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# Development of a Campus Carbon Footprint Intervention Framework

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**Abstract**
Sequel to the setting of the United Nations Sustainable Development Goals aimed at transforming the world, efforts are being made at various levels towards the actualization of these goals. University as one of the agents of socialization has a strong influence in promoting sustainable development. As part of an effort in accomplishing sustainable development, Universities are encouraged to employ sustainable development in the campus. The University campus has been identified as the centre of the larger society where various human activities take place. With myriads of activities that characterize a University campus, the carbon emission is significant. These carbon emissions contribute significantly to global warming. In order to develop an intervention framework for the carbon footprint within the campus, there is a need to evaluate and categorize the carbon footprint of the campus. This study presents the measurement and analysis of carbon footprint of a University in Kuala Lumpur, Malaysia. The carbon emissions from the major activities were identified. Carbon footprint mitigation strategies were proposed in order to ameliorate consumption behaviour within the University campus.

## 1. Introduction

The sustainable development issues have been growing and have become a global trend. The United Nations came up with Sustainable Development Goals (SDGs) in 2015. It is a blueprint to achieving a better and more sustainable future for all and requires support from all the leaders around the globe [1]. There are 17 goals which make up the SDGs, and are targeted to be achieved by the year 2030 based on the three pillars of sustainability namely economic, environmental and social [2]. On the environmental aspect, the goals are set to counter the problems that exert environmental stress on the earth [3].

Industrialization, changing of lifestyle, and world population growth in the last few decades, have led to a rapid increase in climate change and global warming. These has drawn the attention of many countries, stakeholders and researchers [4]. The Intergovernmental Panel on Climate Change (IPCC) reported that by the year 2100, there is a projected increment in the global temperatures from 1.1°C to 6.4°C, and sea level would rise from 16.5cm to 53.8cm [5]. One of the main causes of the environmental degradation is the uncontrolled GHG emission by human activities. GHG in the atmosphere include Carbon Dioxide ($CO_2$), Carbon Monoxide,

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Nitrous Oxide, Methane Gas, Sulphur Dioxide, Chlorofluorocarbon and Ozone. *GHG* is important to the Earth in maintaining the surface temperature by trapping the heat absorbed from sunlight, regulating the temperature at an optimum level for the organism to live on the Earth's surface. The level of GHG has been on the rise due to the unconstrained emission from industrial and agricultural activities [6]. The consequential threats like climate change and global warming might lead to more serious environmental issues in the future. Therefore, the SDGs are necessary, as a quick response from the globe is imminent.

Identification of the sources of carbon emission is the first step towards the estimation of Carbon Footprint (CF). There are a few definitions of CF given by various organizations. However, the most generally accepted definition is *"a measurement of the total amount of carbon emission whether directly or indirectly caused by human activities, or taking into account of the total emissions accumulated throughout the different stages of certain product"* [7]. CF is an estimation of the total emission of Greenhouse Gases (GHG) in carbon equivalents [8]. One of the main reasons why CF has become a serious problem is the emission of GHG. The sources of emission include the different scale of activities from individuals, governments, corporate organizations, processes and industrial sectors etc. [4]. From the different scale, the human activities, which contribute to the carbon emission are from manufacturing plants, power plants, transportation, construction, etc. Either directly or indirectly, the cities are responsible for the majority of carbon emissions due to the focused population in the cities [9]. With the growing human population in the urban areas in the past few decades, making up half of the population in the world, the energy consumption within the urban sector is the most critical. With the high concentration of population, the demand on energy is higher which contributes to higher emission [10]. Consumption of energy that contribute to direct carbon emissions includes the use of fossil fuels, water and so on. On the other hand, the indirect emissions are inherent in the energy production processes from power plants like burning of fossil fuels for electricity. It has been found that the carbon emission produced from the indirect energy consumption is greater than the carbon emission of the direct energy consumption based on an urban household study [11]. Thus, both of the emissions should be accountable in estimating the CF.

An American software engineer, Tom DeMacro in the year 1982 stated, *"You cannot control what you cannot measure"*. Thus, it is difficult to manage things that are unquantifiable. Hence, in order to reduce the GHG emission, the amount of GHG emission has to be determined. Since it is very tedious to determine the emission of all types of GHG, it has become necessary to determine the CF that is the equivalent carbon to the GHG. The information is limited due to the fact that the Malaysian Government has no specific regulation on CF of buildings. Therefore, the development of building emission baselines and building policies is limited [12]. Some of the available models do not take into account the particular environment, thus it is necessary to conduct a CF study using a campus setting as the study case. Furthermore, it is necessary to develop an intervention framework for the reduction of carbon emission within the University community.

