ESTIMATION OF CARBON FOOTPRINT FOR AN EDUCATIONAL INSTITUTION LOCATED IN AN URBAN PART OF COIMBATORE


Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore - 641008 Tamil Nadu, India.
e-mail: ezhil.1990.kumar@gmail.com;

Abstract
This paper presents the Carbon Footprint (CF) emission contribution from different activities in an educational institution named Sri Krishna College of Engineering and Technology (SKCET), Coimbatore. In this study emission source were categorized under three scopes as per the standards of ISO 14064. Among the three scopes, scope 3 i.e. other indirect emission factors contributed the maximum of 54.3%. The personal CF in this study campus estimates 0.05 t CO2e per year which is quite less than other reported studies of local and global universities. The results of this study present the demands for focused management in Green House Gas (GHG) emission based activities contributed directly and indirectly by the institute. Also the estimates show clear picture of the CF hot-spots of the institute administration for better sustainability. However the study provides an overall insight and awareness of CF impact contributed from the daily activity of the campus community. Few suggestions were discussed in this paper for emission specific CF management which can be adopted by the institute administration to control or reduce the impacts.

Keywords - Carbon emission; Education; Green House Gas; Emission scope; Coimbatore;

I. INTRODUCTION
The awareness of the increasing global environmental pollution and greenhouse gas emission is the need of the hour. Approximately each year eight billion tons of carbon dioxide (CO2) was emitted in the atmosphere by human activities [1]. For a country, sustainable growth with minimum carbon emission is a big challenge now. For developing countries like India, the major emission (80%) of greenhouse gas from power generation only [2, 3]. To achieve the target of minimum greenhouse gas emission and sustainable development continuous efforts has been taken at various levels like implementing the emission reduction policies and continuously monitoring the industries, organizations etc. [4, 5].

The increasing interest about the environmental impact and sustainability growth of industrial sectors and organizations also includes the higher educational sectors. Several studies were made and reported that educational institutions also influence in greenhouse gas emissions. CF emission study for educational institutions are one of the present needs as they deal with large community of peoples involving regular and intense energy consumption for mixed activities. Many universities like University of Pennsylvania University of British Columbia Erasmus University, Netherland, University of California Berkeley, and University of Brighton, UK started to estimate and control their greenhouse gas emissions activities to achieve the low carbon emission target [6].

To control and minimize the carbon emission from education sector UK Department of Trade and Industry (DTI) made an action plan through their Carbon Trust for Higher Education Carbon Management Programme (HECMP). They developed a toolkit to estimate the carbon footprint which focused on all the CO2 emission sources connected with the structure [7].
II. STUDY AREA

Several studies have been reported estimating CF emission for educational sectors falling under university category. In this study an attempt was made for a degree college - Indian institution. The present study was carried out for an urban educational institution named Sri Krishna College of Engineering and Technology (10°56'14.5"N 76°57'22.9"E) located in the southern part of Tamil Nadu, India. The total study area taken was 20.9 hectare. The campus has enormous green cover regions covering 7 hectare. College has a state of art library facility with sustainable and energy saving architectural design. The campus population is around three thousand plus students and two hundred plus staffs (teaching and non-teaching).

III. METHODS

There are several estimation tools for carbon footprint (CF) analysis [8]. Here we have used the procedure mentioned in the standard ISO-14064 [9]. The estimating is carried out through three different scopes. Scope 1 (Direct emission): Estimation of GHG from emissions identified within the campus boundary; Scope 2 (In-direct emission): Estimation of CF from energy consumption such as electricity and heating activities by the in-campus community; and Scope 3 (Other In-direct): Estimation of emissions from other process or activities such as transportation, waste generation, purchase of materials by the institute.

3.1. DATA INVENTORY ANALYSIS

As a first step possible emission factors under each scope was identified with respect to the scope of study area. Through this, emission factors were finalized for each scope and data were collected through survey and from the respective facility in-charges.

<table>
<thead>
<tr>
<th>Category</th>
<th>Emission from</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope 1 (Direct emission)</td>
<td>Consumption of petrol and diesel other than</td>
<td>Campus administrative office</td>
</tr>
<tr>
<td></td>
<td>transport purpose</td>
<td></td>
</tr>
<tr>
<td>Scope 2 (Energy In-direct emission)</td>
<td>Consumption of electricity purchased from the</td>
<td>Campus power house</td>
</tr>
<tr>
<td></td>
<td>government authority</td>
<td></td>
</tr>
<tr>
<td>Scope 3 (Other In-direct emission)</td>
<td>Transport, Waste generated through food and water</td>
<td>Survey, Campus Sewage Treatment Plant (STP), Mess</td>
</tr>
</tbody>
</table>

3.2. EMISSION FACTOR

Emission factor for identified emission sources are given under table 2.

