IMPLEMENTATION OF CLEANER PRODUCTION STRATEGIES FOR OFFSET LITHOGRAPHY PRINTING INDUSTRY

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FACULTY OF ENGINEERING
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UNIVERSITY OF MALAYA
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2017

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ABSTRACT

Malaysia is starting the journey towards greening its industries, especially the Small and Medium Industries (SMIs) where there are more than 600,000 of active one. There are many strategies that can be implemented to achieve green industry status. One of the strategies is Cleaner Production (CP) which was introduced in Malaysia in 2000 even though its implementation is still not widespread. In this study, Cleaner Production strategy will be used to demonstrate the feasibility of using the strategy in greening the printing industry.

For this purpose, a printing premise with an annual production capacity of 300 tons was selected as a case study. Initially a CP audit was conducted systematically and options were generated using various components focusing on energy consumption, solid waste and scheduled waste generation. Subsequently, the options were evaluated in terms of carbon emission reduction, a major criteria in greening the industry.

The results showed that the total carbon dioxide (CO_2) emission generated at the premise was 244.6 tons per month, of which electricity consumption was the main contributor. More than 100 options were generated targeting on reducing CO_2 emission through various means. Implementations of nine (9) major options are expected to reduce the CO_2 emission of the premise as much as 190,718 tons per month which is a reduction of 78%.

Of the nine (9) options proposed, there are four (4) options that can be implemented without any cost incurred. By implementing these options, 96.5 tons of CO_2 emission or 0.321 tons of CO_2 emission per ton of paper can be reduced monthly by the premise. These four options if implemented by 1000 active printing premises in Malaysia will

result in CO_2 reduction of 96,510 tons per month. By assuming, 15% of 600,000 SMEs in Malaysia are implementing these four options, about 8.7 million tons of CO_2 can be reduced per month.

The study proves that CP strategy can be used for greening the industry, which has been reflected in the study where proposed CP options are capable of reducing CO_2 emission in the printing premise. The process of greening the industry, which adopts the CP strategy can be extended to other types of industries as well. This concludes that the greening of industry can be achieved by implementing CP in the premise of the industry especially the manufacturing premises.

ABSTRAK

Malaysia sedang menuju ke arah penghijauan industri, terutamanya Industri Kecil dan Sederhana (IKS) di mana terdapat lebih 600,000 premis yang aktif. Terdapat pelbagai strategi yang boleh dilaksanakan untuk mencapai status industri hijau. Salah satu strategi adalah Pengeluaran Bersih (CP), yang telah diperkenalkan di Malaysia pada tahun 2000, meskipun pelaksanaannya masih belum meluas. Di dalam kajian ini, strategi Pengeluaran Bersih akan digunakan untuk memperlihatkan kebolehlaksanaan strategi ini dalam penghijauan industri percetakan.

Bagi tujuan ini, sebuah premis percetakan dengan kapasiti pengeluaran tahunan sebanyak 300 tan telah dipilih sebagai premis kajian kes. Pada awalnya, audit CP telah dijalankan secara sistematik dan opsyen CP telah dijana menggunakan pelbagai komponen yang memfokuskan kepada penggunaan tenaga, dan penghasilan sisa pepejal dan sisa terjadual. Seterusnya, opsyen-opsyen tersebut telah dinilai dari segi pengurangan emisi karbon, yang merupakan kriteria utama dalam penghijauan industri.

Hasil kajian menunjukkan bahawa jumlah emisi karbon dioksida (CO_2) yang terhasil di premis adalah sebanyak 244.6 tan/ bulan, di mana penggunaan tenaga elektrik merupakan penyumbang utama. Lebih 100 opsyen CP telah dijana yang mensasarkan untuk mengurangkan emisi CO_2 melalui pelbagai cara. Pelaksanaan sembilan (9) opsyen utama dijangka dapat mengurangkan emisi CO_2 yang terhasil di premis sebanyak 190,718 tan/ bulan iaitu pengurangan sebanyak 78%.

Daripada sembilan (9) opsyen CP yang telah dicadangkan, terdapat empat (4) opsyen boleh dilaksanakan tanpa melibatkan sebarang kos. Dengan melaksanakan opsyen-opsyen ini, premis boleh mengurangkan sebanyak 96.5 tan emisi CO_2 atau 0.321 tan

emisi CO_2/tan kertas sebulan. Jika keempat-empat opsyen ini dilaksanakan oleh 1,000 premis percetakan yang aktif di Malaysia, sebanyak 96,510 tan emisi CO_2 boleh dikurangkan sebulan. Dengan andaian bahawa 15% daripada 600,000 IKS di Malaysia melaksanakan keempat-empat opsyen ini, kira-kira 8.7 juta emisi CO_2 boleh dikurangkan sebulan.

Justeru, kajian ini membuktikan bahawa strategi CP boleh digunakan dalam penghijauan industri, di mana opsyen-opsyen CP yang dicadangkan berupaya untuk mengurangkan emisi CO_2 di dalam premis percetakan. Proses penghijauan industri, yang menggunapakai strategi CP juga boleh dikembangkan pelaksanaannya kepada jenis industri lain. Maka, boleh disimpulkan bahawa penghijauan industri boleh dicapai melalui pelaksanaan CP di dalam premis industri, terutamanya premis pembuatan.

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LIST OF SYMBOLS AND ABBREVIATIONS

For example:

CP	:	Cleaner Production
°C	:	Degree Celcius
CO2	:	Carbon Dioxide
BTU	:	British Thermal Unit
KG	:	Kilogram
RM	:	Ringgit Malaysia
CTP	:	Computer to Plate
CTF	:	Computer to Film
VOC	:	Volatile Organic Compound
L	:	Liter
m^3	:	Cubic Meter
kWh	:	kilo Watt hour
Hr	:	Hour
UNEP	:	United Nation Environment Program
UNIDO	:	United Nation Development Organization
CP	:	Cleaner Production
ROI	:	Return of Investment
%	:	Percentage
DOE	:	Department of Environment
GHG	:	Greenhouse Gases
SCP	:	Sustainable Consumption and Production

EQA	:	Environmental Quality Act
SME	:	Small and Medium Enterprise
SMI	:	Small and Medium Industry
LCA	:	Life Cycle Analysis
MIDA	:	Malaysian Investment Development Authority
OECD	:	Organisation for Economic Co-operation and Development

CHAPTER 1: INTRODUCTION

1.1 Background

Carbon dioxide (CO_2) has long been recognized as the most significant greenhouse gas that produced by humans, primarily through industrial activities, transportation and electricity. It contributes to 76% of the total greenhouse gases (TeunBrouwer, 2013). The increasing level of CO_2 and other gases such as methane in the atmosphere have aggravated the greenhouse effect and caused a rise in global temperature (Lenny Bernstein et al., 2007). This eventually leads to change of weather or climate which has become a phenomenon that has been discussed by all concerned parties, especially the policy maker due to its impact on human and the environment.

In view of this threatening effect, the Kyoto Climate Change Conference was held in December 1997 to plan a concerted efforts in tackling the problems of climate change. The main goal of the conference was to encounter and negotiate limits on the future release of CO_2 into the atmosphere in order to prevent further climate change caused by human activities (R. Fletcher, 2005).

As far as Malaysia is concerned, the Prime Minister of Malaysia has made an announcement at 2009 United Nation Summit on Climate Change that Malaysia volunteered to reduce CO_2 by 40% in terms of emission intensity based on the Gross Domestic Product (GDP) by the year 2020 compared to the level of 2005 (Uggah Embas, 2011). Malaysia contributes 5.97 metric tons CO_2 per capita in 2009 and ranked third among ASEAN countries (Othman & Yahoo, 2014)

At United Nations Climate Summit in 2014 in New York, the Prime Minister of Malaysia once again informed the assembly that Malaysia was well on track to hit its target of cutting the carbon emissions intensity of the country's Gross Domestic Product (GDP) by 40% by 2020. The prime minister confirmed that Malaysia had already

reduced the emissions intensity of its GDP by more than 33% despite facing difficulties in fulfilling the pledge made in Copenhagen six years ago (Bernama, 2014).

Previously, dilute and disperse strategy was adopted by most of the industries when dealing with industrial wastes. Then, the industries began to install the treatment units at the end of the emission pipes of various production processes. This reactive waste management is the so called "end-of-pipe approach (EOP)". EOP approaches played an important role in controlling industrial pollution to a certain extent. However, the EOP approach is not the solution because it usually causes secondary pollution and increases both the capital costs and operation costs that are burdensome to most enterprises (Shi Lei, Li Ruirui, & Xianghu, 2016). As time goes by, pollution prevention concept has been adopted to reduce the environmental impacts from the manufacturing process.

The term of "greening of industries" has been coined by UNIDO as a strategy that is not only targeted to bring the industry to the compliance of existing environmental regulation, but also to reduce the consumption of raw material, energy and water and generate less waste. Green industry can be achieved by different pollution prevention strategies and approaches. One of the strategies is Cleaner Production (CP) (United Nations Escap, 2014).

CP has been successfully practiced in various types of industries in many countries including Malaysia. Examples of CP implementation in the industries are lead acid battery manufacturing industry in Australia (Dahodwalla & Herat, 2000), poultry slaughter house in Brazil (Teresinha Kist, El Moutaqi, & Leandro Machado, 2009), Printed Wire Board (PWB) manufacturing industry (Lang Tseng, Hsu Lin, & S.F. Chiu, 2009) and Batik making industry in Malaysia (Masrom, 2012) This strategy contributes to sustainability of industries through efficient production, environmental management and human development.

From the study undertaken by Ecologic Institute (Martin Hirschnitz-Garbers & Srebotnjak, 2012) on ten (10) possible indicators to measure how green the industry is, it was shown that to date, there is no clear and specific indicator that can describe the status of industries that are green and environmentally friendly. Good indicators should include both direct and indirect resource consumption as well as their related environmental effects.

Meanwhile, Green industry initiative which involve the collaboration of UNIDO and UNEP, has introduced RECP as a mechanism to not only optimize the productive use of natural resources (materials, energy and water), but also minimize the impacts on the environment and nature through reduction of wastes and emissions (UNIDO, 2015). A couple of studies on the greening of industry indirectly have adopted carbon reduction as an indicator to measure the green industry. This is in line with the concept of RECP which aim to reduce emission from the industry. But, the greening of industry through the application of Cleaner production in the printing industry is not common in Malaysia and there is limited knowledge about it .

The key environmental issues in the printing industry are high energy consumption, inefficient waste management, handling of hazardous materials, and air pollutions. It is a chemical – intensive industry that produces many types of waste (Department of Environment and Conservation NSW 2006). For example, printing premise generates an array of both hazardous and non-hazardous wastes. The waste is grouped from various printing activities such as plate making, printing and finishing. Some of the wastes are hazardous, such as cleaning solvents, waste ink and photographic chemicals. There are also non-hazardous solid wastes that pose a significant impact on the environment. Paper is the main bulky solid waste produced in the printing industry (RAC/CP, 2003).

Even though, the status of compliance of the printing industry with environmental regulations in Malaysia have improved from 2007 to 2013, but this compliance is based on the end of pipe approach that requires the industry to comply with Environmental Quality Act 1974 (Department of Environment, 2013). This does not reflect that the industry is green and environmentally friendly. Because of this, the need to greening the printing industry is really important in the wake of global warming that plague the world nowadays.

1.2 Research problem

The need for greening the industry, especially small and medium enterprise (SMEs) has become an important agenda in Malaysia as one of the efforts to tackle the problem of climate change especially global warming. This is also in line with Malaysia's commitment to reduce CO_2 by 40% in terms of emission intensity based on the Gross National Product (GDP) by the year 2020 compared to the level of 2005. SMEs is a fast growing industry with a total number more than 600,000 (Hashim, 2013) and contributes to 70 % of environmental pollution caused by the industry as a whole (Zuraidah, Abdekhodaeean, & Nagarajah, 2012) .

End of pipe approach which has been practiced since 1975 was able to increase some of SMEs towards compliance of environmental regulations (Department of Environment, 2013). However, this compliance does not contribute to the improvement of environmental quality because the industry still uses environmental resources such as raw materials and utility in a business as usual (BAU) because there is no effort to reduce the consumption of raw material, utility and generation of waste. Because of this, the greening of the industry should be carried out because it does not only improve industry compliance with environmental requirements, but also improves the overall

efficiency of the premise such as reducing the consumption of raw materials, utilities and generation of waste and also reduce risks to human and the environment.

Cleaner Production is seen as the best strategy for greening the industry because it possesses the characteristics of green industry, which is widely publicized by UNIDO, such as process optimization, cost saving, higher return business and higher compliance to environmental laws and regulations (Abdul Raman, Raja Ehsan Shah, Rahim, & Kai Shing, 2014). This strategy of using CP as a tool for greening the industry should be tested and evaluated in the aspects of the green industry in terms of its effectiveness by using the relevant and effective indicator. Meanwhile, the selection of an industrial premise to carry out CP audits and implementation of CP options need to be made. The printing premise is selected for this purpose because the premise consumes lots of raw materials such as paper and very high electricity.

1.3 Aims, objectives and scope

1.3.1 Aims

The aim of this study is to demonstrate that the greening of the printing premise can be achieved through the implementation of CP practices. To achieve this aim, the following objectives are identified :

a) Conduct CP audit on the selected premise.
b) Estimate the carbon emissions equivalent that generated from the premise in the current form.
c) Generate and evaluate the feasibility of CP options for reducing carbon dioxide emissions and operating costs of the premise.

1.3.2 Scope of the study

The study focused only on the printing premise, which is a SME, with the aim of greening the operating activities of the offset lithography printing premise through the implementation of green industry practices. The scope of the study covers the entire printing process from planning and design to final product packaging, as well as activities that support the printing process. However, the transportation of raw materials and finished product is not taken into account in this study.

1.4 Thesis outline

Chapter 1 contains an introduction of research background including background of the study problem, aim, objectives and scope of research.

Chapter 2 describes the literature review, covering the overview of climate change and industry and the greening of industry, which include the benefits and case studies in Malaysia and other countries. This chapter also compares a couple approaches, including CP strategy that can be adopted to implement green industry practices in premise. It further evaluates various indicators that have been used to measure the green industry, even though they are not perfect indicative. This chapter also looks into the environmental problems contributed by SMEs as a whole and printing industry. SMEs' status of compliance with environmental regulations and level of awareness to environmental problems was also reviewed.

Chapter 3 describes the methodology used in the research, such as cleaner production audit, cleaner production options generation tools, and cleaner production options evaluation.

Chapter 4 consists of data and information gathered, analysed and discussed in order to compare the results before and after the CP options implementation. The amount of CO_2 emission reduction of each identified option is also calculated.

Chapter 5 presents the conclusion of the research and recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Industry and its relation to climate change

Climate change is one of the main issues facing the world today. Both human activities and natural processes contribute to climate change. Climate change is addressed through two approaches: adaptation and mitigation. Adaptation refers to actions taken to help communities and ecosystems cope with actual or expected impacts of climate change. Mitigation refers to actions taken to reduce greenhouse gas emissions, which are one of the main causes of global warming, and enhance carbon sinks to lessen the impacts of climate change. In addressing climate change, particularly its impacts on humans, both adaptation and mitigation should be implemented in an integrated and balanced manner (Ministry of Natural Resources and Environment Malaysia, 2009)

The issue of climate change is more than just a warming trend. The increasing temperature will eventually lead to changes in weather, including major wind patterns, the amount and intensity of precipitation, and increased frequency of severe storms and weather extremes. This impact are apart from the direct and indirect impacts of climate change in other areas such as the ecosystems, freshwater resources, flood, forest products, coastal system, low lying areas and small islands, industry, society and health (Department of Environment, 2014).