A University can be regarded as a small city based on the concentration of population and a variety of human activities that are taking place within it. As a small city, it is the center of the human activities that include electricity usage, water usage, transportation as well as other activities that cause emission. The direct and indirect emissions from this environment contribute immensely to the environment degradation [13]. Hence, the University can be considered as a good model to study the CF, where the emission from different sources can be tracked easily within a smaller compound. The data collection will be more focused.

*1.1. Significance*

The essence of studying and measuring the CF of the Campus is to promote the SDGs in order to protect the planet for the future generations. The SDGs are goals that are aimed at emphasising the three pillars of sustainability

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such as economic, environment and social in all human activities. With the emerging economies leading the global economic growth per person, the world population has reached seven billion as at year 2011. The world population is projected to reach eight billion by the year 2024. This projection in population undoubtedly implies more stress on the Earth's ecosystem [14].

This study reemphasizes the need for evaluating the environmental impact of the human activities in order to come up with a measure to counter the current global trends such as climate change and global warming. A study of the CF and subsequent intervention framework is going to contribute to the sustainable development of the University. It will also serve as a source of education to the University, the environs and the society. Hence, this study serves as a model for future empirical studies on the estimation of CF of any community.

## 2. Sustainability

### *2.1. Sustainable development*

Ever since the introduction of industrialization, human development has been rapidly growing as the environment is being exploited in order to fulfil human needs [15]. The rapid growth of human community and the accompanying over-exploitation of the nature have given rise to increase in climate change and global warming [5]. Understanding the relationship between humanity and the environment implies that action need to be taken to mitigate these problems. Hence, the natural resources have to be managed properly to ensure long-term development [15]. Sustainable development is the intersection of the three aspects, which are the economy, society and environment [4]. They are interwoven for the well-being of the future generations [16]. The Brundtland Commission defined the sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [17].

### *2.2. Campus Sustainability*

Environmental issues are direct consequences of human activities. The University campus is a beehive of human activities ranging from high consumption of energy, high volume of traffic, intensive waste generation, infrastructural usage and many more. The University conducts numerous activities and operations which have significant impact on the environment. These activities generate tonnes of waste, water usage and material consumption, as well as electricity and fuel consumption [13].

From the benefits and importance of energy sustainability, there is lack of universal direction and consensus towards achieving the campus sustainability. It shows that the scenario is confusing in terms of the direction and universality [18]. The University itself should come up with its very own concept and definition of sustainable campus that should be specific and different from other communities. As a guide or basic principle, *"a sustainable higher educational institution, as a whole or as a part, should promote on a regional or a global level the minimization of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfil its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable life-styles"* [19].

No matter how campus sustainability is defined, or how it is measured, there is no absolute value for sustainability, in social, economic and ecological terms. The definition might differ from institution to institution, which makes campus sustainability a challenge to achieve. Some ongoing debate were on the specific definition of sustainability either scientifically or politically. Hence, the terms form a useful base for organising concepts [20, 21].

## 3. Methodology

### *3.1. Process and data collection*

The transportation sector covers only part of the energy consumption by the University campuses and the facilities in the campuses require electricity for the lighting, air-conditioning, machines, appliances, etc. The environmentally extended input-output (IO) analysis will be implemented for this sector. This method is quick and simple, and is less time-consuming to use after the model has been established [22]. This is a rough analysis for CF. The assessment is made based on the

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aggregated data provided by official departments. This assessment is a top-down approach with broader view on the total emissions where the aggregated data and emission factors are employed [23].

The CF estimates the carbon emission of transportation vehicles considering the different stages of life cycle by collecting actual data, namely, type of vehicle, fuel consumption, and distance travelled without using the average data [24]. University campus has very high traffic due to high concentration of human activities that require transportation for conveyance. The use of transportation requires fuel for the operation. Hence, the carbon emission is direct from the engine of the vehicle, measured by determining the distance travelled within the campus. This method is more to bottom-up approaches where various sources of GHG emission at specific location are measured directly [23].

The details of the process adopted in this study are explained here under. The measurement of the variables and outcome will be discussed which is followed by analysis and interpretation of the data collected. The process flow is shown in Figure 1.

