Greenhouse Gases Calculator (GHGCal) For Carbon Footprint

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Abstract — this research was conducted with the objective to develop a Greenhouse Gas (GHG) calculator and Graphical User Interface (GUI) for an organization, company or person to calculate and analyze GHG emission from their business or personal activities. The GHGCal is developed using Microsoft Visual Studio 2010 using visual basic programming language. This GHGCal calculator consists of two emission scopes: 1) Scope 1; direct emission and 2) Scope 2; indirect emission. The GHGCal application is able to calculate Carbon Dioxide (CO2), Methane (CH4) and Nitrous Oxide (N2O) emission from activities of an organization. Controlling and measuring the GHG is crucial in order to reduce greenhouse effects that bring harm to our earth. Early awareness, knowledge and understanding about greenhouse effect and emission level must be made known to industries so that they can find solutions to control and reduce the emission. This GHGCal software acts as a medium to determine the GHG emission of an organization, event, product or a person.

Keywords - Graphical User Interface (GUI), Greenhouse Gases (GHG), Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O).

I. INTRODUCTION

Climate change has been widely discussed over the past few decades. Climate change and global warming refer to an increase in average global temperatures which is caused by natural events and human activities. These activities primarily increase the greenhouse effect which is emission of gases to the atmosphere such as Carbon Dioxide (CO2), Methane (CH4) and Nitrous Oxide (N2O) [1]. The term ‘Carbon Footprint’ is usually used to quantify the greenhouse gases and can be defined as “The quantity of Greenhouse Gases (GHG) emissions directly and indirectly caused by a company’s operation” [2]. These GHG comes from fuel combustion, generation of electricity at generation plant, production of foods and goods, fugitive emission from coal mining and handling, fugitive emissions from oil and gas system and burning of biomass fuel.

Among the South East Asia countries, Malaysia is the highest emitter for CO2. Even worst, Malaysia, which has rapidly transformed from an agricultural economy to an industrial in the last four decades, was ranked 26th largest greenhouse gas emitter in the world in 2007 [4]. CO2 emissions in Malaysia have increased by 221% since year 1990 to 2004 [5] where fossil fuels contribute more than half of the total CO2 increment. Many efforts have been placed by Malaysia’s government to reduce the emission level and these efforts should be carried out continuously.

According to GHG protocol, there are three scopes of emission have been defined: 1) Scope 1-direct emission, 2) Scope 2-indirect emission (from upstream activities) and 3) Scope 3-indirect emission (from upstream and downstream activities). Scope 1 emissions are direct emission occur from sources that are owned or controlled by the organizations. These include emissions from combustion in owned or controlled boilers, furnaces, vehicles, chemical production or process equipment [8]. Scope 2 emissions are indirect GHG emission which are being released into the atmosphere and are associated with the generation of purchased electricity consumed in its owned, controlled equipment or operations in the organizations [8]. Scope 3 emissions include indirect GHG emissions from sources which is not owned or directly controlled by the organization but related to the organization’s activities.

This research is conducted to create awareness of society by developing a GUI to calculate Carbon Footprint from daily activities. The GUI is developed using Microsoft Visual Studio 2010 with Microsoft SQL Server Management Studio 2008 acts as a server Database for GHGcal. By understanding the Carbon Footprint level, the society able to monitor, control hence reduce carbon emission to the atmosphere. This GHG calculator is able to
calculate emission of Carbon Dioxide (CO2), Methane (CH4) and Nitrous Oxide (N2O). The GUI software requires user to key in data regarding the activities in the organization based on the Scope 1 and Scope 2 emission.

II. GHGCAL GUI DEVELOPMENT

A. GHGCal Framework

In this paper, the software application for Option B energy saving is developed using web application by asp.net. Web application calculates energy savings based on data provided by users. Using this web application, user can calculate energy savings based on Option B for two types of ECMs, i.e. 1) retrofit chiller 2) variable speed drive.

The steps to use GHGCal is shown in the flowchart in Figure 1a, 1b and 1c. Figure 1a shows the overall framework of the GHGcal that consists of Scope 1, Scope 2 and the database. Figure 1b and 1c shows the input required to calculate GHG emission for Scope 2 and Scope 1 respectively.

