ORIGINAL ARTICLES

Framework for Carbon Footprint Estimation

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ABSTRACT

The objective of this paper objective is to calculate carbon footprint (CF) of appliances and locations of electrical devices usage in the Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi, Malaysia. The green house gas emissions would contribute to the climate change caused from the electricity consumption. The statistical science package social analysis showed that the highest green house gas emissions in UKM was in April, May and November for 2225.22, 2083.45 and 2103.40 kgCO₂eq respectively. The faculty has contributed 30% of electricity consumption due to the heavy and huge equipments such as induction motors, mechanical instruments, generators and others which emit carbon dioxide directly to the atmosphere. Based on the respondent perceptions, air-conditioner is the highest rank of index value of electricity consumable appliances for 4.562 kgCO₂eq. About 95% of respondents were aware of this issue on the effect of green house gas emission to the environment. In future, renewable energy and efficient energy practice are the alternative methods to be adopted in order to reduce CF. This calculation can be used as a benchmark for the country in order to reduce 40% CF by 2020.

Key words: carbon footprints, green house gas, energy consumption, carbon dioxide.

Introduction

The world is facing challenge of global warming and climate change issues. The anthropogenic driver of climate change is the increasing concentration of greenhouse gases (GHG) in the atmosphere. Carbon dioxide (CO₂) is the most important anthropogenic GHG, and the global increases in CO₂ concentration are due primarily to the fossil fuel use and land use change (Nicolas et al., 2001; JPM., 2006; IPCC., 2007).

Regards to this issues, an energy footprint is a measure of land required to absorb CO₂ emission. Electricity is generated by burning fossil fuels released carbon to the atmosphere which is converted to CO₂. The increasing level of CO₂ in the atmosphere enhances the greenhouse effect and contributes to global warming. Other than that, combustion of fossils fuels from power generations, automobile engines, furnaces used in residential and commercial buildings, industrial extraction processes, burning of land clearance also caused this matter.

There are several perspectives made on the causes of carbon (CO₂) footprint in past years. However, some personnel investigated and carried out research and survey to prove what really causes the carbon footprint. In Shanghai, on July 2008, it was described that the energy consumption of the air-conditioner system was at the first place, and it contributed for 45% of total energy consumption as shown in Fig.1. However the lighting system is relatively concise, so the energy consumption of the lighting system was just less than 10% (Wang et al., 2010).

Other than that, the energy demand in Malaysia has grown up rapidly for the last few years that contributed to the significant amount of CO₂ emissions which may be resulted from the energy consumption and utilization (Bari et al., 2006). Following to the Fourth Assessment Report of IPCC, global surface temperature increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the 20th century (IPCC., 2007).

Statistically, burning of fossil fuel are involved roughly 25% of the world energy supply and 40% of carbon emission (Pattanapongchai and Limmeechokchai, 2010). The demand for energy and its growth is critical particularly in developing nations. GHG must be cut by 20% from 1990 level by 2020 and be further reduced afterwards (Araujo et al., 2001; Capros et al., 2008). The emission need to be reduced universally by 30% to 60% by the year 2050 to keep CO₂ concentration in the atmosphere below 550 ppm (parts per million) so that to limit the temperature rise between 2.4°C and 2.8°C compared to pre-industrialized levels (Tick, 2010).

Primary energy consumption refers to the direct usage of the source, or supply to users without transformation of crude energy, that is energy which has not been subjected to any conversion (Hannan et al., 2010) or transformation process (Hannan and Mohamed, 2005; Hannan et al., 2008). The synonyms statement
can be defined as the use of energy as a source of heat or power or as a raw material input to a manufacturing process. Major sectors that involved in the energy consumption are residential, commercials, transportations and industrials.

**Fig. 1:** Component of energy consumption (Wang et al., 2010).

Carbon footprint (CF) calculator is based on the first ecological footprint calculator (Saidur et al., 2007). There are two methods to assess the ecological footprints: (a) compound foot-printing method and (b) component-based footprinting method. The compound footprinting measures consumption at the national level, where a county footprint is calculated by subtracting exports and imports from the national domestic production; i.e. consumption = production - exports + imports. The second approach component-based footprinting is applied to measure the footprint of individuals and organizations. This approach divides the given population activities into different categories of consumption (e.g. food, transportation, energy), then adds up the values to calculate the total footprint of activities.

