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CARBON ACCOUNTING INITIATIVES: CASE STUDY OF A PETROLEUM REFINERY IN MALAYSIA TO PREPARE FOR FUTURE CARBON MARKET

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Abstract

Petroleum refining process produces a large amount of atmospheric pollutants including greenhouse gases which are attributed to global warming. The international community inevitably addressed the global warming issue by introducing a market-based mechanism known as Emission Trading Systems (ETS) under the Kyoto Protocol which imposes binding limits to developed nations using three flexibility mechanisms, including the Clean Development Mechanism (CDM). This case study was carried out in a petroleum refinery in Malaysia to explore the possibility for the refinery to participate in CDM. Information was collected through observatory field survey at the refinery and documentation review. Results show that the current monitoring tool using indirect calculation of fuel consumption provides a comprehensive coverage of emission sources but the reporting frequency should be increased for data accuracy. An accounting system was then created to predict the emissions gap of the refinery with reference to the baseline-year set by the Kyoto Protocol. It was concluded that the refinery showed promising potential to participate in CDM to benefit from technology transfer by selling their 'credits' to Annex I countries despite the uncertainty on the impact of the carbon market in a Non-Annex I country.

Keywords*:* Refinery, Kyoto Protocol, Clean development mechanism.

1. Introduction

Petroleum refining processes such as crude oil separation processes, heavy to light hydrocarbon distillation, process heaters and utilities generate substantial

Nomenclatures

R	Correlation coefficient

Greek Symbols

$\sum$	Summation of total components

Abbreviations

CDM	Clean development mechanism
CEMS	Continuous emissions monitoring system
ETS	Emission trading systems
GHG	Green house gas
GWP	Global warming potential
IPCC	Intergovernmental panel on climate change
VOC	Volatile organic compounds

amount of wastes and atmospheric pollutants. These emissions originate from various sources such as from storage tanks, transport pipelines, combustion from furnaces and boilers. The hydrocarbon fuels originates from vented gasses, refuse (waste) gases and liquids from emptying, canalization cleaning, incidents or accidents of fabrication [1].

Common air emissions from refining processes are carbon dioxides (CO_2), carbon monoxides (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x), methane (CH_4) and volatile organic compounds (VOC). These air emissions enter the atmosphere and undergo chemical and physical changes to eventually produce air pollutants, which becomes hazardous to both the environment and to human health. In addition, some of the pollutants such as CO_2, CH_4 and NO_x are also part of global warming species [2].

The vast emissions of these atmospheric pollutants pose a great concern to global communities due to their contributions towards global warming. The Green House Gas (GHGs) identified to contribute towards global warming are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro-fluorocarbon (HFC), sulphur hexafluoride (SF_6) and perfluorocarbon (PFC). The Kyoto Protocol imposes binding emissions limits on developed countries that are listed under Annex I beginning from the first commitment period during 2008 to 2012 when average annual emissions have to be at least 5.2% below the levels in 1990. Malaysia became a signatory to the Kyoto Protocol on 12th March 1999 and announced the country's ratification of the Protocol during the WSSD Summit on 4th September 2002. For Malaysia, Clean Development Mechanism (CDM) is the only one of the three flexible mechanisms that can be implemented in order to participate in climate change mitigation while assisting in their emission reductions. Malaysia is of the view that the CDM can create opportunities for investments in projects on greenhouse gas emission reductions, contributing both to economic and environmental well-being of the country [3, 4]. In light of this, the Government has set about developing a national strategy on the CDM.

As a high-energy consumer, the petroleum refining company in Malaysia is likely to be affected by the future carbon constrains if Kyoto restrictions are extended to Non-Annex I countries. The oil refinery has a licensed production capacity of refining 16,000 to 17,000 tonnes of crude oil per day and produces a comprehensive range of petroleum products, some 90% of which are consumed within Malaysia. The refinery is also committed to prepare its organization for future regulations by tackling current environmental issues such as for the requirements of the recently passed Kyoto Protocol Malaysia has ratified.

The CDM concept under the Kyoto mechanisms provides an opportunity for the refinery to benefit from the transfer of technology while achieving emission reductions when industries in Annex I countries purchases the ‘extra amounts’ of emission reduction credits through the open market. This case study was carried out to analyse the possibility for the refinery to participate in CDM project with their current emissions monitoring and reporting tools and to prepare a carbon accounting system to determine the current level of exceedance relative to the Kyoto requirements.

2. Methodology

This study is carried out in a two-step process. The first step involves the collection of data relevant to the air emissions quality from the refinery. Three methods were used to collect the data of interest that is by conducting field survey, verbal questionnaire to the refinery personnel and a thorough analysis of historical and current documents. The second step is to compile and analyse all data collected, to create a carbon accounting system for the refinery and to propose future plans to the management with reference to the current trend of greenhouse gasses (GHGs) emissions.

