conservation, and sequesting through planting trees or offsetting of any remaining emissions. A 50 kWp PV rooftop system is proposed for the Marine campus which will make the campus 100% renewable for its electricity use and offer a net annual GHG reduction of 13 tCO₂. This can entail a 17% reduction in the net annual electricity emissions. The energy audit of the campus established the base case in the RET Screen analysis for which energy efficient measures were proposed. A cost and benefit analysis was carried for the proposed cases for facility lighting, air-conditioning, fans and computer equipment. The energy audit revealed the much needed room for improvement in terms of employing more energy efficient measures. The CF analysis results show that the large contribution of emissions is from commuting. Although this can be seen to be outside of the operations boundary of the campus, staff and students can be encouraged to practice greener methods when commuting and therefore creating awareness can be a strategy to cut overall emissions.
Chapter 5- Conclusions

The Marine Campus GHG inventory and reduction plan represents an important step forward in the university’s efforts to pursuing a green campus and sustainable development. This research intended to analyze the baseline CF for the marine campus and suggest mitigation strategies to reduce emissions for the campus.

Theoretical literature revealed that a scientific definition for the term CF is yet to be established, however CF assessments have gained recognition in the world of science and have been classified into two groups; LCA (product CF) and corporate-based analysis (organization CF). CF standards for organization reporting have been analyzed and hybridized to create a model for the marine campus and develop mitigation strategies. The research questions were investigated and the key outcomes are stated below:

5.1 Objective 1: Conduct an Analysis of the Existing tools and Methodology

The IPCC guidelines methodology is the reporting standard for the national GHG inventory. This was important to this research because it uses emissions factors that are country and region specific and accounts for the uncertainties. The widely accepted standard at organization level is the GHG protocol. This has clearly defined scopes for the emission source categories.

5.2 Objective 2: Creating a CF model for the Marine campus

The operational and organizational boundary was established for the marine campus to help determine the significant sources of emission. The sources were then classified under the GHG Protocol scopes:

- Scope 1: department vehicles, boats, diesel generator
- Scope 2: Energy indirect- purchased electricity
- Scope 3: staff/student commuting, staff business air travel, MSW, paper consumption

A GHG inventory workbook was created for the source categories with the activity data, emission factors and conversion factors stated explicitly.
5.3 Objective 3: Mitigation strategy

Mitigation strategy suggested

- Goal - Reduce GHG emissions by 30% (suggested)
- Objective
  - Conduct an energy audit
  - Make the campus 100% renewable for its electricity use
  - Suggest campus greening efforts and energy efficiency
- Mitigation action plan
  - A 50kWp PV rooftop system will ensure that the campus is 100% renewable. This will also offer the campus a 15% reduction in net annual emissions.
  - Developed scenarios for internal reductions e.g. changing lighting fixtures
  - Implemented measures to reduce emissions for energy, waste and transport

The purpose for this work was to establish a CF baseline, monitor trends and measure future progress. Emissions from transport held the largest share of the overall emissions for the lower campus which comprised mainly of staff and student commuting. The CF for the lower campus was estimated to be 2666 tCO$_2$e in total, about 1 tCO$_2$e per student (EFTS) and 0.07 tCO$_2$e per square meter. These values are quite low as compared to other universities around the world.

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 emissions contributes about 20% of the overall emissions. Since the CF for the whole of Laucala campus included similar scope 1 and 2 emissions category 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$_2$e per student (FTES), the lower campus contributing 0.1 t CO$_2$e 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. Hence among the carbon reduction strategies, there is a suggestion to install an additional 50 kWp PV rooftop system which will make Lower campus 100% renewable in terms of electricity consumption. Other internal reduction strategies are recommended which involve following simple practices by the staff and students to make a difference and contribute towards the campus greening efforts of the University.

5.4 Future work and prospects

This CF study has potential to be implemented in entities with larger organizational and operational boundary. Business organizations, government ministries, non-government organizations and municipalities can have CF analysis carried out to account for their emissions and 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 to the many more dots that need to be connected to 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.

