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GHG accounting framework: Development of the GHG assessment indicator for the petroleum refinery sector

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Abstract. The petroleum refineries sector is one of the highest-ranked sectors in terms of GHG emissions per facility. As a way forward in managing climate change, GHG assessment has become crucial in achieving net zero emissions. The objective of this study is to develop appropriate measurements for GHG assessment performance for the Malaysia petroleum refinery sector. The framework includes establishing indicators and parameters to quantify and assess carbon footprint and to obtain an approximate measure for carbon footprint accounting. The overall methodology for the GHG assessment framework is separated into two main parts with a total of eight steps for this study to be completed, however in this study the focus is only on the familiarization of plant, determination of parameters and indicators and greenhouse gases mapping which are part of the indicator development. With all information of the study being prepared, the next goal is to develop a comprehensive framework that can be used in the petroleum refinery process for carbon footprint accounting.

Introduction

Climate change is real, and Malaysia is not excluded from being impacted by this phenomenon. Rising temperatures, floods, droughts, and rising sea levels are among the examples of impact brought by climate change. Climate change occurs due to the emissions of greenhouse gases (GHG), for example carbon dioxide, methane, and nitrous oxide. As part of the effort to fight climate change, on July 30th 2021, the government of Malaysia has approved the unconditional Nationally Determined Contributions (NDC) target to reduce the intensity of greenhouse gas (GHG) emissions by 45% based on gross domestic product, also an initiative called the net zero carbon emission need to be achieved by 2030 [1] [2]. However, in order to meet the target, various initiatives, policies and instruments may need to be established. In light of this, GHG assessment and reporting from the industrial sector is expected to be one of the critical elements of the action plan. *Peter Drucker, the Management guru has famously said; "you can't manage what you can't measure"* [3]. Therefore, be it at the level of a country or an organisation, it is critical to determine the current status of GHG emissions and to establish a GHG baseline so that the relevant mitigation strategies and actions could be effectively designed to address the root causes of GHG emissions then to further with effective mitigation strategies. From the nature of the refining process, refinery process contributes to the increasing amount of CO_2 emissions. In 2020, CO_2 emissions in Malaysia was 262.2 million tonnes, and one of the top contributor of CO_2 emissions is the oil and gas industry [4]. With increasing demands and high market value of petroleum refinery products, the processes are further developed and

improved to cater the demands and to obtain high profitability in business. Rapid development and growth have developed both positive and negative impacts on business, economy, social and the environment. Focusing on the environmental aspect, the development has caused negative impacts towards sustainability and emission of greenhouse gases (GHGs) which will lead to climate issues gradually. The emission of GHGs is one of the negative impacts due to the nature of the petroleum refinery process, it is important for companies in petroleum refinery sector to measure carbon level, or to conduct carbon footprint accounting. However, they were limited studies or framework focusing on the carbon accounting assessment of petroleum refineries in Malaysia [5]. One of the study calculated the carbon emissions of the products transported through pipeline [6]. While [7] has developed a well-to wheel method focusing on the bitumen processing area. The literature that is closely related to this study is summarized in Table 1. Therefore, this study is required to be conducted to establish a comprehensive framework on carbon accounting by identify relevant carbon footprint parameters and indicators to quantify the GHGs in the petroleum refinery process.

Table 1 Review carbon footprint research studies

Title and Author	Objectives	Application	Method	Research Gaps
Carbon footprint of oil products pipeline transportation [6]	To build a comprehensive Life Cycle Assessment (LCA) model of carbon footprint for oil products pipeline	Oil and Gas Industry: Oil products pipeline transportation	Life Cycle Assessment (LCA) model	This framework establish a Life Cycle Analysis (LCA) by studying the life cycle inventory of petroleum products pipeline system only not including the process of petroleum refining.
Statistically enhanced model of oil sands operations: Well-to-Wheel comparison of in situ oil sands pathways [7]	To investigation variability in well-to-wheel (WTW) GHG emissions	Oil and Gas Industry: Refinery with respect to bitumen	Well-to-Wheel method	This model have been developed for refinery process but only focusing on bitumen production
Assessing the carbon footprint of a university campus using a life cycle assessment approach [8]	To evaluate the carbon footprint of Clemson University's campus using a streamlined life cycle assessment approach	Public Buildings: University	Streamlined life cycle assessment approach	This model framework developed is suitable for public building such as universities only, however methodology of research can be used as reference.

