APPLICATION OF CLEANER PRODUCTION STRATEGY FOR REDUCING CARBON FOOTPRINT IN A HEALTHCARE PRODUCTS MANUFACTURING PREMISE

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2018

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RESEARCH PROJECT SUBMITTED TO THE FACULTY OF ENGINEERING UNIVERSITY OF MALAYA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF ENGINEERING (SAFETY, HEALTH AND ENVIRONMENT)

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2018

UNIVERSITY OF MALAYA

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ABSTRACT

A Healthcare product manufacturing premise was chosen to study the Cleaner Production (CP) strategy that aims to reduce the CO_2 emission from the manufacturing activities. CP audit was conducted to quantify the resources consumption, energy usage, raw material usage and waste. The audit confirms that the carbon emission of a product is 323 kg CO_2 / 1000 litre of healthcare product which mainly contributed by 74% electricity and 25% fuel consumption. Besides that, the remaining 1% is contributed by solid waste, water, and waste water. In this study, 31 Cleaner production options were identified to reduce the carbon footprint. The analyses confirm that the identified CP strategy could reduce carbon footprint about 38 kg CO_2 / 1000 litre of healthcare products with the strategies focused mainly on the design changes, improved operational, good housekeeping. This is equivalent for reducing 912 ton CO_2 /year for this premise. The estimated investment required for this reduction was RM 1.6 million with the payback period of 2 years. Therefore, the CP strategies were the beneficial options to reduce CO_2 emission and useful tool for a growing healthcare manufacturing industry.

Key word: Carbon emission, Cleaner production, Healthcare products

ABSTRAK

Kilang pembuatan produk penjagaan kesihatan telah dipilih untuk mengkaji strategi "Cleaner Production" (CP) yang bertujuan mengurangkan pengeluaran gas karbon dioksida CO_2 daripada aktiviti perkilangan. Audit CP telah dijalankan untuk mengetahui kuantiti penggunaan sumber, penggunaan tenaga, penggunaan bahan mentah serta sisa pepejal, dan sisa air yang dihasilkan. Audit mengesahkan bahawa aktiviti perkilangan dianggarkan menjana karbon dioksida sebanyak 323 kg CO_2 / 1000 liter yang kebanyakannya berasal daripada 74% penggunaan elektrik dan 25% penggunaan bahan api. Selain itu, sisa pepejal, air, dan air sisa masing-masing menyumbang kepada 1% karbon dioksida. Dalam kajian ini, "Cleaner Production" (CP) telah mengenal pasti 31 pilihan untuk mengurangkan penjanaan karbon dioksida. Analisis membuktikan bahawa CP strategi yang telah dikenal pasti dapat mengurangkan penjanaan karbon dioksida produk penjagaan kesihatan sebanyak 38 kg CO_2 dengan strategi yang tertumpu pada perubahan reka bentuk, operasi dan pengemasan yang lebih baik. Ini setara dengan menurunkan pengeluaran karbon dioksida sebanyak 912 CO_2 tan / tahun untuk premis ini. Anggaran pelaburan yang diperlukan untuk pengurangan karbon dioksida adalah RM 1.6 juta dengan tempoh bayaran balik 2 tahun. Justeru, strategi CP adalah pilihan berfaedah untuk mengurangkan pelepasan CO_2 dan berguna untuk kilang pembuatan produk penjagaan kesihatan.

Kata kunci: "Cleaner Production", Karbon dioksida, produk penjagaan kesihatan

ACKNOWLEDGEMENT

.

I would like to express my sincere gratitude to my respectable supervisor, Professor Ir. Dr. Abdul Aziz Abdul Raman from Chemical Engineering Department, University Malaya for the guidance, knowledge and continuous support throughout the research. His consistent feedback and support allows me to successfully complete this project on time. Thank you for giving me the opportunity to work under you. It was a great pleasure working with you.

Besides, I also would like to thank the company and experts that allows me to conduct the research in their company. Each and every one of them in the premise has shown the willingness to share and help me throughout the research. Last but not least, I would like to thank my batch mate, family and friends for their morale support and encouragement throughout the study. Thanks to everyone who have been part throughout this journey.

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LIST OF UNITS, SYMBOLS AND ABBREVIATIONS

°C	: Degree Celsius
CH_4	: Methane
CO_2	: Carbon Dioxide
CFP	: Carbon Footprint
CIP	: Clean in Process
CP	: Cleaner Production
DOE	: Department of Environment
EPA	: Environmental Protection Agency
m^3	: Metric
GHG	: Green House
GWP	: Global Warming Potential
HCFC	: Hydro chlorofluorocarbon
N_2O	: Nitrogen dioxide
IPA	: Isopropyl alcohol
ISO	: International Standard Organization
IQC	: Incoming Quality Check
kWh	: Kilowatt hour
Kg	: Kilogram
LCA	: Life Cycle Assessment
LED	: Light Emitting Diode
UNIDO	: United Nations Industrial Development Organization
UNEP	: United Nations Environmental Programme
PCP	: Personal Care Products
PV	: Photo Voltaic
RM	: Ringgit Malaysia
ROI	: Return of Investment
WWTP	: Waste water treatment plant
ZMWTL	: Zero Manufacturing Waste to Landfill

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

The global beauty market which includes cosmetic, toiletries and healthcare products has grown by 4.5% a year on the average with the annual growth rates ranging from 3% to 5.5 % over the last 20 years. This has proven the healthcare market has stable and continuous growth. There are several well-known healthcare products manufacturers which are expanding widely such as L'oreal, Procter & Gamble, Unilever and Johnson & Johnson. They manufacture various types of healthcare products which can be divided into fragrances, make up products, skin care, hair care and toiletries. Some of the examples of healthcare products include skin care lotions, powder, shampoo, hair conditioner, deodorants, baby products, gel, body wash, hair colors, hair spray and other types of products.

The industry is expanding widely due to the rising in population and increased in the market demand. The healthcare products are manufactured with the growing advanced in formulas, research and technologies. The manufacturing of healthcare products involves the high amount of raw material consumption, water consumption, electricity consumption, fuel consumption and followed by products packaging. During the manufacturing process of the healthcare products, there are certain amount of waste generated such as solid waste, hazardous waste, waste water and GHG emission. The GHG such as CO_2 will leads to environmental impact as global warming. Manufacturers are focused on sustainability where to make sure the products they create are not harmful to the environment. In the context of sustainability, the healthcare industry addresses environmental footprint in many aspects and the major attentions are driven to operational efficiency, raw material sourcing, green chemistry formulation, sustainable production methods, waste management, green formulation, sustainable packaging, energy sources, and carbon and water management (Sahota, 2014). It is greatly important to make the manufacturing as efficient as possible towards the effort to use fewer resources and to generate less waste.

Eco efficiency in healthcare products manufacturing is important to manage the resources consumption, water, waste, energy and CO_2. The reduction in environmental impact will directly drive better performance in manufacturing as well as contributes to reduction in operational cost. There are some long term sustainability goals in the healthcare products manufacturing premise which includes the use of 100% renewable energy which will potentially reduce the CO_2 emission. Some control measures are taken by the healthcare products manufacturing industry towards zero manufacturing waste to landfill. Healthcare product manufacturer use tons of packaging materials such as plastic bottles, pouches, caps, pumps, shipper and plastic shrink wrap in their operation and this can end up as waste in landfill. Initiative has taken by the respective manufacturers to work towards reduce, recycling, reuse of packaging materials. Besides that, transformation to renewable and organic materials has been part of the initiative. Water reduction about 30% to 50% in the production has been set as a target in the healthcare product manufacturing which have a greater impact in CO_2 emission. Therefore, the healthcare product manufacturer should take accountability to practice green initiatives in the operation to reduce waste and at the same time to improve efficiency.

1.2 Problem Statement

The healthcare products manufacturing premise involves high consumption of raw materials, water, energy, electricity which eventually contributes large amount of waste and GHG emission such as CO_2 during their operational activities. Due to the higher contributions of GHG from healthcare products manufacturing premise, thus it is necessary to study and identify the possible contributions of carbon footprint. The GHG poses significant effect to the health and environment. The high generation of GHG in healthcare products manufacturing premise will lead to global warming and climatic change. There are limited studies and literature review conducted in Malaysia healthcare product manufacturing premise. This study will help to identify the possible CP strategies to reduce the GHG emission in the healthcare products manufacturing. Besides that, the study conducted at healthcare products manufacturing premise will identify and evaluate greening initiatives to achieve the aim as well as to answer the following research questions.

1) What are the potential sources of CO_2 emission produced in the premise?
2) What is the estimation of carbon footprint generated per 1000 litre of healthcare product?
3) How does the implementation of cleaner production option reduce the carbon footprint in the premise?
4) Is the suggested CP option feasible in terms of environmental and economic benefits?

1.3 Objectives

The research study aims to reduce carbon footprint at healthcare products manufacturing premise by implementing cleaner production strategy. To achieve this aim, the objectives of the study are as follows:

1) To determine current status of the healthcare products manufacturing premise through cleaner production audit.
2) To estimate carbon footprint generated per 1000 litre of healthcare product at the selected premise.
3) To generate and evaluate CP options to reduce carbon footprint at the premise.

1.4 Scope of the study

This study will be conducted at the healthcare products manufacturing premise located in Klang Valley. The study focuses on the entire production process in the premise. The cleaner production which includes preliminary site visit, CP audit, generation of CP options and CP option prioritization based on the feasibility studies. This study will focuses on the resources consumption, waste generation and potential CO_2 emission per 1000 litre of healthcare product.

1.5 Report Layout

Chapter 1 Introduction gives an overview on the healthcare products manufacturing industry, operation process and the environmental impact. The aim, objectives, scope, research questions are explained in this chapter.

Chapter 2 Literature Review discussed on the literature review of production process involves in the healthcare products, the environmental impact of healthcare product manufacturing, overview on carbon footprint, cleaner production approach and case studies involving of greening of healthcare premise using CP strategies.

Chapter 3 Methodology detailed down the process flows involve in the operation, cleaner production audit methodology, carbon footprint calculation, payback period calculation, CP option rationalization and prioritization.

Chapter 4 Discussion explain on the audit result analysis, evaluation of carbon footprint, ROI evaluation and recommendation of CP implementation.

Chapter 5 Conclusion highlights the findings of the study and provides recommendation for future work.

CHAPTER 2: LITERATURE REVIEW

2.1 Global Warming

Global warming is happen due to the rise in atmospheric GHG level. The gases that will contribute to the greenhouse effect are known as CO_2, N_2O, CH_4 and fluorinated gases (EPA, 2017). The major anthropogenic contribution to GHG is through the emission of CO_2. Global warming likely will cause the gradual increase in the temperature of earth (Ghommem, Hajj, & Puri, 2012). The greater emissions of GHG will leads to higher concentration in the atmosphere. The Global Warming Potential (GWP) is developed to calculate the amount of energy absorbed by the GHG. The GHG with greater GWP will highly contributes to the global warming. The GHG concentrations will be measured in the parts per million (ppm), parts per billion (ppb), and parts per trillion (ppt). Figure 2.1 shows the total GHG emission in 2016 which illustrate the percentage of carbon dioxide, nitrous oxide, fluorinated gases and methane.

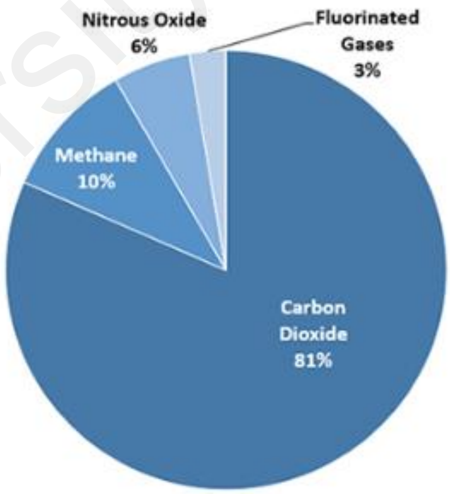

Figure 2.1: The Greenhouse gas emissions in 2016

Source: (EPA, 2017)

Rapid development has taken place around the globe over the years which had improved the quality of life but at the same time poses significant negative effects on the environment (Georgiadis et al., 2006). Malaysia as a developing nation has rapidly transformed from an agricultural to an industrialized economy with rising of greenhouse gases (GHG) emissions that are produced by the power plant, factories and automobile (Zaid et al.,2015). The main contribution of CO_2 in Malaysia is from the electricity generation, transportation, residential and industrial activities. Malaysia government has stated its intention to reduce the GHG emission by 40% in 2020. There are several measures have been introduced to protect from environmental damage.

2.2 Production Process Involving Healthcare Products

The healthcare products manufacturing industry has a greater level of capital intensity. Major products include skin care and hair care is mass produced and the small scale of very specialized cosmetics and skin care products may require higher levels human input. Due to the existence of advance technology requires only less than 20 employees to work within the industry. Generally, the industry operation involves blending and mixing readily available raw materials in the batch operations. Various chemicals is used in the manufacturing of healthcare products which compromise of surfactants, oils, fats, fragrances, emollients, fragrances, cleansing agents and mineral oils.