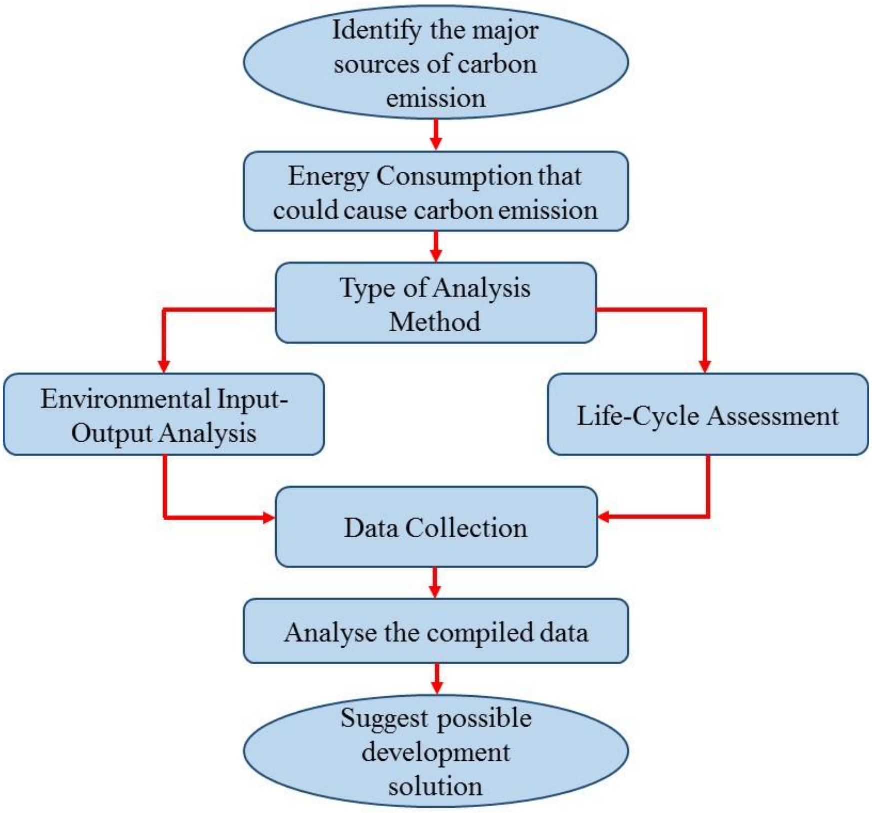


**Figure 1.** The process flow of project

*3.2. Identifying the sources*

In Peninsular Malaysia, when 1 kWh of electricity is generated from the power plant, there is 0.747 kg of $CO_2$ released to the atmosphere [25]. Hence, the metered electrical power consumption device, a compulsory device installed in every building that records the electricity consumption monthly. The sole distributor of electricity in Peninsular Malaysia, Tenaga Nasional Berhad (TNB) will charge a monthly utility fee on the usage for previous month. Based on the electricity consumption within the University premises, it is easy to determine the indirect carbon emission by using the data provided by the University. The data obtained from the University Logistics Department is the monthly bill issued by TNB. It displayed the amount of electricity consumed by the University Campus. The range of data collected is from January 2018 to December 2018.

For commuting within the University campus, some student or staff needs transportation to the campus by the means of vehicles. Whether it is by University shuttle bus, or by own vehicle, each of which emits certain amount of $CO_2$ due to the burning of fuel by the engine unit. For a land mass of 20 acre, the vehicles entering the University Campus need to travel a certain distance before getting a parking spot while other vehicles enter the compound to drop off or pick up passengers or goods. For the distance travelled within the compound, the emission produced along the distance was recorded.

Various criteria make the emission different from car to car. For example, engine capacity, type of fuel used, engine configuration and so on. Hence, the study looked at the official data for the emission of the vehicle only.

Calculation of total fuel consumption by the vehicle was adopted from the Development of Carbon Dioxide Emission Assessment Tool [26]. The formula was modified to fit into our study case.

$$TE = \left(\frac{N \times D \times W}{eff}\right)(E) \quad (1)$$

Where:
$TE = Total\ emission\ (kCO_2)$
$N = Number\ of\ vehicle$
$D = Average\ distance\ travelled\ (km)$
$W = Number\ of\ working\ day$
$eff = Fuel\ efficiency\ (km/L)$
$E = Emission\ factor\ (kCO_2/L)$

The emission factor of fuel and fuel efficiency by type of vehicle for the calculation used are presented in Table 1 and Table 2.