IV. RESULTS

4.1. SCOPE 1 CONTRIBUTIONS

To estimate the scope 1 CF emissions, the consumption of total diesel and petrol for the purpose other than transport such as generator, gardening machines and laboratories were obtained from the campus administrative department. It was observed that campus consumes about 2500 liters of diesel fuel on an average for a period of one month to serve various purposes other than transport. This estimates to the consumption of 30 thousand liters of diesel an year. Under scope 1, the campus estimates to emit 80400 Kg CO₂ equivalent to the atmosphere.

4.2. SCOPE 2 CONTRIBUTIONS

The energy required for the daily activity was majorly utilized from the government. Institute consumes about 2 lakh units (kWh) on an average per month for electrical operations which includes academic and non academic consumption. Through this, yearly average consumption of electricity by the institute is found to be 24 lakh units (kWh). About 57 tons CO₂ equivalent is emitted from electricity consumption per year by the institute.

4.3. SCOPE 3 CONTRIBUTIONS

Under scope 3, three categories of data were collected using survey method and direct measurement. Two types of commuting are done by students and staff members for daily round trip from their place of residents to college. One is by personal vehicle and other by college facilitated bus pooling system in majority and the remaining
by walk as they stay in the campus hostel or in private facilitated rooms outside the campus. Those who travel by public transport are not included in the survey due to negligible count.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Emission Source</th>
<th>CO₂ equivalent (Kg of CO₂ / unit consumption)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diesel fuel</td>
<td>2.68 / Lit</td>
<td>[10]</td>
</tr>
<tr>
<td>2</td>
<td>Petrol fuel</td>
<td>2.31 / Lit</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Electricity</td>
<td>43 / kWh</td>
<td>[11]</td>
</tr>
<tr>
<td>4</td>
<td>Wheat</td>
<td>0.10 / Kg</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rice</td>
<td>0.43 / Kg</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Vegetables</td>
<td>0.57 / Kg</td>
<td>[12]</td>
</tr>
<tr>
<td>7</td>
<td>Milk</td>
<td>1.15 / Kg</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Oil</td>
<td>0.05 / Kg</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>STP</td>
<td>0.03 Kg CH₄ / kg BOD 0.16 kg N / kg protein 0.0005 kg N₂O-N / kg N</td>
<td>[13]</td>
</tr>
</tbody>
</table>

4.3.1. CO₂ EQUIVALENT EMITTED FROM BUS POOLING

Around 14 buses were operated by the institute each in varying directions covering different distance (table 3).

<table>
<thead>
<tr>
<th>Category</th>
<th>No of buses operated</th>
<th>Distance traveled per day (km)</th>
<th>No. of operating days in a year</th>
<th>Total distance covered in a year (km)</th>
<th>GHG emission factor for buses (kg CO₂ / km)</th>
<th>t CO₂e emitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short distance</td>
<td>2</td>
<td>5</td>
<td>180</td>
<td>1800</td>
<td>0.73</td>
<td>1.31</td>
</tr>
<tr>
<td>Medium distance</td>
<td>7</td>
<td>70</td>
<td>180</td>
<td>88200</td>
<td>0.73</td>
<td>64.39</td>
</tr>
<tr>
<td>Long distance</td>
<td>5</td>
<td>135</td>
<td>180</td>
<td>121500</td>
<td>0.73</td>
<td>88.70</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>154.44</td>
</tr>
</tbody>
</table>

*considering that condition of all buses remains same; GHG - Green House Gas;

4.3.2. CO₂ EQUIVALENT EMITTED FROM PERSONAL TRANSPORT

The two major vehicles are used for personal transport by the commuters opting personal transport to reach the campus daily i.e. two wheeler (TW) and four wheeler (FW). Also the vehicles are classified by their engine capacity, as the emission factors vary accordingly. The details of the same are shown in figure 1 and 2.
Figure 1. (a) Classified two wheeler vehicle data and (b) its CO$_2$ equivalent emission
From the estimated GHG emission based on the fuel consumption, vehicles were classified based on the distance traveled and grouped under three categories say Short Distance (TW < 7.5km; FW < 17.5km), Medium Distance (TW < 22.5km; FW < 37.5km) and Long Distance (TW < 40km; FW < 55km). By the data confined from survey, CF emissions were estimated using respective CO2 equivalent conversion factor (table 2).