Global warming is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation. Since the early 20th century, Earth's mean surface temperature has increased by about 0.8 °C (1.4 °F), with about two-thirds of the increase occurring since 1980 (The National Academies Press, 2011). It is caused mainly by the emission of greenhouse gases (GHGs) to the environment by human activities. There are several greenhouse gases responsible for warming, and

humans emit them in a variety of ways. Most come from the combustion of fossil fuels in cars, industries and electricity production.

Global warming has become a phenomenal today and threatens the existence of human being and environment if no concrete actions being taken to overcome the problem. In view of the seriousness of the problem, Intergovernmental Panel on Climate Change (IPCC) was created in 1988 to assess the current effects of global warming on human and the environment and published the first assessment report in 1990. This was followed by the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) that recognizes Climate Change as a global problem that requires concerted efforts and common course of action by all nations in the world. The role of the UNFCCC is to set an "ultimate objective" of stabilizing "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system" (Ministry of Natural Resources and Environment Malaysia, 2011).

Four main greenhouse gases which cause the global warming are Carbon Dioxide, Methane, and Nitrous Oxide and Fluorinated gases. The primary sources of greenhouse gas emissions in the United States based on 2010 greenhouse gas emissions are Electricity production (34%),Transportation (27%), Industry (21%), Commercial and Residential (11%), Agriculture (7%) and Land Use and Forestry (offset of 15%). As far as industry is concerned Greenhouse gas emissions come from burning fossil fuels for energy as well as greenhouse gas emissions from certain chemical reactions necessary to produce goods from raw materials (USEPA, 2013).

Direct emissions are produced by burning fuel for power or heat, through chemical reactions, and from leaks from industrial processes or equipment. Most direct emissions come from the consumption of fossil fuels for energy. A smaller amount, roughly a

quarter, comes from leaks from natural gas and petroleum systems, the use of fuels in production (e.g., petroleum products used to make plastics), and chemical reactions during the production of chemicals, iron and steel, and cement. Indirect emissions are produced by burning fossil fuel at a power plant to make electricity, which is then used by an industrial facility to power industrial buildings and machinery.

Meanwhile, at the global scale, industry contributes 26% of carbon dioxide based on the global carbon budget from 1959 - 2011. The main contributor of CO_2 still from electricity generation followed by the transportation sector as shown in Figure 2.1 (Le Quéré, 2013).

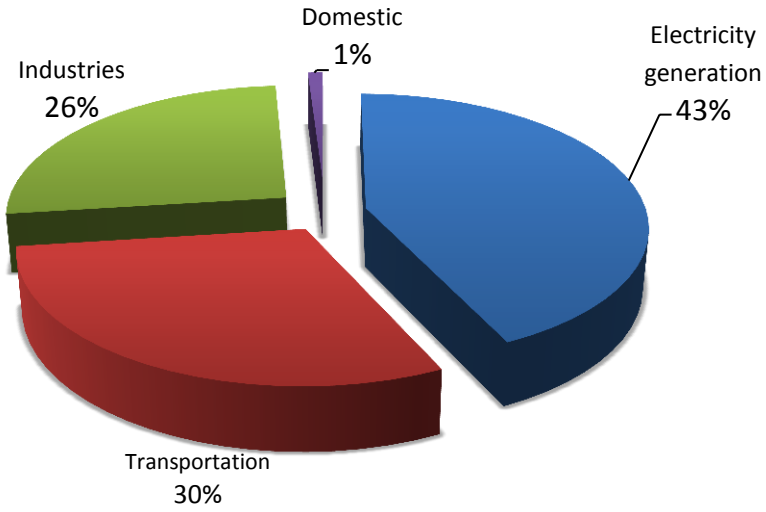

Figure 2.1 : The global carbon budget 1959-2011 (Le Quéré, 2013)

As far as Malaysia is concerned, Carbon dioxide emission has steadily increased from 2006 to 2014 with exception in 2013 where the emission has slightly decreased. The increase was due to the significant increase in CO_2 emissions from the Energy sector (YChart, 2015). The increase in CO_2 emissions is shown in Figure 2.2

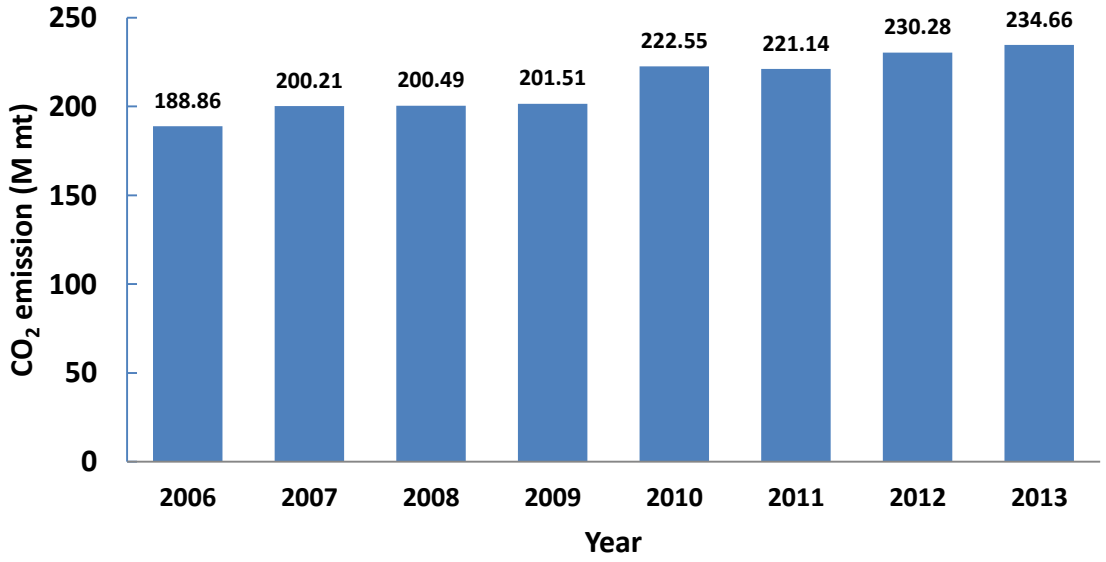

Figure 2.2: Malaysia Carbon dioxide emission (M mt) (YChart, 2015)

2.2 Greening of Industry

Green Industry is the component of a Green Economy which focus on production and consumption. Policies relevant to Green Industry are similar to those relevant to a Green Economy but are industry specific, covering macro and micro interventions that require changes in policy and regulatory instruments, investment and business operations, and behavioral changes in society (UNEP, 2015).

Green Industry is an effective point of entry for and a driving force in the transition to a Green Economy and ultimately, Sustainable Development. Green Industry approaches focus on upgrading industry and increasing the productive capacity without corresponding increases in resource use and pollution burdens. The goal is to enable industries in developing and transition countries to actively participate in developing the solution needed for continuous improvement in their environmental performance (UNIDO, 2011a).

Simply defined by UNIDO, Green Industry is industrial production and development that does not come at the expense of the health of natural systems or lead to adverse human health outcomes. Green Industry is aimed at mainstreaming environmental, climate and social considerations into the operations of enterprises. It provides a platform for addressing global, interrelated challenges through a set of immediately actionable cross cutting approaches and strategies that take advantage of emerging industry and market forces (UNEP, 2015). This definition is internationally accepted and will be used throughout this research to facilitate the process of defining the green industry initiative for small and medium industry in Malaysia.

A green industry is the concept of promoting sustainable consumption and production patterns in the manufacturing of products. This involves both the greening of existing products and the creation of green industries that deliver environmental goods and services. A green industry requires manufacturers to accept responsibility for the environmental impacts of their product or service throughout its whole life cycle (UNIDO, 2011a).

A green industry aims to (United Nations Escap, 2014):

- Improve the efficiency of conventional industries and supply chains
- Create new types of products, such as renewable energy, recycling technologies and organic food production.
- Create environmental analysing and advisory services, such as an energy service company, which includes analysis and calculation of ecological footprints.
- Create new types of services that are more ecologically friendly, such as eco-tourism.

Green Industry involves a two-pronged strategy to create an industrial system that does not require the ever-growing use of natural resources and pollution for growth and expansion. These two components are (1) the greening of existing industry, and (2) the creation of new "Green industries" is shown in Figure 2.3 (UNIDO, 2011a).

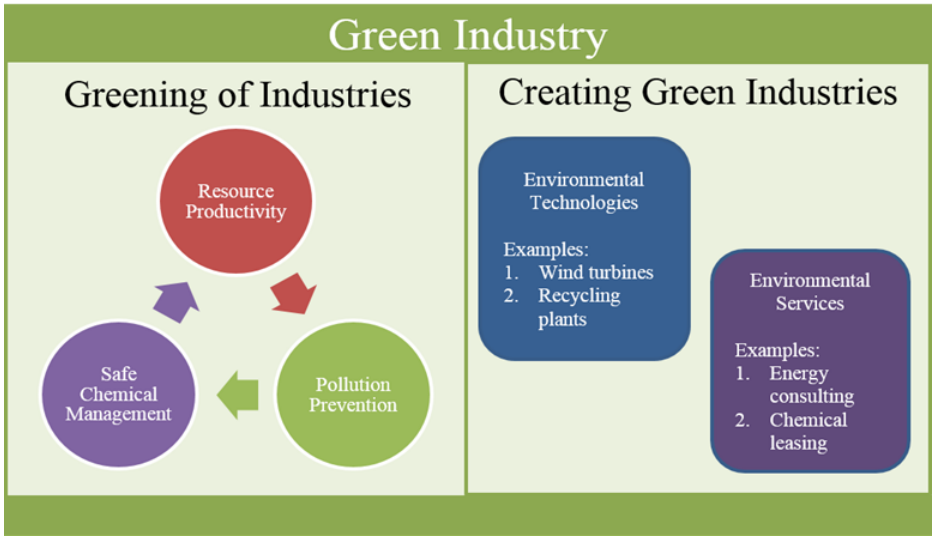

Figure 2.3: Greening of Industries and Creating Green Industries (UNIDO, 2011a)

2.2.1 Greening of existing industry

Enable and support all industries regardless of their sector, size or location, to green their operations, processes and products to (UNIDO, 2011b):

- Use resources efficiently: increase the productive use of materials, water and energy in industrial production, through such approaches as: dematerialization of products and value chains; use of materials with longer service lifetime; replacement of virgin materials with recycled materials; recycling, reuse and recovery of materials, energy and water; and use of materials, water and energy from sustainably managed and/or low-impact sources.
- Minimize the generation of wastes and emissions: minimize and where possible eliminate the creation of waste and emissions within factories, through such approaches as: improvements in process operation, monitoring and maintenance;

waste minimization; application of advanced process technologies with higher efficiency and specificity; and recycling, reuse and recovery of process streams.

- Minimize risks associated with chemicals and (hazardous) wastes: minimize risks associated with production, use, and disposal of chemicals, through such approaches as: sound management of chemicals; phasing out of toxic and other environmentally harmful substances (including those contributing to ozone layer depletion and/or climate change); application of Best Environmental Practices and Best Available Techniques to prevent unintended formation and emissions of POPs and other hazardous pollutants; replacement of chemical processes by non-chemical processes (biological, physical, etc.); and replacement with safer, more specific and/or more effective alternative chemicals.

2.2.2 Creating green industries

Establish and expand (new) green industries that deliver environmental goods and services to (UNIDO, 2011b):

- Reduce, Reuse and Recycle waste materials: support industries to develop and deliver advanced integrated waste management, recycling and resource recovery technologies, services and systems, for municipal, commercial, industrial, construction, demolition and other specific waste streams, and produce there of reliable supplies of recycled materials and products;
- To improve industrial energy efficiency and make use of renewable energy: support industries to deliver technology, equipment, products, management systems, know how and/or services that enhance industrial energy efficiency and the use of renewable energy (solar, bio - etc.) or other low carbon energy sources (in particular waste heat).

- Collect, manage and dispose (hazardous) wastes and/or emissions in environmentally compatible ways: support industries to develop and deliver technology, equipment, products, management systems, know how and/or services that collect, manage and dispose, without threats to the environment, (hazardous) wastes and/or emissions, including for example chemical and medical wastes, electronic waste, etc.

This includes material recovery, recycling, waste treatment and management, as well as the provision of environmental and energy consulting and services, such as energy service companies and companies that provide monitoring, measuring and analysis services

2.3 Why greening the industry is required?

Nowadays, Green industry is becoming very important in achieving the goal of sustainable development in the nation, especially for the developing countries. Developing countries need to expand their industries to alleviate poverty, deliver goods and services. At the same time, these countries need to create jobs and improve standards of living for their people. Compared to developed countries, most developing countries are characterized by conditions such as low standards of living, low levels of productivity, relatively high rates of population growth, dependence on primary exports, and rapid rates of urban growth (UNIDO, 2011a).

In order to expand their industries, they might resort to unsustainable economic growth, which results in resources depletion and severe environmental degradation. In many countries, production and consumption patterns are outpacing the renewal capacity of natural resources and the capacity of local governments to manage waste products. The greening of industries by governments is a proactive way to decouple environmental pressures from economic growth (UNIDO, 2011b). Furthermore, the developing

country has the unique opportunity of avoiding the environmental pitfalls that the developed country has fallen into, in the course of its industrial development; it can use past experience to build a Green Industrial infrastructure at the very outset (UNIDO, 2011a).

A Green Industry strategy aims at mainstreaming environmental and social considerations into the operations of enterprises. This can be realized by demonstrating how using resources more efficiently can lead to cost reductions and thereby enhance their competitiveness. Furthermore, it enables industries, especially in developing and transition countries, to actively participate in developing solutions needed for a Green Economy. Green Industry approaches ensure a sustainable upgrading of industry and increase in productive capacity without corresponding increases in resource use and pollution (DCED, 2012).

2.4 The benefits of greening the industries.

Among the benefits of greening the industries are as follows:

a) Economic benefits

Green Industry provides significant economic value by developing the skill-sets necessary for businesses to start working proactively on improving their environmental performance. Improving environmental performance is associated with the generation of income and jobs through improved efficiencies in existing industries such as through the recovery of valuable materials from waste streams and the subsequent creation of new products or production techniques that incorporate these former wastes, enabling access to new markets and improved market penetration. As enterprises become more efficient in their production and waste management processes, they are also less reliant on virgin materials, saving additional income. Further benefits of improved environmental performance include

increased labour productivity due to improved working conditions, as well as increases in product quality, reduced likelihood of accidents, decreased risk of liability, restitution or remediation costs, and reduced insurance costs (UNIDO, 2011a).

b) Creating jobs

Jobs are created through the greening of industries. The number of green jobs is already on the rise with the most rapid expansion being seen in the renewable energy sector. Current employment in renewable and supplier industries stands at a conservatively estimated 2.3 million worldwide. Basic manufacturing industries such as steel, aluminum, cement and paper are starting to stimulate green jobs through scrap use, greater energy efficiency, and reliance on alternative energy sources. Secondary scrap-based steel production requires up to 75 % less energy than primary production. Worldwide, 42 % of steel output was based on scrap in 2006, possibly employing more than 200,000 people (Michael Renner, Sean Sweeney, & Kubit, 2008).

