GREENING COIL COATING PAINT MANUFACTURING PREMISE USING CLEANER PRODUCTION STRATEGIES

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ABSTRACT

Coil coating paint manufacture premise was chosen to evaluate the opportunities for using cleaner production strategies to green the premise. This study aims to reduce the carbon dioxide emission included total resources usage and waste generation from the coil coating paint manufacturing activities. The audit result shows that the carbon emission from coil coating paint is 166.0 kg CO_2 / 1000kg of coil coating paint. To produce one kg of paint, it requires 0.19 kWh electricity, 0.8g LPG and 0.016 kg of the waste generation which include solid and liquid waste. Total of twenty-seven (27) cleaner production options were identified to reduce carbon emission. The cleaner production options mainly focus on the design changes, improvement in term of operational, and good housekeeping. The analyses show that the cleaner production options can reduce the carbon emission about 55.5 kg CO_2 / 1000kg of coil coating paint. This will be a total reduction of 33.3 x 10^4 tonne CO_2 per year for selected coil coating paint manufacture premise. The implementation of cleaner production options required approximately RM 1,000,500 investment with the payback period of about 4.4 years. Therefore, the cleaner production strategy helps to reduced carbon dioxide emission and it is a useful tool to green the coil coating paint manufacturing premise with attractive financial return.

Keywords: Cleaner Production, Coil Coating Paint Manufacturer, Carbon Dioxide Emission

ABSTRAK

Premis pembuat cat salutan gegelung telah dipilih untuk menilai peluang-peluang menggunakan strategi pengeluaran bersih untuk menghijaukan premis. Kajian ini bertujuan untuk mengurangkan pelepasan karbon dioksida termasuk jumlah penggunaan sumber semula jadi dan penjanaan sisa daripada aktiviti kilang pembuatan cat salutan gegelung. Keputusan audit menunjukkan bahawa pelepasan karbon dari cat salutan gegelung adalah 166.0 kg CO_2 / 1000 kg cat salutan gegelung. Untuk menghasilkan satu kilogram cat, ia memerlukan 0.19 kWh tenaga elektrik, penggunaan bahan api 0.8g LPG dan 0.016 kg penjanaan sisa yang termasuk sisa pepejal dan cecair. Sebanyak dua puluh tujuh (27) jumlah pilihan pengeluaran bersih telah dikenalpasti untuk mengurangkan pelepasan karbon. Pilihan pengeluaran bersih yang terutamanya memberi tumpuan kepada perubahan reka bentuk, penambahbaikan dari segi operasi, dan pengemasan yang baik. Analisis menunjukkan bahawa pilihan pengeluaran bersih boleh mengurangkan pelepasan karbon sekitar 55.5 kg CO_2 / 1000kg cat salutan gegelung. Ini akan menjadikan pengurangan sebanyak 33.3 x 10^4 tan CO_2 setiap tahun untuk premis pembuat cat gegelung yang terpilih. Pelaksanaan pilihan pengeluaran bersih dijangka memerlukan pelaburan sebanyak RM 1,000,500 dengan tempoh pulangan lebih kurang selama 4.4 tahun. Oleh itu, strategi pengeluaran bersih juga membantu mengurangkan pelepasan karbon dioksida dan ia merupakan alat yang berguna untuk menghijaukan premis pembuat cat salutan gegelung dengan pulangan kewangan yang menarik.

Kata Kunci: Pengeluaran Bersih, Pembuat Cat Salutan Gegelung, Pelepasan Karbon Dioksida

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LIST OF SYMBOLS AND ABBREVIATIONS

CO_2	:	Carbon Dioxide
NOx	:	Nitrogen Oxides
SOx	:	Sulfur Oxides
CP	:	Cleaner Production
IPCC	:	Intergovernmental Panel on Climate Change
GHGs	:	Greenhouse Gasses
UNEP	:	United Nations Environment Programme
DOE	:	Department of Environment Malaysia
SIRIM	:	Standards and Industrial Research Institute of Malaysia
DANIDA	:	Danish International Development Agency
VOCs	:	Volatile Organic Compounds
IPCC	:	Intergovernmental Panel of Climate Change
LPG	:	Liquified Petroleum Gas
ERP	:	Enterprise Resource Planning

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Background

Coil coating products show increasing demand due to its specialty of anti-corrosion and various design. Coil coated products are more robust and versatile with the ability to compatible well on complex substrates. Conventional coil coating paint uses a crude oil-based solvent as the key component. Therefore, solvent-based coil coating paint tends to emit high amounts of volatile organic compound to the environment (ReportBuyer, 2018). Coil coated material is used for exterior building wall cladding, roofing, awning, ceiling, cleanroom, blinds, and composite panels with thermal or noise insulation (Sander, 2014). There are several well-known coil coating paint manufacturers set up a manufacturing plant at Malaysia such as PPG, AkzoNobel, Kansai and Beckers Group. They manufacture various type of products that suit different weather condition, various architectural design, interior, and exterior application. Due to its versatility, the application of the coil-coated product is commonly used to replace the conventional material in modern architecture design.

Coil coated substrate is generally coated with two or three layers of different coating. The first layer is the base coating which functioning as the primer to enhance the adherent of the top coat to the substrate. The second layer is the top coat which functioning as colour coating and the last layer will be the clear coat which functioning as a protective coating. Coil coating paint is available in polyurethanes, polyesters, silicone-polyesters, acrylics, fluorocarbon, vinyl, and others. New coil coatings paint is continuing to be develop. Coil coating paints are available in various degree of glossiness, hardness, and resistance to chalking and colour fading (United States Steel Corporation, 2016).

According to the Department of Statistics Malaysia, Malaysia's manufacturing sales recorded RM65.5 billion, an increase of 8.2% in April 2018 compared to March 2018.

Petroleum, chemical, rubber, and plastic are the manufacturing sector that contributes high sales value of 6.3% in April 2018. For the construction sector, the value of construction work completed in the second quarter of 2018 recorded a moderate growth of 5.3% year on year to record RM35.6 billion. In terms of contributions, civil engineering sub-sector dominate the performance of value of construction work completed with 41.7% share, followed by non-residential buildings, 28.8%, residential buildings, 25.0% and special trades activities, 5.1% (Department of Statistics Malaysia, 2018).

The growth of chemical manufacturing and civil engineering sub-sector shows a direct growth in coil coating paint manufacturing as both industries are inter-related. In the process of chemical and coil coating paint production, it requires a lot of input which includes natural resources, energy, and chemical. During the process of production, carbon dioxide emitted as a waste and other waste generated from the process will released to the environment. Currently, there is no strict restriction on the quantity of carbon dioxide release and quantity of waste generated from the process of manufacturing, this cause a continuous release of carbon dioxide and high quantity of waste generated. The generated carbon dioxide and waste that release to the environment had become a burden as it takes a long time to degrade. The accumulated carbon dioxide in the atmosphere are one of the causes of global warming and climate change. Therefore, to control the situation of global warming and climate change, greening initiative and strategies need to be identify according to different industry. Carbon dioxide and waste are expected to control and reduce after the implementation of green strategies. The greening of the industry is a method to achieve sustainable economic development. It includes policy making, enhanced industrial production process and resource-efficient output (United Nations Industrial Development Organization, 2010).

1.2 Problem Statement

The coil coating paint manufacturing premise consumes a high quantity of volatile organic compound, electricity, galvanized iron, and aluminium composite panel which eventually generates a large amount of waste and CO_2 emission during the operational activities.

The exponential growth in human civilization and depletion of natural resources are the key reason driving the development to be more sustainable. Remarkably, the paint and coatings industry is the foremost players in using petroleum-based chemical for developing its broad range of products (Tiwari, 2017). According to Asia Pacific Report from Coatings World (2016), the total coatings market in term of revenue breakdown by country Southeast Asia 2014, Malaysia has 13.1% of revenue for coatings. The Asia-Pacific region is rapidly expanding, fuelled by a growing economy and emerging middle class. This growth is driving demand for many building and industrial materials including paints and coatings. Therefore, it is important for the industry to initiate the efforts to move toward the direction of self-sustainability. Government and industrial sectors invest the resources significantly for the development of an environment-friendly product with lesser carbon dioxide emission and the product requirement remain unchanged (Tiwari, 2017). In order to identify a suitable greening strategy to use for sustainable development, the premise should be assessed and improved by using CP strategies.

The study conducted at coil coating paint manufacturing premise will identify and evaluate the greening strategies to achieve the aim and answer the research questions below:

I. What are the carbon footprint generating activities in the premise?
II. What is the carbon dioxide emission per unit product in this premise?
III. What are the practical CP options that can be implemented in this premise?

IV. What is the possible approximate reduction per unit product in this premise?

V. What is the ROI for implementing the options?

VI. Can the options be expanded to other such premises in Malaysia and what is the total possible carbon footprint reduction?

1.3 Aim and Objectives

The aim of this study is to reduce the emission of carbon dioxide from coil coating paint manufacture. The objectives of this study are listed below:

I. To conduct a cleaner production audit at the coil coating paint manufacturing premise

II. To generate cleaner production options in the audited premise.

III. To evaluate and prioritize for possible implementation in the premise.

1.4 Scope of Study

This study will be conducted at the coil coating paint manufacturing premise located in Klang Valley. The plant is a manufacturing site for coil coating paints. The processes needed for coil coating paint manufacturing including grinding, color mixing, and final color adjustment. The coil coating paint produced will be supply to the coil coater industry.

Based on the data collected on the material used, waste generated and consumption of energy, cleaner production options will be proposed for the plant to reduce the carbon dioxide emission.

1.5 Report Outline

The research project composes of five chapters as stated below:

Chapter 1: Introduce the background of the research project. Overall view of coil coating paint manufacturing growth and what are the strategies used to reduce the emission of carbon dioxide. The problem statement, objectives of the research and scope of study are included in chapter 1.

Chapter 2: A literature review on the current situation of global warming and importance to reduce carbon dioxide. The overview of coil coating paint manufacturing process and related environmental issues. The greening strategies, cleaner production concepts, methodology to achieve cleaner production and case studies of CP in paint manufacturing will be included in this chapter. The summary of the literature review will summarize the findings in the literature.

Chapter 3: Introduce the methodology of cleaner production audit, develop suitable cleaner production options and evaluate cleaner production options. The methodology to prioritize which CP options and the profile of premise and safety precaution. This chapter will explain the data collection.

Chapter 4: The information and data collected were analyzed and evaluated. Data were presented in the form of table and charts. The result of CP audit and carbon footprint calculation will include in this chapter. The environmental issues and opportunity for the greening of the selected premise and CP options were suggested to achieve the objective of the study. The plan of CP options implementation and monitoring and overall opportunity for Malaysia were discussed this is chapter.

Chapter 5: Conclusion of the research to summarize the finding and proposed a recommendation for future study.

CHAPTER 2: LITERATURE REVIEW

2.1 Global Warming

Global warming is a worldwide issue that related to the environment. This issue creating adverse effects on the humankind and environment. According to Worldometers (2018), the current world population is 7.7 billion as of September 2018. The world population is expected to range up to 8 billion people in 2023 (Worldometers, 2018). The increase in world population leads to greater food and products consumption. This will eventually generate a high quantity of waste which causing impact on the environment (Severo, de Guimaraes, & Dorion, 2018). According to NOAA Climate (2018), the global typical atmospheric carbon dioxide in 2016 was 402.9 ppm with a range of uncertainty of plus or minus 0.1 ppm. The carbon dioxide concentration is increasing generally because of the burning of fossil fuels by people for energy. Coal and oil that contain carbon that plant absorbed out from the atmosphere through photosynthesis over millions of years (Lindsey, 2018). European Project for Ice Coring in Antarctica (EPICA) had collected ice core data for the level for atmospheric carbon dioxide. Based on the data from EPICA, the level for atmospheric carbon dioxide is below 300ppm but it reaches 405.0 ppm in 2017.

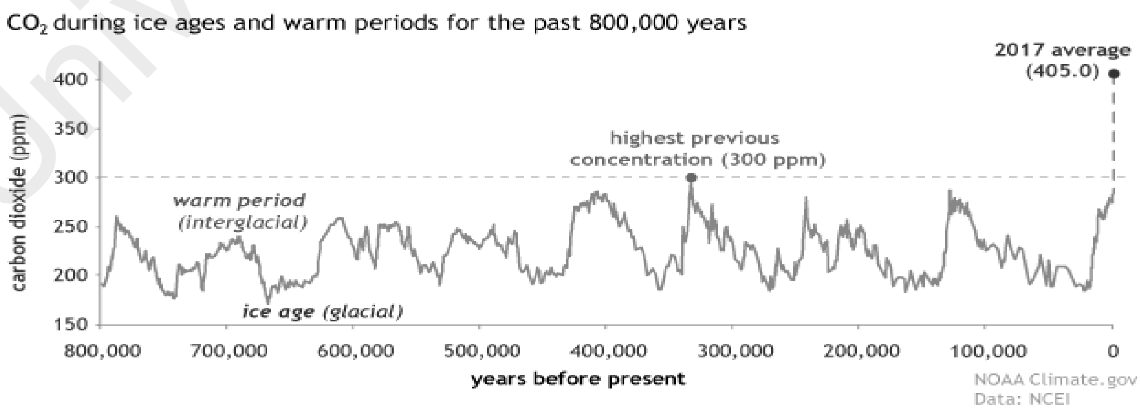


Figure 2.1.1: The concentration of carbon dioxide concentration in parts per million (ppm) for the past 800,000 years.

