INTEGRATED CARBON ASSESSMENT AND SUSTAINABLE DEVELOPMENT GOALS FRAMEWORK TOWARDS GREEN INDUSTRY

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DEDICATION

This thesis is dedicated to Mama, Adam, Adra and Adriana. Thank you Mak and Ayah for the life time support.

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ABSTRACT

Green industry can be defined as an economy striving for sustainable pathway improvement, implementing public policy initiatives and undertaking green public investments that encourage environmentally responsible private investments. Malaysia had passed the bill on the renewable energy act and has also implemented the low carbon city framework as part of the national policy to reduce the carbon emission. Malaysia is committed to contribute to the global climate change mitigation especially in the city level by mobilising a transition to low carbon emissions, setting the standards in formulating research-based programs and effective climate action plans. Based on previous studies, there are no specific tools that can integrate the carbon assessment in the industries because the available tools only show the total greenhouse gas emission within the studied system boundary. The main objective of this study was to establish integrated carbon assessment and mitigation framework (INCAM), to establish sustainable development goals trade-off and co-benefit analysis framework (STOCBA) and to apply INCAM and STOCBA in selected case studies. INCAM can provide two purposes which are to track the carbon emission on-site in specific sub section and identify potential emission reduction strategy in a holistic manner. The study was done at selected oleo-chemical industries in Pasir Gudang, Johor based on the stratified analysis for this research. In this study also, Pugh analysis method was adopted to determine the weightage of the STOCBA. The INCAM found that before the industry applied INCAM, the total monthly tCO_2e was $7.80x10^8$ tCO_2e and after applying the INCAM, the total monthly tCO_2e was $6.28X10^8$ tCO_2e. It was found that the industries can reduce 20.3% of their carbon emission electricity consumption by applying the carbon reduction initiatives. The developed framework named STOCBA found that by installing photovoltaic solar panel as the carbon reduction initiatives strategy can give the score of 8 for the sustainable development goals SDG trade-off scoring which is positively significant for the Pugh analysis. This shows that INCAM can be integrated with SDG to define better carbon reduction initiatives. The contribution of the study is that the INCAM can provide relevant information that makes carbon profiling visible to various levels of an organization, enabling the industry to plan, make decisions and take effective actions to reduce carbon emission towards greening the industry. The developed frameworks verified that the industries can reduce their carbon emission by applying the proposed framework. In addition, the INCAM also can be integrated with the SDG using STOCBA framework. The STOCBA will help the industry and also the policy maker such as local authorities to review the best carbon reduction initiatives to reduce the carbon emission. Thus, this study can be promoted as a green initiative for a green industry development in Malaysia and also can help users to evaluate the economic and environmental impacts for reducing the carbon emission.