**Table 1.** Emission factor of the fuel

| Type of Fuel | Emission Factor ($kCO_2/L$) |
|---|---|
| Diesel | 2.67 |
| Gasoline | 2.32 |

**Table 2.** Fuel efficiency by the type of vehicle

| Type of Vehicle (Type of Fuel) | Fuel Efficiency (km/L) |
|---|---|
| Bus (Diesel) | 2.50 |
| Car (Gasoline) | 9.76 |
| Motorcycle (Gasoline) | 30.54 |

Adapted from (Chen, 2003; Huo, 2011; Hao, 2010)

## 4. Result and discussion

### *4.1. Indirect carbon emission by major activities in the campus*

The electricity consumption by the buildings of the University campus was obtained from the monthly electricity bill issued by TNB. From the bill, the quantity of electricity used by each building in the campus was recorded in KWh. The amount was totalled up and calculated with the carbon emission factor. The monthly carbon emission by the University campus buildings is presented in Table 3. From the electricity consumption, the emission factor of 0.747 $kCO_2/kWh$ is inserted into Table 3 to obtain the carbon emission.

**Table 3.** Carbon emission by campus buildings

| Year 2018 | Electrical consumption (KWh) | Carbon emission ($kCO_2$) |
|---|---|---|
| Jan | 578928 | 432459.22 |
| Feb | 549903 | 410777.54 |
| Mar | 712111 | 531946.92 |
| Apr | 672000 | 501984.00 |
| May | 669763 | 500312.96 |
| Jun | 689082 | 514744.25 |
| Jul | 772981 | 577416.81 |
| Aug | 746736 | 557811.79 |
| Sep | 602208 | 449849.38 |
| Oct | 727186 | 543207.94 |
| Nov | 632048 | 472139.86 |

| | | |
|---|---|---|
| Dec | 498745 | 372562.52 |
| Total (KWh) | **7,851,691** | **5,865,213.18** |

The indirect carbon emission from electrical consumption obtained from the campus buildings for year 2018 was 5,865,213.18 $kCO_2$, with an average of 488,767.75 $kCO_2$ per month. Based on the area covered by the major activities within the University as shown in Figure 2, the electricity consumption in 2018 by each type of activity was estimated.

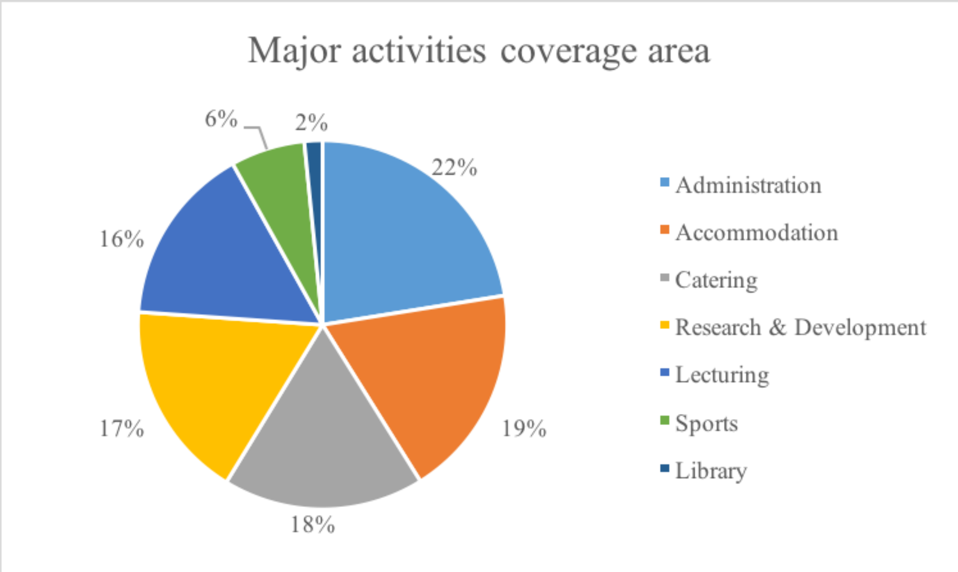


**Figure 2.** Major activities coverage area in the University campus building

*4.2. Direct carbon emission from transportation*

The direct emission from the vehicle entering the campus was determined. The daily average carbon emission from transportation is shown in Table 4. It is grouped according to fuel type and daily consumption. An average distance was considered due to the difficulties of tracking the distance travelled by every vehicle entering the campus. The number of the vehicles and the type of vehicle entering the campus were recorded during the operating hours of the University campus, from 6.00 a.m. to 10.00 p.m. The carbon emission from transportation is solely from the average distance travelled by the vehicle only disregarding the activities carried out.

