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Development of Carbon Dioxide Emission Assessment Tool towards Promoting Sustainability in UTM Malaysia

Isiaka Adeyemi Abdul-Azeez

Department of Urban & Regional Planning, Modibbo Adama University of Technology, Yola, Nigeria
Email: azeezabu@yahoo.com

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Abstract

Universities are challenged to play a leadership role in addressing unsustainable practices that are exacerbating global warming. Basically, many assessment tools have been suggested for measuring emission scenarios and achieve sustainability within university campuses. However, majority of the existing tools consider greenhouse gas emissions outside the campuses upon which universities have no control. This study identifies energy as a major driving force for Carbon Dioxide (CO_2) emission and a universal variable for the assessment of CO_2 emission in university campus. It proposed the Malaysia University Carbon Emission Tool (MUCET) to estimate Carbon Dioxide from the sources of energy use within the campus and assess the CO_2 emission scenario within Universiti Teknologi Malaysia (UTM). The result was compared to that of similar carbon emission inventory initiated by the UTM in 2009, a total emission of 46,000 Mt CO_2 was observed in 2011 using MUCET compared to 82,578 Mt CO_2 given as the total CO_2 emission value for the campus in 2009. Also MUCET presented 74% CO_2 emission for electricity and 26% in the transportation sector in variance to 78% and 20% offered for electricity and transport respectively in 2009 using the contemporary method of assessment. The difference in values was attributed to the contribution of the indirect and off-site emissions (*i.e.* Scope 3 emissions) from external sources. The study showed that MUCET presents a more realistic emission value and would promote sustainability on the campus.

Keywords

Assessment Tool, Carbon Emission, Energy Use, University Campus Sustainability

1. Introduction

A critical aspect of developing a sustainable university campus involves the assessment of activities that relate to Carbon Dioxide (CO_2) emission such as combustion of fossil fuel that promotes atmospheric warming within the campus. Global warming is caused by increasing carbon emission from energy consumption by human activities through the current technological practices that favor the use of fossil fuels as major sources of energy [1]. In view of the global concern about climate change, many universities and organizations are completing greenhouse gas emissions inventories to determine their global warming potentials [2] and set emission reduction targets as pathways to emission-free and sustainable university campus environment.

Declarations of university sustainability are vague about the specific actions needed to reach broader goals [3]. The use of assessment tools offers opportunity to characterize situation, determine how to focus efforts and develop concrete actions [4]. The trend in most countries and universities worldwide is seeking ways to reduce emission of greenhouse gases (GHG) by taking inventory and setting emission targets. There are different estimation methods of measuring university campus carbon emission, popularly described as carbon footprint. Most Carbon Dioxide emission accounting tools are cumbersome, require expert knowledge of environmental sciences to interpret and are not easily understood by administrators for planning purposes.

The implementation of sustainable practices in university campuses is one method of addressing the global climate change [5]. An important step is to adopt quantitative operational approach to meet this goal in the colleges and universities as prerequisite for institutions to define and defend quantitative targets in the direction of CO_2 emissions from energy use [6]. Some authors believe that universities can make significant impact in promoting a sustainable future [7], while others propose the engagement of universities in environmental sustainability [8]. Generally, carbon emission is the common global sustainability issue of today as a result of fossil fuel based energy consumption [9] [10] [11]. There is a growing interest among universities that carbon emission reduction is an important tool to aid the shift to sustainability [12]. Therefore, carbon inventory or the measurement of carbon emission quantities becomes desirable in order to promote campus greening efforts and improve sustainability performance in universities. This may involve the analysis of the sources and types of emission that impact negatively on the global environment and the measurement of the extent of emission on the campus.

The study of carbon emission from energy use in campuses offers a unified direction for sustainability, hence universities are developing carbon emission inventories [13] [14] [15] [16] [17], and setting targets to reduce emission of CO_2 as a measure of campus sustainability and a step towards reducing contribution of campuses to global warming in an attempt to mitigate the condition. However, constraints do exist from the lack of understanding of the process of

determination of the carbon footprint by administrators. This usually affects the formulation and implementation of carbon emission reduction policies in the campus.

The assessment of the environmental implications of university activity on the campus is not uncommon [18], however, until recently, it is not very common to calculate CO_2 emissions within Malaysian university campuses. This is probably because of lack of adequate data for the existing tools, which were mostly designed for regions outside Malaysia, and also because most energy assessment methods and existing energy software are complex, expensive and difficult to understand [19]. Consequently, the measurement of carbon emission as a drive towards sustainability assessment is not popular among Malaysian University Campuses.

Energy is central to sustainability because it connects everything more universally and more quantifiably than any other element [20]. Sustainability of university campus can be better realized when common criteria (such as carbon emission) are assessed through adequate measurement of emissions from energy use [21].

This paper developed a prototype tool known as the Malaysian University Carbon Emission Tool (MUCET) for the assessment of Carbon Dioxide emission and measured the CO_2 emission from energy use in Universiti Teknologi Malaysia (UTM) Malaysia. The tool is a MS-Excel based software program which considers the parameters set by the Intergovernmental Panel on Climate Change for national level inventories and includes all the calculations needed to obtain total carbon emissions from transportation and electricity consumption within the campus.

2. Existing Carbon Dioxide Emissions Assessment Methods for Universities

Several assessment methods exist to account for Carbon Dioxide emissions in the universities, yet the assessment of environmental emissions within higher education remains in its infancy. Carbon Dioxide is the predominant greenhouse gas (GHG) produced from a number of different sources including transportation, on-campus stationary sources, purchased energy, refrigerants, and solid waste among others. The extent of Carbon Dioxide emission is a measure of the contribution to global warming as a consequence of transportation, domestic energy use and lifestyle within the university campus [22]. Therefore, accounting for Carbon Dioxide emissions in the campus offer benefits such as identifying the opportunities associated with the challenge of climate change, increased energy efficiency and energy cost reductions as well as intelligent management of CO_2 emissions based on empirical information.