Source: (Lindsey, 2018)

In recent years, the occurrence of lighting floods, droughts, tropical cyclones, and landslides had caused an impact to affected countries in the aspect of politic and economic, life quality and public health. The sea level at Southeast Asia is predicted to be increased about 3-16 cm by 2030 and 7-50 cm by 2070. The major contributors of CO_2 in Southeast Asia are power generation plant, a production that using heat, manufacturing, construction, and transportation. Chemical, petrochemical, steel and iron, cement, paper and pulp, and other metal and minerals industries often emitted a high amount of CO_2 to the environment (Lee, Sethupathi, Lee, Bhatia, & Mohamed, 2013).

The rapid industrial development and human population growth in developing countries, production waste is significantly increasing along with development and growth. In Malaysia, based on the current waste generation rate of 1kg per person per day, the municipal solid waste is expected to exceed 9 Mt per year by 2020. There are almost 90% of the waste is disposed through landfill which can release a significant quantity of GHGs due to the decomposition of the solid waste (Bong, et al., 2016). The GHGs that releases to the environment will accumulate at the atmosphere. The accumulated of GHGs had caused an impact on the global average land temperature. Based on the data from NOAA (2018) in figure 2.1.2, the global average land temperature had increased from 0.73℃ in the year of 2000 to 1.06℃ in August 2018.

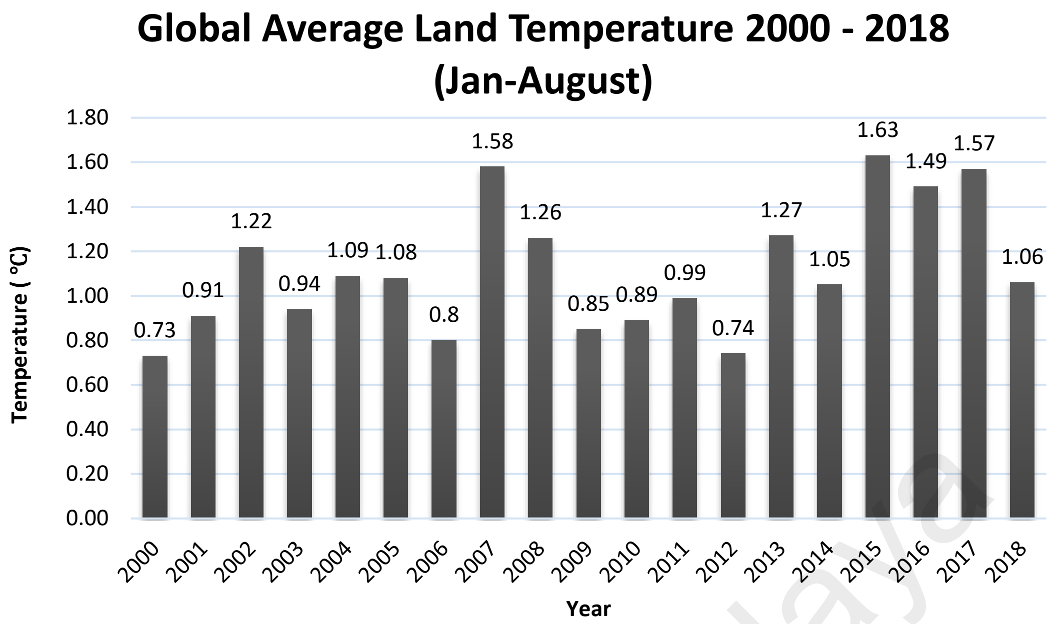


Figure 2.1.2: Global average land temperature from the year 2000 to 2018 from January to August.

Source: (NOAA National Centers for Environment Information, 2018)**.**

2.2 Carbon Footprint

Carbon footprint is defined as the total greenhouse gas emission from industrial activities, civilization, and human activities. It commonly expressed in equivalent tons of carbon dioxide (CO_2). This emission had global warming potential. Carbon footprint often used as a method to quantify the amount of GHGs emission to the environment. Carbon footprint will convert the GHGs which contribute to global warming into CO_2 equivalents (Balaguera, Carvajal, Alberti, & Fullana-i-Palmer, 2018).

Southeast Asia countries are a small contributor to the world's carbon dioxide (CO_2) emission compare to the big contributor which are China and United States. In the year of 2006, China contributes 6103.49 million ton of CO_2 and United States contribute 5975.10 million ton of CO_2.

The increase of CO_2 emission in Southeast Asia was related to the development of industry in the countries (Lee, Sethupathi, Lee, Bhatia, & Mohamed, 2013). This issue requires attention to reduce CO_2 emission in Southeast Asia. To meet a balance between sustainable development and reducing CO_2 emission in the country has become a hard-hitting task for most Southeast Asia countries.

CO_2 gives the greatest influence in global warming due to the emission to the atmosphere is comparatively higher compared to other GHGs. Based on Figure 2.2.1, generally, energy industries, transport and manufacturing, and construction were found to be the major source for CO_2 emission for Malaysia (Ministry of Natural Resources and Environment Malaysia, 2015).

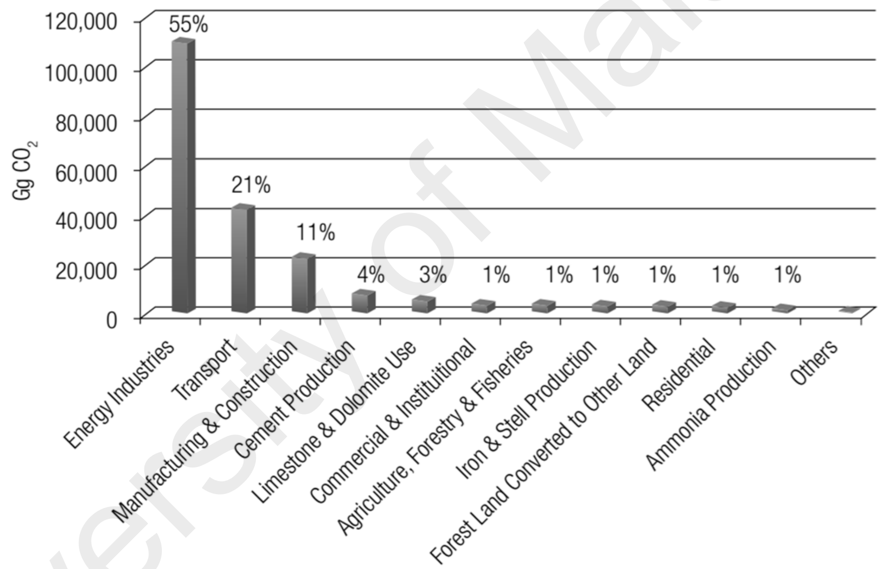


Figure 2.2.1: Major sources of carbon dioxide emission in 2011.

Source: (Ministry of Natural Resources and Environment Malaysia, 2015)

As shown in Figure 2.2.2, in 1970, the CO_2 emission intensity for Malaysia was 0.33 tonne CO_2/1000 USD. (Knoema, 2018). The first data on the CO_2 emission intensity was recorded in 1970 and the CO_2 emission intensity decreased to 0.24 tonne CO_2/1000 USD in 1973,1975,1977 and 1985. The carbon emission intensity was showing a trend of increasing and reached the highest value of 0.38 tonne CO_2/1000 USD in 2008. After

2008, the CO_2 emission intensity showing a decreasing trend and in 2016, the value had decreased to 0.33 tonne CO_2/1000 USD.

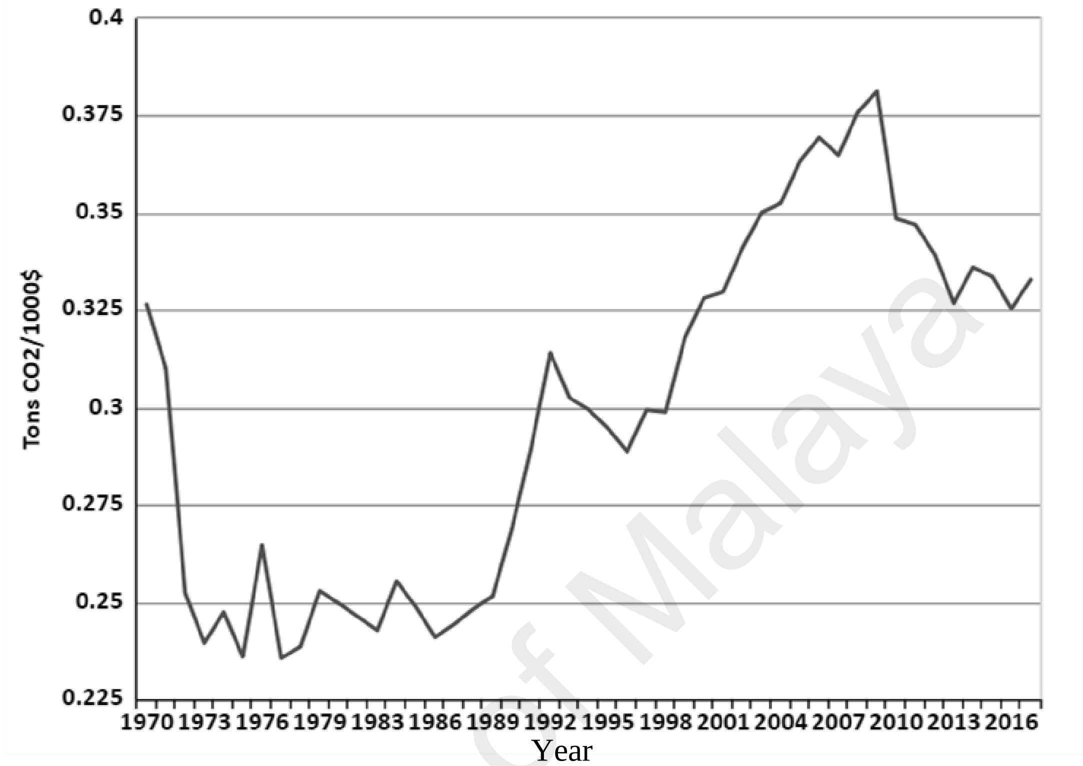


Figure 2.2.2: The graph of the carbon dioxide emission intensity from 1970 to 2016 in Malaysia.

Source: (Knoema, 2018)

There are paint manufacturers self-initiate to reduce carbon emission from their manufacturing activity. For example, Beckers Group, PPG, and AkzoNobel. Beckers Group had successfully reduced 13% carbon emission per ton of product within 4 years. Beckers Group had completed their first solar panel project at Malaysia site and it gives clean energy resources to support the operation. The successful solar panel project had inspired the organization to explore more opportunities to install more clean energy resources across their business site to reduce the carbon emission.

PPG who is a global manufacturer of flat glass, fibre glass, fabricated glass products, industrial coatings and resins, and industrial specialty chemicals had successfully reduced

46% of carbon emission in 5 years. PPG's research and innovation centre focus to develop their product to be more sustainable, durable, and less waste generated while application.

AkzoNobel the experts in making paints and coatings, they had reduced 7% of carbon footprint within 7 years. They focus on cradle-to-grave carbon emission reduction; therefore, they focus on reformulation their new product and raw material to a lower carbon footprint. AkzoNobel had set a high target of carbon footprint to reduce approximate 25-30% per ton of products.