Assessment of carbon footprint emissions and environmental concerns of solid waste treatment and disposal techniques; case study of Malaysia [9]	To alert Malaysian stakeholders on the uneven danger of carbon footprint emissions of waste technologies	Waste Management	2006 IPCC Methodology Assessed by 3 scenario: Scenario 1: Waste dumping in sanitary landfills equipped with gas recovery system Scenario 2: Anaerobic digestion of organics and recycling of waste Scenario 3: Waste Incineration	This framework developed is suitable for waste management, however methodology of research can be used as reference

Methodology

The overall framework of this GHG assessment is separated into a two-part process as shown in Fig. 1 with eight steps in total. Part 1 consist of three main steps of indicator development and Part 2 of the study framework consists of five main steps to quantify the carbon. The second step is to compile all related data obtained throughout the study, to quantify and assess the carbon footprint accounting with reference to IPCC guidelines and MYCarbon Malaysia. However, the methodology in this study only focuses on indicator development from steps 1 until 3 in Part 1. A structured methodology has been developed to select indicators as the applicability of the framework depends on the relevance and importance of these indicators. An overall framework of the development of petroleum refinery carbon footprint accounting is presented in Fig. 1.

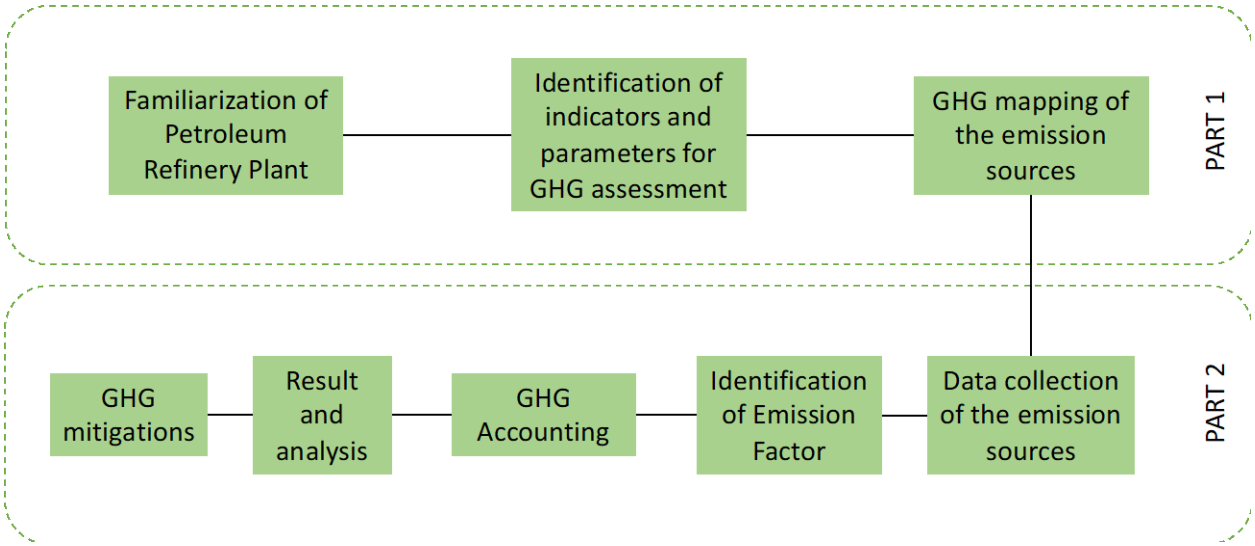

Figure 1 Development of Petroleum Refinery Carbon Footprint Accounting

Part 1: Development of Carbon GHG Footprint Accounting for Petroleum Refinery Process

The first part of developing petroleum refinery carbon footprint accounting first is to understand the overall process of the refinery, determine the parameters and indicators for carbon footprint accounting and map the emission sources to the respective parameters as shown in Fig. 2.