However, majority of the online carbon-footprint calculators rely on data which unlike energy use are not universally applicable to universities. CO_2 emission from energy sources such as transport and electricity energy use is more universal and contributes above 95% of overall GHG emissions [23] and the

quantities of emission from energy sources can be compared with other universities as a strategy to promote sustainability and reduce CO_2 contribution to global warming.

For instance, sustainability assessment methods such as Life Cycle Assessmenttool (LCA) and Ecological Footprints are used toassess the amount of materials consumed and wasteproduced. Thesehave been applied more recently to university campuses [24] [25] [26], however, they of ten consider factors outside energy use within campuses. Other carbon-footprint accounting methods measure emission from energy but have been criticized to be to ocumber some, focusing on greenhouse gases (GHG) and based on Emission Scopesoutside the campus, ratherthan simple emissionfromknown and familiar CO_2 sources. These factors affect the strength of most existing calculators in direct reduction of CO_2 emission within campuses.

Among such calculators or tools for carbon inventory are the Clean Air Cool Planet (CACP) Campus Carbon Calculator, the Greenhouse Gas Protocol, Carbon Trust, Agricultural and Land Use National Greenhouse Gas Inventory Software (ALU), the Climate Action Registry Reporting Online Tool (CARROT), Electronic Greenhouse Gas Reporting Tool (eGGRT) and the Extended Snapshot Tool (ExSS) [27] [28]. The ExSS is a comprehensive calculation tool developed to illustrate quantitative future snapshot of settlements, commonly used in Asian cities, towards achieving Low Carbon Society (LCS). The ExSS evaluates feasibility as well as analyze relationship between socio-economic conditions and environmental load among others as well as facilitates the measurement of GHG emissions.

Although, each of these calculators has its own merits, however, the tools adopted to account for carbon emission depend on the context of the inventories. Majority of these tools are applied widely to specific range of issues relating to carbon emission and the assessment of global warming potentials of cases in their respective areas of application.

A review of some of the existing calculators commonly used for the assessment of emissions of Carbon Dioxide or greenhouse gases (GHG) in universities is given below.

1) The Clean Air Cool Planet (CA-CP Calculator) Campus Carbon Calculator is commonly used to conduct campus greenhouse gas emission inventory [2] [29] as an assessment of university campus sustainability. The tool is sponsored by the Association for the Advancement of Sustainability in Higher Education (AASHE). It is an electronic MS Excel workbook based on the Intergovernmental Panel on Climate Change (IPCC) for national-level inventories that calculates the estimates of the greenhouse gas emissions through energy use, agriculture, refrigerant, and solid waste data gathered from the campus. This tool provides procedural protocols and a framework for investigation of campus GHG emissions which has been adapted for use at colleges or universities. For instance, the American College and University Presidents Climate Commitment (ACUPCC) team recommended the Clean Air Cool Planet (CA-CP) Inventory Calculator

based on GHG Protocol methodology in accordance with the Greenhouse Gas Inventory Brief.

CA-CP covers all sources within the defined scopes of the ACUPCC and is currently available for application in the context of higher education. Though it is adapted for campus use for more accurate and precise picture of emissions, CA-CP focuses more on input of the exact fuel mix used and GHG emissions from sources that are not common to most universities [21].

2) The GHG Protocol Calculators Sponsored by World Resources Institute (WRI) is the most widely-used international accounting tool for government and business leaders to quantify and manage greenhouse gas emissions. It gives a step-by-step guide for clients to use for quantifying and reporting GHG emissions. This tool calculates the CO_2, CH_4 and N_2O emissions and consists of a Guidebook for customizing existing GHG Protocol calculation tools for a specific GHG program or to more closely reflect national, regional, and institutional circumstances. The calculator recommended both fuel use and distance data for non-public transport sources to be provided and requires that users should first strive to improve their fuel use records.

3) The Climate Action Registry Reporting Online Tool (CARROT) is another emissions calculation and reporting tool, mostly used by California signatories. This is a web-based spreadsheet consistent with the GHG Protocol Initiative. Its results are aligned with the American College & University Presidents' Climate Commitment (ACUPCC) standardized reporting framework. CARROT is only accessible to Registry participants and to California signatories that wish to report to the Registry. The tool is still under development and commonly used to provide guidance for businesses, government agencies, and non-profit organizations and it is customized for the purpose of Certification in the California region of the United State [30].

Among other online calculators and assessment tools for GHG emission assessment is the Carbon Trust (Online calculator). Aside of not being user-specific, it does not present specific CO_2 emission from operational sectors; hence it is not very suitable for target setting and emission mitigation in the University campus. Also, it is complex and users find it difficult to understand how the variables relate as they often require expert knowledge of environmental scientist to interpret.

In most cases, ready-made calculators have been criticized as functioning like a black box, thereby offering less credibility and instruction to improve the existing emission situation [31]. In addition, they consider the indirect and off-site emissions such as upstream emissions from the production and transportation of purchased goods or procurement, whose contribution is usually quite high and accounts for about 80% of total greenhouse gas emissions [32].

3. The Need for the Development of MUCET

Colleges and universities have been at the forefront in addressing energy and global warming issues [33]. The concern for global warming associated with CO_2 emis-

sion from energy use, require the university campus to establish new thinking by way of research programs, investment decisions and training directed towards the management of energy use in order to reduce CO_2 emission.

The measurement of carbon emission is popularly referred to as carbon inventory or carbon footprint. There are different methods of estimation of carbon emission within the campus, towards achieving university campus sustainability. The use of assessment tools offer opportunity to characterize situation, determine how to focus efforts and develop concrete actions [4].

The need for the development of MUCET arose from the concern to account for Carbon Dioxide emission from universal sources of energy consumption related to most university campuses. Energy is a vital input for social and economic development [34] and it is a common criterion for carbon emission in most universities.