2.3 Coil Coating Paint Manufacturing Process

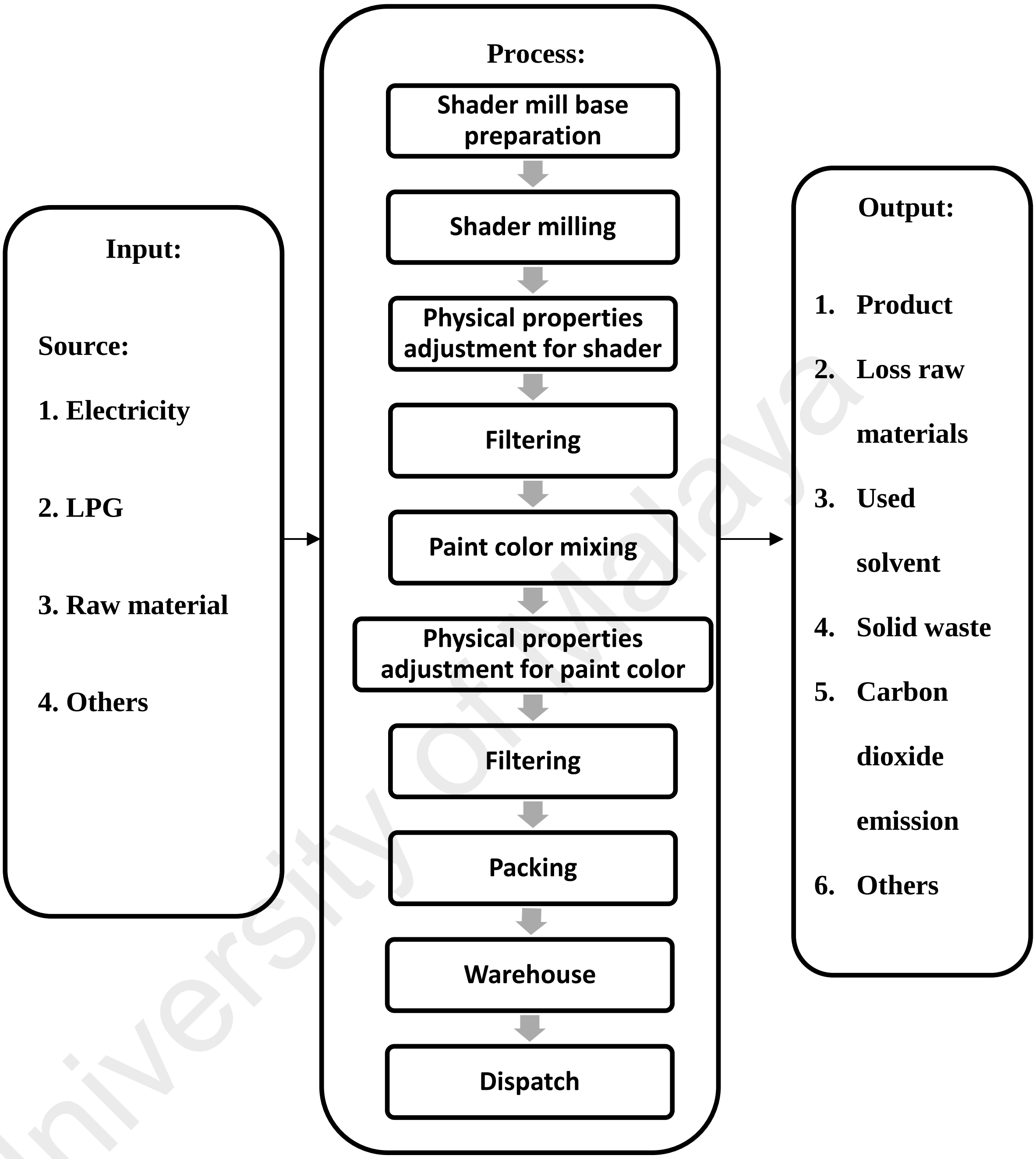


Figure 2.3: The process flow of coil coating paint manufacturing process.

Coil coating paint manufacturing process needs input from raw materials, non-electricity, fuel, and other resources to produce coil coating paint. The output generated from the process includes product, loss of raw materials, used solvents, solid waste, CO_2 emission and others. Total of 10 steps needed in the process to produce coil coating paint. Shader mill base preparation is the first step in the process. All required raw material will be prepared in production equipment and proceed for shader milling. Shader milling and physical properties adjustment for shader will take about several hours to complete and it will be confirming through quality inspection. When the shader is ready to be use, it will be filter and store for color mixing. When the paint color mixing is complete, the physical properties of the paint color will be adjusted according to the product specification and filter before proceeding for packing. The finished goods will be stored at the warehouse and arrange for dispatch according to order.

2.4 Environmental Issues

The coil coating paint is known to be widely used to develop architecture design. During the manufacturing process of coil coating paint, it contributes to air pollution, land pollution, and the greenhouse effect. The manufacturing process involves chemical as raw material, LPG, and electricity as input. To produce coil coating paint, the raw materials required including color pigment, resin, solvent, and additives. The color pigment to provide color, hiding performance and gloss level. Color pigments that commonly use are titanium dioxide, chrome green oxide, yellow and red iron oxides. The resin is used as a binder to ensure the pigment particles adhere to the substrate. Epoxy, alkyd resin and urethane are widely used as a binder in coil coating paint. The solvent will act as a carrier for the colour pigment and resin. Xylene and toluene are examples of the solvent used in coil coating paint. To enhance the coil coating paint performance additives will be added (Porwal, 2015).

Most of the raw materials including solvents, pigment, resin, and additives used are not environmental friendly. The conventional paint contains high VOCs which is approximately 50% VOCs in the product (ABB, n.d.). As the paint dries, it emits VOCs to the air and in the presence of nitrogen oxide and radiation, the VOCs will react with oxygen in the air and form ozone (Porwal, 2015). Therefore, the coil coating paint manufacturing premise plays an important role in identifying the environmental impact of their products.

In the process of shader mill base preparation, raw material packaging will be generated as schedule waste and ended up in a landfill. This will create adverse effect on the environment as decomposing the waste takes a long time to break down. Another source of the environmental impact is the used solvent generated during the manufacturing process. The solvents are used as a cleaning solvent to clean the equipment and tools. During the stage of product physical properties inspection, there is waste generated such as used coated galvanize iron, used paint, paper and tissue contaminated by paint and used solvent. To support the physical properties inspection, a high-temperature oven is required to cure the paint. During the paint curing, it needs a high amount of electricity to maintain the oven temperature and emission of VOCs from paint curing.

According to Paint & Coating Industry (2015), the carbon footprint that emits by coating manufacturing from cradle to grave is generally 10% of the carbon footprint of coatings is generated during formulation, with 50% generated upstream under raw material manufacturing premise and 40% generated downstream in use and disposal (Mash, 2015). The amount of CO_2 emitted to the environment due to coil coating paint manufacturing activities is high and it forms an invisible layer around the earth. This layer of CO_2 will retain the heat inside the earth and this process is known as the Greenhouse effect. The consequences of the greenhouse effect include climates changes in various countries. The amount of rainfall also rises globally and extreme weather occurs more often. The ocean water will become more acidic and eventually will affect the coral reef and species lives underwater. Due to climate changes, many animals unable to live in a natural environment and eventually this will cause a distinction between many species (Carbon Stock Editor, 2018).

2.5 Greening Strategies

Greening strategies are widely used to reduce the emission of greenhouse gasses. In Malaysia, the strategies that adapted are the development of renewable energy and cleaner production. The renewable energies that currently available in Malaysia are wind, solar, biomass and hydro (Lee, Sethupathi, Lee, Bhatia, & Mohamed, 2013).

Developing countries in Southeast Asia which include Singapore, Malaysia, Thailand, Vietnam, Indonesia, Philippines, and Laos need to develop their industrial sector to improve poverty, deliver goods and services, create job opportunities, and improve the standard of living. However, many countries face severe environmental pollution and resources depletion, which threaten opportunities for sustainable economic growth. Green strategies promote sustainable methods of production and consumption. These methods involving the aspect of resource and energy-efficient, low carbon emission and low waste generation, no pollution and safe, and which produce products that are responsibly managed throughout the life cycle (UNIDO, 2011).

The scope of green strategies covers from product development to management of the complete product life cycle including such environmental practices such as eco-design, clean production, recycling, and reuse with a focus on minimizing the expenses associated with manufacturing, distribution, use, and disposal of products. Green strategies focus on both product and product-oriented environmental practices. Green strategies ensure quality and environmental conformance, preventing negative corporate reputation by environmentally friendly products. In the process of green strategies implementation, it focusses on closed-loop processes that involve practices like recovery and recycling to reduce waste, capture the residual value of products and deploy environmental technology and cleaner transportation in the downstream supply chain for pollution prevention. The green strategies can lead to a shorten the life cycle of the product and reduces the cost of the product. The established policies ensure the producer and the consumer greater responsibility for the safe disposition of their products (Paul, Bhole, & Chaudhari, 2014).

To enhance the level of 'green' in the country, Malaysia's government had put in the effort to establish new policies, acts, and law to reduce the CO_2 emission (Lee, Sethupathi, Lee, Bhatia, & Mohamed, 2013). Based on Table 2.1, the Malaysia government had established policies, act and regulation to ensure the process and development is environmentally friendly and cost-effective.

Table 2.1: Relevant policies/acts/regulations in Malaysia that will reduce CO_2 emission.

Policies/Acts/Regulations	**Aims/Objectives**
National Energy Policy	- To promise the sufficient, safe, cost-effective and diverse sources of energy supplies. - To promote the efficient utilization of energy and environmental protection are considered in the production and use of energy.
Five-Fuel Policy 2002	- To reduce the dependence on oil as an energy source by optimizing the fuel mix up with oil, gas, hydro-electric and coal and renewable energy.
Efficient Management of Electrical Energy Regulation 2008	- To implement efficient electrical energy management.

Policies/Acts/Regulations	Aims/Objectives
National Green Technology Policy 2009	- To promote the development of green technology activities toward sustainable development in energy, environment, economy, and society.
Malaysia National Renewable Energy Policy and Action Plan 2010	- To enhance the utilization of indigenous renewable energy sources to contribute towards national electricity supply security and sustainable socio-economic development
Renewable Energy Act 2011	- To provide the establishment and implementation of a special tariff system to catalyse the generation of renewable energy and to provide for the related matters.
Sustainable Energy Development Authority Act 2011	- To provide the establishment of the Sustainable Energy Development Authority of Malaysia and to provide for its functions and powers and for related matters.

Source: (Lee, Sethupathi, Lee, Bhatia, & Mohamed, 2013)

The establish of relevant policies, acts, and regulation in Malaysia had promoted awareness among the manufacturer, public and investor on environmental protection. For instance, the implementation of efficient management of electrical energy regulations 2008 help to manage the industry who use equal or more than 3,000,000 kWh shall comply to electrical energy management by appointing a competent electrical energy manager. The electrical energy manager is responsible to audit and analyse on the electrical energy consumption, advice on the electrical energy efficiency and monitor the effective implementation of electrical energy management programme (Suruhanjaya Tenage, 2008).

2.6 Cleaner Production Strategy

The Department of Environment Malaysia strongly recommends the cleaner production strategy. CP was defined by UNEP as an integrated strategy for minimization of residual and risk for products, process, and service as well as increasing the production efficiency in 1989. CP concept and strategy was launch in 1996 under supports from Department of Environmental Malaysia (DOE), Standards and Industrial Research Institute of Malaysia (SIRIM) and international funding agencies such as Danish International Development Agency (DANIDA). The adoption of CP mostly performed by the large organization but not in Small and Medium Industries (SMIs). Small and Medium Industries are facing challenges to adapt CP strategy in term of awareness, finances, and resources. CP is friendly to the environment simply by reducing the waste and consuming the pollutant. The impact on the environment can be diminished by reducing the demand on non-renewable resources, recycling and reusing products and resources (Department of Environment, Ministry of Natural Resources & Environment, Malaysia, 2010).

In the 20th century, growth in worldwide to change the way industries interacts with the environment and paradigm shift from pollution control to pollution prevention. Pollution prevention involves process improvement, practices, or materials that minimize or eliminate the source of pollution or waste. Cleaner production fits with pollution prevention concept and commit toward prevention, rather than control the pollution. Cleaner production refers to the continuous implementation of an integrated pollution prevention strategy to processes and products to reduce risks to humans and the environment. Cleaner production includes conserving natural resources and energy, eliminating toxic materials and reduce the quantity and toxicity of all emissions (Nilsson, Persson, Ryden, Darozhka, & Zaliauskieme, 2007).

The use of cleaner production strategies will help the industry to identify the source of wastage and pollution and maximize the output with minimal input. Conventional strategies focus on environmental pollution control without considering the quantity or amount of waste generated. The awareness and enforcement in Malaysia are focus on the handling of generated waste. Handling of the generated waste is insufficient to protect the environment, therefore moving forward to pollution prevention is a global trend and been promote to worldwide. Environmental pollution prevention includes CP strategies that promote the identification of the input, process, and output in their manufacturing activities. In CP strategies, the analysis must be done to the identified and evaluate the source of pollution and appropriate actions were taken to minimize the emission.

2.7 Cleaner Production Strategies Implementation Methodology

Cleaner production strategies are referring to the management of resources in a more efficient method. These consists of careful use of resources, the closing of material streams, and resource substitution. There are five general principles of cleaner production as stated below (Nilson, Persson, Ryden, Darozhka, & Zallausklene, 2007):

1. Input Substitution

   Input substitution is the substitution of hazardous material to a less hazardous option. For example, the substitute the use of solvent with high VOC emission with a lower VOC emission solvent for environmental and health protection.

2. Good Housekeeping

Good housekeeping will increase the material and energy efficiency in the process. For instance, the equipment that did not switch off after use will cause energy waste during the idle time of the equipment.