The production process in the healthcare production premises includes the operations which includes the sourcing of raw materials, packaging materials, bulk intermediates, products, formulation and production process (grinding, mixing, heating, cooling, filling, packaging). It also involves the quality control, release, storage and distribution of the finished goods. There is improvement in the operation technologies with increased mechanization and automation. The continuous blending and mixing batch process are involved in the production of liquid products. In the daily operation, water, energy, electricity, raw materials and packaging materials are used majorly to produce the healthcare products. Water is essential and used in the formulation of most types of healthcare products. It is the key component in creams, lotions, bath products, cleansing, skin care products moisturizers, shampoo, hair conditioners and others. Water acts as primary solvent in healthcare products which functions to dissolve the ingredients such as cleansing and conditioning agent.

The type of water used in the personal care production known as process water and it is monitored based on Good Manufacturing Practices defined in FDA's Guidance on Cosmetic Manufacturing Practice Guidelines, and also in international guidelines on Good Manufacturing Practices known as ISO 22716. The manufacturing industries involve high usage of raw materials, water, electricity, chemicals and energy which discharges waste and GHG that has significant effects to environment and human health. In the operation process, there are large amount of electricity required to operate several process such as raw material extraction, mixing, filling, packaging, heating process, IT, lighting.

2.3 Environmental Impact of Healthcare Products Manufacturing Process

The healthcare products which are known as soap, lotion, moisturizer, shampoo, deodorant hair colors are used to improve quality of daily life. The healthcare industries should play important role in the identification of healthcare products in the environment. The main source of healthcare products enter the environment is through the use of products and removal from the body through bathing activity. The healthcare industry should understand the impact of their products to the environment so that steps can be taken to reduce the environmental impact. The packaging materials of healthcare products such as bottles, pouches, tubes and other packaging container are discarded after use and build up in landfills where they can take hundreds of years to break down. The healthcare industries are working towards green formulation as well as ecofriendly packaging to reduce the environmental impact.

Recently, there has been increasing awareness of the presence of healthcare products in the aquatic environment at the concentrations which is likely to cause harmful effects to the environment (Ebele, Abou-Elwafa Abdallah, & Harrad, 2017). Study conducted has shown the presence of triclocarban (TCC), triclosan (TCS) which is known as the antimicrobial agents in the algae samples (Coogan et al., 2017). Even though, PCP is detected in freshwater environment at very low concentration, the PCP and metabolites are biologically active and can have a greater impact on non-target aquatic organism.

2.4 Measurement of Environmental Impact through Carbon Footprint

The manufacturing industries are one of the major contributors of emission factors such as SO_2, NO_X and CO_2 that considerably damage the environment (Ramli & Munisamy, 2015). Carbon footprint is the total volume of greenhouse gases discharged by manufacturing activities, and individuals (Zhou & Sun, 2016). Carbon footprints compromise of all greenhouse gases emission such as carbon dioxide, nitrous oxide, hydrofluorocarbons, methane, perfluorocarbon, sulfur hexafluoride and stated as tons of carbon dioxide equivalent (Wróbel-Jędrzejewska et al., 2016). The carbon footprint assessment is one of the activities that many are consider reducing global climatic change. In our current state on climatic change effects, carbon footprint is used as an environmental performance indicator in production activities or products (Laurent et al., 2010). Figure 2.2 illustrates the atmospheric CO_2 level measured at Mauna Loa Observatory, Hawaii. The CO_2 has reached its highest level which is at 410ppm.

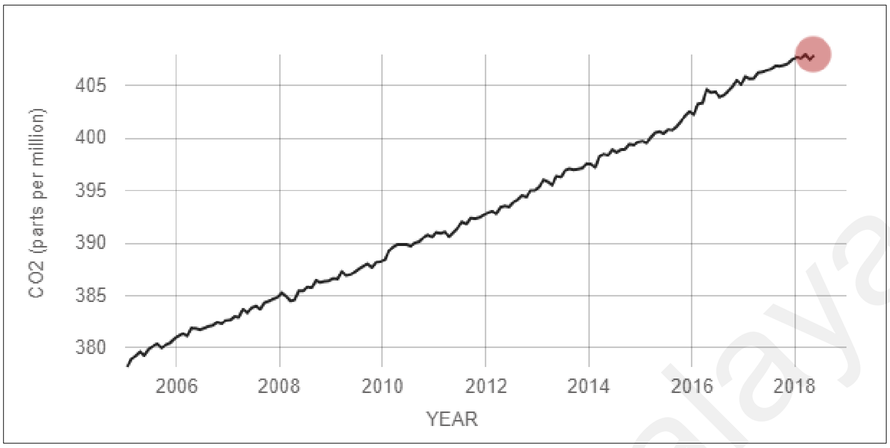

Figure 2.2: The atmospheric CO_2 level (ppm)

Source: (NASA, 2018)

Industrial development has been among the major factors for the increased CO_2 emission through the consumption of electricity and fuel. The major source of greenhouse gas emissions in manufacturing are electricity consumption, combustion of fuel in production and fuel consumption in logistic activities (Hosseini et al., 2013). The extensive use of existing renewable energy sources and energy efficiency would capably improve energy, decrease its dependency on fossil fuel and carbon dioxide emission by 2035 (Gan et al.,2013). The increase in demand for energy consumption had contributes to the rise in CO_2 emission; energy efficiency strategy is the key for sustainable economic development and at the same time to minimize social and environmental impacts (Sabori et al, 2012).

The reduction in carbon emissions will directly lead to reduce in the level of CO_2 or CO_2 equivalent gases that eventually contribute to global warming and climate change (Fernando & Hor, 2017). The source of carbon emissions in industry can be classified into two categories which are on site carbon emission due to operation within the premises and indirect carbon emission at the external premises due to resource consumption within the business premises. The tremendous increase on the economic, social and environmental impacts of CO_2 and GHG emissions have encouraged the implementation of various strategies and tools for CO_2 emission mitigation (Fais, Sabio, & Strachan, 2016). There are some limitations presences in the companies such as lack of strong long term policy framework for the reductions of carbon dioxide emissions (Okereke, 2007).

Subsequently, large quantity of waste and emission are generated mainly in form of CO_2 produced from the production process which significantly impact health and environment. The contribution of CO_2 emission is mainly by the usage of electricity and other activities including chilling, heating, cooling, drying and other processes (Rahim & Abdul Raman, 2017). Recent study shows, greater environmental impacts generated from the electrical or thermal energy used in the life cycle processes (Laurent, Olsen, & Hauschild, 2010).

2.5 Cleaner Production Strategy to Reduce Carbon Dioxide Emission

The strategic management of CO_2 emission through process integration will provide sustainable alternative to control the rise in CO_2 emission (Azhar Khan, Zahir Khan, Zaman, & Naz, 2014). In the fruit juice production industry, the CO_2 emission quantified by assessing consumption rate of electricity, water, fuel, solid waste and waste water generation. In the studies, electricity was identified as the major contribution of CO_2 emission with 88% of total emission in the plant (Rahim & Raman, 2015). The efficient operation of the refrigeration system which includes increase of air conditioning system was suggested as CP options. It has contributed to electricity savings which directly had caused the reduction of CO_2 emission.

Besides that, the refrigerated storage of raw materials, semi-finished good, finished goods are the major contributors of CO_2 emission in the production process of fruit paste technology with 77% of total emission (Wróbel-Jędrzejewska, Stęplewska, Kuleta, Przybysz, & Polak, 2016). It is essential to optimize the process to reduce GHG emissions by reducing capacity, maximize the use of cooling areas and rationalization of storage chamber.

Based on the study conducted, the emission reduction strategy will be focused on higher priority area such as the packaging. Study revealed that switching to 100% recycled plastic bottles will cause about 20% reduction in materials and eventually reduced the CO_2 emission by 55% from the bottle production (Carbon Trust, 2008). The manufacturing of plastic resin from recycled plastic involves the usage of large quantity of chemicals, raw materials, energy and water. Subsequently, large quantity of waste and emission are generated mainly in form of CO_2 produced from the production process which significantly impact health and environment. The contribution of CO_2 emission is mainly by the usage of electricity and other activities including chilling, heating, cooling, drying and other processes (Rahim & Abdul Raman, 2017). There are few CP option have been introduces in the plant to reduce the CO_2 emissions such as the installation of LED energy saving bulbs for lighting system, the increase of air conditioning temperature and optimisation of temperature in heating and extrusion process.

2.6 Cleaner Production Strategy

Cleaner production is defined as the integrated preventive environmental approach to manufacture products and services with the objective of improving efficiency. CP includes the change in technology, process, resources to reduce the waste generation, use of energy and resources efficiently, improves business profitability and increase the efficiency of operation. Due to rapid urbanization and economic growth, it is necessary to implement a wider and integrated approach with advance technology, policies and ethics to achieve sustainability development in future (Hens et al., 2018).

Sustainable development is the practice to fulfill the needs of the current generation without affecting the needs conceding the needs of the future generation (UNEP, 2002). Cleaner production which highlights the sustainability concept is green procurement, eco efficiency and zero emission. CP approach will expand reduction in carbon footprint through improvement in energy conservation by shifting renewable energies including solar, wind, geothermal, hydro and bio based energy (Almeida et al., 2014). Cleaner production approach has demonstrates economic and social benefits as well as mitigating environmental damages through its application (Peng and Liu, 2016). It shows that the cleaner production has potentially reduces pollution including greenhouse gas emissions generated by operation (Matos et al., 2018).

The guidelines, policies and regulation for pollution prevention and cleaner production correspondingly intended at managing environmental externalities in industry (Khalili, Duecker, Ashton, & Chavez, 2015). CP is known as the long term strategy to prevent negative effects to the environment and as an important tool for improving environmental performance (S.-w. Bai, Zhang, & Wang, 2015). The cleaner production management system compromise of monitoring the efficiency of materials usage and the energy flow at particular cost centre, set up baseline for improvements, the identification of differences from the standard operation performance, stimulation of traditional approach of CP options, implementation of feasible of CP measures, monitor and track the performances of implemented CP (Dobes,2013).

The CP strategy allows identifying major trends for the future which compromise of integrated CO_2 reduction approaches such as optimization of manufacturing process, improved product design, identifying and monitoring the outputs and impacts, sustainability-targeted quality control, maintenance of waste, stakeholder engagement and awareness training (Huisingh, Zhang, Moore, Qiao, & Li, 2014). Current development of CP application has brought greater energy efficiency that significantly will reduce the carbon dioxide. CP is suggested to be better approach because it identifies the preventive strategies to reduce the environmental impact of production whereas LCA only able to identify the environmental impact of process or products (Rahim & Abdul Raman, 2017).

2.7 Case Studies involving Greening of Healthcare Premises Using CP Strategy

Healthcare products manufacturing premises have developed greening initiatives to create more sustainable process and products. The green initiatives carried out by the healthcare manufacturing premises using CP strategy are studied for further understanding.

2.7.1 Greening Initiatives in Procter & Gamble Company

Procter & Gamble is one of the leading manufacturers of healthcare products. A case study report on Procter & Gamble was gathered through available information in open source. The team is committed to progress towards 100% renewable energy vision.

There are several initiative implemented to accomplish the goal such as upgrading the existing onsite biomass to a large-scale combined heat and power operation, build of large scale offsite wind farm, onsite solar photovoltaic (PV) projects across multiple region, onsite geothermal, use of renewable electricity from hydropower and wind. The Huangpu plant in China has join together with the local utility supplier to install rooftop solar panel. The installation of solar PV panels will eliminate 600 metric tons of CO_2 emissions annually. P & G have committed to reduce the GHG emission through the application of renewable energy.

Moreover, some initiatives are undertaken for a sustainable water management. The team are working towards improved filtration and recycling technology. This technology has helped a wide range of manufacturing plants reuse water. They have also committed for reduction in water use by 20% per unit of production. Besides that, the P & G sustainability vision is to drive towards 100% recycled or renewable materials in the packaging and products. They are looking forwards to invent technologies to substitute the petroleum derived raw materials with renewable materials. Some of the materials they used include plastic resins and cleaning agents. P & G team have conducted researches and have figured out development in plastic resins used in packaging. Bio-derived resins have been identified to be used three packaging of polyethylene (PE), PET and Polypropylene (PP). The Bio-derived PE has been commercialized and used in the packaging of Hair Care Category known as Pantene Nature Fusion. The use of bio-PE has provides reduce environmental footprint.

In addition to that, P & G also announces a goal to be achieved in 2020 which is to make sure 90 % of their product packaging is recyclable. P & G also have taken effort to reduce the manufacturing waste and drives towards to achieve Zero Manufacturing

Waste to Landfill (ZMWTL). P & G has increased the number of ZMWTL sites from relatively 10 % to about 50% at their manufacturing sites globally since 2013 (Procter & Gamble, 2016).

2.7.2 Greening Initiatives in Unilever Company

In 2017, a total of 61 million ton of CO_2 is generated which are compromise of emissions associated from various range of products including healthcare products. Unilever have practices eco efficiency in manufacturing to use resources efficiently as well as to generate less waste. The factory has reduced the CO_2 generated from energy by 47% per ton of production compared to 2008. They have focused on the key areas such as waste, energy, water and CO_2 in 274 manufacturing sites in 69 countries. Unilever have target to reduce 40% of CO_2 emissions per ton of production by 2020. The team aim to source 100 % energy across the operation from renewable sources by 2030. The management have increase the use of renewable energy in the factory by 33.6% compared to 2008. Other initiatives as source all the electricity purchased from renewable resources and elimination of coal in energy mix by 2020. Unilever had managed to reduce the energy use in the manufacturing site by 29% since 2008.