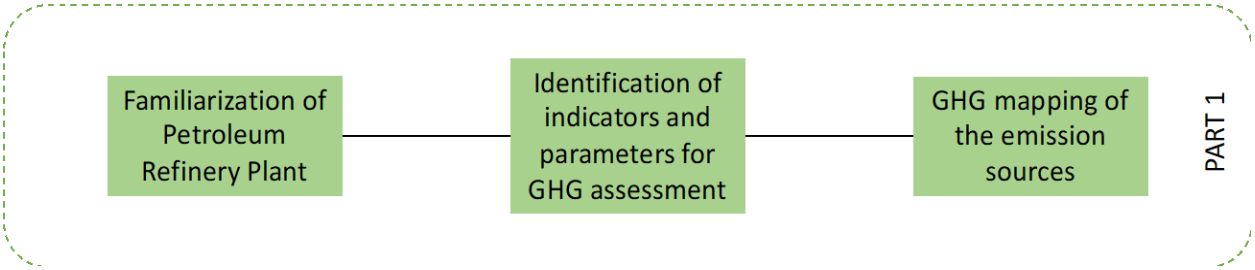

Figure 2 Part 1 of development of petroleum refinery carbon footprint accounting

Familiarization of Petroleum Refinery Plant

In the first step, a brief introduction of the petroleum refinery industry and the overall process of petroleum refining was explained. This step is crucial as it is important to understand the process involved, the main component of a petroleum refinery and the operational data that is required for the next step of the study. Moreover, this study is going to focus on the main process units in the petroleum refinery process. The main process units determined in the petroleum refinery process are the crude oil tankage, crude distillation unit, secondary process unit, product treatment unit and the final product tankage. The flowchart of the main process unit and overall process flow diagram of petroleum refinery processes can be referred to Fig. 3. and Fig. 4.In this study, the space boundary of the assessment is limited to the kerosene production plant as in Fig. 4.