For the purpose of ensuring credible emissions accounting, the amount of GHGs the refinery emits must be quantified as accurately as possible. When there are situations where information on the sources was unavailable, the amount of GHG has to be estimated from historical information. This underlines the importance of having proper documentations. Based on this, studies were then proposed to improve the current monitoring system by estimating the emissions directly from areas of interest within the refinery.

3. Results

It was observed that the refinery monitors their air emissions both qualitatively and quantitatively. Qualitative monitoring involves the use of Closed-Circuit Television (CCTV) on emissions from the stacks and observation of flame properties at least three times daily by the operators during their rounds. Quantitative monitoring comprises of two tools. One of which is the use of Continuous Emissions Monitoring System (CEMS) at the final emission points which is the stacks. Such monitoring was carried out in compliance to the refinery’s license to operate as agreed with the Malaysian Department of Environment. This was reported on a quarterly basis to the governmental department.

The second quantitative tool was to calculate the emissions indirectly from the monitoring of fuel consumption. The amount of CO_2, SO_x, NO_x, NO, CH_4 and VOC emissions is calculated by factoring the volume of fuel consumed in several equations that are derived by the parent company with reference to international organizations such as the American Petroleum Institute and United States

Environmental Protection Agency. Such monitoring was carried out on monthly frequency. These equations would consider all the possible sources for emitting the pollutant rather than focus on a single source such as from the stacks as monitored by CEMS.

For example, the calculation of CO_2 takes into account the combustion sources, flaring, venting and amount of coke burnt. This is given as:

$$\Sigma_{CO_2} = \Sigma_{combustion} + \Sigma_{flare} + \Sigma_{vent} + \Sigma_{coke\ burnt}$$

where

Σ_{CO_2} = Total CO_2 per month

$\Sigma_{combustion}$ = Total CO_2 from combustion sources

Σ_{flare} = Total CO_2 that is flared

Σ_{vent} = Total CO_2 that is vented

$\Sigma_{coke\ burnt}$ = Total CO_2 from the burning of coke

The total of CO_2 produced by each process is defined as below:

$\Sigma_{combustion}$ = total fuel gas and fuel oil consumed × factor

Σ_{flare} = total fuel gas flared per month × flare efficiency × factor

Σ_{vent} = amount of vented gas × factor

$\Sigma_{coke\ burnt}$ = amount of coke burnt per month × factor

Similar to the example given above, general formulas for other parameters measured consists of the amount of fuel consumed multiplied by a factor. The term ‘fuel’ refers to a general term consisting of waste gases termed as ‘fuel gases’, torch oil termed as ‘fuel oil’ and the heavy, non-commercial compounds that are termed as ‘coke’. The other parameters measured are nitrous oxide (N_2O), methane (CH_4), sulphur oxides (SO_x), nitrogen oxides (NO_x) and VOC. The calculation of chlorinated hydrocarbon (HCFC) is different as the amount of pollutant is estimated by multiplying the number of equipments with a default factor. Table 1 gives an overview on the types of processes measured for each parameter.

Table 1. Processes that Contribute towards the Calculations of Each Parameter.

Parameter	Types of processes
CO_2	Combustion, Flared gas, Venting, Coke burnt
N_2O	Combustion, Flared gas
CH_4	Combustion, Flared gas, Venting, Storage tanks, Fugitive sources
SO_x	Combustion, Flared gas, Coke burnt, Sulphur Recovery
NO_x	Combustion, Flared gas, Coke burnt
VOC	Combustion, Flared gas, Venting, Storage tanks, Fugitive sources, Wastewater treatment
HCFC	Number of equipments multiplied by a factor

From this table, it is observed that the three GHG parameters monitored are CO_2, CH_4 and N_2O and these emissions contribute directly towards the amount of Global Warming Potential (GWP) reported by the refinery (Fig. 1).

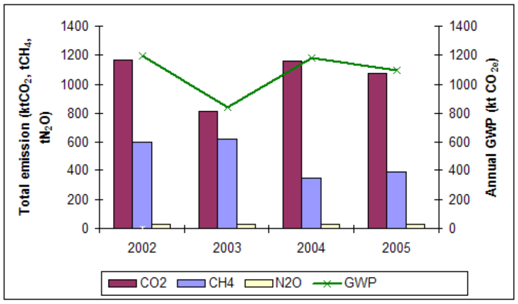

Fig. 1. Greenhouse Gasses Monitored in the Refinery and their Corresponding Global Warming Potentials from year 2002 to year 2005.

It is observed that the total GWP is heavily dependant on the amount of CO_2 emitted. This is proven by using a simple regression model to test for the relationship between GWP for each of the three GHG parameters by comparing the R^2 value. GWP and CO_2 were calculated to be very closely related with an R^2 value of 0.9997 (close to 1) while GWP is independent of CH_4 (R^2=0.2445) and N_2O (R^2=0.1636) (Fig. 2). As such, initial GHG inventory is focused on CO_2 emissions.