By conducting an investigation of the energy consumption, the energy audit focuses mainly on the equipment consumption, especial on the air-conditioning systems, electronically equipments, lighting systems, and elevators, etc. Based on the energy audit results on the total energy consumption of the building from 2005 to 2008, the outer climate and office occupancy rate are two leading factors for the change of the total energy consumption. The energy consumption of the air-conditioning system is at the first place, which accounts for about 45%. The energy consumption of the lighting system is just less than 10% (Xu et al., 2009).

The increase in GHG concentrations in the atmosphere affects processes and feedbacks in the climate system. Qualitatively, an increase of atmospheric GHG concentrations will lead to an average increase of the temperature of the surface-troposphere system. In this respect, CO₂ is the most important anthropogenic GHG. Increasing of CO₂ emissions from fossil fuel used to be the dominant influence on the trends in atmospheric CO₂ concentration that eventually resulted in rising global temperatures and sea level (IPCC., 2005).

**CF Estimating Framework:**

In order to calculate the CF in the Faculty of Engineering and Built Environment (FKAB), the most important section in this research is obtaining the data of energy consumption of Universiti Kebangsaan Malaysia (UKM). The flow chart is shown in Fig. 2. The data obtained was used for CF assessment in FKAB which would benefit the University for the future research of our country. Firstly, the checklist of the parameters will be developed. There would be various types of responses required including qualitative and quantitative. The next step would be the interviews with engineer at the ‘Jabatan Pengurusan Pelajar’ (JPP) which located in UKM regarding bills of the university.

The steps of calculation GHG emission are as below:
1. Identify the amount electricity used, in units of kWh
2. Multiply this value by the conversion factor for UK Grid Rolling Average electricity.

The GHG can be measured by recording the emissions at source by continuous emissions monitoring or by estimating the emitted amount using the activity data and applying relevant conversion factors. These conversion factors allow organisations and individuals to calculate GHG emissions from a range of activities such as electricity consumptions. The CO₂ equivalent is a universal unit of measurement used to indicate the global warming potential of one unit of carbon dioxide. It is used to evaluate the releasing of different GHG against a common basis (DECC., 2010).
Equation 1 shows that formula of GHG emissions due to the electricity consumption in kwh, where $R$ is electricity consumption in UKM, Bangi. The value conversion factor for UK Grid Rolling Average Electricity is 0.54284 kgCO$_2$/kwh.

$$R(Kwh) \times \left(\frac{0.54284 \text{ kgCO}_2\text{eq}}{\text{kwh}}\right) = \text{TotalGHGemission (KgCO}_2\text{eq)}$$

**Results and Discussions**

There are many ways to assess respondent data that have been collected in qualitative and quantitative forms. However, the focus is only to the CF calculation, assessment and awareness. From the interview with engineer in JPP of UKM and observation of electricity bills, the most GHG emissions on electricity consumption are in April, May and November for 2225.22, 2083.45 and 2103.40 kgCO$_2$eq respectively. The least GHG emissions on electricity consumption are in January, October and December for 1733.57, 1659.11 and 1757.47 respectively. This can be seen in Fig. 3.

![Flow chart of CF Assessment](image1)

**Fig. 2:** Flow chart of CF Assessment.

![GHG emissions in UKM, Bangi](image2)

**Fig. 3:** GHG emissions in UKM, Bangi.
From the result shown in Fig. 4, the floor/pathways was contributed the highest GHG emissions of 400757 kgCO₂eq with 0.73 Gwh of electricity consumption. This is due to the operation of the lights for 24 hours daily in FKAB. This is followed by office / administrative which GHG emission was 286250 KgCO₂eq with 0.52 Gwh of electricity consumption. Meanwhile, computer lab was contributed 267169 of GHG emissions and 0.49 Gwh of electricity consumption. This is because the computer lab had not been used frequently and it was only running during the day. The least of GHG emissions were restrooms, library and automated teller machines (ATM) and vending machines with 57247, 76334 and 76334 kgCO₂eq.

![Fig. 4: Trends between CF and electricity consumption at different location in FKAB.](image)

The question is whether they switch off or not if they do not use appliances such as lightings, air conditioners, fans and so on. Based on Fig. 5, the result showed that 75% of respondents switched off appliances such computer, air-conditioner and others, when they did not use them. Meanwhile, 25% of respondent did not switch off appliances when they did not use them. It showed that most of respondents have a very positive concern in reducing CF and on the energy savings.