The environmental goods and services industry is likely to expand significantly in the future. More stringent legislative requirements coupled with investments in infrastructure have created a growing demand for services and products directed towards cleaner technologies, reductions in environmental risk, and resource management (including recycling and resource recovery). The growing focus on resource efficiency, productivity and competitiveness will increase the demand for "next-generation" environmental services targeted towards renewable energy and resource efficiencies. It is estimated that India alone could create some 900,000 jobs by 2025 in biomass gasification. Of this, 300,000 jobs would be with manufacturers

of gasifier stoves (including masons, metal fabricators) and 600,000 would be in biomass production, supply chain operations, and after-sales services (Saptarshi Das, 2014).

c) Alleviating Poverty

The greening of industry has an important role to play in poverty alleviation. First, greater efficiency in resource use over the life cycle of goods and services results in improved productivity and consequently, reduced costs.

Growth in consumer demand for sustainable products can provide sustainable producers in developing countries with access to new markets (e.g. Environmental goods and services), job opportunities, and price premiums for their products – all of which can facilitate the transition towards a green economy. Moreover, the greening of industry can provide development opportunities in instances where labour intensity (and associated employment) replaces a high dependency on inputs or energy-intensive mechanised processes. Environmental sustainability initiatives can also be part of a wider shift towards socially and economically responsible production and consumption, which can further strengthen the benefits of poverty alleviation (UNIDO, 2011b).

The greening industries can improve health conditions in developing countries through access to clean water (resulting from water supply infrastructures and protection programmes), clean energy (from decentralised renewable energy programmes), and improved nutrition from sustainable agricultural practices. Greening industries can also help build resilience to environmental risks by reducing direct harmful exposure to pollutants (e.g. those in air, water, food and solid waste) in developing countries (UNIDO, 2011b).

d) Increase environmental quality and regulations compliance

Greening the industries will reduce demands on non-renewable resources and by recycling and re-using products and resources, the impact on natural environment will also be reduced. This will contribute to the conservation of the environment (Department of Environment, 2010a). Meanwhile, green industry uses fewer raw materials, energy and generates less waste which reduces the quantity of waste to be treated or controlled. This will reduce the size of pollution control equipment and treatment facilities that help industries to comply with environmental regulations.

e) Reduce carbon emission by industrial sector

It is projected that global industrial production is to increase by 2050. The industrial sector uses more energy globally than any other end-user sector, and current consumption equals one-third of the world's total delivered energy. The manufacturing industry is responsible for a third of global greenhouse gas (GHG) emissions from fossil fuel use and industrial processes, one-fifth of global water use, and most of the raw materials used. Industry also causes emissions of other GHGs (methane, nitrous oxide and chlorofluorocarbons gases that have the highest global warming potential than CO_2).

Many industries use more materials and energy than their production processes would require, due to continued use of obsolete and inefficient technologies and methodologies. Producers and consumers have adopted patterns of production and consumption that do not take into consideration the limits of the planet's available resources and its assimilative capacity for emissions, a situation further complicated by continued population growth (UNIDO, 2012). Greening of industries not only

assist industries to improve compliance of environmental requirements, but can also contribute to the reduction of greenhouse gas emission.

2.5 Approaches to greening of industries

There are many practical approaches to greening an industry. Among the approaches are (United Nations Escap, 2014):

2.5.1 Circular economy

A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models (Ellen MacArthur & Waughray, 2014).

In a circular economy, manufacturers create more value from each unit of resource. Since products are designed with the goal of maximizing reuse, greater value is derived from the initial labour, material and capital costs. The circular economy is a means of allowing businesses to decouple future economic growth from resource constraints. Rising commodity and energy prices are a major motivation behind the shift. The shift to a circular system would significantly lower cost and help to create jobs. The consumer goods sector alone would save as much as $700 billion annually by applying circular principles to current business models (Vaughn, 2014)

One example of country experience in circular economy is Circular Economy Policy in China. The country is implementing far-reaching policy measures to increase its resource efficiency which includes the Resource Saving Initiative (2006–2010), which was introduced in the Eleventh Five-Year Plan for Strengthening the Vision of a Green

China. The circular economy policy was established in 2008 through the Circular Economy Promotion Law, which was intended to guide China's economic development in ways that conserve energy, water and materials and protect the environment. The Chinese Government believes development, based on the circular economy, will be essential for the country to sustain its fast paced growth while mitigating negative ecological impacts and creating more job opportunities (United Nations Escap, 2014).

Among several companies that have been implementing the concept with the strong backing of China government are (United Nations Escap, 2014):

- Yanjing Beer Group, the world's eighth-largest and Beijing-based brewery, invested in several technologies to cut water and energy consumption in its facilities. This included installation of devices to trap heat and gases generated during the fermenting and brewing processes for use in other procedures and wastewater recycling for use in the cooling system.
- Tangshan Iron & Steel, based in Tangshan City in Hebei Province, installed desulfurizing and dust-removal devices to reduce the air pollution its facilities generated. It also uses secondary energy and constructed a 300 million yuan wastewater treatment plant. The facility is the largest in northern China. It treats urban wastewater for use in the steel manufacturing process and thus avoids the consumption of fresh water.

2.5.2 Cleaner Production

From the mid-1970s, leading businesses, communities and governments have started to realise that prevention is the desired environmental management strategy. It makes good environmental and business sense to minimize and where possible eliminate the generation of waste and emissions. A number of different terms were introduced, including, for example, pollution prevention, waste minimization, eco-efficiency and 3R

(Reduce, Reuse and Recycle). The United Nations Environmental Programme (UNEP) brought key elements of different terms together as Cleaner Production (UNIDO, 2014).

The UNEP definition of Cleaner Production (CP) is: "The continuous application of an integrated preventive environmental strategy to processes and products so as to reduce risks to humans and the environment". The main focus is an integrated waste minimization, environmental pollution prevention and sustainable development. It provides a practical way of moving towards sustainable development which allows the producers of goods and the providers of services to produce more with less raw material, less energy, less waste, and thus, less environmental impact and greater sustainability (Department of Environment, 2010b).

Cleaner Production is not a new concept. It is a logical extension of our desire to conserve materials and reduce waste. It requires a person to examine what they are doing and look for better, more efficient ways to do it that result in increased productivity, reduced resource inputs and reduced waste and most importantly reduced risk of environmental impact. Cleaner Production techniques are dynamic, and although industry has improved its environmental performance over the last two decades, there is continuing room for improvement. Improvement, which when implemented through Cleaner Production, leads both to improved economic efficiency and environmental protection (ANZECC, 1998).

Cleaner Production strategy is aimed at (Department of Environment, 2009b):

- Production processes – conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes before they leave the process.

- Products – reducing the environmental impact along the life cycle of the product, from raw material extraction to ultimate disposal
- Services – incorporating environmental concerns into designing and delivering services.

Cleaner Production requires changing attitude responsible environmental management and evaluating technology options. Cleaner Production is expected to bring lots of benefits to the industry which include (Department of Environment, 2009b):

- Reduce waste management costs through lower on-site handling costs, less waste storage area (more available production area), lower off site transportation & disposal costs, and lower paperwork & record keeping costs.
- Reduce raw materials costs and energy through direct use or reuse of waste in a process, recovery of secondary material for a separate end use – recovery of energy sources and removal of impurities from the waste to obtain a relatively pure reusable material.
- Enhance productivity and product quality. Cleaner production improves operation of a premise through yield improvement and increased production capacity, which leads to savings, especially when calculated on a long term basis.
- Improve human health and public image by creating a healthier environment for workers and the public at large.
- Reduce environmental hazards and liability risks by reducing the amount of waste being handled on site. It also minimizes long term liability for treatment, storage or disposal facilities.

One example of country experience in Cleaner Production is Cleaner Production in the management of water use at a poultry slaughterhouse of Vale do Taquari, Brazil. The scope of the study includes the layout characterization for the production process of a

poultry slaughterhouse using qualitative and quantitative flow charts for water management; analysis of general parameters for pollution load in the wastewater produced in critical stages of the production process and assessment of environmental impact indicators. The prognoses for cleaner production based on water management were established. The diagnostic stage revealed that the scalding, pre-chilling, separated points of wastewater disposal for the wastewater treatment plant and disposal of treated and non-reused wastewater were critical for water management. Dissolved oxygen depletion and eutrophication account for the major environmental impacts of these wastewaters, resulting in an environmental pressure index of 32.1. The study also identified the opportunities for cleaner production implementation which includes the reuse of wastewaters from pre-chilling and chilling for pre-washing of carcasses, since average temperatures of these wastewaters range between 4 and 16°C. This will contribute to lowering the oil and grease pollution load. Another strategy concerns the standardization of cleaning procedures with rational water use in all work shifts and implementation of water meters on a sector-by-sector basis. In the latter case, which has already been implemented, water consumption was reduced by 13% (Teresinha Kist et al., 2009).

2.5.3 Industrial Symbiosis

Industrial symbiosis principally concerned with the recovery and reuse of wastes (materials, water and energy) from one industry as an alternative input in a neighbouring facility. This re-use is an iconic application of industrial ecology and is regularly combined with other collective environmental management initiatives into eco-industrial park. Industrial symbiosis is more common than initially assumed, which has sparked an interest in comparing industrial symbioses in different region (Rene van Berkel, 2009).

Industrial symbiosis have the benefits on economic, environmental and social as follows (Chertow, 2007):

Economic benefits

- Fewer sources of waste;
- Improved production processes;
- Reduced raw material costs;
- Reduced disposal costs;
- Increased revenue through the sale of by-products;
- Optimised waste management;
- Increased potential for innovation;
- Development of eco-products from recycled material;
- Initiation improvement of waste/industrial waste channels;
- Creation of new markets;
- Increased business opportunities.

Environmental benefits

- Reduced exploitation of natural resources/ preservation of natural resources.
- Decreased greenhouse gas emissions;
- Reduced environmental impacts linked to waste disposal;
- Lowered risk of water, air and soil contamination;
- Improved environmental risk management and regulatory compliance.

Social benefits

- Participation and collaboration between various stakeholders in the symbiosis;
- Development of new partnerships (products, services, businesses etc.);

- Creation and retention of local jobs;
- Raised awareness of industrial ecology and sustainability by management and employees.
- Improved corporate image.

One of the best-known examples of industrial sysmbiosis can be found in Kalundborg, a small industrial zone 120 km west of Copenhagen in Denmark. This unplanned industrial park has evolved from a single power station into a cluster of companies that rely on each other for material inputs. The project began in 1972 and by 1994, 16 contracts had been negotiated. The extent of the material and energy exchanges in 1995 was about 3 million tonnes a year. Estimated savings totalled US $10 million a year, giving an average payback time of six years (Ergon energy, 2011).

2.5.4 3 Rs - Reduce, Reuse and Recycle

The principle of reducing waste, reusing and recycling resources and products are often called the "3Rs". Reducing means choosing to use items with care to reduce the amount of waste generated, Reusing involves the repeated use of items or parts of items which still have usable aspects and Recycling means the use of waste itself, as resources (Department of Environment 2009).

Waste minimization can be achieved in an efficient way by focusing primarily on the first of the 3Rs, "reduce," followed by "reuse" and then "recycle." The waste hierarchy refers to the "3Rs" i.e., reduce, reuse and recycle, which classify waste management strategies according to their desirability. The 3Rs are meant to be a hierarchy, in order of importance. The waste hierarchy has taken many forms over the past decade, but the basic concept has remained the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste as shown in Figure 2.4 (Rissanen, 2010).

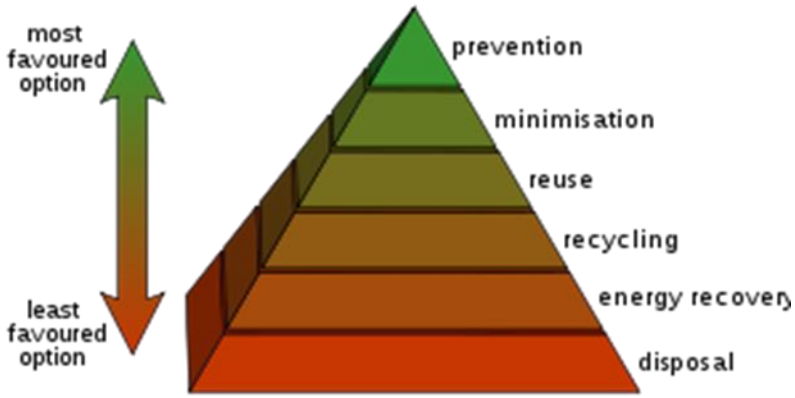

Figure 2.4: Waste Hierarchy (Rissanen, 2010)

The concept of minimizing waste impacts in terms of quantity or ill-effects, by reducing the quantity of wastes, reusing the waste products with simple treatments and recycling the wastes by using it as resources to produce same or modified products is usually referred to as "3R". Purchasing and using resources with care can reduce the pace of consumption of resources and further connected energy and resources. Ultimately, reducing wastes multifold for waste streams when long lasting goods are reused time and again, it offsets harvesting of new similar or the same products. This saves fresh resources exploitation and waste generation quantity. Some waste products can be consumed as resources for production of different goods or the same product, meaning recycling the same resource. This too saves fresh resources and offsets waste generation. All in all, the 3Rs individually or collectively save fresh resource exploitation, added value to the already exploited resources and very importantly minimises the waste quantity and its ill effects (Department of Environment 2009).

One example of country experience in 3Rs is Reducing, Reusing and Recycling Policy in Japan. The Government of Japan adopted the policy of reduce, reuse and recycle (3Rs) to create a sustainable society – one that achieves a balance between the economy and the environment. To reach that balance, the Government is moving from a sole focus on hazardous substance management towards a greening of the entire economy.

The 3Rs policy promotes technological development in the areas of resource efficiency and waste recovery and recycling. Additionally, it fosters the development of new green products for both economic and employment growth. As a result, there have been substantial investments in developing energy efficient home appliances, office equipment and recycling infrastructure (United Nations Escap, 2014).

2.6 Carbon reduction as an indicator of low carbon green city in Malaysia

Low Carbon City can be defined as a city that comprises of societies that consume sustainable green technology, adopt green practices and emit relatively low carbon or GHG as compared with present day practice to avoid the adverse impacts on climate change (KeTTHA, 2011).

In line with the National Green Technology Policy (NGTP), the Low Carbon Cities Framework (LCCF) was initiated to provide a framework to achieve sustainable developments that will subsequently reduce carbon emissions. The document can be used by all stakeholders, in human settlements of any size, be they cities, townships or neighborhoods either new or existing, to measure the impact of their development decision in terms of carbon emissions and abatement. LCCF is a national framework and assessment system to guide and assess the development of cities and to support holistic sustainable development in Malaysia (Malaysian Institute of Planners & Shafii, 2011).

The framework provides for equivalent CO_2 as a result of human activities in cities so that there may be aware of how the CO_2 can be reduced. In short, this framework aims to (KeTTHA, 2011):

i. Create awareness, encourage and promote the concept of green cities in Malaysia, thereby helping to reduce carbon emission in cities and townships;

ii. Guide cities in making choice decisions towards green solutions for their cities and townships;

iii. Allow cities and townships to measure their current and baseline carbon emissions; and,

iv. Allow cities and townships to define their carbon strategies and subsequently measure the performance of their action.

The four main focus areas are urban environment, urban transport, urban infrastructure and buildings. Urban infrastructure comprises of elements such as Construction and Industrial Waste Management, Energy Optimisation and management and efficient water management. These elements are part of the industrial sector that contributes to 19 % of total greenhouse gas emission (KeTTHA, 2011). This shows that in order to build a low carbon city in Malaysia, the greening of industries need to be carried out as well. Carbon reduction can be used as an indicator to achieve the green industries and low carbon city.