Unilever also plays their part in using their water efficiently in the manufacturing. In 2017, there is a reduction of water use in the factories by 39% per tons of production since 2008. There is also continuous improvement to reduce, reuse and recycle the water. The improvements in process and water efficiency technology can be part of the water reduction initiatives. In 2017, a new tank cleaning system which can saves about 3500m^3 of water per year has been installed in Goiania factory at Latin America. It has also delivers great quality performance uses less chemicals in the operation. Reuse and recycling of water is encouraged in the factories. There are about 50 sites where waste water is treated and reused on the site. Treated wastewater will be used for utilities such as cooling towers and boilers. Water efficiency features are included in the core design of new facility upgrade. The reduction in water usage will help to save energy as there are no heating, pumping and treating of water. Water efficiency strategy will helps to build resilience to the effects of climate change. A detailed metering, monitoring and targeting (MM&T) system have been practiced. This will provides hourly data on water usage and it has also been used to update the shutdown procedures to include closing of water access to non-essential areas. This initiative will reduce the annual water use by 15,000m^3 per year without additional cost.

Some efforts have been taken by Unilever to manage waste and packaging efficiently. In the year 2017, the total waste produced by Unilever is about 739 kiloton and this is equivalent to 0.6g waste per consumer use. Based on the analysis, it shows primary packaging accounts for over 60% of the total waste footprint. The laundry, hair care and beverages products contribute about more than one-third of the total waste footprint. The team has worked together to reduce the waste impact per consumer by 29% compared to 2010. Apart from that, total of 98% reduction of waste was achieved per ton production since 2008. This goal was achieved by improvements in the recycling and recovering of packaging materials, innovation in packaging material as reduction of weight of material used (Unilever, 2018)

2.7.3 Greening Initiatives in L’Oréal Company

L’Oreal is one of the leading healthcare products manufacturing in the world and has potentially increased its production volume by 29% between 2005 and 2016. At the same time, the company has taken initiatives to reduce the GHG emission by 67 %. In the healthcare products manufacturing, the entire industry beginning from raw material sourcing to disposable of packaging materials for used up products will possibly leave environmental footprint. In 2016, the company has taken initiative in becoming L'Oréal's Carbon Balanced Company which had saved about 8,300 tons of carbon dioxide. L'Oreal collaborated with its supplier Olvéa and Burkinabe social enterprise Nafa Naana to substitute the traditional "three-stone" stoves with acquisition of 1,500 improved metal stoves for the purpose to boil water to scald shea nuts in the process to procure shea butter. The change in the process modification had possibly reduced the emission of 2,300 tons of CO_2 and cutting of nearly 800 tons of timber a year. Moreover, there are several initiatives taken by L'Oréal in terms of reducing CO_2 such as strategies in improving energy efficiency through improved building design, insulation, energy efficient technologies, optimization of industrial process that has potentially reduce the energy consumption by 33%, in kWh per finished product. In addition to that, the use of renewable energy such as biomass, solar panel, biomethanation are adapted to certain sites to run the projects.

Apart from the green initiatives taken in manufacturing, L'Oreal also plays major role to reduce the emissions contributed through transportation of the products from plant to the distributors. Actions including the use of rail transport instead of road freight in China and reduction of air transport have been practiced and these have shown reduction in emission. Stepping up towards the deployment of renewable energy, L'Oréal will take some initiatives in US to reduce the CO_2 emission in 2020 by 80% from a 2005 baseline with the use of 4,000 solar panels, solar installation, and installation of 12 wind turbines. In addition to that, L'Oréal assured to play a part in reducing water consumption by 60% per finished product unit by 2020 from a 2005 baseline. There are two key actions should be taken to achieve this target such as optimizing the water consumption, reuse and recycling water at the operation.

L'Oréal has come up with a recognised sustainable water management policy which set out to reduce the water consumption of the plant by 33% since 2005. It shows reduction in water consumption in litres per finished product about 48% by the end of 2016. The team have developed a tool which known as Water scan to standardises water consumption and identifies possibilities to reduce water consumption in cleaning equipment and packaging lines. In this case, the quantity of washing water required is adapted based on the formula of the product and equipment used. Besides that, plant has improved the wastewater treatment system to deliver high-quality water. This water will be recycled and reused for cleaning the equipment.

Other than that, L'Oréal also moves forwards with ambitious waste management policy to reduce the waste at source. Waste will be categorized includes obsoleted products, packaging materials, raw material packaging and sludge from waste water treatment plant. In 2016, the team has work closely to reduce the quantity of waste generated per finished product by 35% as compared to 2005. One of the major achievements by L'Oréal's industrial sites is through reaching a "zero waste to landfill" target in 2016. There are plenty of initiatives done by the team to reduce the waste generation at source such as reduction of waste related to transport packaging (optimization, standardization, reuse, eco design), continuous improvement in packaging and manufacturing line to reduce losses, development of recovery of obsolete product inventories to minimize disposal. The packaging used in L'Oreal has improved about 57% since 2005 with the reduction of weight and volume of bottle (L'Oréal, 2016).

2.7.4 Greening Initiatives in Johnson & Johnson Company

Johnson & Johnson have developed initiatives to create more innovative and sustainable products. The team approach focuses on product life cycles from formulation, manufacturing, products usage and disposal. The life cycle approach includes the application of green chemistry, improvement in the packaging sustainability, recycling reprocessing and reuse of the used equipment. There are major improvements done across key areas which compromise of materials, packaging, energy, waste, water and innovation. Johnson & Johnson has put effort in the raw material and ingredients substitution. The team has removed formaldehyde releasing preservatives and reduces the traces of 1, 4-Dioxane in baby and beauty products. In 2013, Johnson & Johnson became the first company committed to remove polyethylene micro beads from the healthcare products and replace with jojoba beads. Johnson & Johnson has shown effort through energy management for more than 30 years ago.

They have established their first enterprise-wide public commitment to reduce CO_2 emission in 2000. Johnson & Johnson aim to reduce 20 % carbon emissions by 2020 and 80% by 2050. As part of Johnson & Johnson initiative, the company aim to produce 20% electricity from clean and renewable sources by 2020 and to power the facilities with renewable energy by 2020. The improvement in the efficiency of the utility systems at the largest production facilities has reduces the energy about 5.2% from 13,537 terajoules (TJ) in 2010 to 12,837 TJ in 2015. As the initiatives to reduce energy and water, Johnson & Johnson has implemented five targeted demand-side efficiency efforts. Project Cold implemented as the control technology where the existing chilled water systems to optimize variable condition. Project Hot was introduced which involves the modernizing steam and hot water systems by application latest technology and best practices approach to increase efficiency. Project Air implemented to improve the compressed air system which includes improvement in control, continuous monitoring, efficient drying and heat recovery. Project Relight which systematically upgrade the existing fluorescent lighting system to LED technology to have better quality of light and improving efficiency. A 3.0 MW wind turbine at the Vision Care facility in Limerick have reduced the energy cost and CO_2 emission at the location about 30% in 2015.The reduction of CO_2 emission is the main focus by the Johnson & Johnson team. Their aim is to attain 20% reduction of CO_2 emission from the baseline of 2010. In 2012, the carbon dioxide has reduced about 2.1% which is from 1,201 metric tons in 2011 to 1176 metric tons. Chlorofluorocarbons (CFCs) have been eliminated in the facilities and Hydro chlorofluorocarbons (HCFCs) are targeted to be eliminated by the end 2025. The alternative refrigerants for the cooling and refrigeration equipment with reduced effect on ozone depletion and climate change will be used. Water is one of the key components in manufacturing. Johnson & Johnson have made substantial progress to reduce the water usage for over 10 years. They have successfully reduced the water usage by 9% from 2005-2010 and 7.2% from 2010 to 2015.

Johnson & Johnson have come up with the Green Building Concept. They have introduced Policy on Sustainable Building Design and Construction which needs sustainability to be incorporated into new building and renovation. This policy establishes design standard based on the Leadership in Energy & Environmental (LEED) standard. In 2015, Johnson & Johnson had 29 LEED-certified building. Johnson & Johnson has effectively reduce the waste by 2.9 % compared to 2010 baseline by reduce and reuse of materials (Johnson & Johnson, 2015). Table 2.1 summarized the green initiatives carried out by Unilever, Procter & Gamble, L'Oreal and Johnson & Johnson.

2.7.5 Summary of Green initiatives in Healthcare Products Manufacturing

Table 2.2: The summary of green initiatives carried out by Unilever, Procter & Gamble, L'Oreal, Johnson & Johnson

	Baseline year	Target year	Green Initiatives					
			Renewable energy	Water reduction	Energy reduction	GHG reduction	Waste reduction	Improvement in packaging material
Unilever	2008	2020	33.6% achieved since 2008	39% reduction per ton of production achieved since 2008	29% achieved since 2008	47% per ton of production	Reduction in total waste of 98% per ton of production since 2008.	In progress
Procter & Gamble	2010	2020	9.6% achieved since 2010	24% achieved Since 2010	20% reduction in energy since 2010	10% reduction since 2010	Zero waste to landfill 55% achieved since 2010	Use of recycled resin 30% achieved
L'Oreal	2005	2020	45% achieved since 2010	48% reduction per finished product	33% reduction in kWh per finished product	67% reduction since 2005	35% reduction per finished product	57% achieved
Johnson & Johnson	2010	2020	Increased on-site renewable energy capacity to 50.1MW.	7.2% reduction achieved in 2015 compared to baseline	5.2% reduction since 2010	9.8% reduction since 2010	2.9% reduction in 2015 compared to baseline	In progress

The reviewed literature has revealed that Unilever, Procter & Gamble, L'Oreal, Johnson & Johnson have taken green initiatives to reduce water, energy, waste and GHG. Besides that, the use of renewable energy and improvement in the packaging material has also been practiced in the companies. They have developed several strategies and making towards to achieve target by 2020. Unilever, L'Oreal, Procter & Gamble companies have achieved their target about more than 10% in the application of greening initiatives especially in the areas of renewable energy, water, energy, GHG and waste. Moreover, Johnson & Johnson Company is currently working on the greening initiatives approach to achieve their target by 2020. Apart from that, all the companies are still on progress towards the improvement on the packaging material.

2.8 General Initiative in Cleaner Production

Cleaner production approach had been practically applied in many industries however there are few industries have not practice CP approach and there are gaps in understanding and identification of challenges can be encountered in its application as well as the advantages (Luken et al., 2016; Vieira and Amaral, 2016; Zeng et al., 2010).
CP is a preventive environmental approach which is applicable to process, products and services to improve resource efficiency and to decrease the risk to humans and environment (Y. Bai, Yin, Yuan, Guo, & Song, 2015). There is lack of clarity in the guidelines and policies which are accountable for establishing the resources and internal collaborations in the organization (Matos et al., 2018). In the manufacturing industry, Shi et al. (2008) the manager and decision maker tend prioritize traditional aspects of operation such as improved production due to unclear policy for application of CP. Besides that, (Büyükbay et al., 2010; Shi et al., 2008) stated in their study as the absence

of reliable data and inappropriate record keeping of the inputs and waste will become a barrier to the success of CP implementation.

The unavailability of resources for cleaner production in terms of financial, human, managerial, technological, information and monitoring was mentioned as difficulties to conduct CP in the companies (Matos et al., 2018). There are cases where economic difficulties will prevent the implementation of CP strategies and proposed solutions Silvestre & Silva Neto (2014). There are difficulties in the application of cleaner production such as the absence of information, methods and tool. In the CP methodology application, the main focus is to minimize the emission and waste produced at the source rather than at the end of the process (Lopes Silva, Delai, Soares de Castro, & Ometto, 2013).

There are internal and external barriers encountered in the application of CP. Some of the internal barriers encountered by CP is human factors which can be classify to lack of communication, leadership, inflexibility in the management (Staniskis, 2011). There is limitation in the identification of opportunities in the implementation of CP due to lack of communication among the individuals who in charge of the operation process and those who authorised to manage the waste generation (Staniskis, 2011). Besides that, lack of manpower and organizational learning tools also act as a barrier for CP implementation (Dobes, 2013).

Apart from the internal barriers, the presence of external barrier such as the lack of concern on the pollution prevention by the society acts as a factor that will interfere on the adoption of CP practices (Vieira & Amaral, 2016). Moreover, the policies and guidelines often favour the use of end of pipe techniques rather than the implementation of CP options (Staniskis, 2011). The application of CP faces social dilemma where certain industries taking initiative to prevent the emissions and protect the environment from environmental damage while others mainly interested in making profits by disregarding the emissions (Y. Bai et al., 2015).