3. Internal Recycling

The used materials and energies can possess the potential to recycle internally for different operation process. For example, containers, water, solvents and others. The solvents that use for equipment cleaning can recycle internally for few times for the cleaning purpose before dispose.

4. Technological Optimisation

In the technological optimisation, it can be performed in a few ways which including implementation of new technologies, improved process control and re-design of processes. For instance, the equipment with outdated specification can be upgraded for a better specification to improve efficiency.

5. Optimisation of the Product

Cleaner production focus to increase the lifetime of the product, easier repair, easier to rework, recycling or dispose and the usage of non-hazardous materials. The implementation of CP in a company can be initiated by getting to know the process. The important tasks are as below (Nilson, Persson, Ryden, Darozhka, & Zallausklene, 2007):

1. Define processing activities.
2. Understand the process with its chemical and physical activities.

3. Draw a flow chart with all input and output stream and all interrelationships in term of quantitative.
4. Focus on the most important material streams.
5. Study the existing cross-media effects.

The implementation of CP will be initiated from data collection through an audit, interview, and observation. The collected data will by analyse and proposed CP options accordingly. The proposed CP options were evaluated its feasibility and ROI before implementation. The CP options will be prioritized for implementation according to the feasibility and ROI.

2.8 Case Studies of Premises Using CP Strategy

Manufacturing premises have developed green initiatives to minimize the environmental impact and change the direction of business development to sustainable process and product. The green initiatives carried out by the manufacturer from different business nature using CP strategies were studied for further research.

2.8.1 Green initiatives in Beckers Group

Beckers Group is a global coatings manufacturer that develops environmental friendly paint systems. Beckers Group structures their business into three segments that are coil coatings, industrial coatings, and consumer design finishes. Beckers Group committed to set new standards in product innovation, customer relationships and sustainable business development. Environmental responsibility had integrated into Beckers Group mission through long-term, sustainable development and life-cycle thinking in their business strategy, operations, product, and service development.

Beckers Group had quantified their reused waste for the first time in 2017 to reduce the total waste generated and burden to the environment. They successfully identified

1547 ton of reused waste from a total waste of 8253 ton. The total waste generated had been reducing from 2013 to the current year 2017. In term of energy management, Beckers Group had moving toward renewable energy to substitute the usage of non-renewable energy. They had successfully reduced the non-renewable energy usage from 93% to 70% through operation process change and technology change. In August 2017, they had installed 300 solar panels with a capacity of 100 kWp at Malaysia site. Renewable energy had successfully reduced the cost of electricity by about 10% within four months.

Beckers Group also successfully reduce carbon emission by 3% per ton of product in 2017 compared to 2016. They target to reduce the VOCs emission from their production site through substitute the high-solvent cleaning system with a low-solvent cleaning system, solvent reused and on-site solvent distillation to regenerate the solvent for internal reuse. They are targeting fully integrate the idea of sustainability in their business development, more sustainable products and solutions, green energy management and social sustainability integration (Beckers Group, 2017).

2.8.2 Green Initiatives in BASF

BASF is a leading chemical manufacturing that had product ranges from chemicals, plastics, performance products, and crop protection products to oil and gas. BASF combines economic success with environmental protection and responsibility. BASF systematically address environment, health, safety and security risk with a comprehensive Responsible Care Management System. BASF is an energy-intensive company, they are committed to reduce the emissions along the value chain and utilize. BASF had the initiative to replace a higher efficiency combined heat and power plants with gas and steam turbines and on the use of heat released by production processes. The emission of

GHGs per metric tonne of sales product in BASF operation excluding oil and gas had been reduced by 35.5% in 2017 compared to the 2002 baseline.

In additional, BASF concern on sustainable water management at all production sites in a water stress area. BASF total water usage in 2017 is 1,816 million cubic meters. They have taken the initiatives to use the alternative source of water to support some of their operation sites such as treated municipal wastewater, brackish water or seawater to reduce the input of freshwater at their operation sites. At BASF, they identified that 87% of water input is for cooling purposes for plant re-cooling. To maximize the water input, BASF had recirculated the water within their operation for several times before discharged (BASF, 2017).

2.8.3 Green Initiative in PPG

PPG is a global manufacturer of flat glass, fibre glass, fabricated glass products, industrial coatings and resins, and industrial specialty chemicals. They started the coating business by the early 20th century. They committed to delivering high quality, innovative and sustainable solutions that customers trust to protect and beautify their products and surroundings. PPG had successfully reduced 15% of waste disposal since 2012, a 46% reduction in greenhouse gas emission intensity since 2012. PPG minimizing the carbon footprint of their operations that includes manufacturing sites to distribution centres, retail stores, and transportation. Their research and innovation centre also work hard to develop the product that is sustainable, durable and less waste generated while application. With this target, they are successfully increasing the sales of sustainable-advantaged products and process to 60% percent compared to 2012.

PPG target to reduce the total waste disposal through a change in their manufacturing processes with the concept of eliminating, minimizing, reusing and recycling the waste material generated from the process. PPG uses the methodologies of lean manufacturing in each facility to eliminate or minimize the identified waste and explore the reuse and recycling options for wastes. In 2017, they successful reduce waste by 19% compared to 2012.

PPG also took some actions to reduce the usage of energy that included:

1. Replacing seven diesel vehicles with hybrid cars
2. Using LED lights in place of fluorescent fixtures
3. Installing more energy-efficient air conditioners
4. Replacing a thermal diesel forklift with an electric forklift
5. Monitoring fuel consumption of non-electric forklift

The actions taken had reduced 15% of the energy consumption intensity in 2017. PPG also set a new goal to increase renewable energy to 25% of total electricity usage exclusive of GHGs reductions by 2025.

PPG also establish relative water risks in their portfolio and rank their sites based on water usage, scarcity risk, and other factors. Although they are moving toward manufacturing more water-based coatings compare to solvent-based to reduce the VOCs emission which will lead to an increase in water consumption but the net environmental benefit will be positive. They success reduce the water consumption by 35% compared to 2012 and 4% compared to 2016.

2.8.4 Green Initiative in AkzoNobel

AkzoNobel is experts in the making paints and coatings, setting the standard in color and protections since 1792. Their brands are trusted by customers around the world. AkzoNobel committed to developing their business in a sustainable direction. They also claimed that sustainability is the heart of everything that they do at AkzoNobel. They committed to producing more output and value with fewer resources.

In the year of 2017, they had successfully reduced the cradle-to-grave carbon footprint per tonne of sold product by 7% since 2012 through reformulations using lower footprint raw materials and new products with customer benefits. Carbon emission from their production is 9% lower than in 2016. AkzoNobel had set a target to reduce their product cradle-to-grave carbon footprint by 25-30% per ton of sales between 2012 and 2020 including the impact of VOCs emissions. The environmental impact caused by the used of raw materials also contributes to the cradle-to-grave carbon footprint. In 2017, 11% of their organic raw material that came from renewable sources.

The energy they use at their site contribute about 15% to the cradle-to-grave carbon footprint. The initiative they have taken is to substitute the non-renewable energy to renewable energy and it had become an important aspect of the improvement required to reduce the carbon footprint. The proportion of renewable energy in AkzoNobel operations increase to 45%.

AkzoNobel had established an operational eco-efficiency program to increase the efficiency in the use of raw materials and energy and decrease emissions and waste in their operations. In 2017, they further improved their eco-efficiency and resulting in an increase of 31% since 2009 with significant improvements on the individual eco-efficiency parameters, such as waste, VOCs, CO_2, NO, and SO_X emissions.

AkzoNobel had set a target is to drive towards ‘zero waste to landfill’ and a program is being developed to achieve this with specific projects. The total waste per ton of production generated and leaving from AkzoNobel site decreased 5%, while total waste volume decreased 4%.

Table 2.2 had summarized the green initiatives in Beckers Groups, BASF, PPG, and AkzoNobel. The green initiatives taken by them had decreased the waste, CO_2

emission and increase production efficiency. They are moving forward to minimize the usage of non-renewable energy and utilize renewable energy in their operation. They also implement the 3R programme to manage their waste.

Table 2.2: Summary of Green Initiatives in Beckers Group, BASF, PPG, and AkzoNobel.

Company	No. of year	Green initiatives
Beckers Group	4 years	• 19% of waste generated are reused. • 20% usage of renewable energy in operation. • 3 % CO_2 emission reduction per ton of product. • Substitute high-solvent cleaning system to a low-solvent cleaning system.
BASF	15 years	• Replace a higher efficiency combined heat and power plants with gas and steam turbines. • 35.5% of GHGs reduction per tonne of sales product. • Recycle water within their operation for several times before discharged.
PPG	5 years	• 15% of waste disposal reduction • 46% GHGs emission reduction • 15% of energy consumption reduces • 25% renewable energy use for the operation • 35% reduction of water consumption

AkzoNobel	5 years	• 7% carbon footprint reduction per ton of product sold. • 11% of their organic raw materials came from renewable sources. • 45% of renewable energy used for the operation. • 5% of waste reduction

2.9 Summary of Literature Review

The literature review had discussed the current condition of global warming and environmental impact. The manufacturing process in coil coating paint and coatings manufacture industry, green initiatives, material and resource consumptions, and waste generated are discussed in this chapter. The information provided in the literature review is adequate to use in this study. The emission of CO_2 from industrial activities had been identified as one of the causes of global warming. The environmental issues contributed by coil coating paint manufacturing process are discussed here. Establishment of green strategies by Malaysia's government that includes policies, act, and regulation aims to reduce the emission of CO_2 from all industrial and human activities. The possible CP options to minimize the environmental impact from manufacturing activities are further discussed. The CP options implemented in other industries include the management of resources, change in operation design, technology, and operation process through the concept of reducing, reuse, recycle and substitution. The reviewed literature discussed manufacturers had realized the importance of sustainable business development. The green initiatives taken by the manufacturer to reduce the environmental impact and CO_2 emission of their product will be used as a reference in this study. The review had provided an overview of green initiatives implemented by Beckers Group, BASF, PPG, and AkzoNobel. The green initiatives taken by the company had successfully reduced the emission of CO_2 per unit of product. The CO_2 generating activities included waste generated from the manufacturing process, water usage, chemical usage, solid and liquid waste, and electrical energy. It is important to understand and explore the possible green initiatives that can be implemented in similar manufacturing premise to minimize the environmental impact and reduce the emission CO_2 of the product as well as improve the resource and process efficiency.

CHAPTER 3: MATERIAL AND METHODOLOGY

3.1 General Research Methodology

Figure 3.1 below describe the methodology for this study. The research started with literature research follow by premise selection. CP audit will be plan and perform on-site and the result of the audit will be analysed. The analysis result will be used for carbon footprint estimation and CP options generation and evaluation.

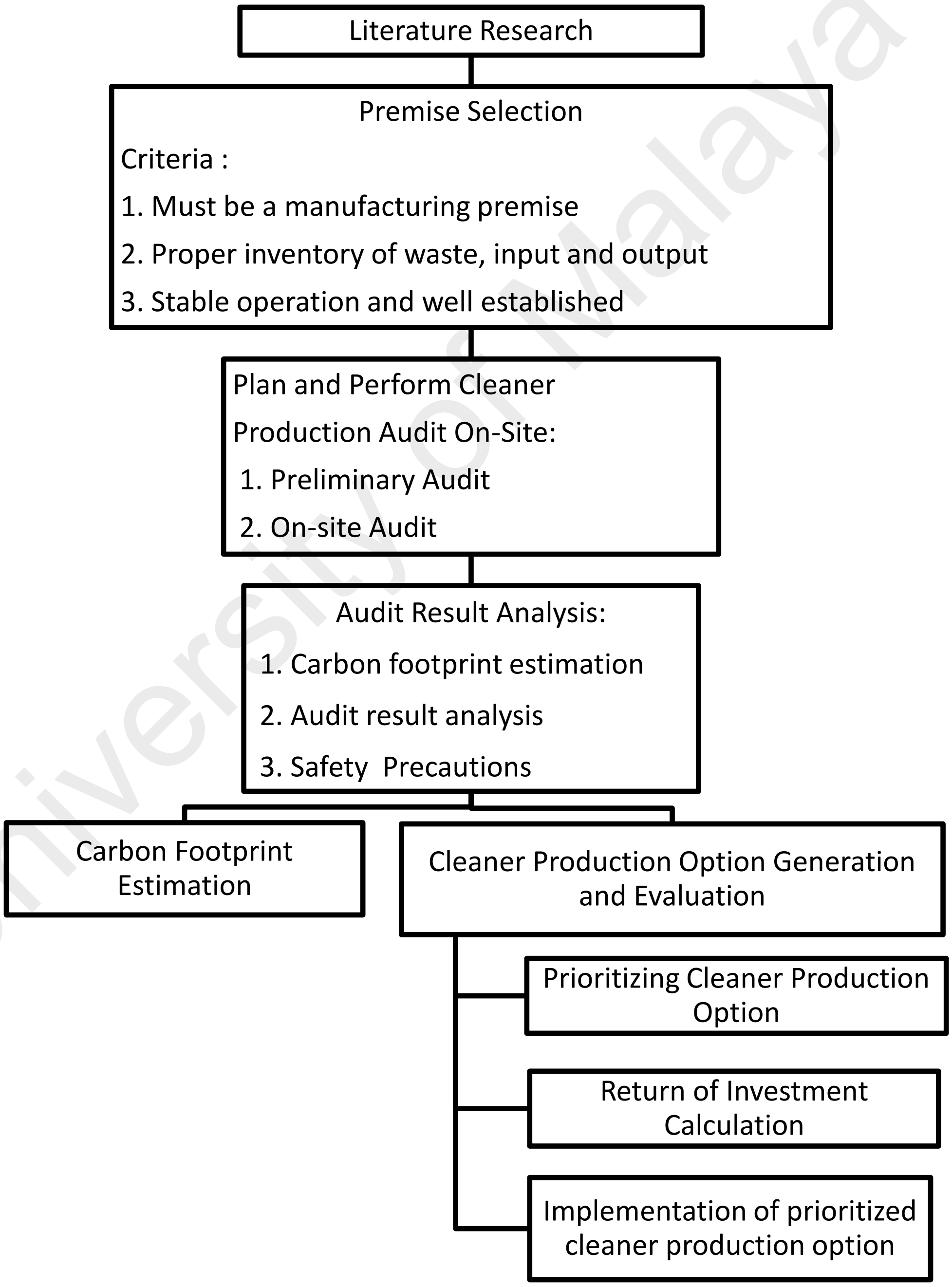


Figure 3.1 General methodology of the research project.