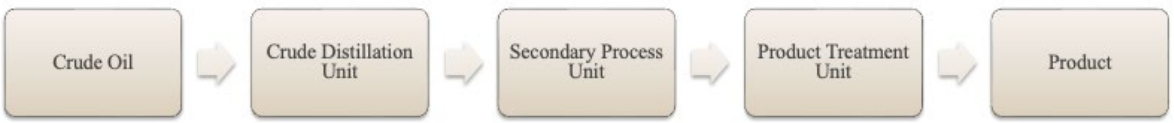

Figure 3 Flowchart of main process units in petroleum refinery process

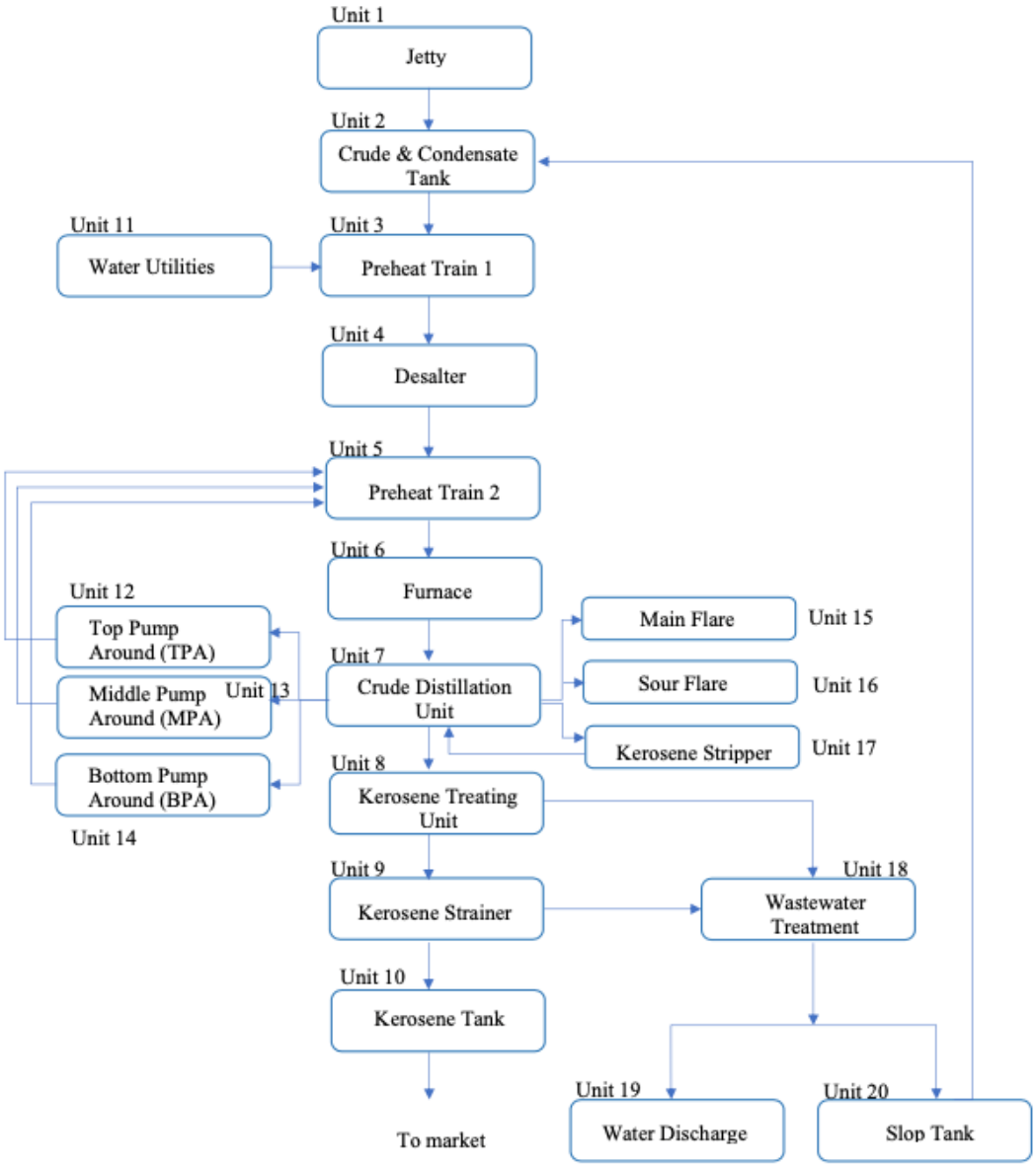

Figure 4 Overview of petroleum refinery processes

Selection of Indicators and Parameters of the GHGs Emission Source

The selection of indicators and parameters was based on the process flow diagram (PFD) of the industry illustrated in Figure 4 and is aligned with the IPCC guidelines. The final list of parameters and indicators is decided based on the input from the expert, subject to data availability. Five potential carbon footprint accounting parameters are identified which are water consumption for the process, water consumption, electric consumption, diesel consumption, wastewater and fugitive emission. The indicator of each parameter are shown in Table 2.

Mapping of Greenhouse Gases (GHGs)

Table 3 shows the mapping of greenhouse gases (GHGs) is conducted by determining which stream in the process unit emits GHGs and the streams with respect to the indicators and parameters. Then, the findings will be used in collecting the data for GHGs emissions.

Part 2: Carbon Footprint Accounting Analysis and Mitigations for Petroleum Refinery Process
The second part of the methodology, it consists of analyzing and suggesting proper mitigations to encounter the emissions produced by petroleum refinery processes as shown in Figure 5.