2.9 Summary of Literature Review

The review had discussed the potential sources of carbon dioxide emission generated in the production process of healthcare products. The operations involve in the healthcare products manufacturing industry and the possible resource consumptions, waste generation are discussed here. This will provide sufficient information to be used in the study. It has identified electricity consumption, fuel consumption and water consumption had greatly contributed to CO_2 emission in the industry. Apart from that, waste water, solid waste are also recognized as the source of CO_2 emission. Moreover, the environmental impact of the healthcare products manufacturing process has been discussed here. The feasible CP options to reduce the environmental impact of the healthcare products manufacturing process are further discussed. The CP options generated in the industries includes change in the design and technology, change in process, reuse, recycling, waste management practice and others has potentially reduce the carbon footprint. CP strategy as an effective management tool to reduce the carbon footprint at the healthcare products manufacturing industry have been highlighted here. The reviewed literature has highlighted the sustainable management of carbon footprint through the greening initiative. The importance and understanding of greening initiative in the healthcare product manufacturing premise had been discussed here. The review have provided the insight of greening initiative that have been practiced in four major healthcare product manufacturers such as L'Oreal, Unilever, Procter Gamble and Johnson & Johnson. The benefits of CP implementation and the initiative practiced by them towards sustainable development also been summarized here. This information will be beneficial and used a point of reference in this study

Apart from that, the literature review underlined the challenges and barrier in the cleaner production which includes technical, economic, guidelines and policies. Therefore, it is vital to understand and explore green initiatives in depth that can be applied in similar industries to reduce carbon footprint, environmental impact as well as to improve process efficiency in the production process.

CHAPTER 3: METHODOLOGY

3.1 General Research Methodology

Methodology for this research study was carried out as illustrated in Figure 3.1.

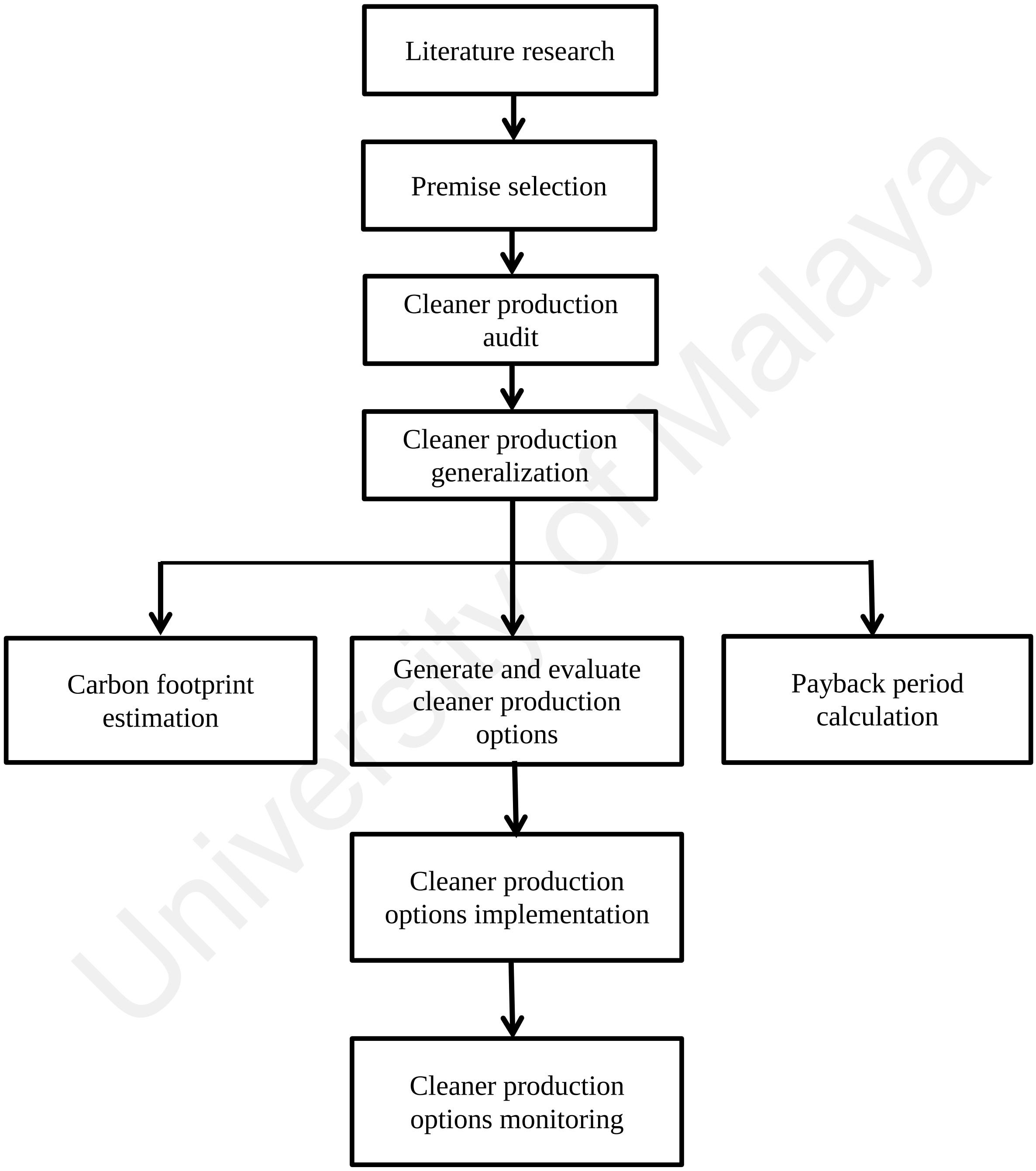

Figure 3.1: Overall methodology of the research project

3.2 Premise Selection

A suitable healthcare product manufacturing premise has been chosen to conduct the research. This premise was selected for study due to the established operation and has good record keeping system. In order to conduct this research; prior permission was obtained from the management. A letter was sent to notify the management on the research study conducted. As requested, in this study the identity of the company is not disclosed and hence will be identified as ABC Sdn. Bhd

3.3 Premise Information

.This premise located in Klang Valley which manufactures various ranges of healthcare products including Body Wash, Lotion, Shampoo, medical devices and other healthcare products. The plants operate 24 hours and have about 150 employees. The premise manufactures about 75 batches of healthcare product per week which is equivalent to 500 ton.

3.4 CP Audit Methodology

Cleaner production audit guidelines were introduced to enhance the efficiency of resource usage, minimization of waste generated, reuse as a cost-effective option to environmental regulatory compliance. CP audit is known as a management tool including a systematic, documented, continuous, objective and participatory procedure to evaluate the function of present or proposed production systems, to identify and implement appropriate management actions and policy, to accomplish integrated objectives of environmental protection and improvement, increased profitability and resources conservation (DOE, 2007).

CP audit is a key tool that gives opportunity to assess the production process and to identify the relevant opportunities to minimize resource consumption and waste generation. This audit enables the management to identify the possible and effective ways to optimize maximum resources and overall process performance. There are few key areas needs to be considered while performing the CP audit such as the sources, quantities and types of waste generated, raw materials, products, water, energy usage, waste produced, information on unit operations, identify process inefficiencies, set goals for CP and permits the expansion of cost-effective waste management strategies and to raise awareness on the benefits of CP. CP audit evaluate the company's operational practices and to identify and provide necessary information to conserve natural resources as well as to emphasize on environmental protection (DOE, 2007). There are six major steps involved in the CP methodology and 18 tasks to be performed.

The main objectives and scope of the audit were identified and to comply with the legislation, minimization of waste management cost, resource and energy consumption and at the same time to improve public relations (DOE, 2007). CP audit checklist was developed prior to this research. The CP methodology suggested by United Nations Environmental Programme and United Nations Industrial Development Organization (UNIDO/UNEP, 1991) includes the planning, pre assessment, detailed auditing on site, and generation of potential CP options, feasibility studies and evaluation.

3.4.1 Audit Planning

In the cleaner production audit, the first initial step is the audit planning. Planning for the audit should be done out at the early stage to ensure smooth and effective cleaner production audit. The objective, scope and requirement of the audit were defined clearly. In this CP audit, the CP team was formed from the different functions which include production, safety; engineering as well as facilities and maintenance are required. The members of the team were selected as they are expertise in the entire operation and could assist in the implementation of CP strategy. An audit schedule was developed to ensure the audit is carried out according to the plan. The audit schedule is shown in Table 3.1.

Table 3.1: Audit Plan Schedule

No	**Date**	**Activities**
1	19 Feb 2018	Preliminary Visit a) To gather basic information on premise b) To identify the units of operation, facilities in premise c) To identify the process involved in the operation
2	20 Mar 2018	On site Audit conducted through walkthrough assessment and interviews a) To observe production process and gather information. i) Material consumption ii) Electricity consumption iii) Water consumption iv) Fuel consumption v) Solid waste, Hazardous waste and waste water generated. vi) Safety and health b) To identify the input and output of resources at each production stage and summarized in process flow chart.
3	8th July 2018	CP option generation a) To conduct environmental, feasibility, technical studies to identify feasible option.

3.4.2 Preliminary Assessment

Preliminary assessment was conducted to gather the basic background information of the premise which includes the operation hours in the plant, the total number of products produced, the number of employees, unit operations involved, type of processes involved. The site layout of the plant was obtained from the facilities and management team to be familiar with the location of operation sites such as the production, storage of raw material, warehouse, administration and WWTP. A process flowchart as shown in Figure 3.2 was obtained from the relevant personnel to further understand the operation.

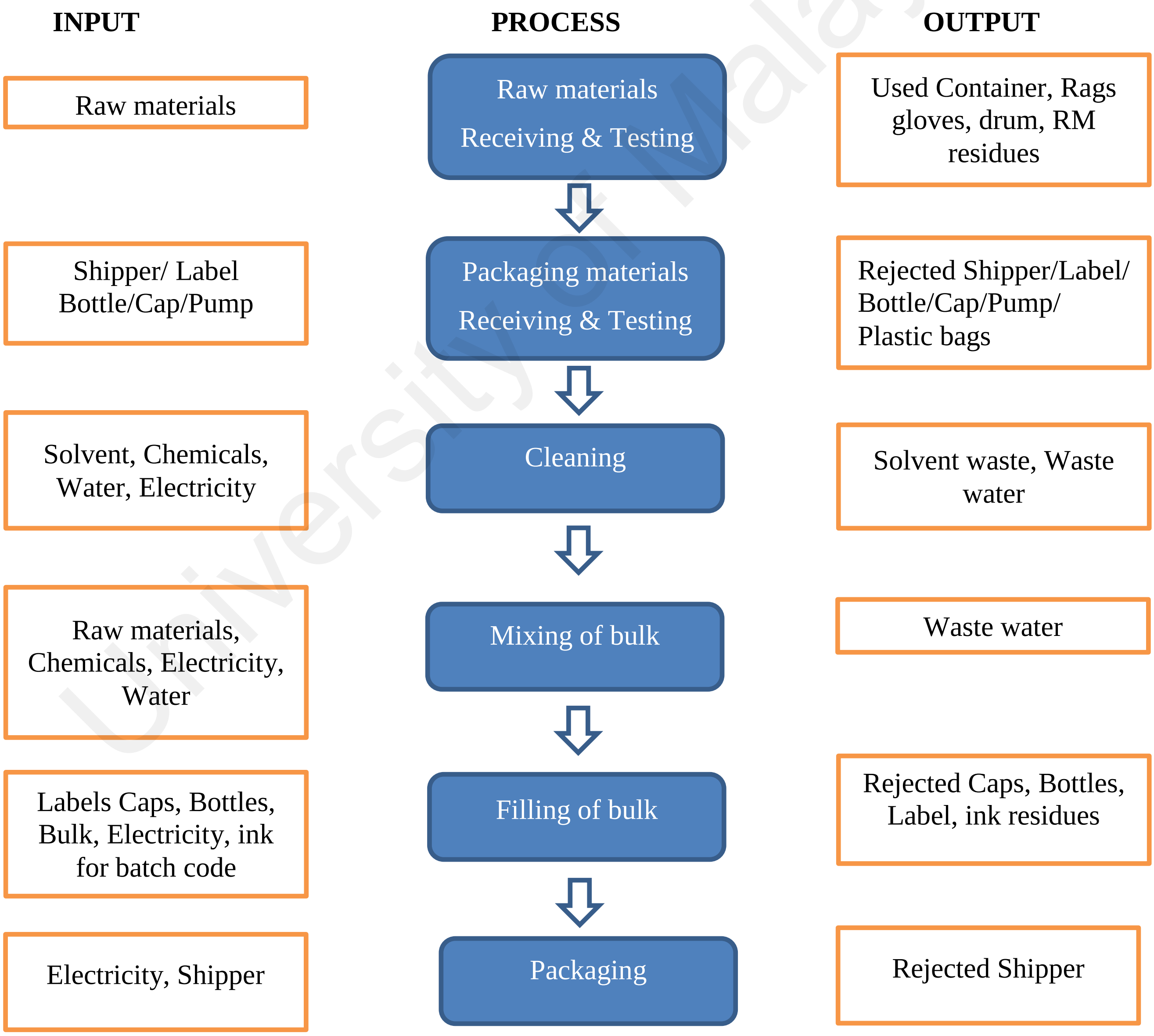

Figure 3.2: Process flowchart in manufacturing

3.4.3 On Site Cleaner Production Audit

The Cleaner Production audit was conducted at the premise by observation and walk through assessment in the plant on 20th March 2018. The machine operator, supervisor, facilities and maintenance team was interviewed during to audit to understand the operation and process flow. The main objective of the audit is to obtain the qualitative and quantitative information on the operation processes, resource consumption and waste generation. The information gathered includes the raw material consumption, water consumption, electricity consumption, fuel consumption, waste water generated, solid waste, hazardous waste, CO_2 emission per unit of healthcare product produced (kg CO_2 / litre) of at the premise. The data were also collected based on reviewing the work flow in each processes, material and utility inventory record. Audit form as in the Appendix I was used during the audit.