The CP audit perform on-site is based on observation, interview employee, and data collection from key personnel. The limitation encountered during data collection is the selected premise do not record the usage of water usage for non-process. Therefore, water usage for non-process is excluded from carbon footprint estimation.

3.2 Premise Selection

A coil coating paint manufacturing has been chosen to conduct the study. This premise was selected due to the well-established and stable operation. They have good and proper record keeping system to monitor their operation, process, and waste generation. Permission was granted by the management to conduct this research. As per request by the company, the identity of the company will not be disclosed and identified as XYZ Sdn. Bhd.

3.3 Information of Premise

This premise is located at Shah Alam which manufactures coil coating paint. The plants operate 12 hours per day and about 60 employees. The premise manufacture about 125 batches of coil coating paint per week which is equal to 125 tonnes.

3.4 Cleaner Production Audit Methodology

3.4.1 Audit Plan

The CP audit is started from the planning of audit followed by the execution of the audit. The planning for the CP audit is important to ensure the audit process is smooth and effective. The scope, objective, and the requirement must be clearly defined. A CP team was formed to conduct the CP audit. The members of the CP team are from different functions which include production, safety, health and environment. and facilities and maintenance. The selected CP team members are experts in the operation and able to give a positive contribution to the CP audit and assist in CP options implementation. A CP audit schedule was prepared as shown in Table 3.1.

Table 3.1: CP Audit Plan Schedule

No.	Date	Activities
1	19th October 2018	Preliminary Visit i. To collect basic information on the premise ii. To identify the operation flow iii. To identify the type of facilities in the premise
2	18th January 2019	On-site audit which included a site visit and interview i. To observe and identify production process a. Material consumption b. Production output c. Electricity consumption d. Fuel consumption e. Solid waste and hazardous waste f. Safety and health ii. To identify the input and output of resources used in the production process
3	1st February 2019	CP option generation i. To study in the aspect of the environment, feasibility and technical study to identify feasible option.

3.4.2 Preliminary Audit

The preliminary audit was conducted to collect background information of the premise. The information collected included raw material used, operation hours of the premise, the total quantity of the product produced, and time needed to produce 1000kg of paint. The preliminary audit will be guided by CP team member from production and facilities and maintenance. An input and output process flow chart as shown in Figure 3.2 was obtained from the relevant personnel to further understand the operation.

Input	Process	Output
Raw Material, Forklift transport	Raw material receiving, testing, and storage ⬇	Used container, contaminated solid waste, raw material loss
Raw material, electricity	Shader mill base preparation ⬇	Raw material packaging material, raw material loss, hazardous solid waste
Raw Material, electricity	Physical properties adjustment for shader ⬇	Used solvent, raw material loss, hazardous solid waste
Disposable filter, electricity	Filtering ⬇	Used filter, raw material loss, hazardous solid waste
Electricity	Color Mixing ⬇	Raw material loss, used solvent, hazardous solid waste

Input	Process	Output
Solvent, electricity	Physical Properties adjustment for color ⬇	Used solvent, used container, hazardous solid waste
Disposable filter, electricity	Filtering ⬇	Used filter, raw material loss, hazardous solid waste
Packaging material	Packing ⬇	Packaging material residue
Forklift transport, electricity	Warehouse	Carbon dioxide emission

Figure 3.2: Input and output process flowchart for coil coating paint

3.4.3 On-Site Audit

The CP audit was conducted at the premise on 18th January 2019 through observation, interview, and walk through assessment in the premise. Interview conducted with the production manager, production supervisor, health, safety, and environment personnel, and facilities and maintenance team to understand the operation and process flow. The objective of the audit is to gather information of operation that includes the operation process, raw material usage, electricity consumption, fuel consumption, and waste generation and management. The information was collected based on the workflow, inventory record, and raw material management record. The audit form used in the audit is as in Appendix 1.

3.4.4 Audit Analysis

The compile audit findings were analysed for further study. The estimation method used for audit findings analysis are tabulated in Table 3.2.

Table 3.2: Estimation method for production activity.

I	Production	Estimation Method
a.	Raw material consumption	Quantity of raw material needed to produce 1000 kg of product
b.	Electricity consumption	Quantity of electricity consumption for operation (refer to premise utility bill)
c.	Fuel Consumption	Quantity of fuel needed to produce 1000 kg of product
d.	Solvent consumption	Quantity of solvent needed to produce 1000 kg of product
II	**Waste**	**Estimation Method**
a.	General waste	Waste generated from operation and non-operation
b.	Hazardous solid waste	Waste generated from the production process
c.	Hazardous liquid waste	Waste generated from the production process
III	**Others**	**Estimation Method**
a.	Operation cost	Production operation cost
b.	Production time per batch	Time required to produce one batch of product
c.	Safety issues	(1) Safety, health and environmental risks encountered during production activities. (2) Safety, health and environmental risk encountered at the manufacturing premise.

3.4.5 Carbon Footprint Estimation

Carbon footprint calculation will be used to estimate the GHGs emitted from the product life cycle. Carbon footprint calculation serves as an assessment tool for GHGs emission. Therefore, the result of the carbon footprint calculation is an indicator of sustainable development (Radu, Scrieciu, & Caracota, 2013). Intergovernmental Panel of Climate Change (IPCC) methodology is the most official reference and it is universally accepted for quantifying GHGs emitted from the product life cycle. The emission factors used in carbon footprint calculation are the values that correlate to the amount of pollutant emitted into the atmosphere and the associated activity to generate that type of pollutant (Radu, Scrieciu, & Caracota, 2013). IPCC method where CO_2 emission of an entity was calculated by multiplying the rate of consumption or generation with the entity emission factor. The entity emission factor used in the calculation is Malaysia emission factors, together with the default emission factors listed in the IPCC guidelines for National Greenhouse Gas Inventories (Rahim & Raman, 2017). The formula used for the study in IPCC methodology is written as in Equation (1):

$$\text{Total } CO_2 \text{ emission (kg } CO_2) = \sum (\text{Entity Data x Entity Emission Factor}) \text{ ------- (1)}$$

Table 3.3: Carbon Emission Factor

Resource and waste	Emission Factor	Unit
Electricity	0.67	kg CO_2/kWh
Fuel- LPG	1.53	kg CO_2/litre
Solid Waste	3.70	kg CO_2/kg
Solvent Waste	1.45	kg CO_2/litre

Source: (Rahim & Raman, 2015) and (IPCC Guidelines for National Greenhouse Gas Inventories, 2006)

3.5 Cleaner Production Option Generation

Upon the completion of the data collection, cleaner production options will be proposed according to the result of analysis for further improvement. Cleaner production is a relatively new concept that focuses on environment and energy protection which will not overlook the aspect of business continuity and profit. CP options can be generated based on the categories listed below:

i. Process / activity optimization

In common industries norm, process / activity optimization is conducted based on supplier or vendor recommendation or experienced staff, but the optimization may not be optimal and ideal for the process. Therefore, to reduce material and energy consumption processes and activities optimization are needed. The ideal processes and activities optimization can be achieved through studies and research.

ii. Process / procedure change

Process/procedure change can be used to generate CP options. The parameters or procedure used in daily operation such as a change in time, temperature, pressure, and the standard operating procedure can change to reduce consumption of energy and raw material as well as waste reduction.

iii. Design change / modification

Design change / modification referring to the change or modification of the machine or equipment used for processes and operation. The change or modification in design can result in a significant improvement if it implements properly.

iv. Housekeeping

Appropriate housekeeping for the work environment can create a clean and safe environment for all the employee to improve work efficiency and productivity. Therefore, the loss of materials can be minimize.

v. Material substitution

Material substitution is the most common method used to generate CP options. The materials used in the operation which includes raw materials, chemicals, additives and cleaning agents. The activity of material substitution may start with the research of existing material characteristic. If the characteristic of the material shows the impact to the environment and it is possible to replace the existing material to an environmentally friendly material, the substitution of material can be one of the methods to reduce the impact to the environment. The material substitution shall not affect the quality of the product.

vi. Technology change

The change in technology can be one of the options for cleaner production. There are various techniques available in the market to reduce the consumption of material and energy, reduce waste generation and improve the productivity of the operation.

vii. Recycling and reuse

The recycling and reuse of waste generated from operation process including office also consider as one of the cleaner production options to reduce the waste generated from the premise.

viii. Training and awareness programme for employee

The awareness enhancement for the employee through training is one of the categories to generate CP options. The employee who lacks CP awareness can be the reason of high waste generation and productivity reduction.

3.6 Cleaner Production Option Evaluation

Cleaner production options are generated based on the data collected from the selected premise. The generated CP options will be classified and implemented based on the priority. The classification of the CP options is through economic, environmental, and technical feasibility studies. The environmental feasibility study will focus on waste and pollution reduction. The technical feasibility study focuses on the practicability of the implemented CP options without effect the performance of the operation. Lastly, the economic feasibility study focuses on the cost of investment, the return of investment (ROI), and annual benefits. The estimated saving after the CP implementation should take into consideration for the feasibility study. Therefore, the selected CP options for implementation are based on minimal investment cost and a short period of time for the implementation process.

The technical evaluation for the CP options will separated into two sections. For the first section of the evaluation, the practicability, and consistency of the equipment. This evaluation covers the effect of the CP option on productivity and utility requirements. Besides that, any changes in the technical specifications of machines or technology shall take into consideration to reflect the input and output of the material and energy after the implementation of CP options.

The second section of the evaluation is the environmental evaluation. This evaluation aim to understand the environmental impact and aspect of the selected CP option. The environmental impact and aspect evaluation cover the potential reduction of CO_2, waste, and energy consumption by the selected CP options.

The prioritization of CP options is based on the criteria such as the return of investment, an improvement on product quality, minimization of the risk in premise, improve efficiency in production operation, minimization of the input to the operation, better motivation, minimization of the environmental issue, better working environment, and carbon footprint reduction.

The implementation of the CP options based on the evaluation and feasibility study below (COWI Consulting Engineers and Planners AS,Denmark):

A. Preliminary evaluation

The preliminary evaluation should involve the CP team and relevant personnel to provide an indication of which options are feasible to implement.

B. Technical evaluation

The technical evaluation will evaluate the potential impacts on products, operation process, and safety aspect of the proposed options. The innovation and process engineering may need to validate and verify the process does not affect product quality and efficiency prior implementation.

C. Economic evaluation

The economic evaluation will evaluate the cost-effectiveness of cleaner production options. The viability is the main parameter that determines whether the options should be implemented or not. The standard measure used in this study is the return of investment (ROI). The investment cost and annual saving are the elements used to calculate the ROI.

D. Environmental evaluation

The environmental evaluation is to determine the environmental impact and aspect of the CP options. The CP options that able to significantly reduce or minimize the environmental impact and aspect will be prioritized for implementation. For example, a great reduction in waste generated or reduction in carbon emission.