ABSTRAK

Industri hijau didefinisikan sebagai industri yang mendokong keperluan berteraskan penambahbaikan kelestarian alam sekitar, melaksanakan inisiatif polisi awam dan mengambilkira pelaburan awam berteraskan hijau yang menggalakkan pelaburan swasta ke arah mengutamakan alam sekitar. Malaysia telah meluluskan akta tenaga boleh baharu dan telah menggunapakai rangka kerja bandar rendah karbon sebagai inisiatif untuk mengurangkan pelepasan karbon. Malaysia bersungguh dalam menyumbang kepada usaha perubahan iklim global terutamanya di peringkat bandar dengan menggerakkan peralihan kepada pelepasan rendah karbon, menetapkan piawaian dalam merangka program berasaskan penyelidikan dan pelan tindakan iklim yang berkesan. Berdasarkan kajian sebelum ini, tiada instrumen khusus yang mengintegrasikan penilaian bagi pelepasan karbon di industri kerana instrumen yang sedia ada hanya mampu menilai pelepasan gas rumah hijau didalam sempadan sistem kajian. Objektif utama kajian ini adalah untuk membangunkan *integrated carbon assessment and mitigation framework* (INCAM), membangunkan *sustainable development goals trade-off and co-benefit analysis framework* (STOCBA) dan mengaplikasikan INCAM dan STOCBA kepada kajian kes yang terpilih. INCAM bertindak secara dwifungsi iaitu dapat menilai pelepasan karbon di sub skop kerja dan dapat mengenalpasti strategi bagi tindakan untuk pengurangan pelepasan karbon secara holistik. Kajian ini telah dijalankan di industri oleo-kimia terpilih di Pasir Gudang, Johor. Dalam penyelidikan ini, kaedah analisa berstrata adalah digunakan. Kaedah analisa Pugh juga digunakan bagi penentuan pemberat yang digunakan semasa analisis STOCBA. Kajian INCAM mendapati, sebelum analisis INCAM dijalankan oleh industri, jumlah bulanan tCO_2e sebanyak $7.80x10^8$ tCO_2e dan selepas INCAM digunapakai, jumlah bulanan tCO_2e adalah sebanyak $6.28X10^8$ tCO_2e. Industri dapat mengurangkan 20.3% pelepasan karbon bagi penggunaan elektrik dengan menggunapakai inisiatif pengurangan karbon. Hasil pembangunan rangka kerja STOCBA mendapati, dengan pemasangan panel solar sebagai inisiatif strategi untuk pengurangan karbon telah memberikan skor 8 bagi skor *SDG Trade-Off* yang memberikan signifikan secara positif untuk analisa Pugh. Ini membuktikan INCAM boleh diintegrasikan bersama SDG bagi mengenalpasti inisiatif pengurangan karbon yang lebih baik. Hasil kajian ini juga mendapati INCAM dapat memberikan maklumat yang releven dalam menjadikan profail karbon yang lebih mudah kepada pelbagai peringkat organisasi dan seterusnya dapat membantu pihak industri untuk merancang, mengambil tindakan dan mengambil langkah yang efektif bagi pengurangan pelepasan karbon dalam usaha menghijaukan industri. Rangka kerja yang dibangunkan ini telah membantu industri dalam mengurangkan pelepasan karbon. Selain itu, INCAM boleh diintegrasikan bersama dengan SDG dengan menggunakan rangka kerja STOCBA. STOCBA dapat membantu industri dan juga penggubal dasar seperti pihak berkuasa tempatan dalam melaksanakan inisiatif pengurangan karbon. Justeru itu, kajian ini dapat dipromosikan sebagai inisiatif hijau untuk pembangunan industri hijau di Malaysia dan membantu pengguna untuk mengenalpasti impak ekonomi dan alam sekitar terhadap pengurangan pelepasan karbon.

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LIST OF ABBREVIATIONS

API	-	American Petroleum Institute
BCA	-	Building Construction Authority
BERMS	-	Building Energy Monitoring and Reporting System
CAC	-	Carbon Accounting Centre
CEI	-	Carbon Emission Index
CEPA	-	Communication, Education and Public Awareness
COP	-	Conference of Parties of United Nation
CPI	-	Carbon Performance Indicator
CPKO	-	Crude Palm Kernel Oil
CPO	-	Crude Palm Oil
DOE	-	Department of Environment
DOS	-	Department of Statistics
EE	-	Energy Efficiency
EIT	-	Eco Industrial Town
EPA	-	Environmental Protection Agency
EQA	-	Environmental Quality Act
GBI	-	Green Building Index
GDP	-	Gross Domestic Product
GHG	-	Green House Gas
GWP	-	Global Warming Potential
IGES	-	Institute for Global Environmental Strategies
ILO	-	International Labour Organization
IM	-	Iskandar Malaysia
INCAM	-	Integrated Carbon Assessment and Mitigation Framework
IPCC	-	Intergovernmental Panel on Climate Change
IRDA	-	Iskandar Regional Development Authority
IS	-	Industrial Symbiosis
KeTTHA	-	Kementerian Tenaga, Teknologi Hijau dan Air
LCA	-	Life Cycle Assessment
LCCF	-	Low Carbon City Framework