2.7 CO_2 emission reduction as an indicator to measure green industry

So far, there is no clear and specific indicator to measure how green the industry is. But, good indicators include both direct and indirect resource consumption as well as their related environmental effects. Ecologic Institute (2012) has published a document analysing the indicator of how green industry has become, called "Scoping of and recommendations for effective indicators". An expert analysis has come out with 10 indicators which were then further analysed and ranked. It was found that none of the indicators were found to be perfect.

2.7.1 EMC: Environmentally Weighted Material Consumption

EMC stands for Environmentally Weighted Material Consumption and it includes 32 materials and their respective environmental effects. There are, for instance, economy-

wide Material flows, accounts (MFA) and the biggest MFA consists of a country's domestic material consumption (DMC). This figure is weighted by impact coefficients from Life Cycle Assessment (LCA). But the EMC can also be applied at every level, from individual industries to industry sectors, right up to the whole economy.

Its biggest weakness is the scarce data availability which requires extensive data coverage and not easily obtained or accessible. However, methodologically speaking, this indicator can be called the best one since it matches all of the above mentioned criteria (Moritz Bühner, 2012).

2.7.2 Energy Intensity by Sector

The term energy intensity is often used interchangeably with the term energy efficiency. Energy intensity refers to the energy used per unit of output or activity. Total energy consumed in a sector, for example, is a product of energy intensity per unit of output and the total amount of output provided. When output is measured in physical units, an estimate of physical energy intensity is obtained (e.g., TJ/tonne). Energy intensity is the most commonly used basis for assessing trends in energy efficiency since a truly technical definition of energy efficiency can only be obtained through measurements at the level of a particular process or plant. Energy intensity is thought to be inversely related to efficiency, the less energy required to produce a unit of output or service, the greater the efficiency (Mallika Nanduri, 1998).

Even though, this indicator is full data availability and easy calculation but it does not directly measure environmental and social impacts. The other downsides are its requirement for additional information, such as on the renewable energy share, and its exclusion of life cycle stages, both of which would require additional effort in terms of data collection (Moritz Bühner, 2012).

2.7.3 Production-based CO_2 Productivity

Production-based CO_2 productivity, i.e., GDP generated per unit of energy-use related CO_2 emitted, is an important indicator for measuring the environmental performance of production processes for climate protection purposes. It helps to measure decoupling of economic growth from carbon inputs required for growth. The Production-based CO_2 productivity indicator fully matches data availability and all criteria apart from LCA compatibility, which it only matches partially. This indicator can measure industry's performance over time in reducing emissions emitted from energy use in industrial production processes. Therefore, it can cover industries and industrial development (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

The biggest advantage is how easily the necessary data is obtained, which is through existing greenhouse gas inventories. However, just like the previous indicator, data are missing; it lacks the possible demand and consumption information making it "only partially LCA compatible" (Moritz Bühner, 2012).

2.7.4 Water Consumption by Sector

Water consumption by sector is defined as the annual water consumption for domestic use, industrial use, agricultural use and other sectors expressed in cubic meters per year or as a percentage of total water consumption. These indicators can be used for water resources management by identifying crucial sectors of consumption in which specific future plans have to be developed. Usually, the heaviest water uses are domestic, industrial, and agriculture in ascending order. Water consumption in the agricultural sector is a crucial factor to assess the vulnerability to desertification of areas already facing water scarcity problems (Martin Hirschnitz-Garbers & Srebotnjak, 2012)

The indicator does not measure impacts, but only pressures (water abstraction). Besides, the indicator also does not match abstraction with availability of water. In order to

evaluate whether the water consumption measured is sustainable and whether it fosters sustainable development, more information would be required. Water consumption must be assessed in relation to water availability, especially the amount of water than can be used for economic purposes without depleting resources or harming the environment (Moritz Bühner, 2012).

2.7.5 Sustainable Process Index (SPI)

The Sustainable Process Index (SPI) is based on the assumption that a sustainable economy is completely comprised of "solar energy" – that is, all natural and anthropogenic activities compete for surface area to utilize the limited supply of solar energy that they need to sustain themselves. The SPI, therefore calculates which surface area, a limited resource, is needed for the conversion of energy into products and services. Accordingly, the foundation of the SPI is surface area: the more area needed to convert a process into a service, the more it "costs" in terms of sustainability. More specifically, the SPI measures the fraction of the area per inhabitant related to the delivery of a certain product or service unit. In this sense, it is a type of "ecological footprint" indicator (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

SPI is used to measure the environmental impacts within LCA, therefore it is compatible with LCA. It is similar to the Ecological Footprint in its use of the area as the metric to calculate resource use in, but the SPI is better suited to cover life cycle stages because it looks at processes and not end-user consumption (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

However, the indicator measures environmental and economic impacts of processes only in terms of land use – it does not provide an estimate of the environmental impacts of resource use. The social impacts of said land use are not self-evident and more

information would be required to draw conclusions. Hence, sustainability impacts are only partially covered (Moritz Bühner, 2012).

2.7.6 Water Abstraction Rates and Water Stress

Water abstraction rates and water stress reflect the intensity of freshwater resource use. Water abstraction rates are expressed as gross abstractions per capita, as a percentage of total available renewable freshwater resources (including inflows from neighbouring countries) and as a percentage of internal resources. Water stress is expressed as gross abstractions in a percentage of total available renewable freshwater resources (including inflows from neighbouring countries), or in a percentage of internal resources (i.e. precipitations - evapotranspiration) (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

This indicator fully matches sustainability impacts coverage, policy relevance and required data efforts. In contrast, LCA compatibility is not matched, while coverage of industries and industrial development and data availability are partially matched (Moritz Bühner, 2012).

2.7.7 Corporations' Turnover, Value Added, and Exports of the Environmental Goods and Services Sector (EGSS)

According to a Eurostat Handbook published in 2009, the environmental goods and services sector (EGSS) is characterized by the four key variables (Martin Hirschnitz-Garbers & Srebotnjak, 2012):

a) Turnover (totals invoiced by the observation unit during the reference period),
b) Value added (the contribution made by these activities towards the income measure of Gross domestic product (GDP),
c) Employment (see indicator table for employment in EGSS), and

d) Exports (consisting of sales, barter, or gifts or grants, of goods and services from residents to non-residents).

This indicator is essential for measuring economic performance within sustainable industries, but several aspects complicate its usefulness. The indicator is used entirely to measure the economic performance and cannot effectively measure greening industries outside the EGSS. Moreover, it lacks LCA compatibility and often requires extra effort in cases where insufficient data exists, making it only marginally appropriate for greening the industries measurement (Moritz Bühner, 2012).

2.7.8 Resource Productivity and Material Productivity

Resource productivity measures the total amount of materials directly used by an economy (Domestic Material Consumption - DMC) in relation to the economic activity (Gross Domestic Product - GDP) through dividing GDP (at constant prices) by DMC (GDP/DMC) or by Total Material Consumption - TMC (GDP/TMC). Thus, Resource productivity enables aggregate measuring of the material efficiency of an economy (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

Resource productivity and material productivity are important indicators for measuring efficient resource use within industries and industrial development. In particular, resource productivity receives great attention on a European level, where it is recommended as a headline indicator to monitor progress on decoupling as a critical element of sustainable development in the EU. Therefore, resource productivity can be used as a relevant indicator for measuring SDGs relating to sustainable industries (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

In spite of the high policy relevance of the Resource productivity indicator and its ability to measure resource quantities used within industries and industrial development,

it remains inadequate to consider environmental impacts and hidden flows, and it lacks LCA compatibility, rendering the indicator only partially relevant (Moritz Bühner, 2012).

2.7.9 Total Material Consumption (TMC)

Similar to Domestic Material Consumption (DMC), TMC measures the total amount of materials directly used by an economy (i.e. associated with domestic production and consumption activities), but it furthermore accounts for the effects of upstream hidden flows linked to imports of raw materials, semi-manufactured and finished products. TMC equals Total Material Requirement (TMR) minus exports minus indirect flows associated with exports (Moritz Bühner, 2012).

This indicator matches coverage of industries and industrial development and policy relevance. However, required data efforts are significant and LCA compatibility, sustainability impacts coverage and data efforts are only partially matched. This shortcomings that make TMC difficult to utilize effectively. TMC requires data on consumption and trade of all materials flowing in and out of an economy. In particular, calculating indirect flows, poses great practical difficulties and significant data efforts (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

2.7.10 The Ecological Footprint (EF)

The Ecological Footprint measures how much biologically productive land and water area is required to (Martin Hirschnitz-Garbers & Srebotnjak, 2012):

a) Meet resource consumption needs
b) Absorb the wastes generated by a human population, taking into account current technology. The methodology also includes a measurement of the annual production of biologically provided resources which called bio capacity.

The Ecological Footprint and bio capacity are each measured in global hectares, a standardized unit of measurement equal to 1 hectare with global average productivity (yield obtained in a particular year from any land class with the locally prevailing technologies) (Martin Hirschnitz-Garbers & Srebotnjak, 2012).

This indicator matches coverage of industries and industrial development, all required data is available and easily comprehensive. In contrast, the indicator is only one impact category; not clearly policy relevant; consumption-oriented. This concludes that even though the ecological footprint is a good general sustainability indicator, it is neither optimally nor specifically suited to measuring industry's sustainability (Moritz Bühner, 2012).

2.7.11 Summary of CO_2 emission reduction as an indicator to measure green industry

From the analysis of the 10 indicators, it shows that those indicators to measure the green industry are not supported by metrics revealing the extent of environmental impacts arising with from resource use. Although the Environmentally Weighted Material Consumption (EMC) has been identified as the most appropriate indicator established for measuring environmental impacts of resource use, the assessment of its limitations shows a clear need to consider other indicator that are directly linked to the problems that the world is facing nowadays which is climate change and global warming.

Another important aspect to be considered in choosing the right and feasible indicator for green industry is the availability of data. The data needed to calculate the selected indicators vary widely in their amounts, accuracy, level of resolution and transferability. This situation tends to be more difficult when it involves greening of Small and

Medium Enterprise (SME) that are lacking in all aspects, especially knowledge, operational data and financial.

Of all selected indicators, none was perfect or outperformed the others on all assessment criteria. Therefore, considering other indicators that complement each other and provide a more complete assessment of the sustainability of an industry is suggested. In this study, an indicator that is simple, practical and represent the actual aspect of greening of the industry will be adopted. Therefore, CO_2 emission reduction has been identified as the most suitable indicator for measuring green industry because of its role as the main greenhouse gas that contribute to the global warming and climate change. The reduction of CO_2 emission is also used as an indicator to other green programmes such as low carbon society and city in Malaysia that is undertaken by Ministry of Energy , Green Technology and Water .

2.8 Green industry practices in other countries

Since its inception, the green industry practices have been adopted and implemented by various institutions and organisations in many countries whether through international bodies, local governments or individual company. Among the green industry implementation include (UNIDO, 2011a):

- A centre in Peru that helped a small lead foundry to attain annual savings of almost US$ 19,000, as well as improved working practices and conditions. Even though the company focused mainly on the decreasing energy use, the integrated approach that was used enabled increased materials recovery, decreased levels of hazardous substances in waste, and reduced GHG emissions
- A centre in Kenya has supported a manufacturer of edible oils and soaps to expand its production capacity and improve production efficiency by using resource efficient and cleaner production methods. Annual benefits include more than

US$623,000 in savings, which fuelled company expansion, including the creation of new jobs and new business ventures; and

- A centre in Sri Lanka helped a coconut mill to save over US$200,000 per year for an investment of less than US$5,000. Options identified by the centre enabled the company to simultaneously decrease waste quantities and reduce the amount of GHG emissions to almost zero through the utilization of waste for energy. The coconut mill has taken a leading role in greening the sector by helping other coconut mills to optimize processes and decrease waste.

2.9 Greening of industries in Malaysia

2.9.1 Existing environmental laws and regulations for promoting Green Industry Initiative

In Malaysia, there is no specific law and regulation that compels the industries to implement green industry initiatives in their premises. Green industry initiative or Cleaner Production has been implemented by the industry on voluntarily basis. From the survey conducted in 2009, it shows that out of 619 respondents, there are 369 premises that have implemented CP or part of CP in their premises. This shows that even no regulation or law imposed on the industries, they have embarked on the CP programs on their own to optimize the process and productivity of the premises (Department of Environment, 2011).

Even though, there is no specific law or regulation on CP, elements of the CP have already been embedded in some of the regulations under EQA 1974. Among the regulations are as follows (Department of Environment, 2001):

i. 1987 - Environmental Quality (Prescribed Activities) (Environmental Impact assessment) Order. The order requires preventive planning for new development

projects. 19 prescribed activities subject to Environmental Impact Assessment (EIA) to be approved by Director General of Department of Environment

ii. 1996 – Section 33A, Amended Environmental Quality Act 1974. The requirement for environmental auditing was made compulsory upon request from the Director General.

iii. 2005 – Environmental Quality (Schedule Wastes) Regulations. New regulation for managing, treating, storing and disposing of Schedule waste which include minimizing waste by best practicable means.

iv. 2009 – Environmental Quality (Industrial Effluent) Regulations. Regulation 9 requires the owner to conduct performance monitoring of the components of the effluent treatment system.

v. 2009 - Environmental Quality (Control of Pollution from Solid Waste Transfer Station and landfill) Regulations. Regulation 11 requires the owner to conduct performance monitoring of the components of the leachate treatment system.

2.9.2 Policies regarding the greening of industry in Malaysia

Greening of an industry in Malaysia is governed by several policies that become the guiding document to all efforts of promoting green industry practices among the industries. The policies are as follows:

2.9.2.1 National Environmental Policy of Malaysia

In the year 2002, the National Policy on the Environment (NPE) was formulated and approved by the Department of Environment, which is under the Ministry of Natural Resources and Environment of Malaysia, which was previously under the Ministry of Science, Technology and Environment of Malaysia. The NPE aims to promote environmentally sound and sustainable development in managing and conserving the environment, for the continuation of economic, social and cultural progress of Malaysia

and enhancement of the quality of life of its people. As it moves towards the status of a developed country by the year 2020, Malaysia envisages their land should remain productive and fertile, and still rich in natural diversity (Ministry of Natural Resources and Environment Malaysia, 2012).

Three main objectives of the Policy are:

- A clean, safe, healthy and productive environment for present and future generations
- Conservation of the country's unique and diverse cultural and natural heritage with effective participation by all sectors of society
- Sustainable lifestyles and patterns of consumption and production

Significantly, under this strategy, NEP emphasises the integration of technologies, financial and innovative approaches, especially by application of cleaner production concept and through research and development (R & D) of environmentally sound technologies to solve the pollution problems of the industries. Also, the NPE serves as an important framework as to ensure Malaysian industries, especially large companies to establish partnership schemes with Small and Medium Enterprises (SMEs) to help facilitate the exchange of experience in environmental management system (EMS) (Ministry of Natural Resources and Environment Malaysia, 2009).

In line with the National Environmental Policy, Department of Environment (DOE) through Green Industry Unit is actively promoting Green Industry practices, especially Cleaner Production (CP) among Malaysian industries especially Small and Medium Enterprises (SMEs). SMEs are the backbone of the economy as the number of SMEs is more than 98 % of the total industry in Malaysia. The term of SMEs here, refers to the definition by SME Corporation (SME Corp) (SME Corp. Malaysia, 2013). Besides stimulating the economy, SMEs also identified as a major contributor to environmental

pollution in Malaysia. The aims of this program are to help the SMEs in the compliance with environmental regulations, to increase the productivity, and to reduce the emission of Carbon dioxide in the atmosphere. Many activities such as seminars, workshops, dialogues, trainings, and demonstration projects have been carried out since 2008 to raise awareness among the industries and encourage them to implement the green industry practices (Department of Environment, 2012).