3.4.4 Cleaner Production Audit Analysis

The audit findings were analyzed and the data were compiled for further study. These are some data identified as the major requirement for the study:

A.	Production	Estimation Method
1.	Raw material consumption	Amount of raw material required to produce 2000 ton
2.	Water consumption	Amount of process water, non-process water and domestic water (Refer to utility bill)
3.	Fuel consumption	Amount of fuel required to produce 2000 ton
4.	Electricity consumption	Amount of electricity consumption for different unit (Refer to utility bill)
5.	Chemicals consumption	Amount of chemicals consumption for testing in laboratory
6.	Steam	Amount of steam required to produce 2000 ton
B.	**Waste**	**Estimation Method**
1.	Solid waste	Waste from rejected packaging material, sampling and testing in IQC
2.	Hazardous waste	Waste from production process
3.	Waste water	Waste from production process
C	**Others**	**Estimation Method**
1.	Operation Cost	Production cost includes labour cost
2.	Batch production time	Production time for one batch
3.	Safety Issues	Risks encountered during production

3.5 Carbon Footprint Estimation

The carbon footprint method will be used to calculate the life cycle GHG emissions which is caused indirectly or directly by an individual, product, process, event or organization (Vasan, Sood, & Pecht, 2014). Carbon footprint (CFP) is the measurement for estimating the impact of human's activities to the climate change. Typically, the calculation for CFP is not just depending on the emission of CO_2 but also the emission of other GHGs. The following are the basic formula to calculate CFP release to the atmosphere. The CO_2 emission was quantified based on the Intergovernmental Panel of Climate Change (IPCC) method to evaluate the GHG emission for major economic sectors (Verge et al., 2013). The Carbon footprint is usually expressed in terms of CO_2 equivalent and will be calculated using the Global Warming Potential (GWP) of a GHG (Vasan, Sood & Pecht, 2014). The Carbon footprint analysis will allows the organization to assess the operational process and identify the greatest environmental impact. Besides, it will give the organizations to identify the inefficient processes that can be improved to reduce the costs and save resources through CP options such as lowering the resource consumption in production (Vasan, Sood & Pecht, 2014). According to the methodology, the CO_2 emission of an entity is calculated based on the formula in Equation (1):

$$\boxed{CO_2e\ (kgCO_2) = CEF \times entity\ utilization\ or\ rate\ (unit\ entity)} \quad \ldots\ldots\ldots\ldots (1)$$

Table 3.2: Carbon emission factor

Resource and waste	**CEF Value**	**Unit**
Natural Gas	53.06	kg CO_2/mmbtu
Electricity	0.70	kgCO_2/kWh
Water	0.32	kgCO_2/m^3
Solid Waste	3.7	kgCO_2/kg
Waste water	1	kgCO_2/kg COD removed
Steam	0.61	kgCO_2/kg

Source: (IPCC, 2006) & (Rahim & Raman, 2015)

3.6 Cleaner Production Generation

Once the data is gathered and analyzed, cleaner production options will be identified and generated at the respective areas of improvement. CP is an effective management tool to improve environmental performance as well as to enhance productivity. CP shall be generated based on 8 types of categories which can be categorized as follows:

1. Process optimization

   To study the operation and process involved in the production process. There may be need to optimize certain process which will enable to save resources and energy.

2. Process change

   Certain process change will potentially save energy and resource consumption. The increase in air conditioning temperature will be able to save electricity consumption.

3. Design change/ modification

   The equipment can be modified to enhance the production process. The oil free air compressor can be suggested to use which will potentially reduce carbon dioxide emission.

4. Housekeeping

   Clean the working area regularly to make sure the environment is clean and safe. This will enable to reduce the material loss and minimize injury of workers.

5. Material substitution

   To further study the materials used in the production process. For example, it is advisable to use less hazardous chemical in the cleaning process.

6. Technology improvement

   There are technologies available in terms of reducing material and energy consumption. For example, the installation of solar PV panels which will enable reduce the electricity

7. Reuse/Recycling

   There are many materials can be recover during the production process. For example the packaging materials can be reuse.

8. Training and awareness for staff

   The staff shall be trained to create awareness on the changes made in the premise. Besides that, staff should be educated on the concept of CP.

3.7 Cleaner Production Option Prioritization Methodology

CP options generated in the key area based on the data obtained. It is equally important to classify the CP option to be implemented based on the prioritization. It is important to carry out environmental, economic and technical feasibility studies for the identified CP options. The economic feasibility study focuses on investment costs, return of investment (ROI) and annual benefits. The CP implementation may require some form of investment. The investment required against savings achieved must be assessed if the CP options are based merely on financial returns. The operational costs before and after the CP implementation should be taken into consideration. Hence, the CP options targeted to be implemented are based on zero or low investment cost and which requires short period of time for the implementation process.

Technical evaluation can be divided into two parts. First, the CP option should be evaluated based on the practicability and reliability of the equipment. This includes the effect on productivity and the utility requirements of a CP option. Besides that, any changes in the technical specifications shall be converted into expected material balance to reflect the input and output of material flow, energy requirements after the implementation of CP options.

Environmental evaluation will be carried to further understand the positive and negative environmental impacts of the respective CP option. The environmental evaluation includes the potential reduction of CO_2 and waste by the CP options proposed. It also includes the changes in the energy throughout the life cycle.

The prioritization of CP options are based on the certain criteria such as financial return, increasing the product quality, reduces the risk in the premise and improve efficiency in production process.

The types of criteria for CP implementation are listed as follows:

<u>Type 1: Implement immediately</u>

CP options without any cost of investment shall be implemented immediately for examples good practices. Good practices such as switching off light during the break hour can potentially reduce electricity consumption.

<u>Type 2: Implement within 6 months</u>

CP options with the available materials, technology and finance can be implemented within 6 months. The planning and implementation of CP options which requires short period of time shall be implemented within 6 months. The implementation of CP options shall be able to reduce the cost of production and improve overall efficiency.

Type 3: Implement only if finance is available

CP options which require high cost of investment will be only implemented once the finance is available.

Type 4: Keep it as future plan

CP options that can be implemented once resources and manpower available should be keep it as future plan.

Type 5: Drop it for at least 10 years

CP options with longer payback period shall be keep it as future plan. This CP option can be addressed as the long term goal.

Type 6: Ignore it

The CP option which is not feasible in terms of environmental, technical and finance shall be ignored.

3.8 Payback Period Calculation

The Payback period calculation will be used in the company for economic feasibility studies. This involves the estimation of the cost of investment required for implementing CP options and determining the expected savings. The payback period is the duration of time required to recover the cost of an investment. The shorter payback period is preferred in the project since investment cost is recovered sooner.

The formula will be used to estimate the payback period:

$$\text{Payback period in years} = \frac{\text{Capital Investment}}{\text{Annual Savings}}$$

3.9 Safety Procedures Adopted during Study

A walk through inspection and interviews will be conducted to observe and gather relevant data from start to end of the process in the operation which includes consumption of water, energy, electricity, emission and the waste generated. During the audit, the operation of machines, handling of materials, storage area will be inspected as well. Safety measures should be taken prior to the visit. There are some steps shall be taken prior to the visit such as the audit checklist and plan the areas to be inspected. The operators working at the area should be informed in advance regarding the visit. This is to ensure some aspects of safety will be taken for example the machines is not operated during the inspection. The interview session with the operators should be carried out at appropriate time where they are not busy with the operation. This is to ensure the operators are not distracted and prevent from any accidents. It is also important to make sure during the audit there are no repair and maintenance work are carried out at the operation area. Apart from that, it is important to follow up on the safety practices that have been implemented in the premise. Some of the safety practices which includes wearing safety shoe, PPE and face mask when entering the production area. There are certain areas need extra precautions such as the mixing areas which involve handling of raw materials, chemicals, and high temperature.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Audit Analysis

In the healthcare products manufacturing premise, cleaner production audit was carried out in the premise as planned. The manufacturing premise operates 24 hours daily with overall 150 workers involved in the daily operation. The premise will cover three shift daily includes morning shift, afternoon shift and night shift. The operators will be paid RM15 per hour. The premise produces 75 batches per week which is equivalent to a total of 500 tons. The manufacturing of one batch of healthcare product will take about 5 hours. In this study, the resource consumption, process flow, operational practices were identified and analyzed. The audit findings are summarized in Appendix A. Table 4.1 summarizes the annual consumption of three major resources used in the production.

Table 4.1: Resource consumption of healthcare product production on annual basis

Resource	**Electricity(kWh)**	**Water (m^3)**	**Natural Gas (mmbtu)**
Annual Consumption	8.2×10^6	6.1×10^4	3.6×10^4
Unit Cost(MYR)	0.219(Off peak) 0.355(On peak)	2.28	30.84
Annual Cost (MYR)	2.5×10^6	1.4×10^5	1.1×10^6

4.1.1 Electricity Consumption

In this study, the quantification of electricity was calculated based on the monthly bill received from TNB. Analysis of the audit findings showed that a total of 416,477 kWh/ month electricity were used in the operation during the peak hours. The electricity was purchased at 0.355 MYR/kWh which accounts about RM147, 849 per month. However, the electricity consumption during the off peak hours is about 272,678kWh and was purchased at the rate of 0.219. The electricity consumption during the off peak hour is about RM 59,716. Overall, the total electricity consumption per month in the premise is 689155 kWh. In the audit finding, the main unit which involves in the operation was identified with the respective energy rating. Table 4.2 shows the electrical consumptions of main unit operation with the energy rating and daily operating hours are presented as below:

Table 4.2: Electricity consumption of different unit

Type	**Operating hours/month**	**Monthly consumption (kWh)**
270kW Air Compressor	312	8.4×10^4
55kWMachine	576	3.1×10^4
1.2kWLight	576	6.9×10^2
37.5kWAir conditioner	576	2.1×10^4
18.5kWMotor pump	576	1.0×10^4
5.25kWComputer	192	1.0×10^3
1728.46kWBoiler	312	5.3×10^5

4.1.2 Water Consumption

Based on the audit finding, it shows that water is essential for manufacturing process in healthcare products. Water is used as the main ingredients and for cleaning purpose in the operation. In the manufacturing process of a shampoo, a total quantity of 7083 kg of process water will be used to produce 10 ton of finished product. Water was purchased with at MYR2.28, with consumption approximately /month which translated into MYR11509/months. Besides that, non-process water is essential for cleaning and sanitization process in the operation which includes cleaning in process and cleaning out of process. The Cleaning in process consists of cleaning of filler, mixing tank, storage tank. The cleaning out of process includes cleaning of floor, hose, and pumps and other items. The cleaning and sanitization process will consume about 2778 m^3 of water per month. Water used for domestic purpose in the premise will be about 853 $m^{3.}$ Table 4.3 summarized the water consumption in the premise.

Table 4.3: Analysis of water consumption in the premise per month

Process	**Water consumption/month (m^3)**
Process Water	1417
Non Process water (CIP)	2778
Non process water (Domestic)	853
Total	5048

4.1.3 Raw Material Consumption and Chemicals

There are huge amount of raw materials used in the healthcare product manufacturing premise. Based on the audit finding, 2917 kg of raw material is required in the manufacturing of 10 ton of shampoo. Audit finding shows that the amount of raw material input in production per month is 598 ton. Based on the audit finding, it is found that 15 ton of raw material was lost during operation. During the audit, the raw material storage area, receiving area, compounding area and packaging area were evaluated to identify the raw materials losses. The raw materials provided in bags and large drums are delivered to the compounding area. These raw materials are weighed and poured into the mixing tank for mixing. It was identified that the raw materials were lost during the storage, transfer, contamination, expired and due to the handling process. During the audit, it was found there is no proper segregation of raw material containers for two different batches and they were placed on the same pallet. This will eventually lead to contamination of the raw materials and reported as waste. Besides that, it is also found that 30 litres of chemical is being used in the microbiology lab and the analytical lab per month.

4.1.4 Fuel Consumption

The plant consumed natural gas to be used in the operation process which includes heating and mixing. The natural gas was quantified based on the monthly record of natural gas purchase where the total price of natural gas was translated into the amount of natural gas in mmbtu. Natural gas was used as the source of fuel for the operation in the plant. The natural gas was consumed at a rate of 3045 mmbtu/month or MYR93, 907/month.

Steam also been used in the heating process during the mixing. Audit finding shows 5852 kg of steam used to produce 10 tons of products. Overall, a total of 1170 ton of steam is required in a month.

4.1.5 Waste Generation

The waste produced in the manufacturing premise can be divided into three categories which are solid waste, waste water and hazardous waste. Table 4.4 shows the quantification of waste produced per month.

Table 4.4: Waste produced per month

Type of Waste	**Quantity per month**
Solid waste	1237 kg
Waste water	3773 m^3
Hazardous waste	5500 kg

The audit finding has shown the total solid waste generated per month is about 1237 kg per month. The solid wastes are comprised of packaging material which includes rejected caps, shipper, bottles, pouches, labels. Based on the audit finding, it shows the number of rejected pouches is highest during the setting of machine. The United States Environmental Protection Agency (EPA) classifies liquid, solid, and gaseous discarded materials and emissions as hazardous if they are poisonous (toxic), flammable, corrosive, or chemically reactive at levels above specified safety thresholds. Table 4.5 shows the analysis of the audit finding of hazardous waste in the premise.