LED	-	Light-Emitting Diode
LPG	-	Liquified Petroleum Gas
MBPG	-	Majlis Bandaraya Pasir Gudang
MPPG	-	Majlis Perbandaran Pasir Gudang
MSW	-	Municipal Solid Waste
OECD	-	Organization for Economic and Co-operation Development
PTP	-	Pelabuhan Tanjung Pelepas
PV	-	Photovoltaic
RE	-	Renewable Energy
RSPO	-	Roundtable on Sustainable Palm Oil
SAJ	-	Syarikat Air Johor
SDG	-	Sustainable Development Goals
SEDA	-	Sustainable Energy Development Authority
STOCBA	-	SDG Trade-Off and Co-Benefit Analysis
TNB	-	Tenaga Nasional Berhad
TSP	-	Total Suspended Solid
UK	-	United Kingdom
UNESCAP	-	United Nation Economic and Social Commission for Asia
	-	and the Pacific
UNDP	-	United Nation Development Programme
UNFCC	-	United Nation Framework Convention on Climate Change

LIST OF SYMBOLS

CO_2	-	Diameter
kg		Kilogram
kWh	-	Kilowatt-hour
L	-	Liter
m^3	-	Cubic meter
NO_2	-	Nitrate
SF_6	-	Sulphur Hexafluoride
tCO_2e	-	Tonne CO_2 emission

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Over the past three decades, Malaysia as a developing country has been experiencing massive economic growth. However, this growth caused a significant impact on the natural environment. The conversion of land areas into industrial townships have resulted in environmental deterioration in many cities, especially on the air pollution, water pollution, soil pollution and many more. In the early 1970s, the environmental protection and management were never a planned agenda in Malaysia although issues pertaining to environmental degradation had already emerged. Subsequently, further development in the economy had resulted in the setting up of more industries, which causes further degradation of the environment especially in the form of water, air, solid waste, toxic and hazardous wastes pollution (Mustafa, 2019).

Local environmental problems must be tackled on an unprecedented scale, particularly those concerning water resources management, waste disposal and the associated environmental pollution. At the same time, greener choices must be made regarding urbanisation and infrastructure design as these will have great implications for both the economic and environmental performance. The Organization for Economic Cooperation and Development (OECD) mentioned that better environmental policies are beneficial for urban growth, as they can enhance cities' efficiency and attractiveness (OECD, 2020). In addition, the exhaust from the industries can release large number of harmful gases, such as carbon monoxide, sulphur, carbon dioxide and other elements that can deplete the air quality. There will be a significant emission of greenhouse gases (GHG) if many industries are concentrated in one place (Sany et. al, 2020). GHGs are gases with high global warming potential (GWP) which contributes to global warming. The GWP of these gases are expressed in relative to one unit of carbon dioxide as the reference gas, which

has a value of 1, CO_2-equivalent (CO_2-eq). Subsequently, further industrial development with increasing factories has led to further degradation of environment in many forms. Economic growth and social development could be achieved if the GHG emissions could be reduced. The massive emission cuts are required to stabilise GHG concentrations and must be done by applying cost-effective policies. This can be applied as broadly as possible across all emission sources. Carbon reduction should be key elements of a policy mix to build a global carbon market, complemented by regulations, standards, increased investment in information-based approach, research and development (UNIDO. 2021).

Since carbon is the most abundant elements on earth, the green industry concept is introduced and many researchers have developed carbon tracking instrument, such as life cycle analysis and carbon footprint, in order to reduce the carbon emission through green and sustainable approaches. Green industry refers to economies striving for a more sustainable pathway of growth by considering the impact on the environment using several methods that could reduce the carbon footprint and the utilization of energy, water and other resources. In other definition, this can be defined as the use of clean energy that offers high environmental protection and free of pollution. In the other words, the implementation of green industry will improve the condition of the environment, promotes stronger economic development, enhances energy reliability and secures human wellbeing (OECD, 2021). Besides, the implementation of green industry will minimize the degradation to the environment by promoting zero or low GHG emission, which will bring effort in combating climate change. The green industry has been implemented continuously throughout the world to address climate change (Chen, et al., 2017). The concept of green industry can be integrated with the concept of low carbon cities to achieve environmental sustainability. The planning of a city can be more functional and implementable by using low carbon city concept (Ho et al., 2018), which can counter the increasing amount of carbon dioxide concentration due to fossil fuel use, rapid urbanization and land use change.