CF is a growing field which is gaining much support in the climate change mitigation efforts. Linking this to the “global stocktake”, CF at smaller scales can be seen as building block for keeping global warming below 1.5-2°C. Since Fiji has demonstrated its commitment to the global climate regime through its NDC and in a more pronounced way by assuming the presidency of COP 23, it has a key role to play, especially in influencing “Facilitative Dialogue” which is still in its developmental phase. Moreover Fiji has a huge task to help drive countries to deliver on their commitments. It therefore requires the support of civil society and research institutes to help in facilitating in the technical sessions. Hence such studies are important to create a knowledge base that can greatly reinforce our commitment and hence influence dialogue at international level.
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 to achieve 30% reduction in CO$_2$ emissions. This GHG emissions inventory gives the foundation for documenting an institution’s emission sources that is quick and inexpensive.

### 5.5 Recommendations

The following elements are recommended for consideration to improve and expand CF analysis for USP.

- All of the USP campuses should be encouraged to produce a CF report annually using this model as a guide.
- The data collection process can be simplified if departments within the campus keep good records of important CF categories such as fuel consumption data, purchased paper and employee commuting and air travel data. Each department could have a person assigned to monitor and update data on a weekly/monthly basis. This can be deemed as a more reliable data keeping system than centralizing information systems for all the departments, since updating data for only one department will be easier and less time intensive than having to update for all the departments which can also result in data gaps and error. Moreover departments themselves can keep track of their emissions and implement their own emissions reduction targets and monitor improvements. This strategy could also invoke competition amongst departments to reduce their emissions and thereby reduce emissions for the campus as a whole.
The category for which data is monitored and updated centrally include electricity consumption. Since the departments do not have separate meters at the campus, the Properties and Facilities section of USP keeps records of electricity consumption. It would also be useful if this department could monitor and collect data annually for the MSW disposed. The properties and facilities section has done some work in this area in terms of creating a waste reduction profile for the lower campus for the year 2016. It would be recommended if CF analysis could be incorporated with this work.

Priority should be given to the proposed emission reduction strategies which can also act as test solutions and be considered for the main campus and the other USP campuses.

The university could consider offering a course on GHG inventory training and the IPCC guidelines which could further raise awareness among the staff, student and the community and produce trained regional human capacity in the field of CF.
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Appendix A: Emission factors used to calculate CO₂ equivalent emissions in this report

Table A-1 Global warming potential (GWP) values relative to CO₂

<table>
<thead>
<tr>
<th>Industrial designation or common name</th>
<th>Chemical formula</th>
<th>GWP values for 100-year time horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Second Assessment Report (SAR)</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>CO₂</td>
<td>1</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>21</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N₂O</td>
<td>310</td>
</tr>
</tbody>
</table>

*(Greenhouse Gas Protocol, 2016)*

Table A-2 Approximate conversion factors

<table>
<thead>
<tr>
<th>To convert</th>
<th>barrels to tonnes</th>
<th>tonnes to barrels</th>
<th>kilolitres to tonnes</th>
<th>kilolitres to kilolitres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquefied petroleum gas (LPG)</td>
<td>0.066</td>
<td>11.60</td>
<td>0.542</td>
<td>1.844</td>
</tr>
<tr>
<td>Gasoline</td>
<td>0.120</td>
<td>8.35</td>
<td>0.753</td>
<td>1.328</td>
</tr>
<tr>
<td>Kerosene</td>
<td>0.127</td>
<td>7.88</td>
<td>0.798</td>
<td>1.253</td>
</tr>
<tr>
<td>Gas oil/diesel</td>
<td>0.134</td>
<td>7.48</td>
<td>0.843</td>
<td>1.186</td>
</tr>
<tr>
<td>Residual fuel oil</td>
<td>0.157</td>
<td>6.35</td>
<td>0.991</td>
<td>1.010</td>
</tr>
<tr>
<td>Product basket</td>
<td>0.125</td>
<td>7.98</td>
<td>0.788</td>
<td>1.269</td>
</tr>
</tbody>
</table>