**Table 4.** Total daily emission by all type of vehicle in year 2018

| | Total number | Fuel consumption, Fuel type (L) | Carbon Emission ($kCO_2$) | Percentage (%) |
|---|---|---|---|---|
| Car | 2834 | 220.55, Gasoline | 511.68 | 95 |
| Bus | 33 | 7.95, Diesel | 21.23 | 4 |
| Motorcycle | 60 | 1.96, Gasoline | 3.36 | 1 |
| Total | **2927** | | **536.27** | **100** |

The carbon emission was calculated based on the fuel efficiency by type of vehicle from Table 1 and carbon emission factor by type of fuel from Table 2. There were 261 working days in year 2018, the daily carbon emission from the vehicles is multiplied by the number of working days. The carbon emission contributed by transportation was 139,967.63 $kCO_2$, with a monthly average of 11,663.96 $kCO_2$. The emission from private cars contributed 95% of the carbon emission in

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transportation, while buses and motorcycles only contributed 4% and 1% respectively.

*4.3. Total carbon emission by the University campus*

After combining all the carbon emission sources, including all the indirect carbon emission from major activities and direct carbon emission from transportation, the breakdown of the monthly carbon emission is shown in Figure 3. This is based on the major activities carried out in the campus.

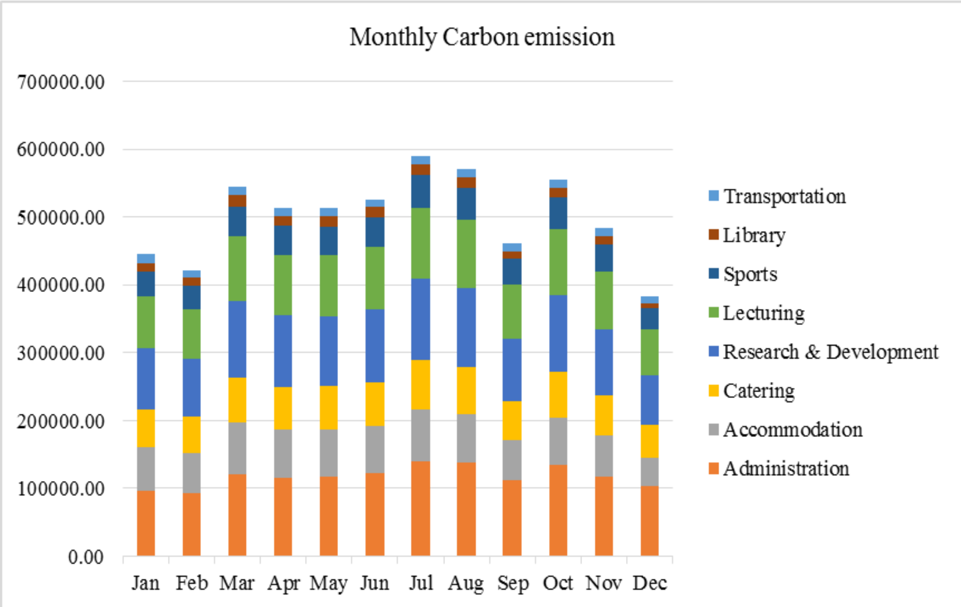


**Figure 3.** Monthly carbon emission in Year 2018

The carbon emission from each major activities was summed up as presented in Table 5. The percentage of the contribution was computed to show the main carbon emission source for the operation of a University campus.

The total carbon emission of Campus in year 2018 from summing the emission from all different categories of activities was 6,005,107.24 $kCO_2$. Table 5 shows that the carbon emission was mainly from indirect carbon emission sources such as Administration (24%), Research and Development (20%) and Lecturing (18%). Direct emission from the Transportation category only contributed 2% to the overall carbon emission.