3.7 Payback Period Calculation

The payback period calculation is used in an organization for economic feasibility research. This calculation involved the estimation of the cost of investment needed for CP options implementation and identification of expected savings. The payback period is the time required to pay back the cost of investment through the return of investment (ROI). The CP options with shorter payback period are preferable in the project since the investment cost able to recover in a shorter period. The formula for payback period calculation as in Equation 2:

$$\text{Payback period in years} = \frac{\text{Total Investment}}{\text{Annual Savings}} \qquad (2)$$

3.8 Safety Precautions

A site visit and interviews are conducted to observe and gather information which covers from the start to end of the process in the operation. The scope covers the raw materials, electricity consumption, solid waste, and hazardous waste and safety and health and production output. During the site visit, the operation of the machine, production process, material handling, and storage are inspected. Safety handbook was given prior to entering the premise. The audit plan, audit checklist, and inspection area are prepared before the visit. The site visit should inform in advance to all operator who working at production. This is to ensure the operators are aware of the visit, interview, and understand the intention of the visit is to improve the operation process and workplace condition. The interview session with the operators who works at the production area should be carried out according to the time arrangement by the production supervisor to ensure the operation is not affected by the site visit and interview. The site visit and interview should be conducted on the day without any repairing and maintenance work are carried out at the operation area. During the site visit, the safety rules and practices that had been implemented and enforced must be followed. To enter the production site, wearing safety shoes, face mask and goggle are compulsory.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Audit Finding

Cleaner production audit was conducted in the premise as per the audit plan and scope in the coil coating paint manufacturing premise. The premise operates 12 hours per day and 7 days per week with 60 workers. The premise produces 125 batches per week which are equivalent to 125 tonnes. The time needed to produce one batch of coil coating paint is 12 hours. In this research, the material and energy consumption and process flow were identified and analysed. The audit findings are listed in Appendix 1. The CP options will be generated based on the analysis result and feasibility study for the CP options will be performed.

4.1.1 Electricity Consumption

In this study, the quantification of electricity was based on the monthly bill received from Tenaga National Berhad and the energy meter to measure the energy output from the solar panel. The premise had installed a solar panel to generate renewable electricity and the output from the solar panel will be used in the production. The audit finding analysis showed that a total of non-renewable electricity in the process is 66 x 10^3 kWh per month and 28 x 10^3 kWh per month in non-process and a total of renewable electricity is 3 x 10^3 kWh per month was 100% used in the process. The total non-renewable electricity consumption is 11.3 x 10^5 kWh per annum with the cost of RM 0.337 per kWh. The total annual cost of the electricity is RM 38,2225. The total electricity consumption includes machine operation, light, equipment operation, and air conditioner. The electricity consumption for each equipment is not able to measure due to lack of equipment to measure. Table 4.1 shows the energy consumption of renewable and non-renewable electricity used in production.

Table 4.1: Energy consumption of coil coating paint production on annual basis.

Energy Resources	Non-renewable electricity	Renewable electricity (kWh)
Annual consumption in process	794×10^3 kWh	388×10^3 kWh
Monthly consumption in process	66×10^3 kWh	3×10^3 kWh
Annual consumption in non-process	340×10^3 kWh	0
Monthly consumption in non-process	28×10^3 kWh	0
Unit cost	RM 0.337 / kWh	0
Annual Cost	RM 382,225	0

4.1.2 Raw Materials Consumption and Chemicals

Coil coating manufacturing premise use a large amount of chemical to produce coil coating paint. Based on the audit result, 1300 kg of raw materials used to produce 1000 kg of coil coating paint. During the production, there are about 10% of input loss to the packaging material, mixing area, grinding process, filtration and evaporation to the environment. Raw material storage area, production raw material preparation area, shader milling area, and packaging area were evaluated to determine the raw material and chemical losses. The raw materials and chemicals are in the paper bag and steel drum will transfer from warehouse to production raw material preparation area for raw material mixing and shader milling preparation. The raw materials and chemical will be weighed and poured to the grinding tank for shader milling. Based on the site audit, it was observed that the raw materials and chemical were loss when raw materials and chemicals poured into the tank, handling, and filtering. Under abnormal circumstances, raw materials and chemical can be lost due to contamination, spillage and expired.

4.1.3 Fuel Consumption

The premise used LPG as the fuel for forklift operation. The forklift will be used in warehouse and production to transport raw material, chemical and finish goods. The LPG usage was quantified based on the monthly purchase record of LPG. The audit shows that the monthly consumption 414kg which is about 29 cylinders of 14kg LPG with a total cost of RM 1,2425.00 per year. Table 4.2 shows the annual LPG consumption of coil coating paint production on an annual basis.

Table 4.2: Fuel consumption of coil coating paint production on annual basis.

Energy Resources	**LPG**
Annual consumption	4970 kg
Unit cost	RM 2.50 / kg
Annual Cost	RM 1,2425.00

4.1.4 Waste Generation

Scheduled waste is any waste that has hazardous characteristics and potential to effect to the environment and public health. There is a total of 77 types of schedule wastes listed in the First schedule of Environment Quality (Scheduled Waste) Regulations 2005. The waste generated in the coil coating paint manufacturing premise classified into two types which are liquid schedule waste and solid schedule waste. The quantity generated for each type of waste per annum were tabulated in table 4.3.

Table 4.3 Waste generated per annum

Type of waste	Quantity generated per annum (kg)
Liquid schedule waste	71,400
Solid schedule waste	24,800

The audit results show that the total liquid schedule waste is 71,400 kg per annum and 5950 kg per month. The liquid schedule waste included a used solvent, waste coil coating paint, expired raw material and solvent sludge. Based on the audit observation, used solvent, waste coil coating paint and solvent sludge have a higher contribution compare to the expired raw material. The solvent sludge is generated by the equipment of solvent recovery equipment in their premise. The equipment will separate the solvent from the used solvent. The particles that left in the equipment will be collected as solvent sludge and disposed as liquid schedule waste. For solid schedule waste is 24,800 kg per annum and 2067 kg per month. The solid schedule waste comprised of a contaminated container, contaminated substrate, contaminated gloves, paper and rags, and raw material packaging. There is no wastewater generated from the process as the coil coating paint is solvent based.

4.1.5 Safety, Health, and Environment Observation

During the audit, safety, health and environment observations in the operation were identified. The risk level of the identified safety, health, and environment observation were assessed for prioritization. The risk evaluation method is defined through likelihood and severity as in Figure 4.1 and the criteria for likelihood and severity are as below:

Likelihood	Severity				
	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Figure 4.1: Risk ranking for risk evaluation.

Source : (Murphy, 2016)

The risk level is defined through multiplying likelihood and severity and the criteria are listed below:

- Low (Risk level 1 - 4)
- Medium (Risk level 5 – 9)
- High (Risk level 10 – 25)

The likelihood criteria are as below:

1. Impossible to happen: Never will happen in the industry
2. Possible to happen: Happened at other industries before
3. Happened 1-2 times: Happened for 1 to 2 times in their operation before
4. Happened 3-5 times: Happened for 3 to 5 times in their operation before
5. Happened more than 5 times: Happened for more than 5 times in their operation before

The severity criteria are as below:

1. First aid treatment: Light injury that can be handled by first aid treatment.
2. Minor injury: Minor injury that needs to be handled by a medical practitioner and no hospitalization
3. Medical Treatment: Minor injury that needs to be handled by medical practitioner and less than 7 days hospitalization
4. Major injury: Major injury that needs to be handled by medical practitioner and more than 7 days hospitalization
5. Fatality: An occurrence of death

The risk assessment of listed safety, health, and environment observations identified in the coil coating manufacturing premise are listed in Table 4.4 below:

Table 4.4: Risk assessment of listed safety, health and environment observations identified in the coil coating manufacturing premise.

No.	Observation	Potential Risk	Likelihood	Severity	Risk Level
1.	No designated place to store PPE and lack of management system to manage inventory of PPE.	PPE contamination and lost of PPE	4	1	Low
2.	Lack of enforcement for PPE usage in operation.	Employee health risk	5	5	High

No.	Observation	Potential Risk	Likelihood	Severity	Risk Level
3.	Insufficient health hazard awareness program.	Employee health risk	4	5	High
4.	Lack of grounding system for equipment to discharge the electrostatic charge to the ground.	Fire hazard	3	5	High
5.	No first aid box installs in the production area	Unable to provide first aid treatment to employees when there is an injury happened	3	2	Medium
6.	No eyewash installs at the production area	Unable to provide first aid treatment if chemical splash into worker's eyes	2	4	Medium

No.	Observation	Potential Risk	Likelihood	Severity	Risk Level
7.	No proper labeling on waste disposal container to segregate hazardous waste and general waste.	The possibility of employee disposes hazardous waste into the bin for general waste.	5	1	Medium

Based on the risk assessment, there are three high-risk observation, three medium risk observation, and one low-risk observation. The identified three high-risk observation should put at the highest priority for action to minimize the risk followed by the three medium risk observation. For low-risk identified observation will be the lowest priority for further action.

4.2 Carbon Footprint Calculation per 1000kg of Product

The carbon footprint calculation had been conducted to estimate the emission of carbon dioxide from the operation. The CO_2 emission was estimated and calculated for electricity consumption, fuel consumption and scheduled waste generated. The formula used for carbon footprint calculation is as in Equation (3):

Total CO_2 emission (kg CO_2) = Total entity data x Emission factor -----------(3)

The CO_2 emission for 1000kg of coil coating paint is calculated for each identified source and tabulated in Table 4.5.

Table 4.5: Estimated CO_2 emission from 1000kg of coil coating paint

Source (Monthly consumption)	Carbon Emission Factor	CO_2 emission / month (kg CO_2)	CO_2 emission / 1000kg of coil coating paint	Percentage of CO_2 emission per 1000 kg of coil coating paint (%)
66 x 10^3 kWh Non-renewable electricity in process	0.67 kg CO_2/kWh	44 x 10^3	88.7	53.4
28 x 10^3 kWh Non-renewable electricity in non-process	0.67 kg CO_2/kWh	18 x 10^3	38.0	22.9
414.0 kg of LPG	1.53 kg CO_2/litre	1.2 x 10^3	2.4	1.5
5950 kg of liquid solvent waste	1.45 kg CO_2/litre	10.7 x 10^3	21.6	13.0
2067 kg of solid schedule waste	3.70 kg CO_2/kg	7.6 x 10^3	15.3	9.2
Total	-	81.5 x 10^3	166.0	100.0

Based on the result in Table 4.5, it shows that non-renewable electricity used for process and non-process contributes the highest CO_2 emission which is a total of 76.3% to produce 1000kg of coil coating paint. The second highest source that contributes CO_2 is liquid solvent waste (13.0 %) follow by solid waste (9.2%) and the lowest CO_2 emission is LPG (1.5%). Non-renewable electricity contributes the highest CO_2 because the equipment highly depends on the electricity as the energy source for production.

4.3 Cleaner Production Options Generation

CP options have been generated according to the audit findings and analysis to enhance production efficiency and minimize the emission of CO_2. Cleaner production has the advantages and benefits to maximize the product output and minimize waste generation and emission. The CP options generated for each source are based on the available technology, common practice in manufacturing and concept discussed in Chapter 3.5.

4.3.1 CP options for Non-renewable Electricity Consumption Reduction

CP Option 1

The non-renewable electricity consumption can be reduced by install additional solar panel system at the premise. The solar panel system can generate renewable electricity source from solar power and the output generated by the solar panel system can up to 1000 kWp. The current solar panel system not able to support most of the electricity needs for the operation. Therefore, expanding the current solar panel system to a 480kWp Solar PV system can reduce the consumption of non-renewable electricity and reduce the carbon emission. The 480 kWp solar system can generate approximate 56,000 kWh per month. In other words, it can reduce almost 59.2% of non-renewable electricity consumption and carbon emission per month. The investment cost and annual saving are calculated as below:

Investment cost: RM 1,000,000 / 480kWp Solar PV system after tax saving Annual Saving: RM 226,464 Payback period = Investment Cost / Annual Saving = RM1,000,000 / RM226,464 = 4.4 year

<u>CP Option 2</u>

The set temperature of the air conditioner should be optimized at temperature 24°C to 26°C. The comfortable temperature can reduce electricity consumption and wastage. According to Elankovan (2019), Tenaga National Berhad recommended the public to set their air conditioner at temperature of 24°C to 26°C. One degree of the air condition temperature increase can save up to 6% of energy (Kader, 2014). In the premise, the consumption of electricity supports office machinery, lights, air conditioners, computers, and others. Therefore, optimizing the temperature of air conditioner at 24°C to 26°C estimated can reduce by 6 % of non-renewable electricity consumption in non-process which is equivalent to 1.1 x 10^3 kg CO_2 per month.

<u>CP Option 3</u>

The light at premise was switch on for whole day long even though no people working in that area. The motion sensor can be installed for the light at area least activity to reduce the energy waste. With the motion sensor, the light can be automatically off when no motion detected and automatically on when there is motion detected. Based on the on-site observation, almost 50% of the area are not actively used. The light used in the site is 60-watt bulb, turning it off for one hour can save 0.06 kWh (Peters, 2017). Install the sensor can reduce the light daily operation time from 9 hours to 2 hours. Turning off the light for 7 hours per day can save a total of 25 kWh per day which is equivalent to 9000 kWh per year. The CO_2 emission estimated can be reduced by 7% per annum which is equivalent to 53 kg CO_2 per month.