*(BP Statistical Review of World Energy, 2016)*

Table A-3 Fuel Efficiency

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Fuel efficiency (*Lge/100km)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger vehicle</td>
<td>6.22</td>
<td>Global fuel economy initiative (GFEI)</td>
</tr>
<tr>
<td>Light duty</td>
<td>6.47</td>
<td><a href="https://www.globalfueleconomy.org/media/44069/wp5-iea-fuel-economy-report.pdf">https://www.globalfueleconomy.org/media/44069/wp5-iea-fuel-economy-report.pdf</a></td>
</tr>
<tr>
<td>Heavy duty</td>
<td>7.54</td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>8.30</td>
<td></td>
</tr>
</tbody>
</table>
Table A-4 fuel conversion factor

<table>
<thead>
<tr>
<th>Fuel consumption activity</th>
<th>Fuel type</th>
<th>Energy content (TJ/Gg)</th>
<th>Emission Factor (Kg CO₂/TJ)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary</td>
<td>Gas/diesel oil</td>
<td>44.3</td>
<td>74100</td>
<td>2006 IPCC Guidelines</td>
</tr>
<tr>
<td>Light-duty trucks</td>
<td>Gas/diesel oil</td>
<td>43</td>
<td>74100</td>
<td></td>
</tr>
<tr>
<td>Domestic water-borne navigation</td>
<td>Gasoline</td>
<td>43</td>
<td>69300</td>
<td></td>
</tr>
</tbody>
</table>

Table A-5 Emission factor for Paper

<table>
<thead>
<tr>
<th>Emission factor</th>
<th>Kg CO₂e /ton</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing paper</td>
<td>939</td>
<td>2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting (DEFRA, 2012)</td>
</tr>
<tr>
<td>Toilet paper</td>
<td>1284</td>
<td></td>
</tr>
</tbody>
</table>

Table A-6 Calculations for A4 paper mass

<table>
<thead>
<tr>
<th>A ream of printing paper</th>
<th>500× A4/210×279mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 sheet A4</td>
<td>80g/m²</td>
</tr>
</tbody>
</table>

Area = 0.21m×0.279m

= 0.06237m²

80g : 1m²

X : 0.06237m²

Xm² = 80g ×0.06237m²

X = 4.9896g

X = 0.00499 Kg (the mass of 1 sheet of paper)
### Appendix B: Data tables

#### Table B-1 Data collection sheet

<table>
<thead>
<tr>
<th></th>
<th>PACE-SD</th>
<th>Marine Studies</th>
<th>IAS</th>
<th>IMR</th>
<th>SGESE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Air Travel (per annum)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air conditioning units</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicles (fuel usage data)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boats</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff commuting</td>
<td>Full time staff: Responses:</td>
<td>Full time staff: Responses:</td>
<td>Full time staff: Responses:</td>
<td>Full time staff: Responses:</td>
<td>Full time staff: Responses:</td>
</tr>
<tr>
<td>Data source</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>Model</td>
<td>Fuel type</td>
<td>Amount spent per annum ($)</td>
<td>Fuel usage for the fiscal year (L)</td>
<td>Data year</td>
</tr>
<tr>
<td>-------------</td>
<td>-------</td>
<td>-----------</td>
<td>-----------------------------</td>
<td>-----------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Location: MSP</td>
<td>Make: DENYO</td>
<td>Size: 230 KVA</td>
<td>$600</td>
<td>400</td>
<td>2015</td>
</tr>
<tr>
<td>Location: IAS</td>
<td>Make: AMEC</td>
<td>Size: 18KVA</td>
<td>$150</td>
<td>100</td>
<td>2015</td>
</tr>
</tbody>
</table>

### Electricity data

<table>
<thead>
<tr>
<th>Description</th>
<th>kWh</th>
<th>Amount spent ($)</th>
<th>Data year</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>1077645.08</td>
<td>$356,700.52</td>
<td>2014</td>
<td>Niranjwan Chettiar Manager design &amp; Engineering services Properties &amp; Facilities</td>
</tr>
<tr>
<td></td>
<td>829836.798</td>
<td>$274,675.98</td>
<td>2015</td>
<td>Niranjwan Chettiar Manager design &amp; Engineering services Properties &amp; Facilities</td>
</tr>
</tbody>
</table>
Appendix C: Survey Questions and Responses

Appendix C-1 Student commuting survey
Q2 What is your program of study?

