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Development of a Framework for Greenhouse Gas Emissions Accounting for Industry Reporting

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Advancement in technology has helped to increase the quality of human lives in many aspects such as transportation, manufacturing, and communication. At the same time, they also contribute to the emission of greenhouse gases (GHG) to the atmosphere be it the production phase, distribution phase, end-user phase, or the waste management phase. It has been found that these GHG emissions is the dominant cause of climate change. This makes it important for organisations from all industries to record their GHG emissions to be able to monitor their GHG emissions and plan mitigation actions. There is presently a lack of comprehensive framework for organisations to use as guidance in their GHG accounting and reporting. This paper incorporates an integrated carbon accounting and mitigation (INCAM) with GHG Protocol standards and MYCarbon (National Corporate GHG Reporting Programme for Malaysia) GHG Reporting Guidelines. This method breaks down a process into several subdivisions as is done in INCAM and then the sources of emissions are divided into scopes according to the GHG Protocol. This method guides industries on the steps of carrying out a GHG emissions inventory and enables them to use their activity data to produce the organisation's total emissions. The total emissions will be broken down based on indicator, source, and scope. This would enable the industries to identify the highest contributor of emissions either by indicator or source, and to identify which scope their emissions fall under. The carbon emissions profile and carbon emissions index can be used to identify and analyse the organisation's emissions performance.

1. Introduction

Over the period of 1880 to 2012, the earth's global temperature has shown an increase of 0.85 °C with the last three decades being successively warmer than any preceding decade since 1850 (IPCC, 2014). Two-thirds of the global temperature increase has occurred since 1975 at a rough rate of 0.15 - 0.20 °C per decade (Carlowicz, 2010). Apart from the rise in global temperature, there are changes in the water cycle that can be seen from the changes in ocean salinity. The ocean is also showing an increase in acidity as a result of increasing uptake of CO_2. Over in Greenland and Antarctic, ice sheet mass is decreasing, and this has led to the increase of the sea level.

A study by Pal and Eltahir (2016) found that heat waves at the Arabian Gulf could reach human survivability threshold limit of wet bulb temperature of 35 °C by the end of the century. Im et al. (2017) found that heat waves in India would come close to the limit also by the end of the century. It is consequently important that the issue of climate change is addressed fully, and changes are acted upon for preventing further increase of the global temperature.

Advancement in technology has helped to increase the quality of human lives in many aspects such as transportation, manufacturing, communication, just to name a few. These advancements all comes at a cost when they contribute to the emission of greenhouse gases (GHG) to the atmosphere. The emissions come from various phases be it the production phase, distribution phase, end-user phase, or the waste management phase. It has been found that these GHG emissions is the dominant cause of various changes to the earth's climate (IPCC, 2014).

Figure 1 and 2 show the global GHG emissions by gas and global GHG emissions by sector. As shown in Figure 1, the global GHG emission is dominated by carbon dioxide (CO_2) from fossil fuel and industrial processes, followed by CO_2 from forestry and other land use, methane (CH_4), nitrous oxide (NO_2), and lastly fluorinated gases (F-gases). In Figure 2, it can be seen that GHG emission comes mostly from the electricity and heat production sector. This is followed by agriculture, industry, transportation, other energy, and buildings sectors.

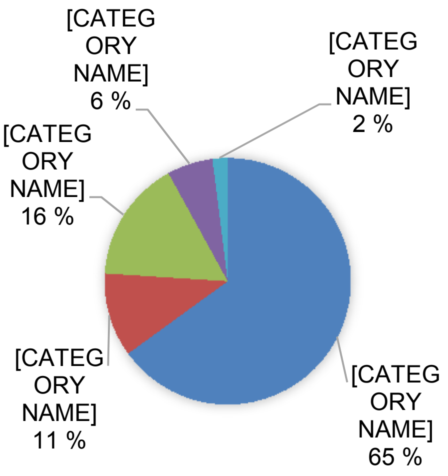

Figure 1: Global GHG emissions by gas (IPCC, 2014)