![Fig. 5: Estimation of respondent consciousness for switching off the unnecessary appliances.](image)

Based on Table 1, the highest energy consumption correlation value is the refrigerator which is 0.9 as compared to others. This is because the refrigerator consumes more electricity. Thus, it would contribute more carbon footprint than others. The highest energy star correlation value is the lighting for 0.295 because most of respondents used the energy star bulb type for their lighting.

Besides, the highest correlation value for green technology is refrigerator for 0.800. It shows that refrigerator could be one of the green technology equipments which require small amount of energy to reduce consumption of electricity.

Table 2 shows that the most responsible party that have to take action towards carbon footprint is the university authority as indicated with the high percentage of 60%. The university should plan and implement
some kind of motivation talks or seminars to all level of students such as undergraduate and postgraduate level in order to increase their awareness of the CF. There are various types of recommendations that can be implemented concerning carbon emissions. One of the methods is during orientation program of student intake where the organizer can distribute brochures regarding the awareness of carbon footprint and also in campus.

Table 1: Solid WG in major urban area in Malaysia.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Energy Consumption</th>
<th>Energy Star</th>
<th>Green Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator</td>
<td>0.900</td>
<td>0.280</td>
<td>0.800</td>
</tr>
<tr>
<td>Lighting</td>
<td>0.104</td>
<td>0.295</td>
<td>0.062</td>
</tr>
<tr>
<td>Compressor</td>
<td>0.096</td>
<td>0.120</td>
<td>0.156</td>
</tr>
<tr>
<td>Computer and Printer</td>
<td>-0.064</td>
<td>-0.005</td>
<td>-0.057</td>
</tr>
<tr>
<td>Photostat Machine</td>
<td>-0.190</td>
<td>0.096</td>
<td>0.680</td>
</tr>
<tr>
<td>Server Networking</td>
<td>-0.180</td>
<td>0.009</td>
<td>-0.081</td>
</tr>
<tr>
<td>Air Conditioner</td>
<td>0.005</td>
<td>-0.069</td>
<td>0.095</td>
</tr>
<tr>
<td>Motor</td>
<td>0.070</td>
<td>0.108</td>
<td>0.109</td>
</tr>
<tr>
<td>Generator</td>
<td>0.000</td>
<td>-0.142</td>
<td>0.058</td>
</tr>
<tr>
<td>Fax</td>
<td>-0.069</td>
<td>0.027</td>
<td>-0.061</td>
</tr>
<tr>
<td>Television</td>
<td>-0.151</td>
<td>-0.222</td>
<td>-0.134</td>
</tr>
<tr>
<td>Oven</td>
<td>0.189</td>
<td>0.159</td>
<td>-0.032</td>
</tr>
</tbody>
</table>

Table 2: Illustrate the result of addressed level.

<table>
<thead>
<tr>
<th>Level</th>
<th>Opinion</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Individual</td>
<td>37</td>
<td>63</td>
</tr>
<tr>
<td>Department</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>Faculty</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td>University</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Utilities company</td>
<td>24</td>
<td>76</td>
</tr>
<tr>
<td>Government</td>
<td>38</td>
<td>62</td>
</tr>
<tr>
<td>Industrial</td>
<td>3</td>
<td>97</td>
</tr>
</tbody>
</table>

Conclusion:

In this research, it is focused on the direct carbon footprint calculation from the electricity consumption in FKAB. Carbon footprint is an issue that has been discussed over the world by scientist and it strongly relates to our environment. From the data analysis, the trend or pattern of the electricity consumption in 2010 in UKM is similar either during peak or off-peak demand. The highest usage was in the month of April. This was because there were semester-end examinations conducted during that period of time. Thus, the usages of equipments such as laptops, printers, chargers, photocopy machines and so on are increased. On the other hands, it is focused on the carbon footprint of the electricity consumption among of administrative staffs, technical staffs, academicians and students. The survey and interview methodology had been conducted to obtain information about energy efficiency, renewable energy, severity and so on. In this research, the method proposed that through questionnaires and interview sessions had proved successful being able to obtain information for the carbon footprint calculation and energy consumption. Thus it can be concluded that the carbon footprint can be reduced by three basic ways such as energy efficiencies, renewable energy and behavioural and lifestyle change, respectively.

References