2.9.2.2 National Green Technology Policy

"Green Technology" is an initiative involving various kinds of methodologies and material enhancement, from techniques for generating energy to non-toxic cleaning products. The main goal of green technology application is to achieve sustainability of the economic development. With many scientific studies pointing to global warming and climate changes caused by greenhouse gases from human activities, there is an ever increasing societal push for environmental friendly mechanisms to help reduce the impact resulting from fossil fuel consumption, landfill and industrial sector wastages. As a result of this concern, green technology has emerged as an alternative to the conventional practices, to overcome the problems of global warming and climate change. The Ministry of Energy, Green Technology and Water of Malaysia has been taking a holistic approach to advocate green technology in the country. This followed by the launching of National Green Technology Policy by the Prime Minister on 24th July 2009 (Abu Bakar, Mohd Sam, Hayati Tahir, Rajiani, & Muslan, 2011).

The national goals of the Green Technology Policy is to provide direction and motivation for Malaysians to continuously enjoy good quality living and a healthy environment. According to the policy, Green Technology shall be a driver to accelerate the national economy and promote sustainable development. The National Green

Technology Policy embodies elements of economics, environment and social policies, as reflected in the five (5) objectives as follows (Punitha Silivarajoo, 2010):

- To minimise growth of energy consumption while enhancing economic development;
- To facilitate the growth of the Green Technology, Industry and enhance its contribution to the national economy;
- To increase national capability and capacity for innovation in Green Technology development and enhance Malaysia's competitiveness in Green Technology in the global arena;
- To ensure sustainable development and conserve the environment for future generations; and
- To enhance public education and awareness on Green Technology and encourage its widespread use

Green technology is one of the important elements in the greening of industry process in which latest and environmentally friendly technology and innovations are capable of creating high quality products that are not harmful to human being and the environment. Green technology is also one of the options in Cleaner production auditing, but required financing for implementation and usually become the last option in cleaner production hierarchy (Punitha Silivarajoo, 2010).

2.9.2.3 National Policy on Climate Change

Climate change is already being observed through rising temperatures, melting glaciers, shifting rain patterns, increased storm intensity and rising sea levels. Greenhouse gas (GHG) emissions from human activities – mainly fossil fuel use, deforestation and agriculture - cause climate change. If GHG emissions are not reduced to significantly below current levels within the next few decades, there will be further warming and sea-

level rise for centuries to come. This will result in adverse impacts on human health, natural ecosystems, and the economy. The risk of serious climate change impacts suggests that urgent action is needed to significantly reduce GHG emissions in the coming decades. There is increasing evidence that the overall benefits of strong and early action to reduce GHG emissions outweigh the costs. But the need to reduce emissions at the lowest possible cost if we are to have a realistic chance of limiting further climate change (OECD, 2007a).

OECD analysis shows that large reductions in GHG emissions are achievable at relatively low costs, if the right policies are put in place. This includes strong use of market-based instruments worldwide to develop a global price for GHG emissions, accompanied by better integration of climate change objectives in relevant policy areas such as energy, transport, building, agriculture or forestry, and other measures to speed technological innovation and diffusion (OECD, 2007a).

In view of this situation, Malaysia has formulated the policy on Climate Change in 2009 to provide the framework to mobilize and guide government agencies, industry, community as well as other stakeholders and major groups in addressing the challenges of climate change in a holistic manner. The National Policy will enable Malaysian to take concerted actions and identify opportunities that can help navigate the nation towards sustainability. Emphasis is on strengthening capacity of the nation to reduce its vulnerability to climate change whilst promoting mitigation responses that also enhance sustainable development (Ministry of Natural Resources and Environment Malaysia, 2009)

The objectives of the National Policy on Climate Change are (Ministry of Natural Resources and Environment Malaysia, 2009):

- Mainstreaming climate change through wise management of resources and enhanced environmental conservation resulting in strengthened economic competitiveness and improved quality of life
- Integration of responses into national policies, plans and programmes to strengthen the resilience of development from arising and potential impacts of climate change
- Strengthening of institutional and implementation capacity to better harness opportunities to reduce negative impacts of climate change.

2.9.3 Early Cleaner Production (CP) Projects in Malaysia.

Among the early CP projects in Malaysia was carried out by DANIDA SIRIM:

2.9.3.1 Promotion of Cleaner Technology in the Malaysian Industry

The project was carried out by SIRIM Berhad and DANCED as a technical cooperation programme. It was launched in January 1996 and completed in October 1998. The objectives of the project were denoted with 4P: pollution prevention, productivity and profitability. The project focused on three specific industrial sectors, which are food, electroplating and textile. The scope of the project includes the industrial audits establishment of a clean technology database, organizing seminars and workshops and publication of newsletter .The most important aspect of the project was six full scale demonstration project incorporating cleaner production options that were implemented to showcase the benefits of pollution prevention in saving money and increasing productivity and profitability (Department of Environment, 2008b).

The demonstration projects were selected based on criteria such as management capability, commitment to cleaner technology, willingness to share information and applicability of the system. Another follow up project entitled ‘Cleaner Technology for Improved Efficiency and Productivity of the Malaysian industry was carried out to reduce the environmental pollution from the small and medium industries (SMIs) and

improve their compliance with environmental regulations and as well as to improve the overall productivity (Department of Environment, 2008b).

2.9.3.2 SIRIM – JICA Study on Promotion of Cleaner Production in the Industrial Sector.

The project was undertaken from October 2000 to September 2002. The project contributed towards the abatement of industrial pollution in Malaysia by promoting CP through capacity building of SIRIM Berhad and other relevant agencies. Besides that, the project also making recommendations and an action plan for CP promotion. The target sectors were electroplating and metal finishing, food and beverages, pulp and paper and textile. The scope of the study covered the review of the present situation of industrial pollution control, analysis of industrial pollution in the targeted sectors survey representative factories, a pilot programme for the promotion of CP, comparative analysis and recommendations on CP promotion measures. The study also proposed the action plans for the promotion of CP, industrial pollution control and implementation of CP demonstration projects for other selected model industries (Department of Environment, 2008b).

2.9.4 The roles played by Department of Environment to promote CP in Malaysia

Department of Environment (DOE) was originally established as Environment Division under the Ministry of Local Government and the Environment on 15 April 1975. The Environment Division was then placed under the Ministry of Science, Technology and Environment in March 1976. Environmental conservation in Malaysia began with the gazettement of the Environmental Quality Act (EQA) in 1974. Based on the importance of preservation and conservation of the environment, the Environment Division was

upgraded to a full department and known as the Department of Environment Malaysia on 1st September 1983 (Jabatan Alam Sekitar, 2011).

The main focus of that time was to address the problem of environmental pollution caused by the crude palm oil and natural rubber mill which were the fastest growing industry in the plantation sector. The EQA 1974 adopted 'end of pipe approach' which set certain standards that must be complied by the industry and continues until the United Nations Environment Programme (UNEP) developed the concept of Cleaner production in 1991. The CP concept integrates a preventative environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment. Department of Environment has recognized the advantage of CP to industry and began the efforts to promote the concept to Malaysian industry. To spearhead the efforts, the Clean Technology Unit was established under the purview of EiMAS with the aim to increase the intake of CP by the industry especially SMEs (Department of Environment, 2004).

Department of Environment Malaysia has embarked on the promotion of Cleaner Production programs to industries since 1990's. DOE aggressively promotes CP starting 2007 during the 9th Malaysian Plan and continue with 10th Malaysia Plan. Among the activities or programs carried out are road shows, workshops, CP audit assistance program, CP website and CP demonstration project. The aim of these programs is to educate industries on the importance and benefits of CP implementation in their premises (Department of Environment, 2011).

In 2011, UNIDO has come out with the green industry concept as a pathway for protecting communities, vital ecosystems and the global climate from escalating environmental risks and emerging scarcities of natural resources. Because of this, Department of environment has adopted this new approach by re-branding Cleaner

Technology Unit to Green Industry Unit to portray the government's intention to greening the industry in Malaysia (Department of Environment, 2012). By doing this, the department aims to not only increase the compliance of industry with environmental regulations, but also reducing the carbon emission in line with the Malaysia commitment to reduce carbon intensity by 40 per cent by 2020 based on GDP compared to the emissions level in 2005 (Bernama, 2014).

Since 2007, 2000 industries have been exposed to the CP concept in road show, seminars and workshops conducted in various states in Malaysia. Two CP demonstration projects have also been carried out which are CP Demonstration Project in MM Vita oils in 2009/2010 and Integration of CP in batik premise in 2011/2012. The aim of these projects is to implement CP in the premise as a model and reference for other premises. Many options ranging from simple housekeeping to modification of the process were generated and the selected options after being evaluated in terms of cost and benefits were implemented in the premises. Meanwhile, the CP audit assistance program has been carried out to a selected SMI premises to assist them in identifying options that can be implemented to increase the premise productivity and process efficiency (Department of Environment, 2011).

The green industry initiatives carried out by the DOE, which are CP demonstration project and CP audit assistance program are the most successful program undertaken by DOE in promoting CP to the industries especially SMIs. The demonstration project proves that implementation of CP in the premise reduces the raw materials and electricity consumption and also generation of waste. Whilst the CP audit assistance program helps the industries to identify room for improvement in their premises where options generated are presented to the management to be evaluated before implementation. These programs meet the objective of CP promotion and awareness

and should be continued in future for the benefits of other SMIs (Department of Environment, 2013).

All Cleaner Production activities undertaken by DOE are based on two important guiding documents which are:

2.9.4.1 Strategic Plan of Department of Environment (2011-2020)

A strategic plan is a document used to communicate with the organization the organizations goals, the actions needed to achieve those goals and all of the other critical elements developed during the planning exercise (Balanced Scorecard Institute, 2014). DOE's Strategic plan outline nine (9) strategic thrust which become the foundation OF DOE's environmental management until 2020. The plan was prepared by taking into account the needs of all relevant stakeholders towards enhancement of national sustainable development. The plan sets the clear objectives and targets for each major DOE activities that ranging from enforcement, pollution prevention, awareness and education, environmental monitoring, air quality and hazardous waste management (Jabatan Alam Sekitar, 2011).

The plan recognized Cleaner Production as one of the important elements of environmental management towards achieving sustainable development and this was translated in the thrust strategic no. 6. The thrust strategic no. 6 stress on the importance of promotion of Cleaner Production practices and the needs to establish the group of subject matter experts and qualified consultants in Cleaner Production. There are three strategies adopted which are to increase the intake of Cleaner Production practices among the small and medium industries, establish a group of subject matter experts of CP in the Department of Environment and finally, establish a group of qualified CP consultants (Jabatan Alam Sekitar, 2011).

2.9.4.2 Cleaner Production Blueprint for Malaysia

The blueprint of Cleaner production was an initiative undertaken by Department of environment Malaysia to spearhead the promotion and implementation of CP among industries in Malaysia. The blueprint becomes the basis for future policy document in the implementation and presentation of CP practices in the country. It outlines eight strategic action plans to address the implementation CP through regulatory, policy and financial commitments. The strategic plan for actions are as follows (Department of Environment, 2004):

- The formulation of national policy of the CP which include strengthening the existing legal framework to incorporate CP requirements.
- Provide education and increase environmental awareness in the industrial sector by championing the benefits of CP through newsletters, TV programmes, newspaper articles, seminars and workshops, information database and website in the internet.
- Establish networking and dissemination of information on CP which includes setting up of CP demonstration projects, enhance CP networking, and carry out national CP roundtable meeting.
- Training and CP audit to give a better understanding of CP concept, benefits of CP implementation, techniques for applying CP, and study trip to the premise that implemented CP
- Provide incentives include all financial facilities to enhance CP implementation such as existing incentives for SMEs, MIDA incentives and CP award.
- Strengthen regulatory - policy framework by employing existing environmental regulations to include the CP requirements to ensure immediate implementation of CP.

- Provide continuous capacity building in CP which includes raising of awareness, training, consultancies, enforcement of CP policies, advisory and research capabilities.
- Establish CP Coordination Centre such as Waste Exchange Management Centre that acts as a dedicated system in buying and selling of all types of waste.

2.9.5 Green Industry practices in Malaysia

2.9.5.1 Cleaner Production Demonstration Project at MM Vita Oils Sdn Bhd

The description of this Cleaner Production Demonstration Project was extracted from the article written by Razuana Rahim (2012). The project has been carried out in 2009 and completed in 2010, was an early entry programme for the Department of Environment with the cooperation of Unit Perunding Universiti Malaya (consultant) and MM Vitaoils (industry). MM Vitaoils Sdn. Bhd. was established in 1999 and located in Industrial Zone Shah Alam, Selangor. The company currently produces and exports 24 types of palm oil based products such as cooking oil, ghee, shortening, margarine and pastry margarine to niche market in South Korea, China, India, Europe, USA, Uzbekistan, Africa and Japan.

The project was conducted with the aim to establish a demonstration premise that implements the approach and elements of cleaner production as a whole especially in the process, service and products. The successful implementation of CP options in the premise in all aspects such as increase of efficiency in the process and premise activities, reduction of safety and health risks and reduction of impacts on the environment has been documented as a showcase to other industries especially Small and Medium Enterprises in Malaysia.

The implementation of CP practices in the premise began with the creation of the CP team comprised of various personnel in the premise. The activities conducted on the

premise include audit and option generation, options implementation and monitoring, workshops and awareness programmes, promotion and video documentation, awards for the most committed employee and information dissemination through CP bulletin.

More than 200 CP options were generated based on the issues identified during audit activities which include process modification, housekeeping and the minimization or prevention of wastage in water, energy, raw material, and other utilities consumption, reduction of generation of manufacturing waste and off spec products, risk reduction and increase of productivity. The company has successfully implemented 78 options of the housekeeping category that did not require financial cost. Based on the evaluation in the aspects of financial implication and the impacts of the implementation, five options of process modification category were implemented and evaluated on its effectiveness as follows:

1) Installation of bypass piping for crystallization unit

   During the manufacturing process of fine ghee, shortening and margarine, the products need to go through the process of crystallization in the crystallizer unit. However, this requirement of operational unit is not relevant to ghee granular product where the crystallization process is not required. Products only need to be streamed directly into the packaging. The company faces a loss in terms of electricity consumption in which the switch of operational unit still needs to be turned on even though there is no need to do so. To resolve this problem, the installation of bypass piping is carried out to control the use of the crystallizer unit according to the appropriate requirements. The crystallizer unit switch will be turned on only for the processes that need them. With the installation cost of RM 2450.00, the implementation of this option is to break even within a month. The bypass piping has saved electricity consumption amounting to RM44, 305.00 per year.

2) Change of pipe diameter

The process of mixing oil and raw materials of different composition in the mixing tank takes about 45 minutes to achieve a homogeneous phase. To resolve this problem, the pipes with a diameter of 2.0 inches was installed to replace the existing 1.5 inch diameter pipe to shorten the time in order to achieve a homogeneous mixture while reducing the cost of electricity consumption. With the installation cost of RM 3150.00 and capital returns during a period of 16 months, the implementation of this option has shortened the mixing period of 1404 hours per year and the electricity consumption of RM 202.00 per year.