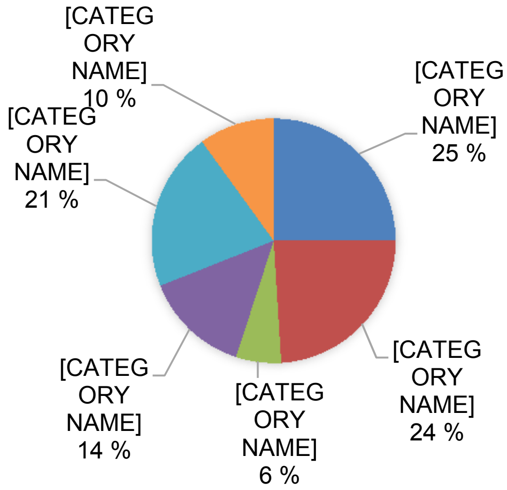

Figure 2: Global GHG emissions by sector (IPCC, 2014)

The increasing annual anthropogenic GHG emissions from 1970 to 2010 can be seen in Figure 3 with the annual emissions of 49 Gt CO_2-eq/y for the year 2010.

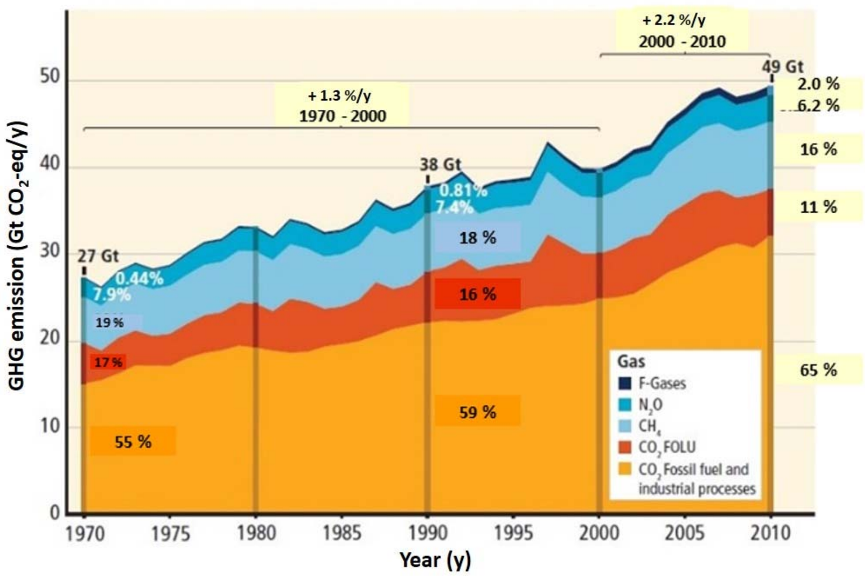

Figure 3: Total annual anthropogenic GHG emissions for the period 1970 to 2010 by gases (IPCC, 2014)

As a mitigation plan to overcome climate change, the United Nations (UN) organised the United Nations Framework Convention for Climate Change (UNFCCC) with the aim to stabilise GHG concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system (United Nations, 1992). As an extension to the UNFCCC, the Kyoto Protocol was adopted in 1997 that commits its Parties by setting internationally binding emission reduction targets (United Nations, 1998). This has been followed by the Paris Agreement which requires Parties to contribute in combatting climate change through “nationally determined contributions” (NDCs). The agreement also requires Parties to report their emissions and implementation efforts regularly (UNFCCC, 2017). In 2015, the Sustainable Development Goals (SDGs) have been adopted at the 2015 UN Summit on Sustainable Development. The SDGs consists of 17 goals that aim to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind (United Nations, 2015). Among the 17 goals, goal number 13 is to "take urgent action to combat climate change and its impacts" and this is in line with the objective of this study – to assist in the efforts to reduce GHG emissions. One of the important steps in GHG emission reduction is the reporting of GHG emissions. It is through this reporting that the present situation of GHG emissions made known and this would in turn enable the identification of the most contributing sources of emissions followed by mitigation plans and actions. In their study, Hashim et al. (2015) developed an Integrated Carbon Accounting and Mitigation (INCAM) framework that allows systematic reporting of emissions, but it does not include the scopes of the emissions that is required in emissions reporting according to the GHG Protocol (WRI and WBCSD, 2013). The GHG Protocol is used as a guide for almost every GHG standard and program in the world and is also being used as guidance in estimating GHG emissions by other studies such as Samanaseh et al. (2017).