The measurement of carbon emission quantities is a necessity in order to promote campus sustainability. A major challenge to achieving a low carbon campus is measuring the quantity of carbon emission attributable to campus operations. Therefore, developing the tool to measure CO_2 emission and set targets to reduce emission from energy sources of the university campus is a drive towards sustainability and a step towards reducing contribution of the universities to global warming [6]. Universities feature large concentrations of population [35], and attract high vehicular traffic thereby requiring energy for operation, and processing. Energy consumption becomes relevant in determining the global warming performance of any campus because the large physical and demographic sizes require energy for lighting, cooling, movements and other domestic purposes. In view of the use of fossil fuels as major sources of energy, the high electricity and transportation fuels result in high Carbon Dioxide emission [36].

The determination of carbon footprint is not an easy task, majority of universities often sponsor consultants to measure their university emission and determine the carbon footprint. The technique and process is not very explicit as figures are allocated to variables based on formulas unclear to the clients. The absence of suitable tool to focus on emission from sources owned or controlled by the university hinders effective reduction of carbon emission and affects formulation and implementation of policies and strategies for carbon emission reduction among campus communities. With MUCET the measurement of Carbon emission from energy variable is easier, more direct and offer knowledge of how the calculations are arrived at. This may give insight into the parameters used and could assist in the formulation of emission reduction policies.

Existing methods to calculate carbon footprints and measure performances vary considerably, and in most cases the calculators or tools are based on Scopes of carbon emission sources [37]. For instance, the most commonly used standard for GHG emissions reporting worldwide is the Greenhouse Gas Protocol Corporate Standard. This GHG accounting framework classifies emission sources around three "scopes"; namely Scopes 1, 2 and 3. Scope 1 refers to direct

emissions that occur from sources that are owned or controlled by the university, such as emissions from university owned or controlled boilers, furnaces, vehicles etc. while Scope 2 accounts for indirect emissions from the generation of purchased electricity, heat or steam consumed by the university. Scope 3 emissions cover large set of elements that occur from sources that are not owned or controlled by the universities.

Methodologies for the assessment of Carbon Dioxide emissions associated with university differ greatly [11] [14] [16] [32] [38] [39] [40] [41]. Among these are the measurement of consumption-based carbon footprint by considering Scope 1, 2, 3 emissions [37] as classified by the WRI/WBCSD Greenhouse Gas Protocol Corporate Standard. Others apply an Environmental Extended Input-Output (EEIO) model to calculate university Carbon Footprint [39] [40]. Furthermore, some also used carbon-based environmental impacts to examine higher education (HE) courses [42]. While the purchase of large amounts of equipment and consumables for scientific use are found to be an important contributor [39].

Although, these methods of assessment of carbon footprints are quite informing and offer opportunity towards sustainable procurement, the emission reduction from Scope 3 sources are beyond the control of the universities and may not be influenced by the emission reduction strategies of the university. The contribution of indirect and off-site emissions is quite high and usually accounts for about 80% of the total greenhouse gas emissions [32]. This explains why majority of the tools mentioned above do not adequately address carbon emission in most university campuses.

Generally, most inventories address Scope 1 and Scope 2 emissions while Scope 3 is considered optional by some authorities such as California Climate Action Registry ACUPCC [43]. Using tools that consider Scope 3 may give ambiguous results, in addition, CA-CP's campus carbon calculator is cumbersome, consisting of about 87 templates or worksheets that consider details on various parameters of greenhouse gases. Similarly, GHG Protocol Initiative (GPI) considered Scope 3 emissions resulting from activities that occur from sources outside the university campus. In view of consideration of Scope 3 emissions, the aforementioned tools may not be effective in the formulation of policy for emission reduction in the universities. Thus the need for MUCET—a tool that focuses on carbon emission from sources within the university campus and upon which the university emission reduction strategies can apply.

Most Malaysian universities depend solely on purchased electric energy from Taman Negera Berhad (TNB) due to the relatively cheap energy cost [44]. Similarly, Malaysian Universities do not purchase steam and co-generation or other energy sources such as residual oil, distillate oil, coal, and propane among others. Therefore, the CA-CP may not be very suitable for the measurement of Malaysia University carbon emission. Hence, the need to develop a prototype tool that utilize Scope 1 and Scope 2 emissions (**Figure 1**) to determine the extent of carbon emission from internal energy consumption sources owned and

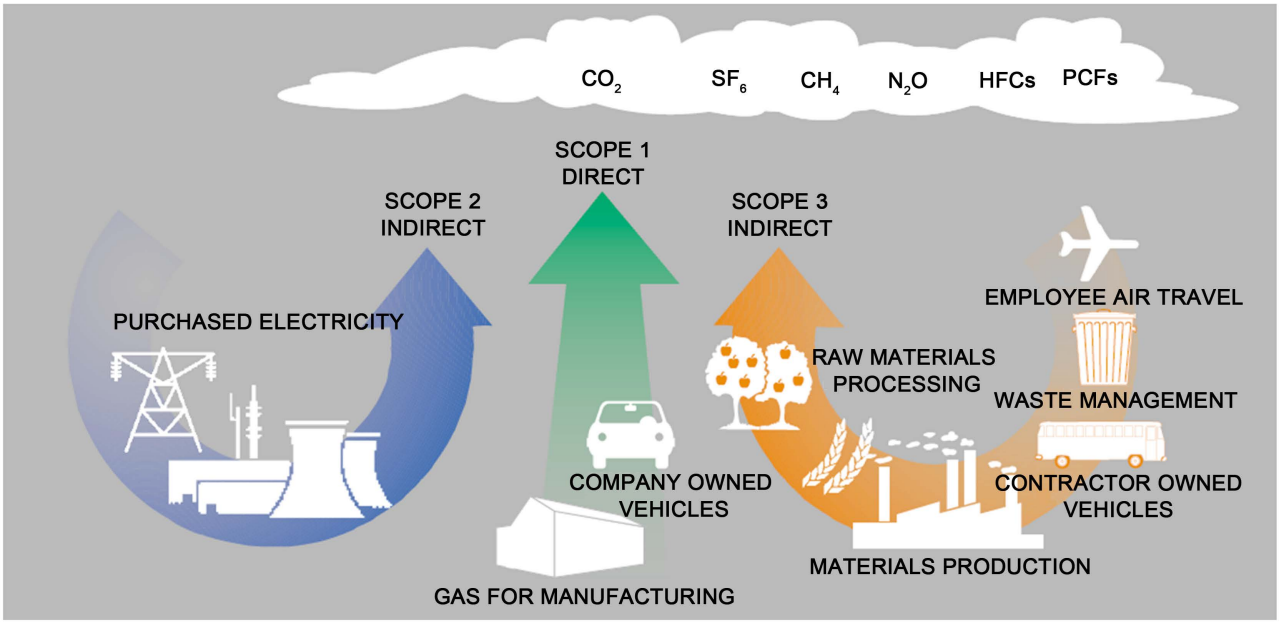


Figure 1. Scopes of carbon emission (Modified after Spiller 2002, New Zealand Business Council for Sustainable Development).