3) Installation of Pneumatic Control Valve

The mixing process using manual control systems requires additional labour and electricity consumption. The installations of pneumatic control valve to replace the manual control system, save the cost of electricity consumption, labours, and improve worker safety. With the installation cost of RM8250.00 and the capital return period of 8 months, the implementation of the option reduces the use of electricity for the motor of RM 1000.00 per year.

4) Use of High Efficiency Motor Pump

During the mixing process, pump is used to rotate the motor shaft. However, the efficiency of the pump used is very low and causing high electrical power usage. The installation of high efficiency pump improves the efficiency level of the process. With the installation cost of RM 16,098.00 and the capital return period of 8 months, the implementation of the option reduces the use of electricity as much as RM 1000.00 per year.

5) Use of Semi Auto Sealing Machine

The packaging process requires a workforce of three people to handle the manual sealing machine. The use of semi auto sealing machine can reduce the number of

workers from three to two people. The installation cost of RM 6700.00 and capital return period of 8 months, the implementation of the option has reduced the wastage of OPP tape of RM 122.00 per year and labour costs as much as RM 18,000.00 per year.

The success of this demonstration project proves that the greening of industry through Cleaner Production (CP) can be successfully implemented with the cooperation of all parties, especially with the commitment of the factory management itself. This project has become a model and reference to other companies in the implementation of the CP and subsequently achieve the DOE objective to promote the implementation of Cleaner Production among Malaysian SMEs.

2.9.5.2 Cleaner Production in the premise of Dagang Batikraf

The description of this Cleaner Production Demonstration Project was extracted from the article written by Nor Azah Masrom (2012). For the purpose of continuing the survival of the batik industry in Malaysia to be more competitive and environmentally friendly, the Department of Environment (DOE) has taken the initiative to implement the integrated Cleaner Production project in Batik Manufacturing Premises in 2011. The project was organized by the Department of Environment in collaboration with University Malaya Consultancy Unit (UPUM). The project was implemented in two phases: Phase 1 (2011) and Phase 2 (2012). CP approach was adopted by the DOE as a strategy for the industry to increase the compliance with the Environmental Quality Act 1974. For this project, batik industry has been given a priority among other industries to showcase the implementation of CP practices. Dagang Batikraf Sdn. Bhd. in Kota Bharu, Kelantan has been selected as a demonstration premise for the implementation of CP options.

This project was an effort toward prevention of pollution in the early stage of the batik making process and would serve as an example of the implementation of CP to other batik making promises. Indirectly, it emphasized on the elements for improving tolerance and awareness of batik industry on the impacts of batik making process to the natural environment. The CP integration project in the batik premise was carried out to prove that the batik industry, which is mostly a cottage industry, could be transformed into a green and economically viable industry. CP options generation which was identified in the premise of Dagang Batikraf comprised of the aspects of energy, raw materials, hazardous solid waste, effluent treatment systems, productivity, safety and health.

A total of 71 CP options has been shortlisted for further detailed assessment and out of that, 28 options were selected for implementation at the premise of Dagang Batikraf. Among the options that have been implemented are:

- Construction of concrete floor in the processing area, 1200 square feet to replace the existing earth floor to prevent ground water pollution in the event of a chemical spill
- Construction of two concrete tank water for rinsing the batik cloth to replace the existing water tank made from empty drum to prevent any leakage of chemical to the floor
- Installation of plywood ceiling in the painting area, 32 square feet to replace the old ceiling that was torn and endangered the safety of workers.
- Installation of two new cabinets to store the containers that contain dye to make them more orderly and easily accessible.
- Construction of a special chamber with the chimney for the purpose of heating the wax to enable the complete combustion and also to avoid air pollution to the neighbours and the workers.

- Installation of two level batik painting frames made from steel to replace the old wooden frames that were torn and risky to human and environment.
- Installation of four panels of transparent roof to give a natural lighting in the batik process area and save the consumption of electricity during daylight.
- Construction of parameter drains in the batik painting area to channel the floor washing water to effluent treatment system.
- Construction of concrete tanks for soaking the sodium silicate to replace the existing drum so as to avoid the spillage and leakage of sodium silicate to the floor.
- Labelling was carried out for the entire process area which includes the material and waste storage to facilitate the identification of process components in the premise.
- Personal Protection Equipment (PPE) was provided for the purpose of health and safety precaution of the workers in the premise.

2.9.6 Other Greening of Industry Programme carried out in Malaysia.

2.9.6.1 My Carbon Programme

Climate change awareness and efforts are gaining the momentum internationally as well as in Malaysia. Mandatory and voluntary efforts in reducing emissions of GHG are observed from governmental to corporations and from non-governmental organisations (NGOs) to individual. In view of the growing important of carbon accounting and reporting, My Carbon - National Corporate GHG Reporting Programme was initiated by by Ministry of Natural Resources and Environment (NRE) and United Nations Development Programme (UNDP) in August 2013 to manage the climate change (Department of Enviroment, 2007).

My Carbon aimed for an advanced GHG reporting and management by organisations in Malaysia, particularly those in the private sectors. This is in line with Malaysia's announcement to work towards up to 40% reduction in emissions intensity of Gross

Domestic Product (GDP) by the year 2020 based on the year 2005 level provided that technology transfer and financial support are provided from the developed countries. Through such reporting, it allows the ministry to measure progress toward achieving the emissions reduction indicator announced by the Prime Minister of Malaysia (Soon Hun Yang, 2012).

Specific objectives of the programme are to (Environmental Management and Climate Change Division, 2012):

- Set up a globally recognised, standard corporate GHG accounting and reporting programme in Malaysia
- Data sources for analysis and development of local emission factors
- Encourage corporate level carbon accounting emissions reduction
- Provide standards, guidance and support measures (training, fiscal, and other incentives)

My Carbon defines the reporting entity – the type of organisations required to report its GHG emissions to the programme – at the corporate level. Under corporate-level reporting, an organization reports emissions from all of its facilities, subsidiaries and other organisations as determined by its organizational boundaries. Defining the reporting entity at the corporate level is consistent with the definitions and rules of financial accounting, which are based on either ownership or control approach (Eco-Ideal Consulting Sdn Bhd, 2014).

2.10 SMEs in Malaysia and the Environment

2.10.1 Definition of Small and Medium Enterprises (SMEs)

Small and medium-sized enterprises (SMEs) are defined as non-subsidiary, independent firms that employ no more than a given number of employees. This number varies

across national statistical systems. The most frequent upper limit is 250 employees, as in the European Union. However, some countries set the limit at 200 employees, while the United States considers SMEs to include firms with fewer than 500 employees. Small firms are generally those with fewer than 50 employees, while micro-enterprises have at most ten, or in some cases five, workers. Financial assets are also used to define SMEs (OECD, 2000).

In OECD countries, SMEs play a major role in economic growth, and provide most new jobs. According to SMEs, which account, over 95% of enterprises in OECD countries are for 60-70% of employment in most of these countries. As larger firms downsize and outsource more work, the weight of SMEs in the economy is increasing. However, many of the traditional problems constrained managerial facing SMEs, capabilities, such as lack of financing, low productivity, and higher sensibility to regulatory burdens, become more acute in a globalised, technology-driven world. Most SME jobs are in the service sector, which now accounts for two thirds of economic activity and employment in OECD countries. Smaller firms are found particularly in the wholesale and retail trade, the hotel and restaurant business, communications and business services, and construction. SMEs also account for a high percentage of manufacturing firms in many OECD countries and provide at least half of manufacturing employment in those countries (OECD, 2007b).

There are many definitions of SMIs applied by various international agencies as shown in the Table 2.1

Table 2.1: Definitions of SMEs

Sources	Definition
World Bank since 1976	Firms with fixed assets (excluding land) less than US$250,000 in value is a small scale enterprise
Grindle et al (1989:90)	Small-scale enterprises are firms with less than or equal to 25 permanent members and with fixed assets (excluding land) worth up to US$ 50,000.
USAID in the 1990s	Firms with less than 50 employees and at least half the Output is sold (also refer to Mead, 1994
UNIDO's Definition for Developing Countries	Large - firms with 100+ workers Medium - firms with 20 – 99 workers Small – firms with 5 – 19 workers Micro –firms with < 5 workers
UNIDO's Definition for Industrialized Countries	Large - firms with 500+ workers Medium - firms with 100 – 499 workers Small – firms with 99 workers

2.10.2 Status of SMEs in Malaysia

Small and Medium Enterprises (SMEs) in Malaysia account for about 97.3% or 645,136 of total establishments in the five main economic sectors of services, manufacturing, agriculture, construction and mining & quarrying in 2011. Most of the SMEs are found in the services sector, accounting for 98.1%. It is clear that promoting a viable SMI sector is essential in the nation's stride towards broadening the sources of growth and sustaining the growth momentum (SME Corp Malaysia, 2011)

SMEs are a backbone of Malaysia's economy which contributes to 57% of employment and 19% of total exports. Besides that, it also contributes to 32.5% of Gross Domestic

Products (GDP) of Malaysia (Hashim, 2013). The number of SMEs establishment in Malaysia by sector in 2012 is shown in Table 2.2

Table 2.2: The number of SMEs establishments by sector (National SME Development Council, 2012)

Sector	Micro	Small	Medium	Total SMEs	Total SMEs	Large Firms	Total Establishments
Manufacturing	21,619	13,934	2,308	37,861	5.9	1,808	39,669
Services	462,420	106,061	12,504	580,985	90.1	10,898	591,883
Agriculture	3.775	1,941	992	6,708	1.0	2,121	8,829
Construction	8,587	6,725	3,971	19,283	3.0	2,857	22,140
Mining & Quarrying	57	126	116	299	0.06	119	418

The performance of Malaysian SMEs remained encouraging despite the difficult business environment. In 2013, GDP growth of SMEs picked up further to 6.3% versus 6% in 2012. SME growth also exceeded the overall GDP growth of the country by 4.7%. The higher SME growth was reflected across all major economic sectors, mainly supported by strong domestic demand, led by both consumption and investment activities (SME Corp. Malaysia, 2013).

Malaysia has adopted a common definition of SMEs to facilitate the identification of SMEs in the various sectors and subsectors. This has facilitated the Government to formulate effective development policies, support programs as well as provision of technical and financial assistance.

In view of many developments in the economy since 2005 such as price inflation, structural changes and change in business trends, a review of the definition was undertaken in 2013 and a new SME definition was endorsed at the 14th NSDC Meeting in July 2013. The definition was simplified as follows (SME Corp. Malaysia, 2013):

- Manufacturing: Sales turnover not exceeding RM50 million or full-time employees not exceeding 200 workers
- Services and other sectors: Sales turnover not exceeding RM20 million or full-time employees not exceeding 75 workers

A business will be deemed as an SME if it meets either one of the two specified qualifying criteria, namely sales turnover or full-time employees, whichever is lower.

Definition by Size of Operation

- Micro enterprises across all sectors: Sales turnover of less than RM300, 000 or less than 5 full time employees.
- Table 2.3 summarises the definition for the small and medium categories for the respective sectors.

Table 2.3: Definition by Size of Operation (SME Corp. Malaysia, 2013)

Category	Small	Medium
Manufacturing	Sales turnover from RM 300,00 0 to less than RM15 million or full-time employees from 5 to less than 75	Sales turnover from RM15million to not exceeding RM50 million or full-time employees from 75 to not exceed 200
Services & Other Sectors	Sales turnover from Services & Other Sectors RM300,000 to less than RM3 million or full-time employees from 5 to less than 30	Sales turnover from RM 3million to not exceeding RM20 million or full-time employees from 30 to not exceed 75

- If a business fulfils either one of the criteria across the different sizes of operation, then the smaller size will be applicable. For example, if a firm's sales turnover falls under micro enterprise, but employment falls under small, the business will be deemed as a micro enterprise.

For the purpose of this research, the definition of SMEs adopted by SME Corp., will be used to describe and classify the industries that its problems and issues to be addressed in the study.

2.10.3 Status of Compliance of SMEs with environmental regulations.

In principle, Small and medium sized enterprises (SMEs) can pose serious environmental problems due to their high numbers and their cumulative effect. The impact of manufacturing SMEs is largely acknowledged as they consume energy and natural resources, and generate waste and pollution. They are thought to be responsible for around 60% of all carbon dioxide emissions and 70% of all pollution (Parker, Redmond, & Simpson, 2009).

Several studies conducted in the OECD countries, show that agriculture is one of the key sectors where polluting SMEs are active. Their activity is a major source for water pollution and land contamination. As concerns service sector SMEs, in particular petrol stations and repair shops, they can pose a risk of significant routine pollution or accidental releases. SMEs in all sectors could have a negative impact on biodiversity due to changes of habitat they provoke, especially in environmentally sensitive areas (OECD, 2007b).

Statistical information on environmental impacts of SMEs is quite scarce in both OECD and non-OECD countries which include developing countries like Malaysia, with only few studies quantifying these impacts. A report on SMEs and the environment produced for the European Commission by ECOTEC Research and Consulting mentions that SMEs are estimated to generate as much as 60% of commercial waste and 80% of pollution incidents in England and Wales. Work by the Wales Environment Centre in rural Wales, where SMEs constitute 97% of businesses, indicates that they produce around 91% of waste in the area (OECD, 2007b).

Research conducted in the Netherlands by TNO concludes that smaller industrial installations significantly raise environmental pressures (around 50%) for a number of pollutants, in particular for nitrogen and phosphorus, heavy metals and some pesticides, ozone-depleting substances, and volatile organic compounds (VOC). They contribute to acidification and waste generation, both hazardous and non-hazardous. The study identifies a number of key sectors where polluting SMEs is active, including (OECD, 2007b):

Another study, commissioned by the Dutch government and developed by KPMG Environmental Consulting, identified some other industrial sectors where SMEs have a particularly significant impact on the environment, such as printing, and some areas of the timber, woodworking and paper industry, textile and leather manufacturing (OECD, 2007b).

Some of the defining characteristics of the SME sector, which contribute to poor levels of environmental compliance in their operations are (Zhengang Z, Weerasiri R.A, & Dissanayake D.M.R, 2011):

- Poor business planning without following the sustainable development framework due to lack of guidance on same;
- Lack of understanding of environmental, public health and safety issues;
- Limited awareness of legal and regulatory obligations;
- Poor environment practices due to non- regularized labour practices;
- Non adoption of cleaner technologies or use of expensive pollution control equipment due to low economies of scale.
- Poor compliance monitoring by the responsible company

Based on the above characteristics, it shows that noncompliance of the environmental regulations and the pollution caused by SMEs is caused by the low level of awareness of the environmental impacts of their business activities.

2.10.4 Environmental Awareness of SME

Existing data show that a large proportion of SMEs tends to underestimate their environmental impacts. A study conducted in the UK demonstrated that only 7% of SMEs believed that their activities were harmful to the environment while 41% of SMEs admitted that had at least one potentially harmful activity when prompted with a list. Similarly, a Belgian study carried out by the Wallonian Union of Enterprises showed that up to 84% of the Belgian industrial SMEs did not feel that they contributed to pollution. Without information about their environmental impacts and associated production inefficiencies, in energy and natural resource use, SMEs will be neither prone nor that would improve their environmental abilities to take decisions performance (OECD, 2007b).

A study by Oksana Seroka-Stolka and Jelonek (2013) on the environmental awareness of the food industry in Czestochowa, Poland showed that 75% of the studied small and medium enterprises do not implement the formal environmental policies of their region, whereas the effect of their operation on the environment is defined as insignificant by 52% of them. Only 6% of them assessed this effect as very big. Almost 44% of the entities, which do not have formal instruments of environmental management, do not plan to implement ISO 14001 and ISO 14031 and over 32% of them do not plan the implementation of the EMAS in the next three years. The ISO 141001 standard is used by only 6.5% of the enterprises in the survey, whereas none of the enterprises implemented EMAS system. On average, a half of the studies enterprises are undecided about whether to implement the formal environmental instruments.