Investment cost: RM 500 Annual Saving: RM 3033 Payback period = Investment Cost / Annual Saving =RM 500/RM 3033 = 0.2 years

<u>CP option 4</u>

Lean manufacturing tool can help to reduce waste generated, improve efficiency, and improve output performance. Implementation of the 7S framework is one of the common tools been used by the manufacturer to manage the workplace. The 7S framework includes seven different components that each start with letter S which are sort, set in order, shine, standardize, sustain, spirit and safety. In the component of sort, all the unneeded tools, equipment, parts are removed from the area. The component of set in order mentions that the remaining tools, equipment, and parts should be stored in a designated place which is near to its work area and convenient to retrieve. Next component, shine is referring to the work area, tools, equipment, and parts must be clean as the work performed. The fourth component is standardized, all the tools, equipment and work area are standardized with consistent cleaning and identification methods. The fifth component is sustained which referring to make the 7S framework into a way of work culture. The sixth component is spirit which referring to it need commitment and engagement of all employee across all levels. The last component is safety which referring to the 7S lean manufacturing tools can help to create a safe work environment.

4.3.2 CP options for Raw Material and Chemical Optimization

CP option 5

The CP option suggested that review the procedure for the material weighing. The procedure can include the weighing tools and precaution for the operator while weighing raw material for production. Besides, a pictogram work instruction should be display at work area to create awareness for all operator. The improper material weighing method had created an approximate 1-5% loss at the raw material packaging due to high viscosity. Improvement on the weighing method and ensuring the material that adheres to the material packaging is utilized.

CP option 6

The CP option suggested that review the procedure for the material loading into production tank. The procedure can include the weighing tools and precaution for the operator while loading material into the production. To create awareness to all operator, a pictogram work instruction can be display at the work area. The improper material loading method can create an approximate 10 % loss at the raw material packaging, container, and environment.

CP option 7

CP option suggested to optimize the usage of chemical and raw material consumption is lean manufacturing tools that had discussed in CP option 4. The implementation of the 7S program to manage chemical and raw material consumption can make the workplace tidy and less spillage during operation. The 7S program also brings all employee to commit and engage to lean manufacturing tools to create a safe, clean and healthy work environment.

CP option 8

CP option suggested that the optimize the product formulation and product process to reduce the loss of material during the process. The high volatility solvent and resin used in the formulation will evaporate into the environment under a long mixing or milling process. The loss of solvent and resin can be estimated up to 5% and the loss quantity will need to be added at the end of the process for physical properties adjustment.

4.3.3 CP options for LPG consumption reduction

CP option 9

CP option suggested the replace the forklift that using LPG as a source of energy to a rechargeable forklift will eliminate the use of LPG. It can reduce the CO_2 emission by 1207.0 kg CO_2 per month. The investment cost and saving are calculated as below:

Investment cost: RM 80,000

Annual Saving: RM 12,425

Payback period = Investment Cost / Annual Saving

= RM80,000 / RM 12,425

= 6.4 years

CP option 10

CP option suggests that to rearrange the storage area for materials to reduce the needs of transport in the premise. For example, rearrange the material according to the material category and the arrangement of material storage should be near to the production material buffering area to reduce the needs and distance of material transport by forklift.

CP option 11

CP option suggests restricting the use of forklift in the operation area for short distance transfer. Only long-distance movement or lifting movement allows using the forklift, short distance movement uses a manual or electric pallet jack. For example, forklift only can be used when the goods are above ground and more than 50-meter transport distance. This practice can help to reduce the use of LPG forklift usage. The CO_2 emission reduction will need further study to quantify the reduction.

4.3.4 CP options for Liquid Solvent Waste Generation

CP option 12

CP option suggests that the optimization study on the usage of solvent for machine, tools, work area, and equipment cleaning should be carried out. The solvent used for cleaning work can be reduced and reuse. Beckers Groups had successfully reduced 3% of CO_2 emission through a combination of activities such as low-solvent cleaning systems, solvent recirculation and on-site distillation (Beckers Group, 2017). Therefore, the solvent waste estimated can be reduced by 0.5% and the CO_2 emission can reduce to 53.9 kg CO_2 per month.

CP option 13

CP option suggests developing and establish a procedure to implement the proper handling of the sample and production process to reduce the need for cleaning using a solvent. The improper handling of the product sample and production process can cause spillage and make the workplace and tools dirty. The green initiative of Beckers Group (2017) for solvent reduction as a reference, the solvent waste estimated can be reduced by 0.5% which equivalent to 53.9 kg CO_2 per month.

CP option 14

CP option suggests implement the 3R program in the premise can help to reduce the waste generated from the production process. The 3R program focus to reduce the generation of waste, reuse the material and recycle the waste. The 3R program also can create an awareness to all employee on waste segregation to eliminate the hazardous waste disposed in domestic waste or vice versa. For example, the solvent used for tank cleaning can be recycled for a few times and the used solvent will be collected and recover by solvent recovery equipment to recover the solvent to by recycling for cleaning purpose. The implementation of the 3R program to handle liquid solvent waste estimated can reduce the CO_2 emission by 0.5% per month which is equivalent to 46.1 kg CO_2.

4.3.5 CP options for Solid Schedule Waste Generation

CP option 15

CP option suggests to optimization on the usage of the glove, tissues, rags, and paper for cleaning and operation. Excessive usage of the item listed above for cleaning purpose will generate a high quantity of waste. Optimization on the usage of cleaning tools able to reduce the solid schedule waste.

CP option 16

CP option suggests establishing a workflow for proper handling of the sample and production process had discussed in CP option 13. This procedure should cover the usage of cleaning tools to reduce the excessive use that generates more waste.

CP option 17

CP option suggests that implementation of the 3R program to reduce, reuse and recycle the waste generated from the production process had discussed in CP option 14. The implementation of the 3R program to handle solid schedule waste estimated can reduce the CO_2 emission by 0.5% per month which is equivalent to 46.1 kg CO_2.

The implementation of CP options 15 and 16 are expected able to reduce the carbon emission by 1.0 % kg CO_2 emission per month which equivalent to 76.5 kg CO_2.

4.3.6 CP options for Process Improvement

CP option 18

Upgrade the machinery in the premise to more energy saving and high-efficiency equipment and machine to reduce the energy consumption and manhour needed for operation. The technology that suitable to the operation must study carefully before implement in the plant. The select technology should improve production efficiency and reduce the lost of material in the equipment.

CP option 19

Re-design the process to grind all the color at once in the same tank instead of grinding it separately. The re-design of the process can help to reduce time to produce one batch of paint from 12 hours to 8 hours. This also will solve the issue of sedimentation after storage and need more shader to produce one batch of product as the color strength changed.

CP option 20

Implementing a barcode scanning system for the warehouse to replace the manual handling system for material inventory. This can be done by adding features to the current ERP system. This additional feature will help to control the FIFO of material to avoid misplace and loss of material. This will need an investment cost of RM40,000. The implementation of a barcode scanning system expected to eliminate 1 hour in the operation due to manual inventory recording and storage allocation.

4.3.7 Safety, Health, and Environment Management

The safety, health, and environment in the workplace are important aspects to ensure the workplace is safe and healthy for the employee to work. There are safety, health and environment issues identified during the audit. Actions should be taken to control the identified issues. The action plan should be evaluated after implementation to ensure the action taken is suitable and sustainable. The issues, risk level and suggested CP options are tabulated in table 4.6 below. The implementation of CP in the aspect of safety, health, and environment will provide a safe environment and it can help to retain the employee.

Table 4.6: Safety, health and environment issues and actions are taken to mitigate the issues

No.	Safety issue	Risk Level	Action
1.	No designated place to store PPE and lack of management system to manage inventory of PPE.	Low	CP option 21 Safety, Health and Environment department shall establish a system to manage the storage and inventory of PPE. The storage including the stock storage and employee's PPE storage area to avoid contamination from chemical and misplace.
2.	Lack of enforcement for PPE usage in operation	High	CP option 22 Safety, Health and Environment department shall establish a system to enforce the PPE usage during operation. This enforcement of PPE can also corporate into the key performance indicator to encourage the employee to comply. The system establishes should include periodic inspection and monitoring on the usage of PPE. The feedback flow on the feasibility of selected PPE should be included under the scope of the established system.

No.	Safety issue	Risk Level	Action
3.	Insufficient health hazard awareness program	High	CP option 23 Company management team shall organize more occupational safety and health hazard awareness campaign for the employee. This campaign is encouraging to conduct in-house to reduce the loss of man-hours for operation.
4.	Lack of grounding system for equipment to discharge the electrostatic charge to the ground	High	CP option 24 The solvent widely uses in the operation for cleaning and as the main solvent for coil coating paint product. Therefore, the grounding system should be implemented to reduce the risk of fire which causes by the electrostatic charge. Maintenance and Safety, Health and Environment department are encouraged to collaborate to design the grounding system for production operation.

No.	Safety issue	Risk Level	Action
5.	No first aid box installs in the production area	Medium	CP option 25 Identify a suitable location to install the first aid box in the production area. The identified location should be easy to access without any blockage and highest activity. The first aid box shall purchase according to the number of employees working in that area.
6.	No eyewash installs at the production area	Medium	CP option 26 Identify a suitable location to install eyewash in the production area. The identified location should be easy to access without any blockage and is located at the high-risk chemical splashing area.
7.	No proper labelling on waste disposal container to segregate hazardous waste and general waste.	Medium	CP option 27 Apply colour coding for the waste bin with proper labelling to segregate hazardous waste and general waste.

4.4 Evaluation of Cleaner Production Options

There propose CP options will be prioritized based on ROI and time required for implementation. The summary of the CP options and aspects tabulated in table 4.7. CP options with lower ROI and shorter required time for implementation will be prioritizing to act accordingly. The CP options with higher ROI and longer time for implementation will be kept in view as the company future improvement plan. There are 5 criteria to be used to prioritize the implementation of CP options listed below:

i. Type 1: Implement immediately

   Criteria: High risk / no cost incurred / no additional resources needed/brings benefit to the operation / ROI less than 2 years.

ii. Type 2: Implement within 6 months

   Criteria: Medium risk/cost incurred / additional resources needed/brings benefit to the operation/need further analysis and study of the action / ROI more than 2 years.

iii. Type 3: Implement only if budget allocation

   Criteria: Low risk / high cost incurred / additional resources needed/brings benefit to the operation / ROI more than 4 years

iv. Type 4: Keep it as a future improvement plan

   Criteria: Low risk / high cost incurred /additional resources needed/brings benefit to the operation / ROI more than 5 years

v. Type 5: Drop it for at least 10 years

   Criteria: Low risk / high cost incurred / additional resources needed/brings benefit to the operation / ROI more than 10 years

Table 4.7: Summary of CP options and relevant aspects.

No.	Aspect	CP options	Time required	Investment needed	Carbon footprint reduction per month (kg CO_2)	ROI per year	Priority criteria
1.	Non-renewable electricity in process	Installation of more solar panel	3 months	RM 1,000,000	26.2×10^3	4.4	Type 3
2.	Non-renewable electricity in non-process	Optimize the temperature of the air conditioner	Immediate	RM 0	1.1×10^3	Immediate	Type 1
3.	Non-renewable electricity in non-process	Installation of the motion sensor for light control	Immediate	RM 500	53	0.2	Type 1
4.	Raw material and chemical consumption	Review the procedure for material weighing	Immediate	RM 0	-	Immediate	Type 1
5.	Raw material and chemical consumption	Review the procedure to load raw material into the production tank	Immediate	RM 0	-	Immediate	Type 1

No.	Aspect	CP options	Time required	Investment needed	Carbon footprint reduction per month (kg CO_2)	ROI	Priority criteria
6.	Raw material and chemical consumption	Optimize the product formulation and product process	Immediate	RM 0	-	Immediate	Type 1
7.	LPG	Purchase a rechargeable forklift	12 months	RM 80,000	1.2×10^3	6.4 years	Type 4
8.	LPG	Rearrange the materials storage area to reduce the needs of transport inside the premise.	6 months	RM 0	-	Immediate	Type 2

No.	Aspect	CP options	Time required	Investment needed	Carbon footprint reduction per month (kg CO_2)	ROI per year	Priority criteria
9.	LPG	Restrict the use of a forklift for short distance transportation.	3 months	RM 0	-	Immediate	Type 2
10.	Liquid solvent waste	Optimize the usage of solvent for machine, tools, work area and equipment cleaning	Immediate	RM 0	53.9	Immediate	Type 1

No.	Aspect	CP options	Time required	Investment needed	Carbon footprint reduction per month (kg CO_2)	ROI per year	Priority criteria
11.	Liquid solvent waste	Develop a procedure to implement proper handling of the sample and production process	Immediate	RM 0	53.9	Immediate	Type 1
12.	Solid schedule waste	Optimization on the usage of the glove, tissues, rags, and paper for cleaning and operation	Immediate	RM 0	76.5	Immediate	Type 1
13.	Solid schedule waste	Establish workflow for proper handling of sample and production process	Immediate	RM 0		Immediate	Type 1

No.	Aspect	CP options	Time required	Investment needed	Carbon footprint reduction per month (kg CO_2)	ROI per year	Priority criteria
14.	Production process	Upgrade machinery in premise	12 months	RM 500,000	-	20	Type 4
15.	Production process	Re-design the process to grind all the color at once in the same tank instead of grinding it separately.	6 months	RM 0	-	Immediate	Type 2

No.	Aspect	CP options	Time required	Investment needed	Carbon footprint reduction per month (kg CO_2)	ROI per year	Priority criteria
16.	Production process	Implement a barcode scanning system for the warehouse to replace the manual handling system for material inventory.	9 months	RM 40,000	-	Immediate	Type 3
17.	Liquid solvent waste and Solid schedule waste	Implement a 3R program for waste handling	Immediate	RM 0	92.2	Immediate	Type 1
18.	Overall	Implementation of 7S at workplace	Immediate	RM 0	-	Immediate	Type 1

4.5 Recommendation for CP Implementation

Based on the CP audit findings and carbon footprint estimation, it shows non-renewable electricity is the major source of CO_2 emission per month. To reduce the total CO_2 emission per year, non-renewable electricity CO_2 will be the main target. The recommendation for CP options implementation is select based on the priority criteria that fall under Type 1 and highest CO_2 reduction for initial CP options implementation stage. The remaining CP options that fall in Type 2, 3, and 4 can be implemented in the continuous year.