![Figure 1a: Overall flowchart of the GHGCal](image)

B. GHG Emission Scope 1 and 2

The GHG emission from Scope 1 and Scope 2 are calculated as follows:

\[
\text{GHG Emission Scope 1} = Q \times EC \times EF \\
\text{GHG Emission Scope 2} = \frac{\text{Elect} \times GI}{1000}
\]

where Q is the quantity of the emission source in t for solid, m³ for gaseous and L for liquid, EC is energy content factor in GJ/t for solid, GJ/m³ for gaseous and GJ/kL for liquid, EF is emission factor in kg CO₂-e/GJ, Elect is electricity consumption in kWh and GI is Greenhouse Gas Grid Intensity in kgCO₂-e/kWh.
There are 6 major forms in GHGcal that work as a GUI to calculate GHG emission for Scope 1 and Scope 2. User will start by opening the GHGcal application, and then a Menu form will pop out as shown in Figure 2 (left). From the Menu form, user can select three options i.e. 1) Scope 1, 2) Scope 2 and 3) Preview Data.

For Scope 1, user can then choose their emission source from three sources i.e. 1) solid fuel, 2) gaseous fuel and 3) liquid fuel (Figure 2 (right)). A different form will be appeared for each of these sources. These forms are shown in Figure 3 and 4. In each of these sources’ form, we provide user with instructions to insert the required input as well as calculating and displaying the GHG emission level. For example, when ‘Solid Fuel’ is selected, user is required to write in the textbox the organization’s activities that contribute to the GHG emission from this solid fuel. After that, user must select the type of solid fuel for each of the activities that added earlier. Next, user needs to provide the quantity of the fuel source in the textbox given. The CO₂, CH₄ and N₂O emissions will be calculated automatically after the ‘Calculate’ button is pressed. The total emission for the whole activities will be also calculated. To display the GHG emission in the graphical format, user can press the ‘Load Chart’ button. Finally, user can save all the data into database by pressing the ‘Save’ button in the GHGCal application.
Similar as Scope 1, for Scope 2, user must first describe the emission activities in the organization (Figure 5). After that, user is required to key in the annual electricity consumption of the organization in the textbox. User is also required to provide the GHG grid intensity (t-CO₂/kWh). The value of the GHG grid intensity can be obtained from power utility of a country. Then user can calculate the GHG emission from Scope 2 by pressing the ‘Calculate’ button. User also can view the emission chart from the ‘Load Chart’ button. Finally, user can save all the data into database by pressing the ‘Save’ button.
After all the activities have been saved in the database, user can preview the activities by pressing the ‘Preview Data’ button in the Menu form. The database will help users to view the GHG emission released by their organization.

III. CASE STUDY

Two case studies have been tested using GHGCal application to determine the GHG emission by two different companies i.e. Tasiron and Enerco. These case studies are obtained from examples of a discussion in a short course on “Tapping on Carbon Market” organized by Malaysia Science Academy in June 2013. Tasiron is a big steel manufacturing company. The GHG emission activities of the Tasiron are primarily come from coking coal that being burnt in the blast furnace to produce pig-iron. On the other hand, Enerco is a small supplier of electricity that produces 50% of its electricity from coal-seam gas and 50% of its electricity from black coal.

IV. RESULTS AND DISCUSSION

A. Tasiron Case Study

There are three main source of emissions identified at Tasiron integrated steel plant:

1) The coking coal used to fire the blast furnace and convert iron ore to pig iron.
2) Black coal to fuel the basic oxygen furnace used to convert pig-iron to steel.
3) Large-sized stationary diesel generator to power heavy machinery.

The amount of coking coal used was 2,003 tonnes, black coal was 879,199 tonnes and diesel was 387,869,000 tonnes. Transport of the ore and steel also contribute to the GHG emission. Tasiron owns and operates the trucks that take the steel to Silverbeach and the international shipping terminal. Tasiron also has subcontracts that transport the iron ore between the mine and the steel making facility. In 2013, Tasiron consumed 80,875,000 litres of diesel from its truck. The subcontracts also determined that a further 102,500,000 litres of diesel fuel was consumed in transporting the iron ore to the plant.

Besides that, Tasiron Company purchased 5,220,160 kWh of electricity from the grid to power lighting, air conditioning and computer systems at the steel-making facility and its head office. The GHG Grid Intensity for Tasiron is 0.89 tCO2/kWh. Tasiron Company also leases a large number of fleet vehicles that being used by their employees. The annual fuel-card show that the employees consumed 32,254,000 litres of unleaded fuel and 21,551,000 litres of e-10 unleaded(10% ethanol, 90% unleaded) fuel.

Table 1 shows the list of activities of Tasiron Company that contributed to the GHG emission in year 2013. Table 2 shows emission that was calculated using GHGCal application. Total GHG emission from Tasiron Company in 2013 from all the activities described was 3,740,706.45 tCO2-e.