Finally, SMEs are much less preoccupied about their images as a good environmental citizen than large enterprises. The SMEs are short of resources and lacking of technical expertise and skills, clearly contribute to the "sceptical" attitude that SMEs show towards the potential benefits, cost savings and customer rewards associated with environmental improvements. A negative company culture towards the environment may even persist despite positive attitudes among staff (OECD, 2007b).

In terms of compliance to environmental legislation, SMEs find it more difficult to comply compared to their larger counterparts. In general, the smaller the company, the more difficult it is. Environmental legislation is general in nature and aimed at preventing and reducing negative environmental impacts, and therefore it does not take into account the specificities of SME operations (OECD, 2007b).

A study by Danish Technological Institute (2010) found that SMEs are aware of the main environmental national legislation and the relevant requirements. However, the level of information and specific knowledge about environmental legislation is still low and lacking. Few SMEs considers main environmental issue that is related to their activities. This can be explained by information asymmetry provided by national competent authorities, but also due to lack of capacity in SMEs, which means that they seldom have an overview of sources of support (legal, technical) and how these can be used strategically. There is a lack of support for companies to implement the changes imposed by existing or new environmental legislation. Therefore, many SMEs are incurring extra costs to hire external environmental consultants and experts. Monitoring and reporting environmental indicators also imposes costs on SMEs, and sometimes reporting has to be provided to different authorities and be presented in different formats. When complying with reporting requirements, allocated person-hours vary substantially among SMEs. Some enterprises estimate that environmental reporting

engages (aggregated) 1 person for 1-1.5 month/year, others allocate a fulltime employee throughout the year.

Many SMEs around the world also have little knowledge about environmental management and do not understand the concept of environmental management. Therefore, it is very difficult for SMEs to see clear link between EMS implementation and the benefits. On the other hand, management systems in SMEs generally focus on every day business and tend to be immediate, responding to critical incidence situation management. Thus long-term intangible environmental benefits will receive low priority (Zhengang Z et al., 2011).

Meanwhile, the environmental performance of SMEs can be improved by many different ways (OECD, 2007b):

- Governmental institutions instruments, could use a mix of policy environmental permitting, pollution charges, pricing policy for natural resources, public procurement practices, etc. to set targets for, and promote, environmental performance. Adapting policy instruments to SME specifics could increase their effectiveness (for instance, the regulatory pressure from public authorities would intensive on SMEs than on larger enterprises); normally be less
- Consumers could demand products that have a lower impact on the environment during the entire product life cycle;
- Investors and banks could evaluate enterprises' due diligence and consider environmental risks when providing loans;
- Suppliers and intermediary clients could require from their partners to apply preventive environmental measures systematically and to reach a particular level of environmental performance;

- Environmental or other investment funds, including those set up with donor assistance, could provide financing for projects, particularly for cleaner production; and
- Public pressure on enterprises to implement measures aimed at reducing environmental impacts could be increased.

2.10.5 Regulatory requirements of SMEs in Malaysia

Generally, all industries in Malaysia including SMEs are subject to the Environmental Quality Act 1974. EQA 1974 is the Act to prevent and control pollution. In addition to the provisions under the parent Act, there are also 19 regulations. 14 orders and 2 rules enacted under EQA 1974 to control pollution of land, water and the sea. This Act adopts the 'end of pipe approach' where standards and emission limits have been set for the release of effluent, impurities in the air and disposal of scheduled waste. For SMEs such as palm oil mill and natural rubber mill, there are specific regulations to control land and water pollution arising from their operations (Department of Environment, 2001).

Among the regulations, including the parent Act, EQA 1974 that regulate the operations of the manufacturing industry are as follows:

- Environmental Quality Act, 1974
- Environmental Quality (Industrial Effluents) Regulations, 2009, formerly known as the Environmental Quality (Sewage & Industrial Effluents) Regulations 1979
- Environmental Quality (Clean Air) Regulations, 1978
- Environmental Quality (Scheduled Wastes) Regulations, 2005.

2.11 Printing industry in Malaysia

2.11.1 Contribution to economy

The printing industry in Malaysia is known to be one of the oldest. All these years, it has played a major role as the main media for education, communication and dissemination of knowledge and information. Compared to the modern electronic media, it is by far, the cheapest means of bringing home the information to the public in every sector of society and in every nook and corner. Because printing being one of the oldest industry, the Malaysian printers over the years have acquired vast experience and technical capability. And being aware of this potential of growth, the Malaysian Government is actively promoting the export of this service (Soo Huat, 2002).

The printing industry in Malaysia is probably also among the top five largest industries in the manufacturing sector, with new licenses being issued every year. Owing to its long existence, this is an industry where the competition has always been great, especially for the general purpose printers who have to face stiff pricing competition. However, this does not deter inflow of foreign funds into the country to set up new printing factories in Malaysia (Malaysia Printers Association (MPA), 2013).

The paper, printing and publishing industry encompasses the manufacture of pulp, paper, paper products as well as printing and publishing activities. In recent years, the Malaysian paper industry has progressively increased its production capacity by two-fold, recording 90 per cent self-sufficiency in the supply of paper and paper products and providing employment opportunities to 4,000 persons to date (MIDA, 2014).

In 2013, imports of paper and paper products amounted to RM6.5 billion, while exports totalled RM3.6 billion. A total of 22 projects were approved in 2013 with investments in RM574.5 million divided between 13 new projects (RM225.1 million or 39%) and nine expansions/diversification projects. The 22 projects are expected to provide

employment opportunities to 2,253 people with 20 % of the employment considered to be in the high income category. The highest investments recorded in 2013 was the paper products sub-sector with RM541.3 million in 17 projects followed by the printing and publishing sub-sector with RM33.2 million in five projects (MIDA, 2014).

In 2012, the import of paper and paper products amounted to RM6.5 billion, while exports totalled RM3.5 billion. A total of 27 projects was approved with investments of RM871.6 million. These projects are expected to provide employment opportunities to almost 2,000 persons, with 20 per cent of the employment in the high income category. The highest investments recorded were for printing and publishing (RM490.3 million) followed by paper products (RM339.8 million) and pulp and paper (RM41.6 million) (MIDA, 2013).

Meanwhile, in 2011, printing and publishing sector managed to attract a totalled investment of RM43.9 million for five projects (MIDA, 2012) compared to RM502.3 million and RM294.6 million respectively in 2009 and 2010 (StarBiz, 2012).

The printing sector in Malaysia presents specific characteristics inherent to the high number of SMEs that constitute the backbone of this sector. The opportunities related to its continuous development remain dependent on the capacity of adaptation and innovation of the sector to face new challenges related to new market demands as well as the minimization of its environmental impact by applying pollution prevention and cleaner technologies. The printing industry is in fact too big to be ignored on all fronts: economic, social and environmental. In Malaysia, there are currently about 1,000 companies in operation mainly undertaking general printing in 2013 (MIDA, 2014).

2.11.2 Defining the printing sector

The definition of the printing sector remains vague and differs from one country to another because no standard industrial classification (SIC) could be applied. In general, the printing industry is defined more broadly as firms, printing by the most common processes, i.e. offset printing, letterpress printing, flexography, rotogravure printing, screen printing and digital printing, as well as newspaper, book and periodical publishers. Study by Regional Activity Centre for Cleaner Production (RAC/CP) on printing industries in the Mediterranean region found that printing industry is not systematically classified as an independent sector but is often integrated with other branches such as the paper or chemical industry. This uncertainty in definition leads to a relative inaccuracy in the statistics on this sector, but still serves to illustrate the socio-economic and environmental conditions of the printing industry in the Mediterranean region (RAC/CP, 2003).

2.11.3 Industrial processes in the printing industry

The printing industry covers a broad range of printing types. They all have potential environmental impacts because of the raw materials and chemicals they use and the waste they generate. The following printing types are as follows (Department of Environment and Conservation NSW 2006):

- Offset Lithographic
- Gravure
- Flexographic
- Digital
- Letterpress
- Screen printing
- Label printing

- Other associated printing types.

Although the equipment applications and chemicals in each of these processes differ, they all print an image on a substrate following the same basic sequence. The basic steps in printing are referred to as pre-press, printing, and finishing (post-press) operations. The type of printing technology that is used depends on a variety of factors, including the substrate used (e.g. Paper, plastic, metal, ceramic, etc.), the length and speed of the print run, the required print image quality, and the end product. The diversity of technologies and products in the printing industry makes it difficult to characterize the environmental issues faced by the sector as a whole. This diversity in processes will lead to different environmental concerns that are critical when developing pollution prevention and control/compliance programs (RAC/CP, 2003).

The brief process for types of printing are as follows:

1) Offset Lithographic

   Offset lithography refers to a printing process where ink is spread on a metal plate withetched images, then transferred to an intermediary surface such as a rubber blanket, and finally applied to paper by pressing the paper against the intermediary surface (Dot Graphics, 2010). It is the predominant printing process and commonly use in the printing industry. Its growth is expected to continue into the 1990s and then stabilize at just under 50% of all printing applications. Sheet-fed lithography is used for printing books, posters, greeting cards, labels, packaging, advertising flyers and brochures, periodicals, and for reproducing artwork. Web offset lithography is used for periodicals, newspapers, advertising, books, catalogues, and business forms (U.S. Environmental Protection Agency (USEPA), 1990). Compared to other printing methods, offset printing is best suited for economically producing large

volumes of high quality prints in a manner that requires little maintenance (Kipphan, 2001). The general flowchart for Offset Lithographic Printing is shown in Figure 2.5

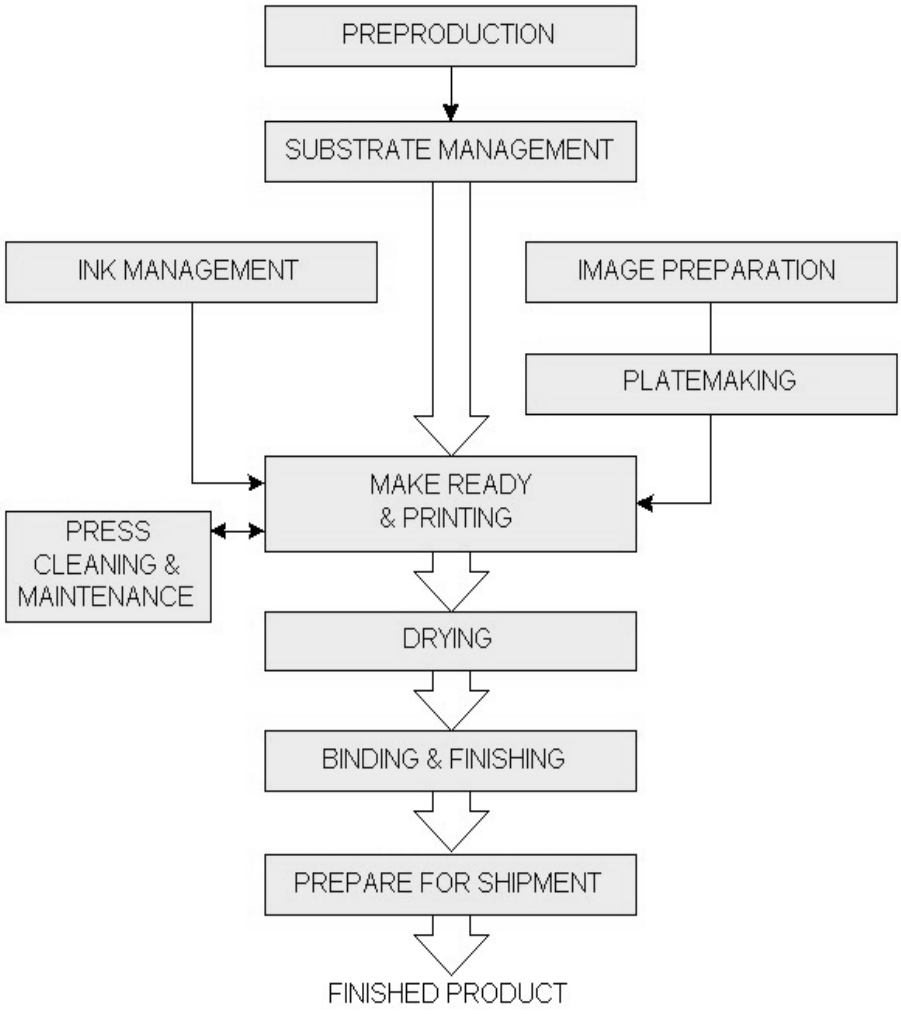

Figure 2.5: General flowchart for Lithographic Printing (PNEAC, 2015)

2) Gravure

Gravure printing is used for large volume runs and high speed runs for printing high-quality publications, magazines, catalogues, and advertising. It also has large volume applications in the printing of flexible packaging (polyolefin packaging), paperboard boxes, and labels. It can print glossy ink films effectively (U.S. Environmental Protection Agency (USEPA), 1990).

3) Flexographic

Flexography, a form of letterpress that uses a flexible plastic or rubber plate in a rotary web press, is used primarily for packaging, such as plastic wrappers, corrugated boxes, milk cartons, shower curtains, foil, and paper bags. Flexography works well when printing a large solid surface area and with appropriate substrate can achieve glossy colours. Because of the growth of packaging, the use of flexography has shown a steady increase (U.S. Environmental Protection Agency (USEPA), 1990).

4) Digital printing

Digital printing refers to methods of printing from a digital based image directly from a computer file to a variety of media without going through some intermediate medium such as a film negative or an intermediate machine such as a plate-making machine. It usually refers to professional printing where small run jobs from desktop publishing and other digital sources are printed using large format and/or high volume laser or inkjet printers (Dot Graphics, 2010).

Digital printing has a higher cost per page than more traditional offset printing methods, but this price is usually offset by the cost saving in avoiding all the technical steps in between needed to make printing plates. It also allows for on demand printing, short turn around and even a modification of the image (variable data) with each impression (Department of Skills Development, 2012). Digital printing is a good option for printing smaller quantities, as the set-up costs are generally lower while the per piece cost is generally higher (Dot Graphics, 2010).

The savings in labour and ever increasing capability of digital presses means digital printing is reaching a point where it could match or supersede offset printing

technology's ability to produce larger print runs of several thousand sheets at a low price (Department of Skills Development, 2012).

5) Letterpress

Web letterpress is currently used for printing newspapers and magazines. However, its use is declining to greater use of lithography. Sheet-fed letterpress is used for books, printed stationery, announcements, business cards, and advertising brochures. Because individual changes can be made on a plate without having to redo the entire plate, letterpress is particularly useful for price lists, parts lists, and directories. In this case, however, computerized image making is replacing the practice of having standing typeset plates upon which small changes are made (U.S. Environmental Protection Agency (USEPA), 1990).

6) Screen printing

Screen printing can print on virtually any substrate, including wood, glass, fabrics, plastics, and metals. It is used for Specialty printing, T-shirts, posters and banners, decals, and wallpapers. This type of printing makes up a small but growing segment of the printing industry. Screen printing is also used to print patterns on electronic circuit boards prior to etching (U.S. Environmental Protection Agency (USEPA), 1990).

7) Label printing

Stickers & Labels are very widely used when an object requires identification with a word or idea. Brand stickers may be attached to products to identify those products as coming from a certain company. They may also be used to describe characteristics of the products that would not be obvious from simple examination.