**Table 5.** Overall carbon emission by different category

| Type of category | Overall carbon emission ($kCO_2$) | Percentage (%) |
|---|---|---|
| Administration | 1410878.89 | 24 |
| Accommodation | 785536.19 | 13 |
| Catering | 742092.24 | 12 |
| Research & Development | 1214881.54 | 20 |
| Lecturing | 1055333.33 | 18 |
| Sports | 496869.20 | 8 |
| Library | 159548.21 | 3 |
| Transportation | 139967.63 | 2 |
| **Total** | **6005107.24** | **100** |

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*4.4. Carbon footprint curtailment*

In order to create sustainable campus, there are steps and initiatives that can be put in place. Basically, the effort in reducing the carbon emission can be divided into two. The first is through the administrative initiatives. The other is by hardware upgrading. The suggested mitigation strategies are presented in Table 6. The effort listed are in connection with the specific category of the major activities in the campus.

As shown in Table 6, administrative initiatives which can be conducted by changing the mindset of the users. One of the strategies is legislating strict management regulations on energy saving. One of such regulations involves staff and student to be reprimanded on energy wasting behaviour [27]. Air-conditioning setbacks is also one of the best way in saving energy. This involves maintaining the room temperature at the comfortable level. The air-conditioner require less load hence consume lesser energy in keeping the optimum temperature [28]. Furthermore, adjusting the opening hour of certain building can also restrict the energy consumption. This is because some buildings are not necessarily being used throughout the day [29]. By having more research on the green technology, it is able to strengthen the research base of the university in finding out environmentally sound technology suitable for the University [27]. The use of common place is one of the energy saving tips as the lighting and the air-conditioning are shared among the other occupants and increase the efficiency [30].

For hardware upgrading, it is recommended that the current lighting system should be changed to Light Emitting Diode (LED) lighting system. This is more energy efficient compared to normal fluorescent lighting and High Pressure Sodium (HPS) lighting. LED lighting consumes only 25% of energy as the traditional lamps [31].

**Table 6.** Carbon emission mitigation framework

| Mitigation strategy type | Activities category | Action |
|---|---|---|
| Administrative | Administration | • Legislate strict management regulations on energy saving<br>• Switch off the lighting and air-conditioner when leaving the office or workspace<br>• Air-conditioning temperature setbacks<br>• Switch off computer when leaving office or switch to power-saving mode when not in use |
| | Accommodation | • Switch off the lighting and air-conditioner when leaving the room<br>• Air-conditioning setbacks<br>• Switch off computer or switch to power-saving mode<br>• Encourage room-sharing |
| | Research and Development | • More research on green technology to be able to implement in the campus |
| | Lecturing | • Switch off the lighting and air-conditioner<br>• Air-conditioning setbacks<br>• Opt for a smaller classroom capacity according to the class size |
| | Library | • Encourage student to study in library<br>• Adjust the opening hours of the library |
| | Transportation | • Encourage walking or cycling to campus<br>• Encourage student to take public transport<br>• Offer car-poolers discount on parking |

| | | |
|---|---|---|
| Hardware | Administration | ● Replace the lighting with energy-efficient lighting, such as LED lamps |
| | Accommodation | ● Install solar panel for water heating |
| | Research and Development | ● Replace the inefficient old equipment in the laboratory |

## 5. Conclusion

The study has looked at overall carbon emission generated by the campus, it was found that the CF of the University campus were mainly contributed by the electrical consumption of the campus. The carbon emission by the electrical consumption constitute 98% of the total carbon footprint, while the remaining 2% is from transportation. As a university campus located in the city, the campus buildings are mostly high-rise buildings which provide more spaces in the campus while occupying a small land mass. The compactness of the campus reduces the distance between the facilities. Hence, the use of vehicle for transportation becomes unnecessary. Therefore, the CF from the transportation was not as significant as it may seem as a direct emission. It was not possible to track down every vehicle to measure the distance travelled by every vehicle. In collecting the data from the transportation part, due to the high traffic, the distance travelled from the University entrance to different locations of parking space was only estimated. However, it is expected that the energy consumption of the campus can be further reduced in order to achieve more sustainable campus and society. The measure of the campus CF is expected to provide a clearer picture of the energy consumption by the campus. This will help in finding a more sustainable approach in the policy of the University. Effective measurement of the CF would support the management of the university in applying more carbon emission mitigation strategies and measures. Further studies is necessary in looking at the waste generated within the university and their $CO_2$ equivalent.

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