Apart from ensuring that the emissions inventory is in compliance with the GHG Protocol, segregating the emissions into their respective scopes is important to enable the identification of emissions that the reporting industry have control over so as to be able to reduce it. The identification of indirect emissions could also allow the 3rd parties upstream and downstream of the process to be aware of how their operations contribute to the emissions and can encourage them to carry out reduction strategies.

2. Methodology

Referring to the INCAM method (Hashim et al., 2015), the activities in the process are divided into sub-processes called carbon accounting centres (CAC). This step narrows down the scope of monitoring both physically and process-wise and would help ease the process of data collection and identification of weak performing indicators. For a more complex process, the CAC may be further divided into sub-CACs.

The next step is to identify the sources of emissions at each CAC or sub-CAC. This step can be carried out by identifying what emission producing activity, as listed in Table 1, occurs in the process. As can be seen in Table 1, the emission-producing activities are categorised into their respective scopes. The process of identification of sources of emissions should consider the scopes that the emissions fall under. Table 1 is the simplified version of the original from the MYCarbon (National Corporate GHG Reporting Programme for Malaysia) GHG Reporting Guidelines (NRE Malaysia, 2014). Industries can refer to the handbook for the full table that also states the potential activity data source for each emission-producing activity.

Table 1: List of emission-producing activities categorised into respective scopes (NRE Malaysia, 2014)

Emission-producing activities		
Scope 1	Scope 2	Scope 3
1. Generation of electricity 2. Physical or chemical processing 3. Transportation of materials, products, waste, and employees 4. Fugitive emissions Any other physical and chemical processing in the physical boundary which will emit or remove GHG. E.g.: on-site waste or sewage processing facilities	1. Purchased electricity/electricity consumption 2. Purchased steam	1. Purchased goods and services (cradle-to-gate emissions) 2. Capital goods 3. Fuel- and energy-related activities (not included in Scope 1 or Scope 2) a. Upstream emissions of purchased fuels b. Upstream emissions of purchased electricity c. T&D losses 4. Generation of purchased electricity that is sold to end-users. 5. Upstream transportation and distribution 6. Waste generated in operations

The identified sources are then arranged into scopes and CACs as shown in Table 2. In Table 2, CAC 1 and CAC 2 refer to the carbon accounting centres that has been determined in the process. For example, as can be seen in the case study later on, the carbon accounting centres for the nickel plating process are identified as process production, and warehouse. CAC 1a, CAC 1b, and so on and CAC 2a, CAC 2b and so on refers to the sub-processes determined under the carbon accounting centres. The letters a, b, c, and d in the table refers to the type of sources of emissions that exists in the process such as fuel consumption, electricity consumption, and waste water treatment. In Table 2, these sources are categorised into the scopes that they fall under.