4.3.3. CO2 EQUIVALENT Emitted FROM FOOD WASTE

The data of food waste generated in the campus mess (both boys and girls) was obtained from the mess catering department serving 1500 residential students daily. The detailed food waste generated in the mess is given under the table 4.
Table 4. CO₂ equivalent emitted from food waste generated in the hostel mess

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Ingredients</th>
<th>Average Daily wastage generated</th>
<th>Annual wastage generated</th>
<th>Emission factor per unit weight of waste generated</th>
<th>Kg CO₂ equivalent emitted</th>
<th>t CO₂ equivalent emitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheat</td>
<td>10 kg</td>
<td>2450 kg</td>
<td>0.10</td>
<td>245.00</td>
<td>0.245</td>
</tr>
<tr>
<td>2</td>
<td>Rice</td>
<td>10 kg</td>
<td>2450 kg</td>
<td>0.43</td>
<td>1054.00</td>
<td>1.054</td>
</tr>
<tr>
<td>3</td>
<td>Vegetables</td>
<td>20 kg</td>
<td>4900 kg</td>
<td>0.57</td>
<td>2793.00</td>
<td>2.793</td>
</tr>
<tr>
<td>4</td>
<td>Milk</td>
<td>0.7 lit</td>
<td>172 lit</td>
<td>1.15</td>
<td>198.00</td>
<td>0.198</td>
</tr>
<tr>
<td>5</td>
<td>Oil</td>
<td>0.2 lit</td>
<td>490 lit</td>
<td>0.05</td>
<td>25.00</td>
<td>0.250</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.540</td>
</tr>
</tbody>
</table>

* Hostel mess operational days - 245

4.3.4. CO₂ EQUIVALENT EMITTED FROM SEWAGE TREATMENT PLANT

Campus has a sewage treatment plant with a capacity of 450 KLD and receives 308.27 KLD only. The treated wastewater in STP is reused for gardening and flushing in toilet. Here the GHGs are estimated from the Biological Oxygen Demand (BOD) generated from the treatment process. The total operational days omitting weekends and semester holidays is 180 days. The detailed GHG contribution is given under table 5-8.

Table 5. Estimation of organically degradable material in campus wastewater (domestic)

<table>
<thead>
<tr>
<th>Location</th>
<th>Campus population (P) (capita)</th>
<th>Degradable organic component (BOD) (kg BOD / cap / yr)</th>
<th>Organically degradable material in wastewater (TOW) (kg BOD / yr)</th>
<th>Organically degradable material in wastewater (TOW) (t BOD / yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4 = 3*2</td>
<td>5</td>
</tr>
<tr>
<td>SKCET</td>
<td>5563</td>
<td>12.41</td>
<td>69036.83</td>
<td>69.03683</td>
</tr>
</tbody>
</table>

Table 6. Estimation of CH₄ emission factor for the domestic treatment of wastewater

<table>
<thead>
<tr>
<th>Treatment type</th>
<th>Maximum methane producing capacity (Bo) (kg CH₄ / kg BOD)</th>
<th>Methane correction factor (MCF)</th>
<th>Emission factor (EF) (kg CH₄ / kg BOD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>0.6</td>
<td>0.05</td>
</tr>
<tr>
<td>Aerobic treatment</td>
<td></td>
<td>0.05</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Table 7. Estimation of CH₄ emission from the wastewater generated

<table>
<thead>
<tr>
<th>Treatment type</th>
<th>Emission factor (EF) (kg CH₄ / kg BOD)</th>
<th>Organically degradable material in wastewater (TOW) (kg CH₄/yr)</th>
<th>Net methane Emissions (CH₄) (kg CH₄/yr)</th>
<th>GWP for CH₄ 298 (IPCC FAR, 2007)</th>
<th>Total CO₂ equivalent kg CO₂e / yr</th>
<th>Total CO₂ equivalent t CO₂e / yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4 = 3*2</td>
<td>5</td>
<td>6 = 5*4</td>
<td>7</td>
</tr>
<tr>
<td>Aerobic treatment</td>
<td>0.03</td>
<td>69036.83</td>
<td>2071.10</td>
<td>25</td>
<td>51777.50</td>
<td>51.78</td>
</tr>
</tbody>
</table>

V. DISCUSSION

A detailed and extensive consumption based carbon footprint of the campus was evaluated. Figure 3 shows the CF contributed under Scope 1, Scope 2 and Scope 3. Results conclude the fact that, institute major CF is contributed through Scope 3 (Transport and waste generated from the consumption of food and water). Under Scope 3, highest contribution was from transport i.e. consumption of fuel (petrol and diesel) by vehicles for commuting by the students and staff community to travel from residents to campus daily. Food and water waste related CF contribution found very negligible compared to transport related CF emission contribution. This is because of
college location having less connectivity with public transport facility and campus functioning time were public transport frequency.