B. Enerco Case Study

The coal seam gas and black coal that Enerco uses come from gaseous underground mine that Enerco owns and located within 3 km of the Enerco combined-cycle power generation. Enerco heavy-vehicle fuel consumption was 156,100,000 litres of diesel fuel in 2013. Enerco consumed 411,920 tonnes of black coal in the power station for electricity generation purpose.

According to the climate change manager, Enerco uses 156,205,000 litres of diesel oil for transportation of black coal. Enerco also consumed 19,501,500 gigajoules.

Besides that, Enerco purchased 4,900,356 kWh of electricity from the grid to power its regional and city-based administration building, including head office. The GHG Grid Intensity for Enerco is 0.89 tCO2/kWh.

Another GHG emission contributor was Enerco employees’ annual fuel consumption. Based on the annual fuel-card accounts, Enerco employees consumed 105,350,000 litres of unleaded fuel and 21,551,000 litres of B-20 Biodiesel (20% biodiesel, 80% diesel) from its trucks.
litres of unleaded fuel and 38,500.00 litres of e-10 unleaded fuel.

Table 3 and Table 4 show the emission activities and the result of GHG emission released by Enerco Company calculated using GHGCal application.

TABLE 3: ENERCO ACTIVITIES THAT CONTRIBUTE TO GHG EMISSIONS

<table>
<thead>
<tr>
<th>No</th>
<th>Activities Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Black Coal for Power Station Electricity Generation</td>
</tr>
<tr>
<td>2</td>
<td>Coal-Seam Gas used for Electricity Generation</td>
</tr>
<tr>
<td>3</td>
<td>Enerco consumed 156,205 KL of Diesel for Black Coal transportasion</td>
</tr>
<tr>
<td>4</td>
<td>Enerco consumed 66500 KL of Biodiesel to reduce their carbon price exposure</td>
</tr>
<tr>
<td>5</td>
<td>Enerco annual Employees fuel (Unleaded) consumption</td>
</tr>
<tr>
<td>6</td>
<td>Enerco annual Employees fuel (e-10 Unleaded) consumption</td>
</tr>
<tr>
<td>7</td>
<td>Enerco purchased Electricity from grid to power its regional and administration building</td>
</tr>
</tbody>
</table>

TABLE 4: OUTPUT OF GHGCAL BASED ON THE ENERCO GHG EMISSION RELEASE ACTIVITIES

<table>
<thead>
<tr>
<th>Source of Fuel</th>
<th>Scop e</th>
<th>CO₂ tCO₂-e</th>
<th>CH₄ tCO₂-e</th>
<th>N₂O tCO₂-e</th>
<th>Total Emission tCO₂-e</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Black Coal</td>
<td>1</td>
<td>980.95 K</td>
<td>333.66</td>
<td>2224.3 7</td>
<td>983508.03</td>
</tr>
<tr>
<td>2 Coal-Seam Methane</td>
<td>1</td>
<td>37.57 K</td>
<td>147.04</td>
<td>22.06</td>
<td>37739.10</td>
</tr>
<tr>
<td>3 Diesel oil-Transportation</td>
<td>1</td>
<td>417.24 K 0</td>
<td>1205.9 0</td>
<td>3014.7 8</td>
<td>421460.66</td>
</tr>
<tr>
<td>4 Biodiesel-Transportation</td>
<td>1</td>
<td>0.00</td>
<td>2761.0 8</td>
<td>5061.9 8</td>
<td>7823.06</td>
</tr>
<tr>
<td>5 Ethanol-Transportation</td>
<td>1</td>
<td>0.00</td>
<td>1081.0 8</td>
<td>1981.9 8</td>
<td>3063.06</td>
</tr>
<tr>
<td>6 Fuel oil-Transportation</td>
<td>1</td>
<td>304.90 K 4</td>
<td>250.94</td>
<td>2309.4 4</td>
<td>307660.38</td>
</tr>
<tr>
<td>7 Purchased Electricity</td>
<td>2</td>
<td>4361.32</td>
<td>0.00</td>
<td>0.00</td>
<td>4361.32</td>
</tr>
</tbody>
</table>

The total GHG emission by Enerco Company in 2013 from all the activities described was 1,765,615.61 tCO₂-e.

V. CONCLUSION

The web application using Microsoft Visual Studio 2010 based on GUI developed in this paper can be used to determine energy saving for Option B of the IPMVP. The web application of energy saving consists of five sections. This Option B for web application GUI could help ESCO and facility owner to calculate energy saving created by ECM adhere to IPMVP. In the future, this software could be extended to include other ECMs such as lighting with dimmer and sensor.

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