The most ambitious low carbon project in Malaysia's emerging effort towards global sustainability is the Iskandar Malaysia Low Carbon Society. In Malaysia, a total of 52 local authorities are now part of the Low Carbon City Framework Programme which encourages strategies and actions to reduce carbon emissions at the local level. The issues of climate change and global warming are paid with greater attention today than ever before, with the mandatory and voluntary efforts in reducing GHG emissions being observed in most countries in the world, including Malaysia. At the 21st Conference of the Parties to the UNFCCC (COP21) in Paris, Malaysia pledged for its GHG emissions reduction target of 40% in terms of intensity of Gross Domestic Product (GDP) by 2030 relative to the emissions intensity of GDP in 2005. Malaysia's recent climate change report to the UNFCCC, an output of a UNDP-Global Environment Facility Project shows that the country's temperature, rainfall and sea levels have been on the rise in the last 40 years and are projected to continue rising to 2050. Average temperatures are projected to hike between 1.2^{o}C to 1.6^{o}C by 2050. This brings about an added vulnerability to a large proportion of our urban population who live in low-elevation coastal areas. Carbon emissions in Malaysia mainly relate to urban settings, where the energy sector (including electricity and transportation) makes up 80% of total emissions. This means that there is enormous potential to reduce emissions from the energy sector to obtain both carbon and cost savings. A joint study by UNDP and the Economic Planning Unit (now known as the Ministry of Economic Affairs) estimated that just by improving energy efficiency in the buildings and transport sectors, RM46.9 billion (USD 11.2 billion) in energy spending could be saved between 2016 and 2030 (UNDP, 2021).

1.2 Research Background

1.2.1 Current Situation and Problem in Malaysia

Many cities in Malaysia have already set a low-carbon vision or developed a low carbon action governance, policy, plan and the preparation of greenhouse gas inventories that can help to track low-carbon actions are also underway. Government has intensively promoted the low carbon programmes throughout

Malaysia. Currently, there are many initiatives for low carbon in Malaysia, for example Low Carbon Cities Framework and Assessment System, Iskandar Malaysia's Low Carbon Society Blueprint and Putrajaya Low Carbon Green City. The launch of the National Green Technology Policy on 24 July 2009 by the Government of Malaysia has opened a new chapter in Malaysia's effort in addressing environmental issues, including climate change and energy use, through the application and development of green technology to reduce Malaysia's carbon footprint in addition to enhance environmental sustainability. The policy has also outlined five main objectives. The first objective is to reduce the energy usage rate at the same time increase economic growth. The second objective is to facilitate the growth of the green technology industry and enhance its contribution to the national economy. The third objective is to increase national capability and capacity for innovation in green technology development and enhance Malaysia competitiveness in green technology in the global arena, where the fourth objective is to ensure sustainability development and conserve the environment for future generation. The fifth objective of the policy is to enhance public education and awareness in green technology and encourage its widespread use. All of these policies lead towards reducing the carbon emission in Malaysia which slowly redirected Malaysia towards a less carbon intensive future (Susskind et. al, 2020).

In order to tackle the issue of the intensive carbon emission, there is a need for global as well as national strategies in the first objective of the National Green Technology Policy which is to reduce the energy usage rate at the same time to increase the economic growth for pursuing sustainability in the urban environments in Malaysia. There is a significantly improve of carbon emissions and correlation role between population density on emissions. Strong political will and leadership are needed to drive effective response to address the climate change at global and regional level because of the concern of climate change policies that may affect economic growth. The increases of CO_2 in Malaysia are due primarily to fossil fuel use, rapid urbanization and effluence lifestyle and land use change. Therefore, the sustainable development principles such as compact cities, eco-cities, industrial symbiosis, eco-industrial town, green cities and other concepts of energy efficiency are vital. Although such environmental quality regulations are protecting natural resources and other initiatives to indirectly reduce CO_2 emission, it is necessary to look into the low carbon

society scenario more holistically especially when the Government has a voluntary pledge for a 40% reduction in emission intensity. Therefore, by implementing the low carbon program, the aims to minimise carbon emission in all sectors, shift to a simpler and quality life can be achieved align with Sustainable Development Goals by the United Nation. In addition, the overall objective of a low carbon program is to significantly reduce its carbon footprint in ways that do not compromise a city's economic development potential. Generally, carbon emissions in Malaysia are high compared to other countries at similar stages of development (Rahman, 2020).