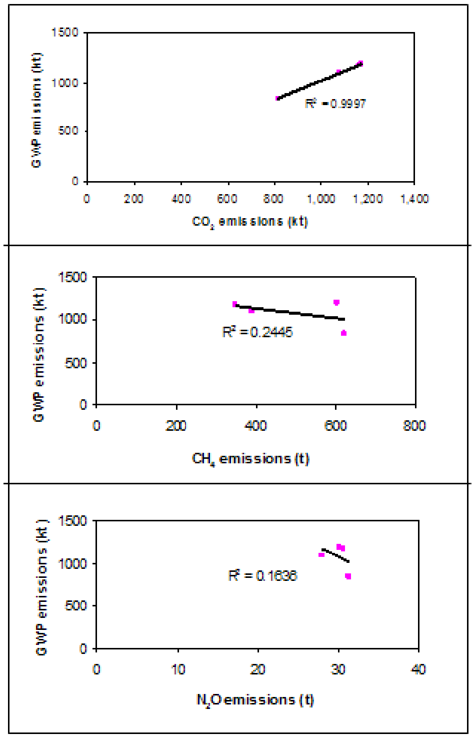

Fig. 2. Regression Models of CO_2, CH_4 and N_2O with Total GWP.

4. Discussion

4.1. Monitoring and documentation systems

The qualitative monitoring method does not serve any purpose to facilitate in quantifying the amount of air pollution produced by the refinery. This form of monitoring is more focused on the safeguarding the operational safety and to prevent any unwanted environmental incidences that will be health hazardous to their neighbours. In addition, the current practice of using stack monitoring of selected air pollutants is in compliance with the requirements of the Malaysian environmental laws but may not fully satisfy the global concerns over the emissions of GHGs, such as the emissions trading market. In lieu of this, both these tools will not be further discussed. The emissions calculation system was found to be a more reliable form of emissions monitoring because the system includes all operational data from crude unloading to waste treatment (adopting the cradle-to-grave ideology).

It requires monitoring of different parameters on specific units, such as furnaces, boilers, turbines, process heaters, catalytic reformers etc. to indicate the unit's operating rate and the amount of emission from that unit. Thus this system provides a better representation on the refinery's activities by closely integrating operational information with environmental compliances for market-based regulations such as in the ETS.

With reference to [5], it is considered that the refinery is moving in the right direction by monitoring their emission levels via fuel consumption. The authors are in the opinion that future market-based regulations are focused on the amount of emissions emitted over a period of time e.g. Mg per year. Further improvements are to increase the accuracy of data for the emission report by increasing the frequency of monitoring and to introduce data accountability on the information provided to cater for missing data or outliers. This could be done by compiling all the information available in a common portfolio to ease future referencing.

4.2. Carbon accounting

Analysis on the current and predicted amount of CO_2 equivalents from the refinery was carried out to determine the impact of the future ETS on current emission levels. Following a step-by-step method called the '$CO_2 e$ Trade Cycle' by CO_2e.com in [6], an accounting of the GHGs was created. Preliminary assessment of current and historical data showed that more than 99% of the refinery's total GHG emissions comprise of CO_2. As such, the accounting system is focused on the CO_2 emissions first.

The first step is to define the boundaries of the accounting. As in this case study, boundaries for this CO_2 emission inventory include emissions of CO_2 from all the primary processes (includes distillation, hydrotreatment and catalytic reforming) and secondary processes (includes thermal conversion, catalytic cracking, hydrocracking and residue hydroconversion). The main sources of CO_2 were identified to be the furnaces, boilers and coke regenerator as these contributes to more than 90% of CO_2 emitted from the refinery.

After determining all the sources and outlining the major contributors and any possible bad actors, the historical and current CO_2 emissions are then plotted against the baseline year. Since Malaysia has yet to confirm a baseline year to the UNFCCC, year 1990 was chosen because 1990 is the base year set by Kyoto Agreement to Annex I countries. Values for the baseline years were then calculated as a five percent (5%) reduction from the total CO_2 emissions in 1990 (as stipulated by the Kyoto Agreement for Annex I countries) to identify the current 'emission gaps' from the probable baseline the refinery will be abide to in future.

In the refinery's environmental report in year 2004, the refinery produces as much as 1,178 kt CO_2 equivalents, consisting of 1,161 kt of CO_2 (99% of total CO_2e) and very little of CH_4 and N_2O. Determination of future forecasts assumes a 'Business as Usual' scenario. This scenario was then compared against the reduction requirement of baseline years chosen to determine potential GHG emission liabilities or emissions 'gaps' (Fig. 3).