Table 2: Arrangement of sources according to scope in data checklist

	Sources	CAC 1a	CAC 1 CAC 1b	CAC 1c	CAC 2a	CAC 2 CAC 2b	CAC 2c
Scope 1	a						
	b						
Scope 2	c						
	d						
Scope 3	a						

The calculation method used in this framework is the calculation of emission using established emission factors as in Eq(1).

$$\text{Emission} = \text{Activity data} \times \text{Emission factor} \tag{1}$$

Activity data is data from the activity (volume of fuel consumed, total electricity consumption, mass of waste produced, etc.) that can be used to calculate the emissions using emission factor. The type of data used to quantify the activity is also called as indicators or sources. Emission factor (EF) is the value of how much emission would be produced per unit of activity. The value of EF can be obtained from various established sources. Once the checklist is complete, activity data is collected, and emission factors are selected. The next step would be to calculate the emissions using Eq(1).
Once emissions have been calculated, other values are calculated i.e. the carbon emission profile (CEP) and the carbon emission index (CEI). The CEP is the percentage of emissions that has been emitted by each sub-CAC or source and is calculated using Eq(2) below. The CEI, on the other hand, indicates how much GHG emission is released per unit of production and is calculated using Eq(3). The CEP and CEI are calculated for each sub-CAC as well as for each different source. The GHG emission in the numerator of Eq(2) and Eq(3) refers to GHG emission for each sub-CAC or source depending on which one the calculation is being done.

$$\text{CEP} = \frac{\text{GHG emission}}{\text{Total GHG emission}} \times 100\ \% \tag{2}$$

$$\text{CEI} = \frac{\text{GHG emission}}{\text{Production}} \tag{3}$$

3. Results and Discussion

Data for the case study used was obtained from another study of similar topic (Hashim et al., 2015). The data is of a process of nickel electroplating which is the deposit of nickel on metal surface. The process includes water rinsing of the metal surface to remove any impurities, the plating of nickel onto the metal surface, neutralisation of the electroplated surface, hot water bathing to wash off any excess substance, drying, and packaging. The flow of the process is shown in Figure 4.

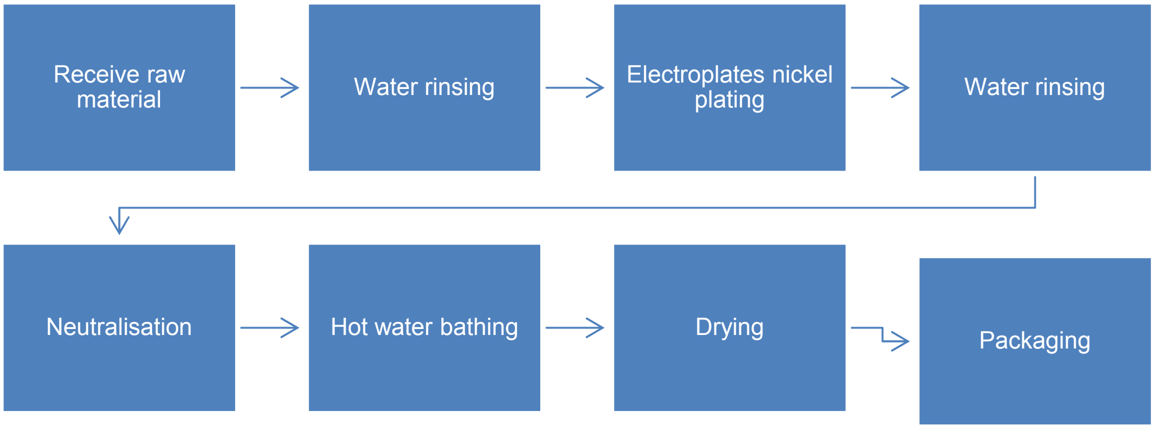

Figure 4: Flow of process of nickel electroplating

This process is divided into two carbon accounting centres (CAC) namely CAC 1, the process production, and CAC 2, warehouse. Each CAC is further divided into sub-CACs which are water rinsing, acid, forklift, and heating for CAC 1, and forklift, air condition, and document for CAC 2. Table 3 shows the checklist of data to be collected for each sub-CAC. The indicators or sources of emissions are identified as fuel consumption, electricity, water consumption, solid waste, and waste water. These indicators are divided into their respective scopes, Scope 1, Scope 2, and Scope 3. Fuel consumption and waste water falls under Scope 1 because it occurs within the process boundary. Electricity usage falls under Scope 2 as defined by GHG Protocol. Water consumption and solid waste falls under Scope 3 as they are emissions that are a consequence of the process but occurs outside the process boundary.