1.2.2 Background of Study

Different methods of carbon accounting are needed in order to carry out different core task of each sector and evaluate their sustainability performances. This can be seen in a number of leading companies such as the German automobile manufacturer, BMW, who adopted life cycle assessment (LCA) to measure the carbon footprint of their whole product life cycle. Similarly, the consultancy company, UK Water Research Centre (WRC) had also developed several methodologies such as Carbon Accounting Workbook and Carbon Abatement Tool to identify and estimate the GHG emissions from water industry activities. In Malaysia a framework for national level corporate GHG reporting programme name MYCarbon has been developed in close consultations with stakeholders. Positive support and feedback were received and there were no major objections to the programme. MYCarbon is a strategic step to engage the corporate sector and industries in the area of carbon reduction and green technology. MYCarbon will compliment other initiatives such as a renewable energy, energy efficiency and green technology development. SAJ Holding (SAJ) had apply the Carbon Footprint Assessment throughout the operations. In recognition of its environmental preservation initiatives, SAJH won second place in the MYCarbon Awards in 2015 given by the Ministry of Natural Resources and Environment Malaysia. Looking forward, SAJH aims to reduce emissions by 5 percent of every cubic meter of water produced by 2017. (SAJ, 2021). It is envisaged that by using this tool, the industry can quantify the carbon emission, monitor carbon emission profiling and take effective action to reduce carbon emission of its premises.

1.3 Problem Statement

Currently in Malaysia, there are no specified tools to evaluate the carbon emission for the industrial sectors. The available tools to evaluate the general carbon emissions are Life Cycle Assessment (LCA), Sustainability Assessment Model (SAM) Intergovernmental Panel On Climate Change (IPCC), Life Cycle Inventory Localization (LCIM) Method and Comprehensive Energy Consumption Method. The availaible tools in Malaysia are Green Building Index (GBI), Guideline For Green Township in Malaysia, MYCarbon and Low Carbon Cities Challenge in Malaysia (Surenthira, Vinod and Yap, 2017). However, these rating tools do not measure performance of a production in terms of their impact on the environment, in particular of their carbon emission levels and there is no integrated framework to quantify the level of the industrial performance indicator available.

Following are the gaps identified in the current tools to evaluate the carbon emission in industries :

1) Absence of systematic framework to measure or estimate the carbon accounting and reporting, thus industry interprets the data reporting differently.
2) No integrated method to track the carbon emissions and to identify potential initiatives to reduce the carbon emission.
3) The importance to identify potential initiatives that can be relate to specific SDG action plan.
4) The effect of emission in industry and their SDG interlinkages.

A specific rating system is constructed in order to visualize the performance of the industry which include, oleo-chemical, petrochemical, food, transportation and heavy engineering industry, in Pasir Gudang. There are five main carbon emission contributors in industry which are electricity, fuel consumption, water consumption, domestic waste, wastewater and also solid waste or recycle activities. From the listed carbon emission contributors, one specific contributor that yield the most effect on industries and be determined as the hotspot of the emission.

1.4 Research Questions

In order to develop the Integrated Carbon Accounting and Mitigation Framework (INCAM) and to interlinkage the mitigation options with the SDG Goals, a few research questions must be addressed. The research questions of this study are as follows :

1) What are the main emission contributors of carbon in industries?
2) How industries calculate their carbon emission?
3) How to interlinkage the 17 SDG goals with the mitigation option in the industry?
4) What is the recommendation for the industries to reduce the carbon emissions?

1.5 Research Objective

The objectives of the research are :

1) To establish Integrated Carbon Accounting and Mitigation Framework (INCAM).
2) To establish SDG Trade-Off and Co-Benefit Analysis (STOCBA) Framework
3) To apply the “INCAM” and “STOCBA” in Oleo-Chemical industries.