The recommended CP options for implementation are listed in Table 4.8. The CO_2 emission before and after CP and payback period are tabulated in Table 4.8. It is significant to avoid the undesired issue. There are four important steps in implementing CP options as listed below:

Step 1: Prepare an implementation plan

The implementation plan includes developing a checklist which contains a complete CP options evaluation, resources needed, responsibility for relevant personnel. Routine meeting to follow up on the progress of CP options implementation and issues encountered.

Step 2: Get approval from top management and give a briefing to various stakeholders

The prepared plan will be submitted to the top management for approval before implementation.

Step 3: Draft Implementation schedule

An implementation schedule was draft to includes the aspect of awareness promotion and implementation progress update. The awareness promotion shall cover the objectives of CP options implementation, selected CP options to be implemented, CP options implementation area and staff involved. The CP implementation progress should be documented and share with all employees. The documented information should include meeting minutes, assessment form, data collection, and others. The documented information will be used as input to generate a CP implementation report which can submit to top management.

Step 4: Execute Training

Training must provide for all employee when the implementation of CP options involves the change of technology, process, operation, procedure, and safety and health requirement. The training must be recorded as evidence and monitor to ensure all employees are competent to perform the task as per requirement.

Table 4.8: Recommended CP options for implementation.

No.	Recommended CP options	kg CO_2 / month (Before CP)	kg CO_2 / month (After CP)	Payback period (Year)
1.	Optimize the temperature of the air conditioner to reduce the consumption of non-renewable electricity.	19.0×10^3	17.8×10^3	Immediate
2.	Installation of the motion sensor for light control to reduce the consumption of non-renewable electricity.			0.2
3.	Installation of addition solar panel to reduce the consumption of non-renewable electricity.	44×10^3	18×10^3	4.4
4.	Optimize the usage of solvent for machine, tools, work area and equipment cleaning to reduce solvent usage.	10.8×10^3	10.7×10^3	Immediate
5.	Develop a procedure to implement the proper handling of the sample and production process to reduce solvent usage.			Immediate

No.	Recommended CP options	kg CO_2 / month (Before CP)	kg CO_2 / month (After CP)	Payback period (Year)
6.	Optimization on the usage of the glove, tissues, rags and paper for cleaning and operation to reduce the generation of schedule solid waste.	7.6×10^3	7.5×10^3	Immediate
7.	Develop a procedure to implement proper handling of the sample and production process to reduce solid schedule waste.			Immediate
8.	Implementation of 7S at the workplace to reduce the usage of non-renewable electricity and raw material and chemical consumption.	-	-	Immediate
9.	Implement a 3R program for waste handling to reduce solvent waste and solid scheduled waste.	18.4×10^3	18.3×10^3	Immediate

Based on the analysis, the implementation of recommended CP options in coil coating manufacturing premise will reduce the CO_2 emission by 33% with a total of 55.5 kg CO_2 /1000kg of coil coating paint. Figure 4.2 compares the CO_2 emission / 1000 kg of coil coating paint before and after CP implementation. The implementation of the CP options will help the premise to save the operation cost by RM 229,497 per year. The total kg

CO_2 emission per 1000kg of coil coating paint had reduced from 166.0 to 110.5 after CP implementation. After the implementation of CP, the CO_2 emission per 1000kg of coil coating paint can be reduced by about 33% per annum. The total reduction per annum is 33.3 x 10^4 tonnes CO_2 which is equivalent to the carbon sequestered by 5.0 x 10^6 of trees seedlings grown for 10 years and 1.12 x 10^8 litre of diesel consumed.

The payback period for the recommended CP options implementation and carbon footprint after CP implementation studies through estimating the cost investment, annual savings, and carbon footprint reduction per annum. The estimated payback period to implement recommended CP options is estimated as below:

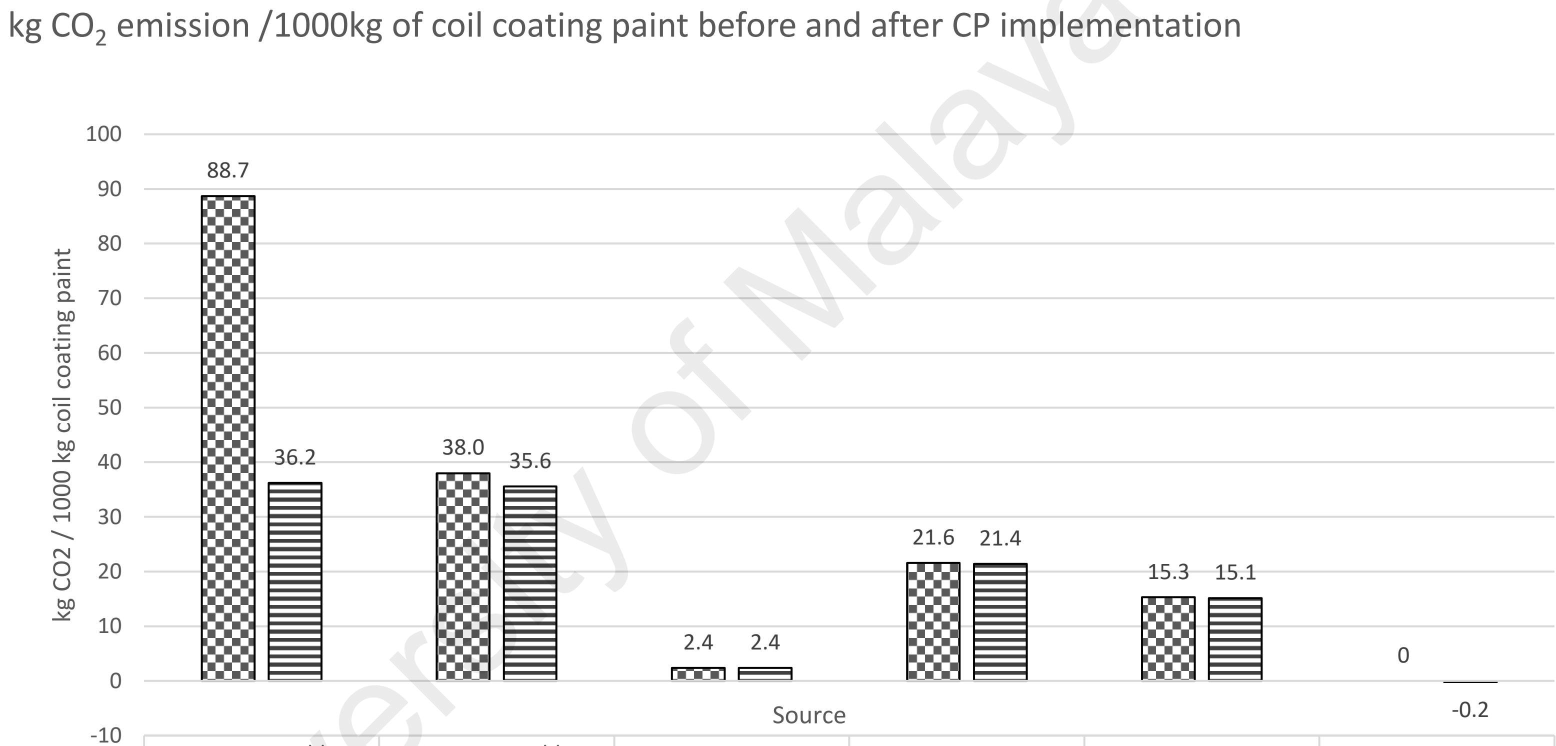
Total investment cost = RM 1,000,500

Total annual saving = RM 229,497

Payback period = Investment Cost / Annual Saving

= 4.4 year

After the implementation of prioritized CP options, the workplace will be more organized and standardized. CP strategies can help to minimize the loss of chemical and material and improve the productivity of the worker. Before the implementation of 7S, the tools in the premise do not have a designated storage area and not organize accordingly. This cause the employee need to allocate more time to search for the tools and material for their work. The implementation of 7S also helps to improve safety awareness in the premise. The implementation of the CP strategies can help to improve organizational image, reputation and competitiveness in the market.



	Non-renewable electricity in process	Non-renewable electricity in non-process	LPG	Liquid solvent waste	Solid schedule waste	3R implementation
CO2 emission before CP implementation	88.7	38.0	2.4	21.6	15.3	0
CO2 emission after CP implementation	36.2	35.6	2.4	21.4	15.1	-0.2

Figure 4.2: The carbon emission (kg CO_2) per 1000kg of coil coating paint before and after CP implementation according to sources.

4.6 Overall Opportunities for Malaysia

Malaysia is a developing country that has a firm initiative to protect the environment and promote sustainable development in civilization. The government had taken initiative to reduce pollution from manufacturing, construction, human activities, and others. The CP strategy implementation is one of the options for the different sector to reduce pollution from their operation. Malaysia government can enforce CP implement as the guideline for high pollution manufacturing to minimize the pollution from manufacturing activity. There is other paint manufacture premise manufacturing different type of paint at Malaysia, this study will serve as a guideline for other paint manufacturers to reduce CO_2 emission from their operation. This study and audit findings expected to be informative and serve as a reference for the similar manufacturer to perform their CP strategy study.

According to Bupalan (2019), there are at least 100 paints and coatings manufacturing companies operating within Malaysia. As recording in 2016, the total sales for paint and coatings is 257,047 tonnes. The implementation of CP strategies can help the paints and coatings manufacturer in Malaysia to reduce the emission by 55.5kg CO_2/1000kg of coil coating paint with the total sales of 257,047 tonnes. In other words, the carbon emission can be reduced by 1.43 x 10^7 tonnes CO_2 per annum.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion and Recommendation for Future Work

This study shows that CP strategies implementation can help to reduce the emission of CO_2 from the coil coating paint manufacturing premise. The CP strategies can help to enhance operational efficiency and reduce the waste of resources. It estimated that the studied premise should be able to reduce CO_2 emission from 166.0 kg / 1000 kg of coil coating paint to 110.5 kg / 1000 kg of coil coating paint. This equivalent to 33.3×10^4 tonnes CO_2 reduces per year. The reduction of 33.3×10^4 tonne CO_2 is equivalent to the CO_2 sequester by 5.0×10^6 trees seedlings grown for 10 years and 1.12×10^8 litre of diesel consumed. The study shows that the major source of CO_2 emission is the non-renewable electricity which is 126.7 kg CO_2 / 1000kg of coil coating paint. After the CP options implementation, the CO_2 emission from non-renewable electricity should reduce to 71.8 kg CO_2 / 1000kg of coil coating paint.

There are 27 options have been identified which included improvement and optimization of the process, non-renewable electricity, chemical, and raw material, process optimization, housekeeping, solid and solvent waste and LPG. In this study, 9 CP options have been selected to implement in the coil coating paint manufacturing premise which requires a total investment of RM 1,000,500 with the payback period of 4.4 years.

The CP options that not selected for implementation suggest to further study. Based on the result of the analysis, the cleaner production strategy for coil coating paint manufacturing premise is feasible in the aspect of technical, economic, environmental and operational. Therefore, cleaner production strategy can help to reduce carbon dioxide it also improves the overall operational efficiency and working environment. This study will be useful for other coil coating paint manufacturing premise and other paint manufacturing premise as the primary model in establishing and implementing CP strategy.

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