Table 3: Checklist for data collection

Sources		CAC 1 Process Production				CAC 2 Warehouse		
		Water rinsing	Acid	Forklift	Heating	Forklift	Air condition	Document
Scope 1	Fuel consumption							
	Waste water							
Scope 2	Electricity							
Scope 3	Water consumption							
	Solid waste							

Once all the data have been obtained, the emission is calculated for each sub-CAC by multiplying the activity data with the EF. To further analyse the data, the CEP and the CEI are then calculated for each sub-CAC and source. From the data used in this case study, the results obtained are as shown in Table 4.
From the values obtained in Table 4, it has been found that the highest contributing CAC of emission is from CAC 1, the process production with a total of 55.32 % of total emissions being released by it. CAC 2, on the other hand, releases a total of 44.68 % of total emissions. The largest contributor of emission from CAC 1 is Heating while the largest contributor from CAC 2 is Air condition with percentages of 54.95 and 44.44.
The CEI was calculated using Eq(3) with the denominator being the production in mass. The pattern of the CEI of the CACs also follows the same pattern as the CEP.

Table 4: Total emissions, CEP, and CEI of nickel electroplating process

Sources		CAC 1 Process Production				CAC 2 Warehouse			Total emission (t CO_2-eq)	CEP (%)	CEI
		Water rinsing	Acid	Forklift	Heating	Forklift	Air condition	Document			
Scope 1	Fuel consumption			1.39×10^6 t CO_2-eq		1.39×10^6 t CO_2-eq			2.78×10^6	0.35	271.80
	Waste water	3.34×10^5 t CO_2-eq							3.34×10^5	0.04	32.66
Scope 2	Electricity				4.34×10^8 t CO_2-eq		3.51×10^8 t CO_2-eq		7.85×10^8	99.39	76,749.28
Scope 3	Water consumption	1.19×10^6 t CO_2-eq							1.19×10^6	0.15	116.35
	Solid waste							4.90×10^5 t CO_2-eq	4.90×10^5	0.06	47.91
	Total emission (t CO_2-eq)	1.52×10^6	0.00	1.39×10^6	4.34×10^8	1.39×10^6	3.51×10^8	4.90×10^5	7.90×10^8		
	CEP (%)	0.19	0.00	0.18	54.95	0.18	44.44	0.06			
	CEI	149.00	0.00	135.90	42,432.09	135.90	34,317.19	47.91			

From the perspective of sources, the source that contributes the largest amount of emissions is electricity consumption from Scope 2. Emissions from electricity consumption makes up a total of 99.39 % of the total emissions. This is followed by fuel consumption in Scope 1 with 0.35 % and water consumption, solid waste, and waste water in Scopes 1 and 3 with CEPs of 0.15 %, 0.06 %, and 0.04 %. Looking at it in terms of scopes, Scope 2 emissions make up most of the total emissions, followed by Scope 1 and Scope 3 with total CEPs of 99.39 %, 0.39 %, and 0.21 %. As in the case of CACs, the CEIs for each source also follow the same pattern as the CEP.

4. Conclusions and Recommendations

From the results obtained in the previous section, this systematic method of reporting GHG emissions can be used by the industries to record their emissions and in turn take mitigation actions in reducing the emissions. This method follows the GHG Protocol whereby the emissions are divided in the respective scopes. This eases the process for the industries where there are no further calculations needed for them to be able to report their emissions. From the emissions inventory, the industries could easily identify the highest contributing sources of emissions and this could help the industry to take mitigation actions to reduce their emissions.

This emissions inventory reporting is only the first step in the efforts of reducing GHG emissions. This study requires an extension whereby mitigation actions are planned and emissions after mitigation are calculated to foresee how much emission can be reduced by each mitigation action. This could ease the decision-making process of planning the most effective mitigation actions for the industry.

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