Table 8. Estimation of nitrogen in effluent reaching campus STP

<table>
<thead>
<tr>
<th>Campus population (P) (capita)</th>
<th>Per capita Protein consumption (Protein) kg/person/yr</th>
<th>Fraction of nitrogen in protein (F_{npr}) Kg N/ kg protein</th>
<th>Fraction of Non consumption protein (F_{non-con})</th>
<th>Nitrogen removed with sludge (default is zero) (N_{sludge}) kg</th>
<th>Total nitrogen in effluent (N_{effluent}) kg N/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6 = (1<em>2</em>3*4)-5</td>
</tr>
<tr>
<td>5563</td>
<td>0.056</td>
<td>0.16</td>
<td>1.4</td>
<td>0</td>
<td>69.78</td>
</tr>
<tr>
<td>Emission Factor (kg N_{2}O-N/ kg N)</td>
<td>Conversion factor of kg N_{2}O-N into kg N_{2}O</td>
<td>Emissions from wastewater plants (default as zero) kg N_{2}O / year</td>
<td>Total N_{2}O Emissions kg N_{2}O / year</td>
<td>GWP for N_{2}O (IPCC FAR, 2007) Total CO_{2}e kg CO_{2}e/yr</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10 = (7<em>8</em>9)</td>
<td>11</td>
<td>12 = (11*12)</td>
</tr>
<tr>
<td>0.0005</td>
<td>1.57</td>
<td>0</td>
<td>0.05478</td>
<td>298</td>
<td>16.32</td>
</tr>
</tbody>
</table>

Total CO_{2}e (t CO_{2}e/yr) = 0.01632

Scope 1 stands second and Scope 2 stands third in the CF emission contribution. The results signify the fact that, campus consumes enormous fuel for operating generator-set and other fuel operated mechanical equipments for its daily operation. As few works need non electrical equipments like grass cutting machines, engines in laboratories and other minor equipments which operated on combustion of fuel. Though Scope 3 stands third in the rank, the CF emission seems to be high. This is because; campus operates residential facility for the students hailing from long distance. So the students stay in rooms shared by three and four members, where the energy consumption increases compared to hostel operating with dormitories. Academic campus consumes more energy through electricity for its daily activities, like smart boards and projectors for lectures, lights and fans for classroom comfort, air-conditioners for community halls and meeting halls, lights for rest rooms and pumps for water transport to serve restrooms and for gardening.

It is estimated that, average annual personal CF of the campus community is 0.05 t CO_{2}e per year. The estimated results were far better compared to the annual average of individual CF emissions estimated for the educational institutions in India, China, United Kingdom, Unites States of America and South Africa [8, 14, 15, 16, 17, 18, 19, 20]. Even though the study results do not reflect the CF emissions for full consumption, the estimates were performed for the major consumption activities.

On comparing the personal CF of a study conducted at BITS Pilani campus (4.65 t CO_{2}e per year), the results of personal CF of SKCET campus is less even though the count of students and staffs in SKCET campus is high. This could be due two factor, (1) Smart consumption of resources contributing to CF emissions and (2) Non accounting of full consumption activities of the campus.
Figure 3. (a) Emission contribution by all three scopes; (b) Percentage contribution by each emission source under three scopes.
VI. CONCLUSION

The campus CF estimates can provide two responsibilities, (1) increasing campus community consciousness of GHG emissions due to their activities and (2) providing a comprehensive basis for sustainable practices and decision-making. This paper assesses the CF of SKCET campus, a technical institute. Impacts are computed on the basis of ISO 14064 standard. This scope classified CF emission estimates helped to identify campus CF contribution and also to identify emission "hot-spots" for adopting sustainable changes to reduce the campus CF contribution to the atmosphere. It is observed that transport sector under scope 3 is the highest contributor to CF emission from the campus. To improve institute must adopt more sustainable transport systems like e-vehicles or to improve the efficiency of buses by scraping down vehicle ageing more than 10 years and buy new ones. Next highest contribution is through the energy consumption through fuel and electricity. Institute must take highest efforts to adopt or increase its energy consumption from natural source of energy i.e. solar panels and wind mills.

The major setback faced during the study is data acquisition to estimate the CF for full consumption by campus for regular activity. The study has raised awareness with faculty and students for possible offsetting of GHG emissions. Also this study can be taken as reference by technical institutions to focus on raising concerns on developing CF management plans.

REFERENCES