Collection of Monthly Consumption or Generation of Data for Each Mapped Stream
Based on the GHG mapping completed, the data of monthly consumption or data of generation for each mapped stream will be identified. Data collection will be done with reference to available petroleum refineries in Malaysia such as Petronas Penapisan Terengganu (PPT) Sdn. Bhd. And Malaysian Refining Company Sdn. Bhd. (MRCSB).

Accounting of Greenhouse Gases (GHGs)
Determination of emission factors from IPCC standard is the initial step to be conducted prior to any calculations. Based on the GHG parameter, the emission factor will be obtained from the IPCC standard. From the values obtained by referring to the IPCC standard, the accounting of greenhouse gas emissions can be completed. The calculations done will be tabulated in table form for easy reference and documentation.

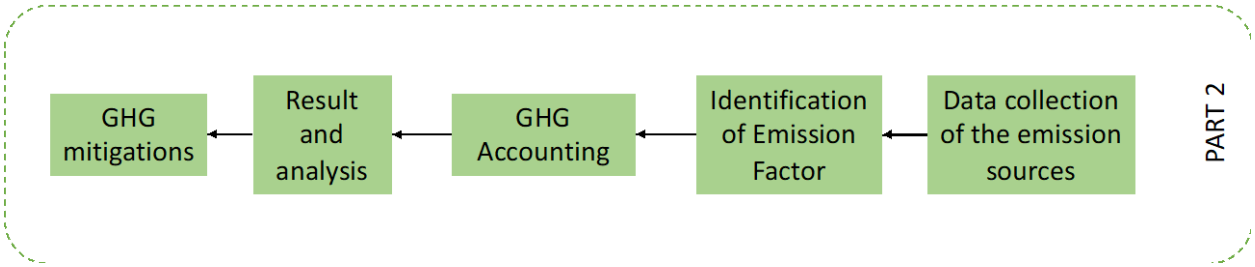

Figure 5 Part 2 of development of petroleum refinery carbon footprint accounting

Results and Discussion
The parameter has been established based on the IPCC guidelines and relevant literature on carbon assessment development. Based on the study, five parameters have been found in the petroleum refinery sector as shown in Table 2.

Table 2 List of parameters and indicators of the GHGs Emission Source

Parameter, p	Indicator, i
Water Consumption	Use of water
Electricity	Electricitiy consumption
Diesel Consumption	Diesel used for transport
Wastewater	Oily water sewer
Fugitive Emission	Fugitive emission

Based on the familiarization of the plant mapping, there are 19 units that contribute the GHG emissions. The name of the unit can be referred to the PFD in Fig. 4. Unit 1, inlet of raw material from the jetty has the most GHG parameters involved in the process, the parameters are wastewater, electric consumption and diesel consumption. While the electric consumption parameter involved with most of the units except units 11 and 19. From these results, it can be expected that the electric consumption will be the highest emitters compared to the other

parameter. Unit 1 also expected the highest unit contribute to the total emissions. Based on this analysis, an effective mitigation study can be conducted to reduce emissions.

Table 3 Mapping of GHGs

Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Water Consumption			/																	
Wastewater	/	/		/				/	/	/									/	
Electric Consumption	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/		/
Diesel Consumption	/																			
Emission															/	/				

Conclusion

This study is aimed to establish indicators and parameters to quantify an approximate measure of carbon footprint accounting in the petroleum refinery process. There are five parameters have been identified associated with petroleum refineries, namely water consumption for the process, water consumption, electric consumption, diesel consumption, wastewater and emission. 19 unit operations have also been identified contributed to the carbon emission. This identification of the correct parameters and indicators is very important to ensure the measurement will reflect the actual emission level. With the aim objective of the study being stated above achieved, the way forward for this study is to do data collection related to the indicator, quantify the carbon footprint, thus analysed the result of the assessment and propose appropriate mitigation for the enhancement of the process.

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