Table 4.5: Hazardous waste in the manufacturing premise

No	Hazardous waste
1	Chemical waste such as residues of raw materials from drums, tank in industry
2	Solvent waste from equipment cleaning
3	The ink used for printing the batch code on the bottles, shipper.
4	Used packaging materials for testing
5	Tested finish products in lab
6	Off specification products (packaging materials and finish products)
7	Used materials such as rags, gloves in contact with chemicals
8	Leaked/spilled raw materials bulk during operation and transportation
9	Residue of the balance supplier packaging such as plastic drums, paper, plastic bags and bins
10	Expired raw material
11	Used chemicals in lab for testing
12	Solvent (methyl ethyl ketone) was used to adjust the ink viscosity and to clean the ink jet head

Besides that, the waste water generated in the operation accounts for 3777 m^3/ month. This waste water generated during the cleaning and sanitization activities of the machines and equipment, waste water from domestic and water due to leakages and overflow during the operation. In the WWTP, the total operation cost is RM39569 per month. Certain chemicals will be used to treat the waste water. The discharged wastewater had a COD value of 62 mg/L.

4.1.6 Safety Issue

In this audit, safety issues encountered during the operation was identified. Some of issues identified are listed as below:

Table 4.6: List of safety issues in the premise

No	Safety issue	Risk
1	Leakage of piping which causes water to be stagnant at the working area.	Slips, trips and falls
2	Insufficient anti slip staircase at the working area	Slips, trips and falls
3	Floor cracked at the working area	Slips, trips and falls
4	Water overflow from the reservoir tank at chiller area	Slips, trips and falls
5	No proper place to keep PPE. Workers will find difficulties in finding PPE.	Hot, wet, slippery surfaces, falling objects, hearing loss
6	Malfunction of light in the label room	Slips, trips and falls
7	No light at the pavement area at night.	Slips, trips and falls

4.2 Carbon Footprint Estimation

Carbon footprint quantification has been carried out to estimate the carbon dioxide emission in the operation. The total CO_2 emission was calculated for the electricity consumption, water consumption, fuel consumption, solid waste and waste water generated. The total CO_2 emission from the premise was approximately 650 ton on a monthly basis, which was equal to 323 kg/CO_2 1000 litre per healthcare product produced. Table 4.7 shows the CO_2 emission in the healthcare product manufacturing premise.

Electricity

The average electricity used = per month

Estimated CFP = 689155 X 0.70 $kgCO_2/kWh$

= 4.8×10^5 kg CO_2

Water

The average water used = 5048 m^3 per month

Estimated CFP = $5048m^3 \times 0.32\ kgCO_2/m^3$

= 1.6×10^3 kg CO_2

Fuel

The natural gas used = 3045 mmbtu per month

= 3045 mmbtu × 53.06 kg CO_2/mmbtu

= 1.6×10^5 kg CO_2

Solid waste

Solid waste generated = 1237 kg per month

= 1237kg × 3.7 kg CO_2/kg

= 4.5×10^3 kg CO_2

Waste water

Waste water generated = 3777 m^3 / month

$$= \frac{3777m^3 \times 1000 \times 62mg/l \times 1\ kg\ CO_2/kg\ COD\ (removed)}{1000000}$$

= 2.3×10^2 kg CO_2

Steam

Steam generated = 1170 tons / month

= 1170 × 1000 × 0.16 kg CO_2

= 1.8×10^5 kg CO_2

Table 4.7: CO_2 emission in the 1000 liter healthcare product

Entities	**CO_2 emission kg CO_2/month**	**kg CO_2 /1000 litre healthcare product**
5048m^3 of water	1.6×10^3	0.8
689155 kWof electricity	4.8×10^5	240.0
3045mmbtu Natural gas	1.6×10^5	80.0
1237 kg of solid waste	4.5×10^3	2.3
3777 m^3 of waste water	2.3×10^2	0.1
Total	6.5×10^5	323

4.3 CP Options Generation

Based on the audit findings and analysis, CP options have been generated to improve the efficiency in production and to reduce the carbon footprint generated in the premise. Cleaner production has intentions for making the efficient use of resources and reducing the generation of emissions and waste. This can be achieved by several ways. Figure 4.1 shows the cleaner production in relation to integrated pollution prevention.

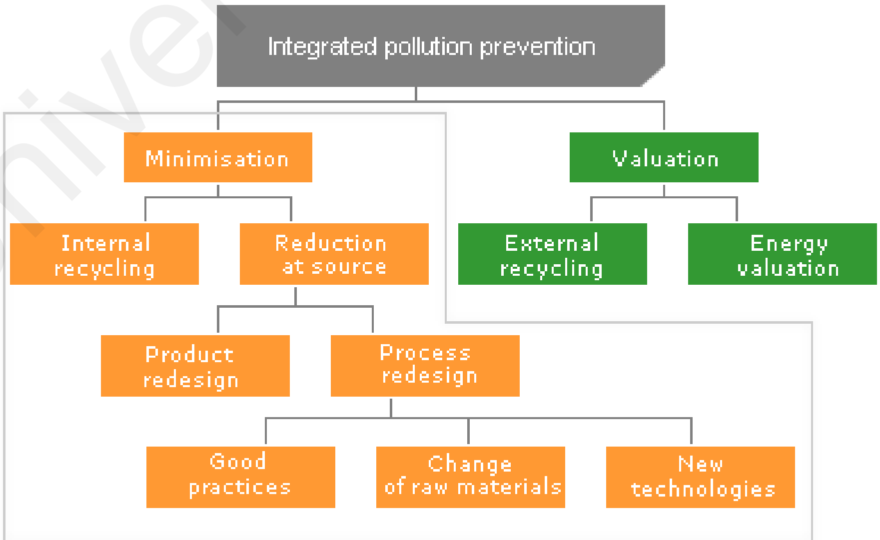

Figure 4.1: Cleaner Production in relation to integrated pollution prevention

Source (Regional activity center for sustainable consumption reduction)

4.3.1 CP Options for Electricity Consumption Reduction

Electricity has been the highest contributor of CO_2 emission in the premise. Most of the electricity consumption is from motor, pump, chiller, air conditioner, boiler, lighting, air compressor. The feasible CP options have been generated to reduce the electricity consumption in the premise as well as the CO_2 emission. The management should play a major role for the continuous improvement to manage energy effectively in the premise. The management should develop record and maintain an energy review. Energy performance indicator should be identified to monitor the energy performance. In terms of energy purchasing, the fuel should be evaluated on the carbon content. The fuel with lower level of CO_2 emission should be purchased.

CP OPTION 1 (Lightning Control zones)

Energy efficient practices should be implemented in lighting area. Lighting control zones by functional area can be set up. The occupancy sensor and timer in spaces should be installed when people move in and out at the reception area and office. The office layout can be modified to introduce day lighting system where there electric light can be switched off. This option can reduce the electricity consumption by 10% and CO_2 emission which is about 69 kWh/ month and 48 kg CO_2 respectively.

CP OPTION 2 (Energy efficient T5 lamp)

The use of energy efficient T5 lamp which has greater luminous efficacy ranges between 90lm/W and 104lm/W. This option has highest energy reduction and has long shelf life which up to 24,000 hours. Total reduction in load per T5 lamp has been suggested to use. Thus, installation of T5 lamp with the capacity of 21W is recommended to use (Mohammad Asif et al., 2013). These T5 lamps will consume about 605kWh/month and reduces energy consumption by 12% compared to the current lamps. This CP option will leads to reduction of 60 kg CO_2 per month. The calculation for payback period for installing T5 lamp is shown below:

Investment Cost	= RM4400
Annual saving	= RM1589
Payback period	= Investment Cost/ Annual Saving
	= RM4400/ RM1589
	= 2 years and 10 months

CP OPTION 3 (Switched off light)

Efficient energy management can achieve by implementing good practices. Ensure the light is switched off during the one hour break. This can be implemented immediately since there is no investment cost needed. This CP option can reduce the electricity by usage by 29 kWh/ month which leads to reduction of 20 kg CO_2 per month.

CP OPTION 4 (Oil free air compressor)

The air compressor is crucial in the manufacturing. Based on the audit finding analysis, it was evident that there are two different air compressors where oil injected and oil free are used. The current air compressor used in the manufacturing is old and the parts are worn out. The cost of maintenance for the old air compressor is increasing. The plant can significantly reduce the operational expenses and yearly CO_2 emission by investing on oil free new compressor. The oil free air compressor consists of coarse and fine dust filters which will remove the dust from the compressed air to prevent contamination. The oil coalescing filters is one of the component in the air compressor to remove the oily contaminants. The oil free compressor consist of air compressor, air receiver tank, oil coalescing filter, air dryer, dust filter, flow meter, dew point meter, compressor controller, cooling tower and condensed water. The investment cost includes the overall estimation cost for installation of all the units of compressor. The annual savings includes maintenance service, energy saving and system service. Installation of oil-free compressor has the potential to reduce energy consumption by 52857 kWh which is equivalent to 37000 kg CO_2 per month.

The calculation for payback period for installing new air compressor is shown below:

Investment Cost	= RM1562000
Annual saving	= RM340640
Payback period	= Investment Cost/ Annual Saving
	= RM1562000/ RM340640
	= 4 years and 7 months

CP OPTION 5 (Installation of inverter for compressor)

Installation of an inverter unit in the compressor will be able to control the flow rate as well as reduce the power consumption. This CP option have been implemented in the fruit juice production plant where by the energy consumption can be reduced to 10% (Rahim & Raman, 2015). Installation of inverter can reduce the energy consumption by 8424 kWh/per month which is equivalent to 5897 kg CO_2 per month.

The calculation for payback period for installing new air invertor for air compressor is shown below:

Investment Cost	= RM28948
Annual saving	= RM22138
Payback period	= Investment Cost/ Annual Saving
	= RM28948/ RM22138
	= 1 year and 4 months

CP OPTION 6 (Air compressor turned off)

The air compressor shall be turned off during the one hour rest time. This can potentially reduce the energy usage by 6480 kWh/ month which leads to reduction of 4536kg CO_2 per month.

CP OPTION 7 (Air conditioner switched off)

The CP options suggested in the study focused on the efficient management of air conditioning system. Some of the CP options suggested are the good practices to be implemented in the plant. One of the CP option suggested is to switch off the air conditioner for about one hour in the office. Instead of using air conditioners, good practice can be implemented by opening the window to maintain good ventilation at the area. It is also recommended to switch off the air conditioning system at the unoccupied area. This results in electricity savings without any investment cost. Besides that, ensure correct temperature setting for certain area to be used. Based on the study conducted by (Abdul Kader, 2014) it shows that there is potential electricity saving about 6% by increasing the temperature by 1°C. Hence, in this study, it was suggested that the plant increase the air conditioning temperature from 18 °C to 20°C which would results in 12% electricity saving without any investment cost. The electricity saving per month will be 2592 kWh which potentially reduce the CO_2 emission by 1814 kg CO_2 per month.

CP OPTION 8 (Performance test of motor and pumps)

CP options suggested conducting performance test and evaluating operation of motor and pumps. The motor and pump used at combustion air fan, boiling feed water pump, cooling tower fan motor, condenser water pump and chilled water pump. The maintenance department needs to ensure the pump and motors are not oversized. The improvement in the efficiency of electric motors will enable to save energy and reduce the operating cost.

<u>CP OPTION 9 (Installation of Solar panel)</u>

CP option suggested using renewable energy by installing the Solar panel which will potentially minimize the electricity usage and eventually reduce the CO_2 emission. The Sustainable Energy Development Authority of Malaysia (SEDA) has governed and manages the implementation of the feed in-tariff which is mandated under the Renewable Energy Act 2011. The development of Photovoltaic technology involves the conversion of sunlight directly into electrical energy and has become a favorable option. The generation of CO_2 emission per kilowatt-h generated from the solar energy is minimal which accounts about 0.03-0.09 kg/hour (Kabir, Kumar, Kumar, Adelodun, & Kim, 2018). In the premise, the installation of 1 unit of 12 kWp solar inverter will cost RM78000. Based on the SEDA project feed on tariff, 12 kWp panels will generate 1250kWh per month. The electricity saving per month will be 1250 kWh which potentially reduces the CO_2 emission by 875 kg CO_2 per month. The calculation for payback period for installation of for air 12 kWp solar panel is shown below:

Investment Cost = RM78000

Annual saving = RM5325

Payback period = Investment Cost/ Annual Saving

= RM78000/ RM5325

= 15 years

Figure 4.2: Solar PV panels

4.3.2 CP Option for Reducing Water Consumption

Water is the major requirement in the manufacturing process. Based on the carbon footprint quantification, water has contributes to 1615 kg CO_2. The feasible CP option and best practices suggested for conserving water in manufacturing. The implementation of CP options will reduce the water usage and carbon footprint.