- Environmental Science
- Earth Science
- Geography
- Marine Studies
- Climate change
- Others

Q3 What is your mode of study?

- DFL
- F2F
- Print mode
Q4 In a typical week, what mode of transportation do you use for commuting to the lower campus?

<table>
<thead>
<tr>
<th>Day</th>
<th>Car</th>
<th>Public transport: bus</th>
<th>USP Shuttle</th>
<th>Car pool</th>
<th>Walk</th>
<th>Bicycle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monday</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of transport</td>
<td>10.71%</td>
<td>29.76%</td>
<td>27.86%</td>
<td>0.00%</td>
<td>31.55%</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>56</td>
<td>47</td>
<td>0</td>
<td>53</td>
<td>0</td>
</tr>
<tr>
<td><strong>Tuesday</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of transport</td>
<td>10.12%</td>
<td>26.79%</td>
<td>28.57%</td>
<td>0.60%</td>
<td>33.33%</td>
<td>0.60%</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>45</td>
<td>48</td>
<td>1</td>
<td>58</td>
<td>1</td>
</tr>
<tr>
<td><strong>Wednesday</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of transport</td>
<td>9.88%</td>
<td>27.16%</td>
<td>29.01%</td>
<td>0.00%</td>
<td>33.95%</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>44</td>
<td>47</td>
<td>0</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td><strong>Thursday</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of transport</td>
<td>11.18%</td>
<td>28.24%</td>
<td>25.29%</td>
<td>1.18%</td>
<td>33.53%</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>48</td>
<td>43</td>
<td>2</td>
<td>57</td>
<td>1</td>
</tr>
<tr>
<td><strong>Friday</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of transport</td>
<td>8.13%</td>
<td>26.25%</td>
<td>29.38%</td>
<td>0.00%</td>
<td>35.00%</td>
<td>1.25%</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>42</td>
<td>47</td>
<td>0</td>
<td>56</td>
<td>2</td>
</tr>
<tr>
<td><strong>Saturday</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of transport</td>
<td>18.75%</td>
<td>43.75%</td>
<td>0.00%</td>
<td>0.60%</td>
<td>37.50%</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td><strong>Sunday</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of transport</td>
<td>17.39%</td>
<td>30.43%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>52.17%</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>
Q5 What is the estimated distance between your home and lower campus?

![Pie chart showing distance distribution between home and lower campus]

Q6 Specify the type of vehicle you drive to the marine campus? (Including a vehicle you use in a carpool, van pool)? Select "N/A" if not applicable.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Total</th>
<th>Sedan</th>
<th>SUV</th>
<th>Minivan</th>
<th>Pick-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>45</td>
<td>30</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
<th>Car</th>
<th>Van</th>
<th>Bus/Coach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>70%</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Appendix C-2: Staff commuting survey

The questions in this section are designed to collect information on your scope 3 emissions and assess your commuting behavior to the USF marine campus.

Department:

Designation:

Full time staff/ part time staff

1. On average how often do you commute to lower campus in week?

2. In a typical week, what mode of transportation do you use for commuting to the lower campus?
   - Car
   - Bus
   - USP shuttle
   - Car pool
   - Walk
   - Bicycle
   - taxi

3. What is the estimated distance between your home and lower campus
   - Less than 1km
   - 1-2km
   - 2-3km
   - 3-4km
   - 4-5km
   - 6-7km
   - 7-8km
   - 8-9km
   - 9-10km
   - More than 10km

4. Specify the type of vehicle you drive to the lower campus (including a vehicle you use in a car pool/vanpool) select N/A if not applicable

<table>
<thead>
<tr>
<th>Year</th>
<th>Type</th>
<th>Vehicle fuel type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passenger vehicles</td>
<td>Diesel</td>
</tr>
<tr>
<td></td>
<td>Light duty vehicles</td>
<td>Unleaded</td>
</tr>
<tr>
<td></td>
<td>Heavy duty vehicles</td>
<td>Biodiesel</td>
</tr>
<tr>
<td></td>
<td>hybrid</td>
<td>LPG</td>
</tr>
</tbody>
</table>