controlled by the university. This will ease planning and implementation and enable the setting of target for carbon emission reduction from energy consumption sources that are quantifiable and universal.

Consequently, MUCET identified electricity and transportation as the major sources of carbon emission via energy consumption and considered energy used for transportation, cooling, lighting and other appliances in the university. This would enable Malaysian universities to focus on making policies that would reduce CO_2 emission based on informed decisions and move university campus sustainability forward. MUCET would also assist to chart the path towards continuous assessment of the energy use condition as well as set targets for emission reduction in the campus by measuring the Carbon Dioxide emission conditions for different operational scenarios on the campus.

4. The Malaysian University Carbon Emission Tool (MUCET)

Development of MUCET focus mainly on energy and carbon emission related infrastructure, based on the pattern of the university's service delivery and the flow of energy within UTM such as Transportation, Teaching and Learning Faculties, Administrative Buildings and Supporting Service Areas, Residential Hostels and Staff Accommodation as well as ICT sectors.

The tool calculates CO_2 emission from the major service sectors of the university energy system. This is arranged into two categories namely; emission from fossil fuel combustion from internally generated electricity and fuel mix of external electricity generation in the case of electricity. The second category considered carbon emission from fuel combustion of vehicular transport movement for goods and services within the campus. The emission of CO_2 associated with University campus electricity energy use was based on the emission factors for

purchased electricity supply from TNB according to the fuel mix data offered by the Pusat Tenaga Malaysia (PTM) or the Low Energy Office [45]. The emission factor for gasoline and diesel combustion in vehicles was in accordance with the Code of Federal Regulations at 40 CFR 600.113-78 based on Inter-Governmental Panel on Climate Change (IPCC) guidelines [46].

Although few staff and students travel by air except for conferences, sports, and other student programs, emission from such sources were considered optional in calculation of campus carbon emission [47]. In view of uncertainties associated with the estimation of GHG from Air travels and because universities have no control over it, MUCET did not considered such emission. Similarly, all other indirect emissions such as upstream emissions from the production and transportation of purchased goods and procurement or upstream supply chain, business travel, students' trips home and visitor travel were eliminated. In view of the uncertainty of calculating Scope 3 emissions accurately, the UK green league exempted it from the sector-wide carbon reduction strategy at the national level pending a nationally agreed methodology for accurately calculating such emissions (Green League 2010 online). Therefore, the tool did not consider Scope 3 emissions for assessment of CO_2 emissions.

MUCET is an electronic MS Excel workbook based on Scopes 1 and 2 emission categories, consisting of rows and columns that represent the sources and nature of energy consumption. The operation of MUCET is that the columns and rows are synchronized together and when the values obtained from these sources are inserted in the tool, the embedded constants (*i.e.* emission factors) automatically generates the carbon emission equivalents in the appropriate rows and columns. It is also characteristic of MUCET to present summations of extent of emission for each sector and types of energy use as well as automatically generate final results when the variables within the rows or columns are altered. This offers the opportunity for monitoring or prediction and will enable emission reduction strategies to be focused directly on targeted sectors of energy use.

Figure 2 presents a detailed description of the Malaysian University Carbon Emission Tool (MUCET). The template and its features consists of 13 columns classified into three (3) groups namely A, B, and C. and five major groups of rows (D, E, F, G and H). The tool calculates CO_2 emission from the major service areas (A) which constitutes the university pattern of energy consumption or system and arranged into two categories of input (G and H) according to electricity and transport energy use respectively.

The functional sections of the tool are listed below:

A—Sources of Carbon Emission;

B—Columns of Measured Parameters;