CP OPTION 10 (Installation of Water Sense Low flow aerators)

Install low flow domestic equipment in the toilets and sinks. This will control the amount of water we used to flush in the toilets. The tap aerators, flow restrictors and trigger hose nozzles shall be installed to regulate the water flow. The Water Sense low flow aerators known as the water saving faucets that can be used in toilets and kitchen (EPA, 2013). Based on the water corporation analysis, this flow aerator can save up to 220 liters per faucet in a month. Thus, the installation of flow aerator will potentially reduce 7 kg CO_2 per month. The calculation for payback period for installation of for 100 air water sense flow aerator is shown below:

Investment Cost	= RM1500
Annual saving	= RM601
Payback period	= Investment Cost/ Annual Saving
	= RM1500/ RM601
	= 2 years and 6 months

CP OPTION 11 (Installation of Tank Jet 360)

The high efficiency cleaning equipment with low volume as high pressure sprays washers and existing hoses to be use. The tanks shall be designed with the spray ball device to cover the entire surface area. Tank Jet 360 tank cleaner can be used for tank with 30m in diameter. Based on Spraying System Co, the Tank Jet has high impact cleaning results with short cycle time and waste saving by 50%. This CP option will reduce the water bill and CO_2 emission by RM3167 and 445kg CO_2 respectively. The Figure 4.3 shows the Tank Jet 360 tank cleaner. The calculation for payback period for installation of for Tank Jet 360 tank cleaner is shown below:

Figure 4.3: Tank Jet 360 tank cleaner

Investment Cost = RM40000

Annual saving = RM38004

Payback period = Investment Cost/ Annual Saving

= RM40000/ RM38004

= 1 year and 1 month

CP OPTION 12 (Use dry cleanup methods)

Dry cleanup methods (dry absorbents) can be used instead of water. This will require lower amount of water usage for cleaning.

CP OPTION 13 (Optimization in cleaning and sanitization method)

To optimizes the cleaning and sanitization procedure in the operation. The cleaning process should be made in effective and reduce the water usage in the sanitization process. This CP option will potentially reduce 50% of water usage in the operation and equivalent to CO_2 emission reduction of 445kg CO_2.

CP OPTION 14 (Reuse of water)

Water used for rinsing in the cleaning procedure can be reused. The rinse water can be used as pre-rinse of the next cleaning cycle. Besides that, the recycled water shall be used for the initial cleanup of floor and spills.

CP OPTION 15 (Rainwater harvesting)

Rainwater harvesting should be suggested as one of the CP Option to ensure the continuous water supply for domestic purpose. Recycling rain water with the existence of rainwater harvesting system will be effective in providing regular clean water supply for domestic purpose.

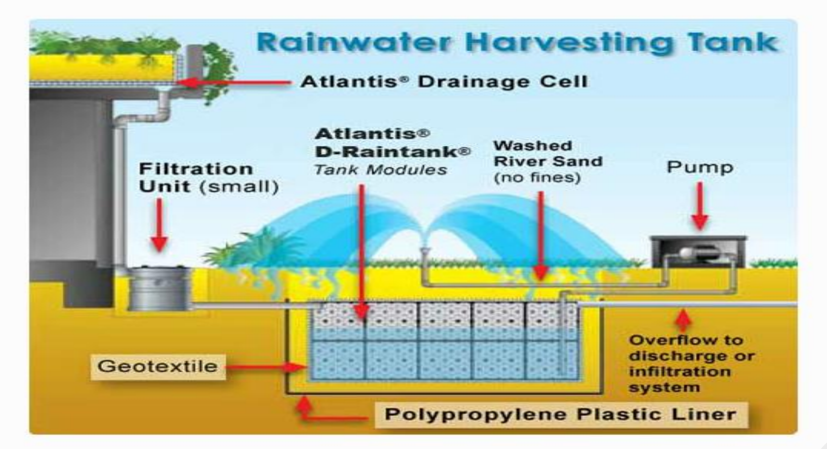

Figure 4.4: The rainwater harvesting tank

4.3.2 CP Options Reducing Natural Gas Consumption

CP OPTION 16 (Insulation of the furnaces)

CP option shall be implemented to reduce the natural gas consumption in industrial process heating system. The furnace shall be well insulated to minimize the heat losses to ensure the temperatures are kept low on the outside surfaces. This CP option will enable to reduce the energy usage by 5%.

CP OPTION 17 (Operation of heating equipment at full load)

Recover heat from the exhaust or flue gas to be used for heating air, water and preheating the material. Besides that, efficient operating practices shall be implemented such as to make sure the heating equipment to be operated at full load and minimize the delays between cycles. This CP option will enable to reduce the energy usage by 15%.

4.3.3 CP Options for Raw Materials and Chemical Optimization

CP OPTION 18 (Eliminate the use of hazardous chemicals)

Eliminate the use of certain hazardous chemicals in cleaning procedure. Reduce the percentage of solvent such as IPA used in the cleaning processes and laboratory.

CP OPTION 19 (Use of natural key ingredients)

Continuous improvement shall be carried out in the raw material, ingredients selection for formulations. Natural key ingredients should be used in the formulations to ensure the product is safe and reduce the environmental impact.

CP OPTION 20 (Segregation and storage of raw materials)

CP option suggested to have designated place for storage and the segregation of raw materials. Ensure the raw material placed on the pallet is for one respective batch. Segregation of the raw materials should be done appropriately at the compounding area. This is to prevent the contamination of raw materials which eventually end up as waste.

CP OPTION 21 (Monitor the inventory of raw material)

The inventory of raw materials should be control to reduce the raw materials lost due to expiry. Production should take note on the expiry of raw materials and used it wisely to prevent waste. Estimate the amount of chemicals and raw material required on a single experiment or project basis rather than purchasing on annual basis. This is because unused of chemicals and raw materials within the period of shelf lives will become unusable and contributes to the significant source of hazardous waste.

4.3.4 CP Options for Waste management

CP OPTION 22 (Introduce composite testing material)

CP options shall be suggested to reduce the overall bulk wastage. Revamp back the method used to test the bulk and product. In the premise, the bulk wastage are mainly comes from the laboratory where the large number of products will be disposed after the testing. Hence, composite testing method shall be introduced to reduce the testing of bulk and products which will reduce the bulk wastage. Apart from that, chemicals and containers used for the testing will also be reduced.

CP OPTION 23 (Reuse the packaging materials)

The drums and plastic bags of the raw materials can be reused by external companies after cleaning. This will reduce the solid waste generated at the site. The carbon footprint can be reduced by 10% which is equivalent to 459 kg.

CP OPTION 24 (Improvisation in machine setting)

Improve in the machine setting at the production to minimize the number of pouches rejected. This will ensure the reduction in rejected packaging material by 50%. Thus reducing the carbon footprint by 2290 kg CO_2. There is no investment cost needed.

CP OPTION 25 (Improvisation in sampling and testing method)

Improve the sampling and testing method in the incoming quality check for packaging materials includes shipper, bottles, cap, pumps and label. This is because there are large number of samples being tested at the incoming and results in waste. Hence, it will have great impact on the reduction of solid waste. The carbon footprint can be reduced by 10% which is equivalent to 459 kg.

CP OPTION 26 (Waste Segregation)

Waste segregation should be implemented at the premise. This is to ensure possible materials can be segregated accordingly and recovering, reuse and recycle of material can be done at the site. Hence, overall the waste will be reduce and it can be managed effectively. The carbon footprint can be reduced by 10% which is equivalent to 459 kg.

4.3.5 CP Options for Process Improvement

<u>CP OPTION 27 (Improve design in cleaning and sanitization)</u>

The effectiveness in the cleaning and sanitization process is crucial to ensure the healthcare products are free form any contaminants. The procedures need to be validated to ensure it meets the hygienic manufacturing requirement. The manufacturing and filling equipment should have good drainage to ensure the cleaning and sanitization process is effective. Moreover, the equipment should reduce the retention of the water or product residual. The cleaning and sanitization process with the improved design and methods will make the process more effective as well as have shorter cycle time. The cycle time for the cleaning and sanitization process can be improved from 2 hours to one hour. The Figure 4.5 shows the design of the equipment of process plants to facilitate cleaning.

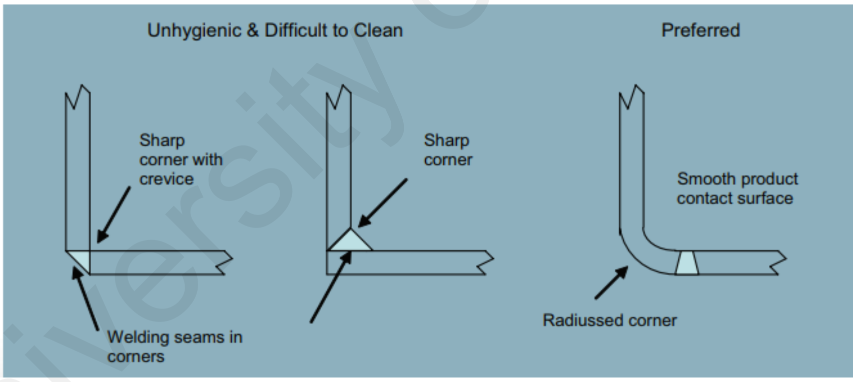

Figure 4.5: The angles and corners of process plants to facilitate cleaning (Hasting, 2008)

<u>CP OPTION 28 (Similar formulation batch production)</u>

Similar formulation batches can be produced that does not require cleaning between batches. This will reduce the water usage, cleaning frequency and have shorter cycle time.

CP OPTION 29 (Implementation of Waste water treatment technique)

CP application shall be implemented to reduce the COD of the waste water generated in the premise. The high level of COD poses significant effect to the health as well as the environment. Waste water treatment techniques such as coagulation-flocculation-sedimentation, and activated carbon absorption can be used to reduce the COD value in the waste water.

CP OPTION 30 (Implementation of FIFO

The implementation of First in First out (FIFO) to prevent the materials been kept up for a longer period than required. The practice of FIFO is important because the expired raw materials will contribute to scheduled waste.

4.4 Safety, Health, Environment & Management Status

CP OPTION 31 (Improve in Safety Health and Environment)

The Safety & Health in the workplace should monitor and actions should be taken to improve the working environment for the employee. There are some safeties issues have been identified during the audit. Based on the finding, actions should be taken to mitigate the issues. The implementation of CP wills improves safety work practices by providing safe working environment. These will ensure the operation to run smoothly without any intervention and downtime. Efficient working environment with maximum production output can be achieved by prioritizing safety issues.

Table 4.8: List of safety issues and actions taken to mitigate the issue

No	Safety issue	Actions
1	Leakage of piping which causes water to be stagnant at the working area.	Maintenances team shall repair the leaking pipe immediately.
2	Insufficient anti slip staircase at the working area	Anti-slip staircase shall be placed at the working area
3	Floor cracked at the working area	The floor basement should be fixed immediately to ensure there are no Slip, Trip and Fall.
5	Water overflow from the reservoir tank at Chiller area	Maintenances team shall repair identify the root cause and solve problem immediately to prevent overflow
6	No proper place to keep PPE	Designated area to keep PPE and ensure the quantity is sufficient for all the employee
7	Malfunction of light in the label room	To install light at the area and make sure the light source is sufficient to work
8	No light at the pavement area at night.	To install light at the area and make sure there is no risk of Slip, Trip and Fall.

4.5 Summary of Recommended CP Options

Table 4.9: Summary of recommended CP options

CP OPTIONS FOR ELECTRICITY CONSUMPTION REDUCTION					
No	**CP Options**	**Time required for implementation**	**Investment**	**Carbon Footprint reduction per months(kg CO_2)**	**ROI per months**
1	The occupancy Light sensor and timer in spaces should be installed	Immediately	-	48	Immediate
2	Installation of T5 lamp	3 months	RM4400	60	2 years and 10 months
3	Light is switched off during the one hour break	Immediately	-	20	Immediate
4	Installation of Oil free compressor	3 months	RM1562000	37000	4 years and 7 months
5	Installation of inverter unit in compressor	Immediately	RM28948	5897	1 year and 4 months
6	Air compressor turned off	Immediately	-	4536	Immediate
7	Increase air conditioning temperature	Immediately	-	1814	Immediate
8	Installation of solar panel	6 months	RM78000	875	15 years

CP OPTIONS FOR WATER CONSUMPTION REDUCTION					
No	**CP Options**	**Time required for implementation**	**Investment**	**Carbon Footprint reduction per months(kg CO_2)**	**Payback period (years)**
9	Installation of low flow domestic equipment	2 months	RM1500	7	2 years and 6 months
10	High efficiency cleaning equipment(Tank Jet 360)	3 months	RM40000	445	1 years and 1 month
11	Optimization of cleaning and sanitization procedure	Immediately	-	445	Immediate
CP OPTIONS FOR NATURAL GAS CONSUMPTION REDUCTION					
No	**CP Options**	**Time required for implementation**	**Investment**	**Carbon Footprint reduction per months(kg CO_2)**	**Payback period (years)**
12	Insulation of the furnaces	Immediately	-	8065	Immediate
13	Heating equipment to be operated at full load	Immediately	-	24248	Immediate

CP OPTIONS FOR RAW MATERIAL AND CHEMICAL OPTIMIZATION					
No	**CP Options**	**Time required for implementation**	**Investment**	**Carbon Footprint reduction per months(kg CO_2)**	**Payback period (years)**
14	Eliminate the use of hazardous chemical in cleaning procedure. Reduce the percentage of solvent used	Immediately	-	-	Immediate
15	Natural ingredients to be use in formulation	Immediately	-	-	Immediate
16	Storage and segregation of raw materials in designated place	Immediately	-	-	Immediate
17	The inventory of raw material should be control to reduce loss of raw material due to expiry	Immediately	-	-	Immediate

CP OPTIONS FOR WASTE MANAGEMENT					
No	**CP Options**	**Time required for implementation**	**Investment**	**Carbon Footprint reduction per months(kg CO_2)**	**Payback period (years)**
18	Implement composite testing method to reduce the bulk wastage	Immediately	-	-	Immediate
19	Reuse the drums and plastic bags of the raw material by external companies	Immediately	-	459	Immediate
20	Improvisation in the technical specification of machine to reduce percentage of rejection	Immediately	-	2290	Immediate
21	Improvisation in the sampling and testing method in Incoming quality check (IQC)	Immediately	-	459	Immediate
22	Waste segregation to ensure materials segregated accordingly for	Immediately	-	459	Immediate

	Reuse and Recycle purpose				
CP OPTIONS FOR PROCESS IMPROVEMENT					
No	**CP Options**	**Time required for implementation**	**Investment**	**Carbon Footprint reduction per months(kg CO_2)**	**Payback period (years)**
23	Production of similar formulation batches	Immediately	-	-	Immediate
24	Implementation of First In First Out (FIFO)	Immediately	-	-	Immediate
CP OPTIONS FOR SAFETY HEALTH MANAGEMENT					
No	**CP Options**	**Time required for implementation**	**Investment**	**Carbon Footprint reduction per months(kg CO_2)**	**Payback period (years)**
25	Monitor and actions should be taken to improve the safety and working environment for the employee.	Immediately	-	-	Immediate

Apart from that, these are the following CP options suggested which requires further study.