First, a projection was made to predict the refinery's CO_2 emission in year 2010 by averaging the refinery's emission from year 2000 to 2005. The graph in Fig. 3 owed that the CO_2 emission from year 2000 fluctuates between 800 kt to 1200 kt and is predicted to be producing some 1000kt to 1100 kt of CO_2 emissions by year 2010 with the assumption of no major projects in plan.

However, from the technical perspective, it is recommended to predict a 10 % to 15 % increase in equipment capacity to accommodate for any design changes. Thus, CO_2 emissions are expected to increase in the same magnitude. The outcome of this calculation could result in the refinery facing a gap that is doubled from the current emission gap that is calculated from averaged values if new equipments are added within the span of four years. This further underlines the necessity of the refinery to start investing in alternative technologies to reduce this large emission gap.

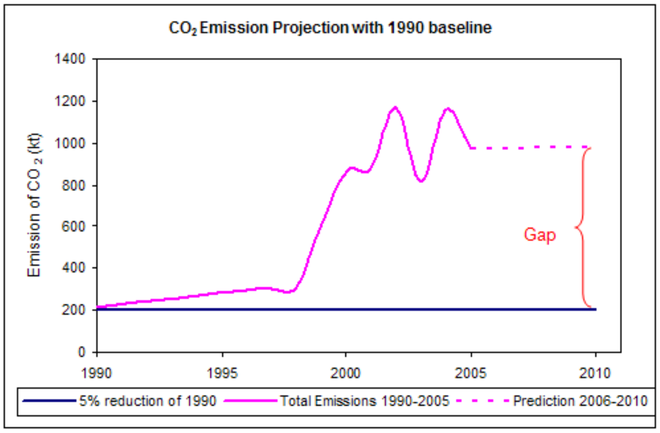

Fig. 3. Example of Determination of Emission Gaps with 1990 Baseline.

4.3. Assurance of data accuracy

Since there are very little information available for future carbon restrictions to industries in Non-Annex I countries, predictions have to be made. The authors in [6] projected that future environmental authorities prescribes the monitoring of operations as well as emission levels to achieve the market-based regulations in order to ensure that emission levels are achieved and maintained. In terms of cost, it was predicted that the future carbon constraint may affect industries in terms of taxes, direct regulations, subsidies, product costs and market mechanisms [7].

Presently, efforts have been made by the refinery to improve the emission data management and verification of information to ensure that the refinery produces accurate and credible environmental information to the refinery's stakeholders. This is a costly affair. For example, Global Reporting Initiative estimates the cost of reporting environmental information to be in the region of US$500,000 [8]. With the introduction of Kyoto Agreement and the CDM, accuracy of data proves to be very valuable and useful to ease the refinery's participation in future CDM projects as well as to accurately predict future emission trends and thus avoid costly emission exceedance post year 2012.

4.4. Emissions reduction strategy

In order to achieve meaningful CO_2 reductions to close such a large emission gap, the refinery in this case study would need to explore various reduction options, including deployment of different technologies to reduce CO_2 emission levels. Emphasis should be placed on fuel replacement and hydrogen fuel technologies to combat the increase of CO_2 emissions from refineries as well as minimizing the coke yield [9]. This is expected to require large capital investments. There are a host of possible technological solutions in the market today but these emission reduction technologies are also very costly. Some of these technological solutions are capable of reducing as much as 90% of CO_2 emissions [9].

Regardless of the options available, the driving force for decision-makers to invest in carbon reduction projects will be from the complexities of the regulatory requirements. In planning of future projects in this industry, decision-makers will need to ensure that these plans are executed within the 'environmental' market constraints. As there is no specific legislation or guidelines at the moment on how industries will be affected by the Kyoto agreement in a Non-Annex I country, speculations are difficult. There are a lot of uncertainties with regards to the Malaysian government's restrictions on GHG emissions if and when the Kyoto agreement is enforced in Non-Annex I countries.

Currently, the only force to drive an industry to participate and create a CDM project is to receive tariffs from the government and benefit from the transfer of technology. With very little detail in place, it proved to be difficult for the refinery to estimate the cost-benefit of employing emission reduction technologies compared to settling for high penalties in support of emission abatement.

5. Conclusions

The petroleum refinery in this case study emits a large amount of CO_2, which comes under the Kyoto restrictions as one of greenhouse gases listed by Intergovernmental Panel on Climate Change (IPCC). However, there are currently no specific guidelines for Malaysian industries to address the probable introduction of carbon restrictions in a Non-Annex I country. Nevertheless, there are many technological possibilities available for the refinery to apply in order to close the large emission gap as determined from this case study. In addition to the current practice of calculating amount of emissions from fuel consumption and a continuous effort to ensure accurate and credible data, the refinery in this case study shows promising potential to fulfil requirements of CDM*d* should participate in the emissions market to benefit from the technological transfer and close the large emission gap.

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