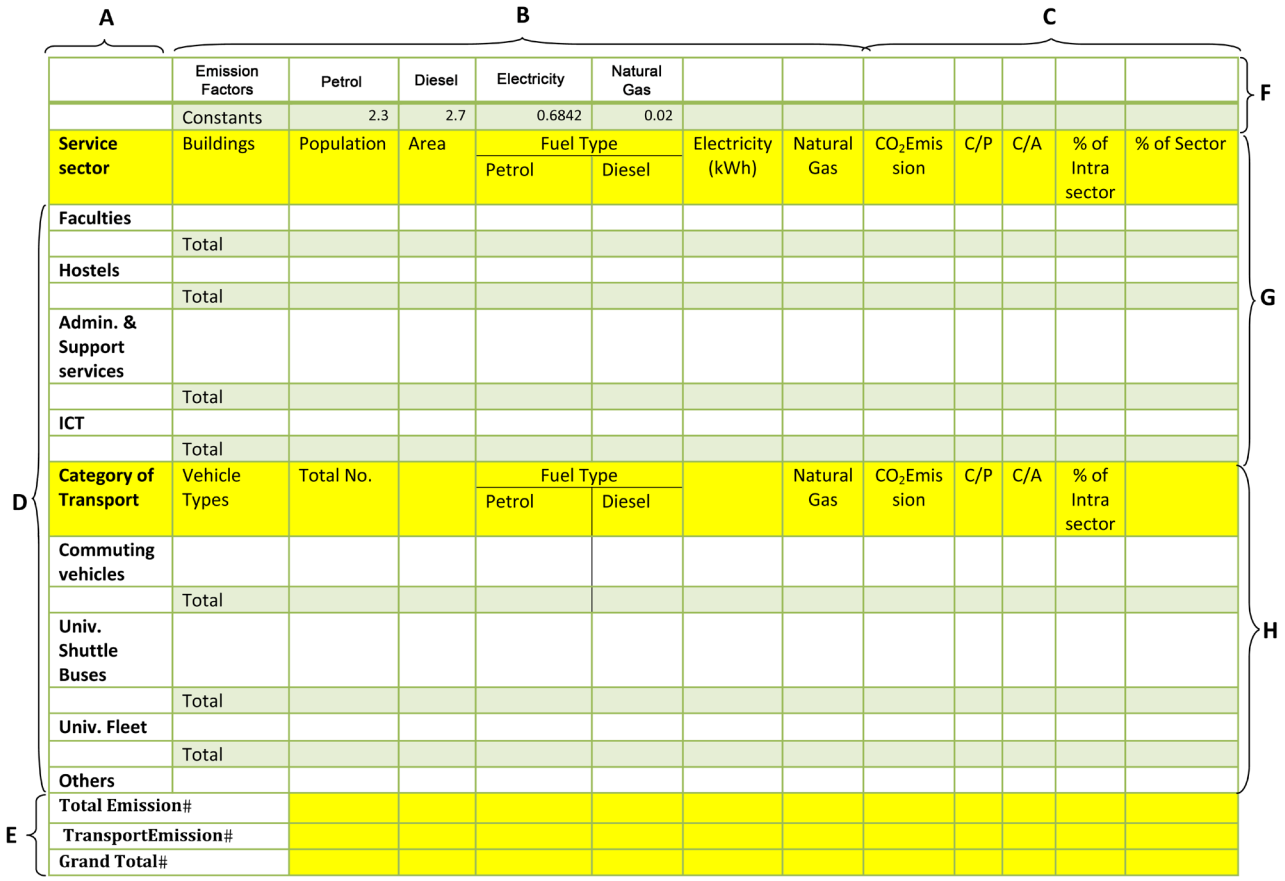
C—Results and Emission Summary;

D—Rows of Input Variables;

E—Total Carbon Emission %;

F—Row of Constants;

G & H—Rows of Category Input Variable;



A	B					C							
	Emission Factors	Petrol	Diesel	Electricity	Natural Gas								F
	Constants	2.3	2.7	0.6842	0.02								
Service sector	Buildings	Population	Area	Fuel Type		Electricity (kWh)	Natural Gas	CO_2Emission	C/P	C/A	% of Intra sector	% of Sector	G
				Petrol	Diesel								
Faculties													
	Total												
Hostels													
	Total												
Admin. & Support services													
	Total												
ICT													
	Total												
Category of Transport	Vehicle Types	Total No.		Fuel Type			Natural Gas	CO_2Emission	C/P	C/A	% of Intra sector		H
				Petrol	Diesel								
Commuting vehicles													
	Total												
Univ. Shuttle Buses													
	Total												
Univ. Fleet													
	Total												
Others													
Total Emission#													E
TransportEmission#													
Grand Total#													

D

Figure 2. Malaysian University Campus Emission Tool (MUCET).

MUCET consider service demand sectors associated with electricity and fuel energy use that determine the university operations from where emission data were obtained. This consists basically of five (5) categories that constitute the university energy system as listed below:

- Teaching & learning faculties;
- Administrative buildings and supporting service areas;
- Residential hostels & staff accommodation;
- Information and communication technologies (ICT).
- Transport or combustion from mobile sources including:

– Commuting Vehicles (including Staff and students Vehicles registered on campus and total in-coming vehicles in the campus);
– University Shuttle Buses;
– University fleet of vehicles;
– Others include vehicles such as mobile/agriculture machinery, construction equipment within the campus.

The above elements of the sectors may differ according to institutional policies, functionality and types of universities.

The parameters used to measure the variables of energy consumption include the Building Use, Population, Floor Area, Fuel Types (Petrol/Gasoline and Diesel)

and the Annual Electricity Consumption measured in kWh. This is represented by seven (7) columns. Other parameters include traffic movement, on-campus electricity generation and Natural Gas consumption where applicable as shown in Figure 2.

The data requirements for these variables are based on the annual electricity consumption for each of the four major service demand sectors of the university namely; Teaching and Learning Faculties, Administrative and Support Services, Information and Communication Technology (ICT) and Residential Hostel Accommodation. The values for total annual electricity and fuel inputs are automatically converted into tons of Carbon Dioxide (tCO_2), using the embedded constant values (*i.e.* emission factors for electricity and fuel-specific carbon coefficients for fuel types).

Furthermore, the next five columns of the calculator constitute the result and summary sections, including columns for carbon emission for each of the service sectors; carbon emission per capita C/P and emission per floor area C/A. This will allow comparison of the carbon emission realized with the population and floor space. The last two columns of the calculator are very important for the purposes of planning and benchmarking as it describes emission percentages between and within the service sectors. The results and values in the columns can be compared at a glance to assist in making informed decision and setting of emission targets. However, for MUCET to operate efficiently, adequate metering and sub-metering of all the buildings is essential, while buildings with multiple or combined functions can be grouped under relevant sectors.

5. Methods and Procedures for Data Collection

There is no existing method of accounting for carbon emissions that accurately reflect "true" emissions levels [20], the best method is that which most encourages the reduction of emissions. Energy use and energy indices constitute significant measure of sustainability; therefore, focusing on accounting for carbon emissions from electricity and transport energy use will enable reduction of carbon emission and promote energy sustainability in the university. The design and structures of most universities and organizations vary, but the major sources of carbon emission arose from the energy that are used for electricity and transport within the campus.

Measuring emission with reference to other units would enable the determination of energy efficiency in buildings and for particular activities as well as demonstrate how improvement in the performance can be achieved [48]. This research focus mainly on emission from category of uses for electricity (Table 2) and also considers emission from vehicles for trips within the campus, whose reduction can be influenced by strategies of the university authority. Among the vehicles considered for the inventory of transport sector include: Commuting vehicles of staff and students, University shuttle Buses and the University Fleet of vehicles (Table 3).