No	Cleaner Productions Options
1	Ensure motor and pump not oversized
2	Dry cleanup methods (Use absorbents)
3	Reuse the rinsing water in the cleaning procedure
4	Rain water harvesting for domestic purpose
5	Improvisation in the design and equipment in Cleaning and Sanitization process to reduce cycle time
6	Implement Waste water treatment techniques to reduce the COD.

4.6 Recommendation for CP Implementation

Based on the, the audit findings and carbon footprint analysis has shown electricity consumption been identified as the major entity that needs to take into concern to reduce the CO_2 emission. Based on the potential CP options identified in the healthcare products manufacturing premise, CP options without any cost of investment shall be implement immediately. The CP option with shorter payback period should be implemented once the financial is available. The implementation of suggested CP options will reduce the CO_2 emissions by 44839kg CO_2. The CP options recommended for reducing the electricity consumption are listed as below:

No	CP OPTIONS	Electricity(kWh) consumption reduction /month	kg CO_2 / month	Payback period
1.	Installation of occupancy sensor and timer in lightning area	69	48	Immediate
2.	Switch off light during one-hour break	29	20	Immediate

3.	Increase the air conditioning temperature from 18 °C to 20°C	2592	1814	Immediate
4.	Installation of oil free air compressor	52857	37000	4 years and 7 months
5.	Installation of inverter for compressor	8424	5897	1 years and 4 months
6	Installation of T5 lamp	86	60	2 years and 10 months

Besides electricity, the natural gas consumption in the healthcare products manufacturing premise is the second highest which had contributed to CO_2 emission. The CP option without any cost of implement to reduce the natural gas consumption in the premise has been selected as the major option. The CP options to reduce natural gas consumption are based on Energy Efficiency and Renewable Energy (U.S. Department of Energy).The implementation of suggested CP options will reduce the CO_2 emissions by 32314kg CO_2.

No	CP Option	Natural gas (mmbtu) reduction/month	kg CO_2 / month	Payback period
1.	Insulation of the furnaces	152	8065	Immediate
2.	Heating equipment to be operated at full load	457	24248	Immediate

Apart from electricity and natural gas, there are some CP options that can be implementing immediately without any cost of implementation to reduce the water consumption. The implementation of suggested CP options will reduce the CO_2

emissions by 452 kg CO_2. In this case, the installation of low domestic equipment and optimization in the cleaning and sanitization process will be implemented first.

No	CP Options	Water consumption reduction/month m^3	kg CO_2 reduction/ month	Payback period
1.	Installation of low flow domestic equipment	22	7	2 years and 6 months
2.	Optimization in the Cleaning and sanitization process	1389	445	Immediate
3.	Installation of Tank Jet 360 tank cleaner	1389	445	1 year and 1 month

CP options without any cost implementation to reduce solid waste shall be implement immediately. The implementation of suggested CP options will reduce the CO_2 emissions by 3667 kg CO_2.

No	CP options	Solid waste reduction (kg)/month	kg CO_2 / month	Payback period
1.	Reuse the drums and plastic bags of the raw materials	124	459	Immediate
2.	Improvisation in the machine setting to reduce rejected packaging materials	619	2290	Immediate
3.	Improve sampling method and testing method in IQC for packaging materials	124	459	Immediate
4.	Waste segregation should be implemented at the premise	124	459	Immediate

Based on the implementation of recommended CP options, there are possible reductions of carbon footprint emission in healthcare product manufacturing premise. Table 4.10 shows the CO_2 emission in the 1000 litre of healthcare product after CP implementation.

Table 4.10: CO_2 emission in the 1000 litre of healthcare product after CP implementation

Entities	**CO_2 emission kg CO_2/month**	**kg CO_2 /1000 litre healthcare product**
3637 m^3 of water	1.2×10^3	0.6
625098 kW of Electricity	4.4×10^5	219.0
2436 mmbtu Natural gas	1.3×10^5	64.6
246kg of solid waste	9.1×10^2	0.5
3777 m^3 of waste water	2.3×10^2	0.1
Total	5.7×10^5	285

Based on the analysis, the implementation of recommended CP options in the premise will reduce the CO_2 emission in the premise by 12% with a total of 40 kg CO_2 /1000 litre of healthcare product. The Figure 4.6 and Figure 4.7 show the sources of CO_2 emission (kg CO_2) before and after CP implementation respectively.

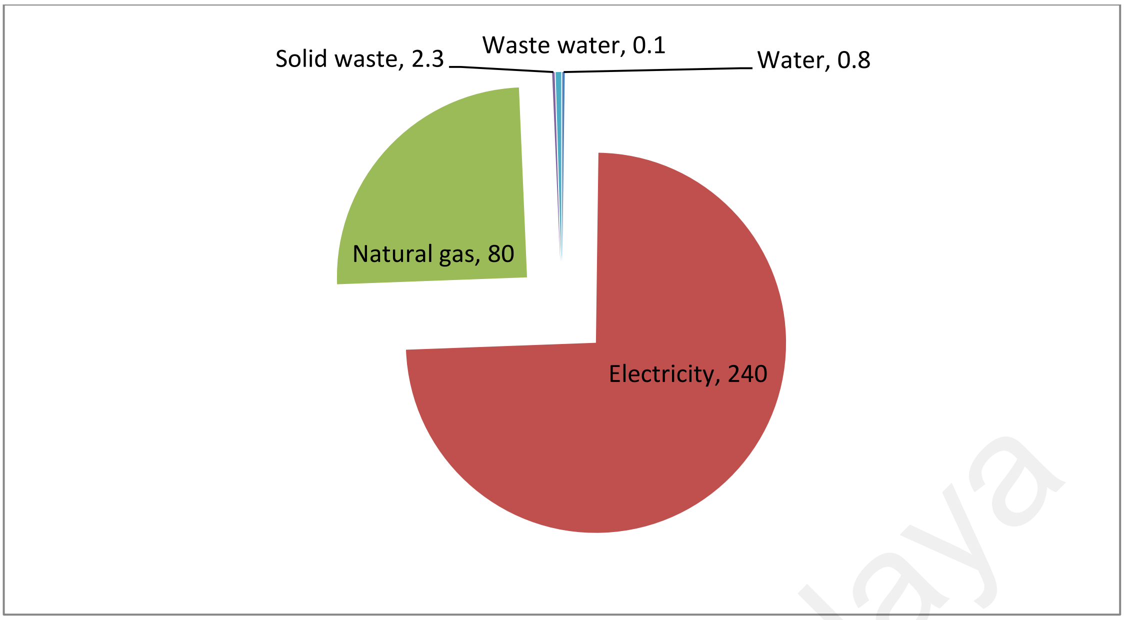

Figure 4.6: The CO_2 emission (kg CO_2) according to sources before CP implementation

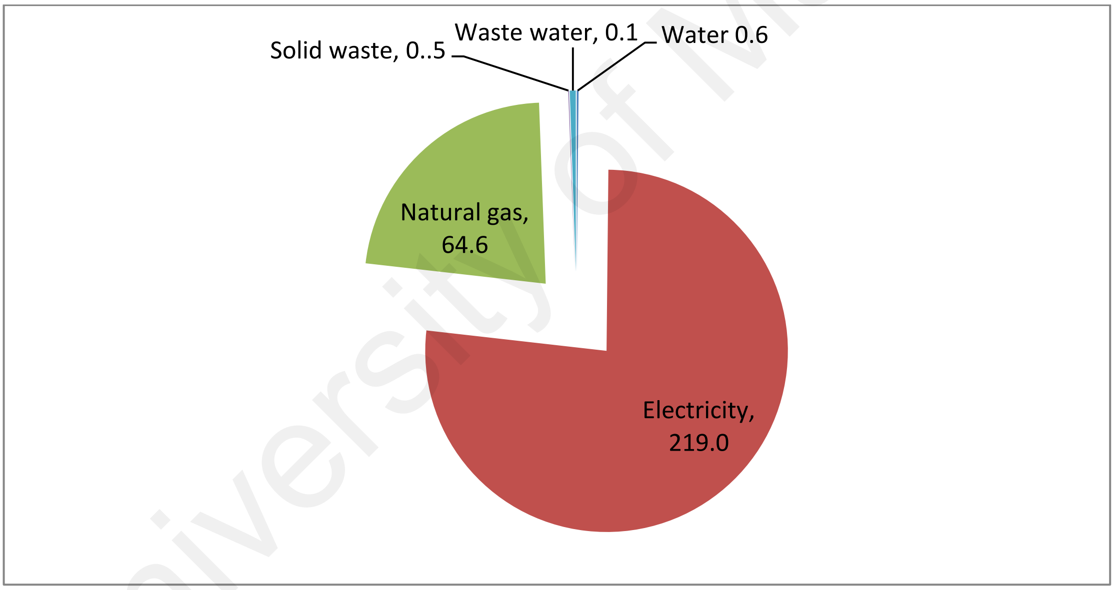

Figure 4.7: The CO_2 emission (kg CO_2) according to sources after CP implementation

The implementation of recommended CP options will reduce the production cycle time of per batch of healthcare product from 5 hours to 3 hours. Thus, implementation of CP option will enable to save the operation cost and labour cost by RM360000/year. The CP implementation plan should be drafted out completely with the timeline, person in charge, resources required, and cost of investment. The CP options involved change in design and equipment, operation practices and others. Thus, training should be provided to the employees on the changes and made.

The economic feasibility for the CP options implementation is studied by estimating the cost investment and determining the expected annual savings achieved. Therefore the expected payback period is calculated as below:

Investment Cost = RM 1636849

Annual saving = RM796836

Payback period = Investment Cost/ Annual Saving

= 2 years

4.7 Recommendation for Monitoring CP Implementation

The CP options implemented should be monitor regularly to ensure the main objective is achieved without any interventions and lost. Data collection and analysis is a part of the activity to ensure the success of the implementation. Any problems encountered during this period can be rectified immediately. Proper photos or videos on the CP implementation are suggested to take during the monitoring process for documentation and training. Besides that, constant feedback from the employee as well as customer is required to further understand accomplishment of CP implementation.

4.8 Overall Effect for Malaysian Scenario

In Malaysia, one of the major contributors of CO_2 emission is the industrial sectors. Malaysia as a developing nation has strongly taking initiative in reducing the Greenhouse emission. The CP strategy will be suggested as one of the preventive strategies should be taken into account by the Malaysia government. This study will serve as a baseline for other industrial sectors to mitigate the reduction of CO_2 emission. This study and findings will be useful among the Malaysia manufacturers and serve as a primary model in establishing CP strategy in their respective industry.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

The study shows that CP strategies could be used to reduce the CO_2 emission in the healthcare products manufacturing premise and to enhance efficiency in the operation. It is estimated that the studied premise in the present study should be able to reduce the CO_2 emission from 323 kg to 285 kg CO_2/1000 litre of healthcare product which is equivalent to 12% with the logical CP options implementation. This is equivalent to 960 tons of CO_2 reduction in a year. Study shows the *Alstonia angustiloba* or known as Pulai tree with the diameter of 11–26 Dbh and a height of 11–22m has sequestered 3433kg carbon per year (Misni et al., 2015). Hence in this study, we need to plant 280 Pulai trees in order to offset the carbon dioxide produced in the premise.

Generally, there are 31 CP options have been identified including efficient management in electricity, water, fuel, solid waste, waste water, operation process, design of equipment and improvement in safety and health issues. In the study, 15 CP options have been suggested to implement in the premise which will enable to save RM796836 annually with the payback period of 2 years.

Some of the CP options suggested need further study. Based on the analysis, it is found that cleaner production strategy is feasible technically, environmentally and economically. Hence, CP strategy identified is not limited to carbon dioxide reduction but also improves the overall operational efficiency in healthcare products manufacturing premise. As for future research work, this study will be useful among the Malaysia manufacturers and serve as a primary model in establishing CP strategy in their respective industry.

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