1.6 Scope of Study

This study will be conduct in Pasir Gudang which located at the south of Peninsular Malaysia. Currently, there are 869 licenced industries operated in Pasir Gudang. With an estimation of more than 320,000 of population by the year 2025, the industrial sector can take advantage of available labour. Thus, there is an important need to focus on developing industrial premises throughout the region especially in Pasir Gudang, a city with a significant number of industrial parks in Iskandar Malaysia. Nonetheless, the rapid development of industrial sector in Pasir Gudang must decouple the environmental pollution from economic growth. There are 69 of oleo-chemical industry that consist of upstream and downstream industry activities in Pasir Gudang which represent the highest number in the type of industry. In addition, in 2020 itself, there were 135 notices of non-compliance under Section 69, Akta Kerajaan Tempatan, 1976 had been issued to various industries in Pasir Gudang related to the environmental pollution.

In order to achieve the research objective, three important tasks have been recognized in this research. The scope of this research includes three scopes. The first scope is the literature review on the current and the latest scenario. In this study, the current carbon emission performance tools in the various industry that measure the carbon emission performance had been review. In addition, the study on the interlinkages between Sustainable Development Goals (SDG) and the mitigation option. The 17 SDG had been studied individually to evaluate the criteria on each SDG based on their goals and targets. The second scope is to develop an integrated tool, namely Integrated Carbon Accounting and Mitigation Framework for the industry. The scope details are to identify potential carbon emission factor for the carbon performance indicators. Secondly, to develop a mathematical model that can identify the carbon emission index in a specific industry. Thirdly, the developed model is apply to a case study in the industry to evaluate the carbon reduction. Finally, the analysis on case study is performed evaluate the INCAM Framework. The third scope is to develop the SDG Trade-Off and Co-Benefit Analysis (STOCBA) Framework. In this scope, the study the details of the Sustainable Development Goals (SDG) and their respective targets had been done. Then, the type of analysis to be adopt to interlinkage the SDG had been identified. Finally, in the third scope, the analysis on case study is

performed to analyse and evaluate the SDG Trade-Off and Co-Benefit Analysis in the selected industry.

In this study, a systematic framework for carbon assessment and mitigation (INCAM) is established to enable comparison of carbon performance indicators (CPI), carbon accounting center (CAC), industry to industry and against appropriate benchmarks. Quantification and modelling the carbon emission or ecological footprint are equally to measure magnitude for monitoring and bench marking CO_2 emission globally and regionally. Hence, it is important for the local authority to carry out "carbon bookkeeping" in dealing with urban problems. Local and regional authorities may need input from experts to have baseline study of carbon emission or ecological footprint to understand the urban demands which will affect global warming and climate change.

1.7 Research Contribution

The main contribution of this research is to develop a structural and comprehensive framework based on integrated carbon accounting tool and to provide mitigation options for the users to evaluate the economic and environmental impacts for the reducing the carbon emission. The specific research contributions are described as follows:

i. Integrated Carbon Accounting and Mitigation Framework (INCAM).
ii. Establish mapping for the SDG and carbon reduction initiatives in integrated manner to support the 17 SDG assessment.
iii. Establish Sustainable Development Goals Trade-Off and Co-Benefit Analysis (STOCBA).
iv. Integrated Framework for INCAM and STOCBA to perform environmental assessment in more holistic method.

1.8 Research Limitation

Several limitations have been outlined for this study. Study area selection has been identified as the first limitation and the overall expected findings of this research especially on the analytical analysis as the second limitation. As for the study area, Pasir Gudang, a primary industrial area in Johor has being chosen as the case study area. This will help local government and the industries to use the framework to reduce the carbon emission. It is also suitable by using similar methodology for future research by choosing other case studies depending on the objectives of the research. Secondly, overall expected findings of this research consist of limited analytical analysis, which in this study is using qualitative method and suggestion for future research, as well as reasonable improvement of enabling factors according to the localized context of carbon emission framework concept to the industries.

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