The method for the selection of inputs for MUCET did not include emissions from agricultural production, refrigerant use, solid waste, water or sewage treatment and the energy embodied in materials consumed within the campus such as paper or food. This is because majority of operations concerning such sources either use one form of energy or the other and the significance of such variables to energy use is very negligible. More so, the indirect emission from such sectors have been accounted for under emission from the fuel used in transport for the collection and disposal of the waste generated within the campusand the electricity used for the generation, treatment and distribution of water supply among others.

Similarly, emission from consumption of natural gases was not considered in this study because natural gas is the cleanest of all the fossil fuels and unlike coal and oil, emissions from the combustion of natural gases are carbon dioxideand water vapor, similar to the compounds exhaled by human [49]. However, MUCET made provisions to include calculations for such emission where natural gas is purchased in a large quantity for heating or cooling purposes (**Figure 2**).

Below is the description of the process of determination ofCO_2 emissions from sources of energy use in UTM, Malaysia.

1) Determination of Carbon emission from Electricity consumption

Figure 3 presents the schematic diagram of the processes for the determination of CO_2 from the university electricity sources. This involves the identification of sources of electricity consumption and collection of data for all buildings. The amounts of electricity purchased from the Malaysian sole distributor of electricity TNB, and fuel consumption by the on-site generators were determined. The total CO_2 emission was determined according to sectors and categories of use calculated based on the emission standard for Malaysia peninsula. According to Pusat Tanaga Malaysia PTM (also known as the Low Energy Office (LEO)) the emission factor is given as 0.6842 KCO_2/Kwh of electricity. This is based on the fuel mix for electricity generation in the peninsula (LEO, 2011). It should be noted that the value represents the molecular weight and usually presented as equivalent of kilograms of carbon dioxide (KCO_2) for every kilowatt-hour (Kwh) of electricity emitted. Based on the total electricity consumption for each sector, this assumption was used to determine the overall CO_2 emission for electricity within the university campus.

2) Determination of carbon emission from vehicular fuel consumption

The circulation of goods and services and the movements of staff, faculty and students within the campus mostly rely on the use of gasoline and diesel oil to power the transport. In the absence of a policy to restrict movement of vehicles, significant fossil fuel based consumption and consequent CO_2 emission from transport sector within the campus is eminent. The process of determination of the total CO_2 emission from transportation sources and vehicular movement from various trips within UTM campus is presented in **Figure 4**. The quantity of CO_2 emission for the transport sector was determined based on Code of Federal

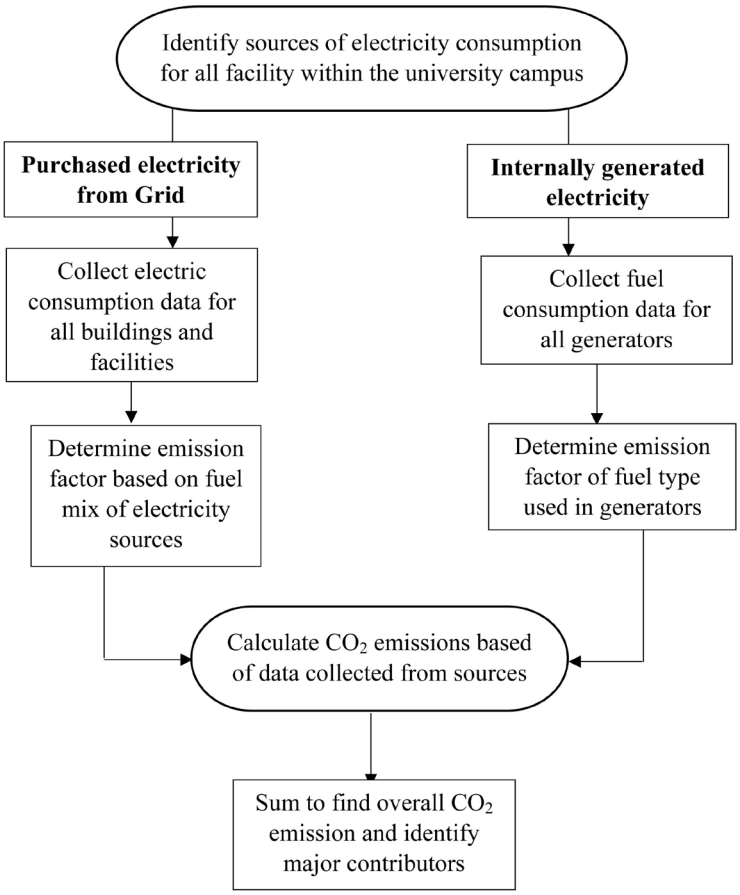


Figure 3. The schematic diagram of the process of determination of CO_2 from electricity sources in the University.

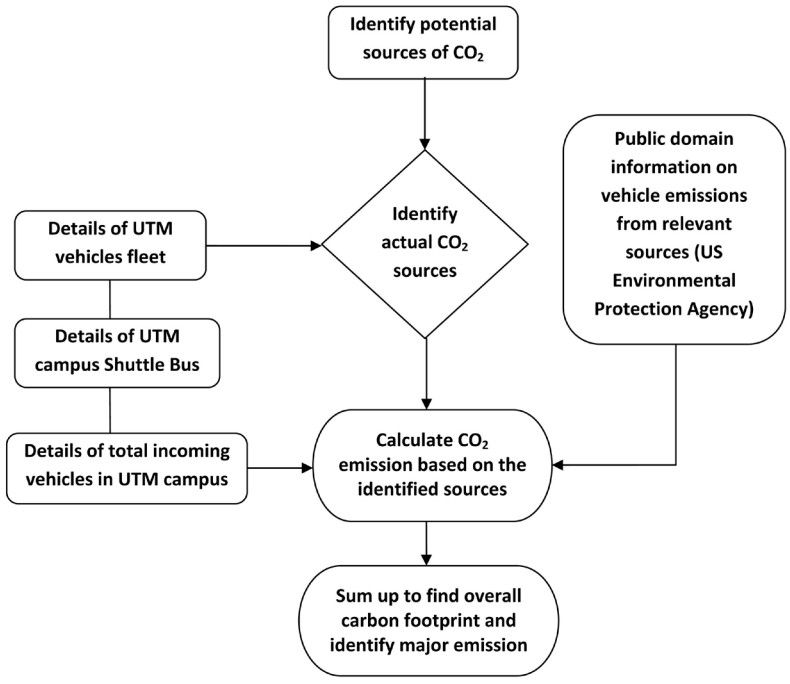


Figure 4. The Process for determination of CO_2 from University transport sources.

Regulations at 40 CFR 600.113-78 and the guidelines of Inter-Governmental Panel on Climate Change (IPCC).

The procedure for calculating the fuel energy use depends on the vehicular fuel efficiency and the round trip for commuting vehicles.

a) The calculation of total fuel consumption was modified based on the formula adopted in the Greenhouse Gas Emissions Inventory for Hobart and William Smith Colleges [50] as given below.

$$\text{Total fuel Consumption} = \frac{\text{total No. of vehicles x average distance travelled} \times \text{No. of working days}}{\text{fuel efficiency of vehicle}}$$

$$TFC = \frac{V \times T \times W}{ff} \tag{4.1}$$

where:

TFC = total fuel consumption (litres);

V = total No. of vehicles;

T = average distance travelled (Kilometers);

W = annual number of working days;

ff = fuel efficiency of vehicles (Kilometer/Litre).

Based on the survey, summary of daily vehicular flow at the entrances of UTM was used to determine the annual carbon emission for commuting vehicles. This enabled the determination of the quantity of fuel consumed for each category of vehicle and the total carbon emission from the transport sector. As a result, it was possible to determine the contribution of the transport sector to global warming according to types of vehicle.

b) For the commuting vehicles, the annual total carbon emission was calculated by applying data fuel-specific carbon coefficients standard emissions factors [46] based on the estimated annual fuel consumption for each vehicle.

$$\text{Total } CO_2 = \left[\frac{\text{total No. of vehicles} \times \text{average distance travelled} \times \text{No.of working days}}{\text{fuel efficiency of vehicle}}\right] \times (\text{standard emissions factors})$$

$$Tcarbon = \left(\frac{[V \times T \times W]}{ff}\right) \times (E) \tag{4.2}$$

where

$Tcarbon$ = total carbonemission (KCO_2);

V = total No. of vehicles;

T = average distance travelled (Kilometers);

W = annual number of working days;

ff = fuel efficiency of vehicles (Kilometer/Litre);

E = Standard emission factor (KCO_2).

The standard emission factor (E) for gasoline is given as 2.3 k CO_2/litre (kilograms of Carbon Dioxide equivalent per litre), while the standard emissions fac-

tors for Diesel oil is given as 2.7 k CO_2/litre equivalent [46].

c) Other University transport sources such as UTM Fleet of vehicles and University shuttle buseswere considered. The UTM Fleet of vehicles purchased fuel from PETRONAS Oil Malaysia using smart card which automatically debit the university's account, while the University shuttle buses are operated by a contractor. The data on fuel consumption for each vehicle was made available for these categories of vehicles and the total carbon emission was calculated thus:

$$\text{Total } CO_2 \text{ emission} = \left[\frac{\text{total No.of vehicles} \times \text{annual fuel consumption}}{\text{fuel efficiency of vehicle}}\right] \times (\text{standard emissions factors})$$

$$Tb = \left(\left[V \times Tf\right]/ff\right) \times E \tag{4.3}$$

Or

$$Tb = \frac{V \times Tf}{ff}(E)$$

where Tb = total carbon emission;

V = total No. of vehicles;

Tf = annual fuel consumption (litres);

ff = fuel efficiency of vehicles (Kilometer/Litre);

E = Standard emission factor (KCO_2).

Given that the overall driving characteristics of the populations for faculty, staff and students are normally distributed, the total carbon emissions for each category of commuting vehicles was based on the total fuel consumption, average round trip distance within UTM and fuel efficiency of the vehicles. The average roundtrip distance for commuting vehicles within UTM campus was given as:

$$\text{Average Roundtrip}(\text{km}) = \frac{\sum fx}{\sum f} \tag{4.4}$$

where $\sum fx$ = the total distance travelled by commuting vehicles, and

$\sum f$ = the total number of respondents *i.e.* commuting population.

However, the fuel efficiency of commuting vehicles should be localized according to regions to obtain a more accurate figure in future researches.

6. Results and Findings

Using MUCET for the inventory of UTM Carbon footprint, a total of 46,000 Mt CO_2 was observed as average emission for all categories of energy use for year 2011. About 55,317,730 Kw Hr of electricity was purchased with emission status of 34,129 MtCO_2 accounting for 74% of the total annual CO_2 emission of UTM. Also, 11,872 Mt CO_2 was realized as annual emission from the transport sector, accounting for 26% of total annual emission for UTM (**Table 1**).

Figure 5 presents the percentage of Carbon Dioxide emission from electricity consumption in UTM, based on the extent of electricity consumption, among

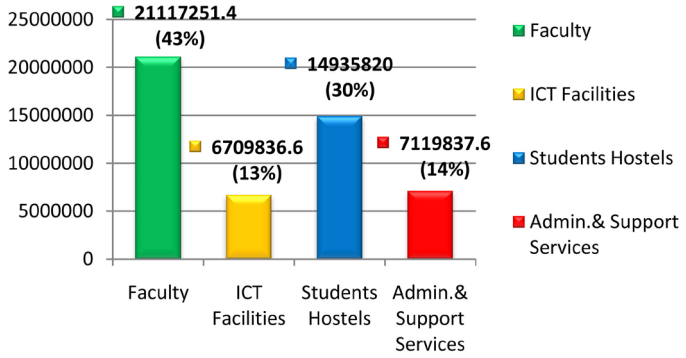


Figure 5. Percentage of carbon dioxide emission from electricity consumption. Source: Abdul-Azeez, I.A. and Ho, C.S. (2015).

Table 1. Carbon emission status from categories of use in UTM.

Category of Uses	Carbon Emission Mt CO_2	Percent of Emission	
Faculty	14,448	31%	
Students Hostels	10,219	22%	Total Electricity emission = 74%
Central Admin.& Support Services	4871	11%	
ICT Facilities	4591	10%	
Transport	11,872	26%	
TOTAL	**46,000 Mt CO_2**	**100%**	

service sectors [51]. MUCET revealed that the Teaching and Learning Activities has the highest emissionof about 43%. The StudentsHostel Accommodations constitute 30% of the total university emission of CO_2 from the electricity energy consumption, while Central Administration and Support Services emitted about 14% and the ICT sector has 13% of the total CO_2 emissions from electricity respectively.

The transport sector of the UTM is powered predo minantly by Gasoline (Petrol) and Diesel engines. Table 2 shows that about 11,872 Mt CO_2 of carbon emission is attributed to UTM's transport sector. The study also shows that daily commuting to work by staff and students vehiclesis the largest contributor to transport emissionin UTM. Carbon emission from commuting vehicles constitutes about 75% of the total transport emission, with about 19% from the university fleet of vehicles, while only 6% was attributed to the University Shuttle Buses. Also, gasoline (Petrol) constitutes about 82% of the total transport emission and 18% is from diesel based sources such as University Shuttle Buses and the University fleet of vehicles among others.

The result of the above study was compared to carbon inventoryfor UTM-main campusinitiated in 2009 to determine the amount of CO_2 emitted into the atmosphere in the average year towards creating a carbon neutral campus [52]. The study adopted the methodology of calculating carbon footprint

Table 2. Fuel consumption and emission from transport sector in UTM.

Category of vehicles	Total No. of vehicles	Annual fuel consumption		Carbon emission	
		Diesel (Litres)	Petrol (Litres)	$KgCO_2$	Percentage (%)
Commuting vehicles	14,540	48,707	2,591,711	8896 Mt CO_2	75%
University shuttle Buses	21	279,300	N/A	754 Mt CO_2	6%
University Fleet	362	376,261	524,527	2222.3 Mt CO_2	19%
Total	14,923	704,268 (18%)	3,116,238 (82%)	11,872 Mt CO_2	100%

from emission Scopes 1, 2 and 3 and observed emission from Electricity, Natural Gas, Business travel, University fleet and Commuting vehicles as well as Water and Waste. Table 3 presents the result of the carbon Footprint for the year 2009, while Table 4 shows the status of Carbon Dioxide emission from the transportation sector based on the contemporary carbon accounting tool employed for the assessment.

The total UTM's GHG emission for (2009) according to Zainura's method [52], was presented as; $E(total) = E(electricity) + E(business\ trips) + E(vehicle\ fleet) + E(waste)$, while the total CO_2 emission of UTM based on emission from energy use was computed by MUCET (2011) as; $E(total) = E(electricity) + E(transport)$.

Although the approaches differ, a comparison of the two results shows some similarities. According to MUCET the CO_2 emission from electricity is 74% against 78%, while emission from transportation was 26% compared to 20% as offered by the contemporary tool. The difference in total carbon emission values could be attributed to the consideration of the Scope 3 emission such as Business Travel, Global Outreach Programme among others included in computing the university carbon footprint of 2009. It was also noticed that the total emission figure from energy use activities for running the university services within the campus in 2011 is 46,000 Mt CO_2 (Table 1) as compared to 82,578 Mt CO_2 (Table 3), which almost doubled as a result of external emissions included in calculating the carbon footprint of 2009.

In view of the above result, it can be justified that the contribution of indirect and off-site emissions is quite high and accounts for a significant amount of the total greenhouse gas emissions within the university campus.

7. Conclusions

Many models for university campus sustainability use varying elements to explain the path to achieve the goals of sustainable development. This study believes that the measurement of quantities of carbon emission from the internal energy use is important for university campus sustainability. It emphasizes the relevance of the energy consumption-based approach to measure emissions

Table 3. UTM carbon footprint for the year 2009.

Source of Emission	Carbon Emission (Mt CO_2)	Percentage %
Electricity Purchased	64,393	78%
Transportation	16,396	20%
Solid Waste Disposal	1789	2%
Total	**82,578**	**100**

Source :Zainura Zainon Noor, 2010.

Table 4. Carbon Dioxide emission from transportation.

Transportation Sources of Carbon Emission	Carbon Emission (Mt CO_2)	Percentage %
Vehicle Owned by University	2774	17%
Staff Commuting	2350	14%
Student Commuting	3125	19%
Business Travel	6384	39%
Global Outreach Programme	1758	11%
Total	**16,391**	**100**

Source :Zainura Zainon Noor, 2010.

from service sectors and suggests that external values of emissions from Scope 3 emission sources should not be built into the analysis of Carbon Dioxide emission because it is beyond the control of universities.

MUCET presents a more realistic carbon emission status upon which the university authority has a control and for which emission reduction strategies could be applied. Also the elimination of values of emissions outside the conventional "boundary" of universities will give a clear picture of emission status and enable university administrators to focus on reducing their global warming potentials based on empirical information.

However, a major challenge for the software is the quality of the data input because inadequate data collection method may yield poor emission results. Similarly, the tool may not be efficient in universities with central and onsite electricity generation in the absence of efficient metering facility. MUCET may also not be suitable in universities with no distinct boundaries or entrances as it may be difficult to separate the thorough-fare traffic from the internally commuting vehicles in determining the transport emission accrued to the campuses.

Another disadvantage is that the tool cannot determine the emission accrued to the university from energy use embodied in processes and consumption of materials such as paper or food and other procurements, while emissions from processes such as water, waste or sewage treatment are expressed as emission due to electricity use or transportation.

MUCET will facilitate uniformity towards accounting for Carbon Dioxide emission and setting of targets to reduce CO_2 emission as well as promote sustainability among universities.

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