They are frequently distributed as part of promotional, advertising, and political campaigns. Print stickers &labels are used to enhance company's marketing program and to reinforce the advertising message (EAN Labels, 2012).

8) Quick Printing (Small offset presses)

Used in small, quick copy shops and Inplant printing departments. These small offset presses can come with either one or two colour units. Equipment is low cost and uses either metal, paper or poly type plates. A paper such as Fore DP, Tidal DP, etc. would be used on such a press. Type of jobs would include letterheads, flyers, ads, etc. Equipment would include an AM Multigraph, A. B. Dick, ITEK, etc. (Dynodan.com, 2013).

9) Reprography

This method of printing is based on the electrostatic transfer of toner to and from a charged photoconductor surface. This type of printing method uses selenium, cadmium sulphide or organic photoconductor to produce the images in the copier. These materials hold an electrostatic charge in the dark, and lose the charge when exposed to light. Press such as the AM Electro-press has found a home in direct and forms printing. Printing is slow (300 ft/min) but each paper can be imaged separately. Reprography today includes copiers, computer printers and high speed output duplicators such as the Xerox Docutech (Dynodan.com, 2013).

Nevertheless, printing technology is commonly classified into four main printing methods and a range of less usual methods. Many of these less customary processes do not play an important role in today's industrial production because of their low material flow and energy (Jepsen & Tebert, 2003). The main printing processes are illustrated in Figure 2.6 .

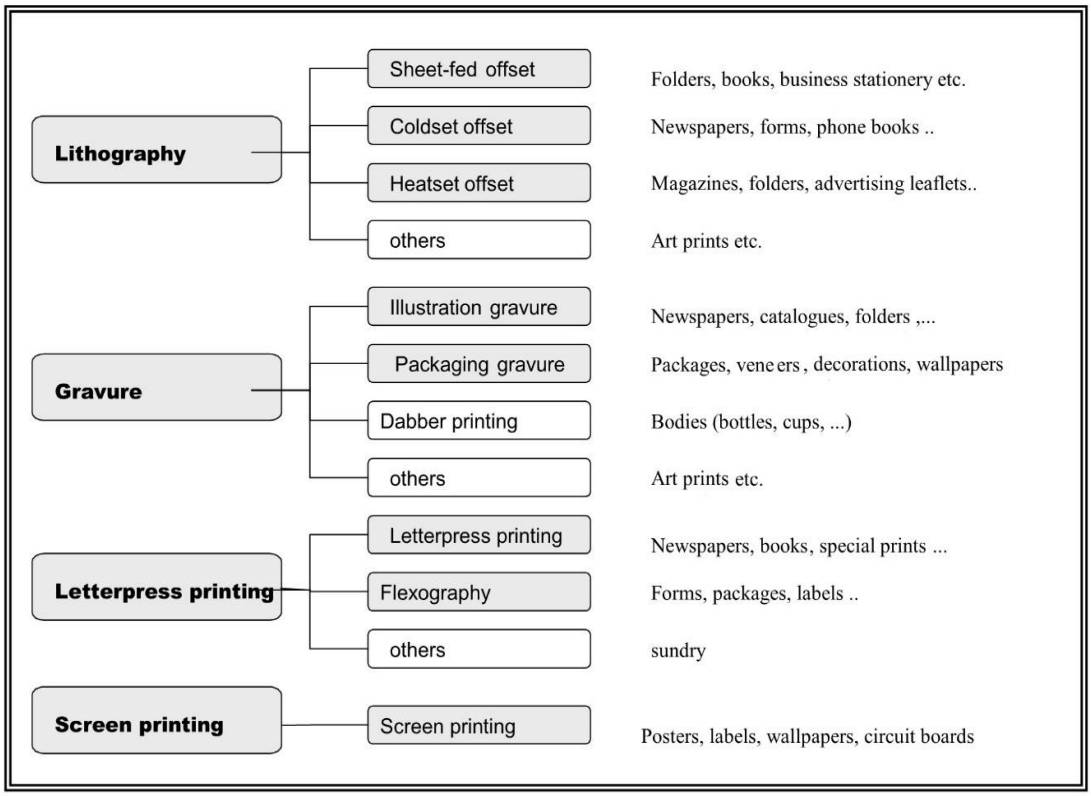

Figure 2.6: Main printing processes with process variables

2.11.4 Impacts to the environment

The printing industry generates several types of wastes that can add up to become a considerable problem in a very short time. The main types of wastes in the printing industry include:

- Air emissions, e.g. releasing volatile organic compounds (VOCs) into the atmosphere due to solvent use. The most common emissions produced by the printing process are gases and emissions of volatile organic compounds (VOCs) from process chemicals and cleaning solutions. Some adhesives, used in post-press operations, also generate VOCs. VOCs released into the atmosphere are toxic and odorous, and also contribute to photochemical smog (ground level ozone). VOCs such as xylenes, ketones, alcohols and aliphatics are contained in printing inks, fountain solutions and cleaning products. Cleaning products such as washes for

rollers, blankets and presses have traditionally been petroleum-based products containing naphtha, mineral spirits, methanol and toluene. VOCs can also be released from Gravure and flexographic printing processes, where volatile solvents emit vapours, Inks and solvents used in the large heat – set, lithographic printing processes, glues and adhesives used in the press and binding areas (Department of Environment and Conservation NSW 2006)

- Waste management, is one of the biggest environmental issues faced by printers. These wastes can be categorized into solid waste and scheduled waste. The main solid waste from printing industry is excess papers produced setting out, trimming and cutting process. The New York printing industry report has stated that more than 95% of waste (by volume) are papers and cardboard (Coleman, 2010). There is occasion the waste are generated as a result of product rejection where the end products do not meet customers' requirement. However, product rejection can be minimized through proper planning and detailed discussion with the customer.

  Paper used in the printing process are normally standard in size based on a series of three different sizes called A, B, or C – all of the same proportions. All sizes have the rectangular proportion of 1:v2 (or 1:1.414) which is mathematically unique – no other size allows paper to be cut or folded in half and yet retain the same proportion. Because these proportions always remain constant, artwork will enlarge or reduce photographically to fit any international size (Morrell & Weier, 2013). Minimal paper excess is generated when the products required by the customer match the standard size. While, should the customers require an odd size, this will contribute to higher amount of solid waste.

  Other waste paper comes from rejecting print runs, scraps from the start and end of runs, paper at the end of the web, and overruns. Overruns are the excess number of

copies that a printer makes to ensure that he has enough acceptable copies. Other paper includes the paper wrappings, cardboard cores, and scrap from finishing operations. Most paper is recycled, incinerated, or disposed of as trash. Scrap photographic material and aluminium plates are sold for metal recovery (US EPA, 1990).

Meanwhile, the scheduled waste comprises of empty ink container, waste ink, spent lubricants, fountain solution, photographic chemicals, glues and varnishes, clean up solvent and cleaning rags containing ink, oil or solvent. These wastes are regulated under the Environmental Quality (Scheduled waste) Regulation 2005 which requires special handling, management and disposal of waste in the licenced premises (Department of Environment, 2001).

Photographic chemicals are the liquids used for processing photographic films and are used in different phases: in the first phase the photographic film is submerged in liquid developer which consists mainly of reducing substances. In this phase, the film is transformed into a visible image in the areas exposed to light; in the second, the film is submerged in a fixing liquid to eliminate the silver halide salts that were not exposed to light and were not developed. Finally, water is used for the final rinsing thus avoiding the deterioration of the film (RAC/CP, 2003).

Fountain solution is an aqueous solution used to wet the plates that use oil based inks in order to make the ink repellent to the areas that are not to be printed. In general, this solution is basically comprises of ion free water, Isopropyl alcohol with concentration from 5% to 15% and additives (RAC/CP, 2003).

Electricity consumption, where printing industries use a great deal of energy to manufacture the printing products, especially from the printing process and

transport. In a typical press set up for offset printing machine, the major electricity consumption load is in a ratio of, press – 78% (68%), utilities – 08%, Light- 06%, & Air conditions – 08% (18%). The high consumption of electricity contributes to the high emission of Carbon dioxide (CO_2) which is the main GHGs that caused the global warming and climate change.

A study has shown that out of 20% savings in energy in industries, 5% savings come from Good Housekeeping, another 5% comes from conventional technology and 10% comes from Innovation and development from the work respectively. Today power has become a prime factor in deciding the product cost at micro level & in dictating the inflation and the debt burden at the macro level (K. Mathur, 2015).

- Water use and wastewater generation are also significant in the printing industry. Domestic water is used for sanitary purpose and equipment cleaning, which indirectly becomes wastewater after use. Wastewater in the printing industry is produced from processes such as roller washing and preparation of printing plates. Silver compounds, used developer, oil, and other chemical compounds are released into water during the process and thus, waste from printing process can be defined as hazardous waste (Jelena Kiurski et al., 2012).

2.11.5 Regulatory requirements of printing industries

The printing industry is an entity unlike almost any other. It is an industry that provides services for other manufacturing industries, it is dominated by SMEs, and the average printing facility is small (< 10 employees). It is also an important player in terms of economic outputs and employment. Indeed, the thousands of enterprises constituting this sector employ thousands of people and account for a significant proportion of the nation's total volume of goods and services. The printing companies are usually not a

major environmental concern when taken individually. But the cumulative impact of the pollution generated by this industry when taken as a whole which comprising thousands of enterprises, makes it a considerable environmental issue that needs to be effectively addressed. The environmental impacts created by the printing industry will become unmanageable every year if appropriate pollution prevention and control measures are not taken in the short run (RAC/CP, 2003).

In Malaysia, the printing industries are primarily governed by two major regulatory bodies which are (Department of Skills Development, 2012):

a) Department of Environment (DOE)

   Department of Environment is involved in the regulation of disposal of collected or generated wastes and air emissions under the Environmental Quality Act 1974 (EQA 1974). Monitoring is done on open burning activities, waste disposal sites and scheduled disposal of factory waste.

b) Department of Occupational Safety and Health (DOSH)

   Department of Occupational Safety and Health (DOSH) is the regulator for Occupational Safety and Health Act 1994 and Factories and Machinery Act 1967. Areas under the supervision of DOSH are the use of chemicals and machinery. However, a stronger focus is given to owners and end users.

When it comes to the conservation of the environment, DOE is responsible in enforcing the EQA 1974 and its regulations on the printing industries in Malaysia. Basically, besides of EQA 1974, there are three major regulations that govern the operation of printing companies. The regulations are:

a) Environmental Quality (Industrial Effluents) Regulations, 2009

These regulations were formerly known as the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979. The Environmental Quality (Industrial Effluent) Regulations 2009 was gazetted on October 12, 2009 and has been enforced since December 2009.

The Regulations, among others, require the operation of the industrial effluent treatment system to be supervised by competent persons. The owner is also required to operate and maintain the systems in accordance with sound engineering practice. A performance monitoring is also required for the components of the effluent treatment system. Under these regulations, the printing industries are required to comply with the effluent discharge standard A or B depending on the location of the premise which is above or below the drinking water intake point (Department of Environment, 2001).

b) Environmental Quality (Clean Air) Regulations, 1978

Under these regulations, the industries are required to comply with the stack gas emission standard of dark smoke, dust, metal and metallic compound, gases and other air impurities which include trace of toxic elements. Besides that, the regulations also specify the types of new installations within residential areas that are not permitted without prior approval from DOE.

These regulations were replaced by the Environmental Quality (Clean Air) Regulations, 2014 which is more specific and comprehensive where all dense smoke are regulated and Pollutant Loadings is a measure for emission limits.

c) Environmental Quality (Scheduled Wastes) Regulations, 2005.

The Environmental Quality (Scheduled Wastes) Regulations 2005 came into force since 15 August 2005, and is replacing the Environmental Quality (Scheduled Wastes) Regulations 1989. On 20 March 2007, the Environmental Quality (Scheduled Wastes) Regulations 2005 are then amended in the First Schedule, in relation to the particular appearing against code SW 104, by inserting after the word "containing" the words "aluminium".

Under these new regulations, scheduled wastes listed in the First Schedule are divided into 5 categories as per Appendix L. Waste generators should determine whether their wastes are classified under scheduled wastes. New generators of scheduled wastes are required to notify the Department of Environment within one month from the date of generation of wastes.

Scheduled wastes can be stored, recovered and treated within the premises of the waste generators. Such activities do not require licensing by the Department of Environment. A waste generator may store scheduled wastes generated by him for 180 days or less after its generation provided that the quantity of scheduled wastes accumulated on the site shall not exceed 20 metric tonnes. However, waste generators may apply to the Director General in writing to store more than 20 metric tons of scheduled wastes. The containers that are used to store scheduled wastes shall be clearly labelled with the date when the scheduled wastes are first generated, name, address and telephone number of the waste generator (Department of Environment, 2001).

On-site incineration of scheduled wastes is not encouraged. If it is deemed necessary, application for the installation of such incinerator must strictly adhere to

the Guidelines On the Installation of On-site Incinerator for the Disposal of Scheduled Wastes in Malaysia" (published by the Department of Environment), including carrying out a detailed environmental impact assessment and display of the EIA report for public comments.

Waste generators shall also keep an up to-date inventory of scheduled wastes generated, treated and disposed of. Proper labelling, containers and storage areas as well as prohibition of storage of incompatible waste are also required by law.

In the case of transporting the scheduled waste from the waste generator to the treatment and disposal facilities, the transporting of waste shall conform to the consignment note system whereby the movement of waste is monitored until it reaches the approved destination. It is the responsibility of a waste generator to monitor and ensure that the waste transported from his factory reaches the approved destination. The waste generator is responsible to inform the transport contractor regarding the nature of the waste and what actions to be taken during accidents to minimise damage to human life and the environment. Schedule wastes transporters should also be licensed by the Department of Environment (CommScope, 2014).

Status of compliance of the printing industries with those regulations from 2007 to 2013 are as shown in Table 2.4, Table 2.5 and Table 2.6 (Department of Enviroment, 2007; Department of Environment, 2008a, 2009a, 2010a, 2012, 2013):

Table 2.4: Compliance with effluent discharge standards (SIER,1979/EP 2009)

Year	2007	2008	2009	2010	2011	2012	2013
No. of inspection	200	126	77	244	387	178	164
Percentage of compliance (%)	56	90	95	93	99	99	100

Table 2.5: Compliance with air emission standards (Clean Air, 1978)

Year	2007	2008	2009	2010	2011	2012	2013
No. of inspection	nil	126	77	244	387	178	164
Percentage of compliance (%)	nil	95	97	92	99	98	100

Table 2.6: Compliance with scheduled waste management, (Scheduled Waste, 2005)

Year	2007	2008	2009	2010	2011	2012	2013
No. of inspection	nil	126	77	244	387	178	164
Percentage of compliance (%)	nil	69	91	88	97	93	99

Status of compliance of the printing industry with three main regulations under EQA 1974 especially regarding the treated effluent discharge to a watercourse, emission of impurities in the air and scheduled waste management increase from 2007 to 2013. Low compliance was recorded in 2007 for effluent discharge from the printing premises which accounted for only 56 %. But, no inspection was carried out to determine the level of compliance with air emission standards and scheduled waste management in that year.

2.12 Summary of literature review

From the literature review, it was shown that Green Industry is a sectoral strategy for achieving Green Economy and Green Growth in the manufacturing and related productive sectors. It assures the security of natural resources by alleviating the pressure on already-scarce resources such as water, materials and fuels, contributes to mitigation and adaptation to climate change by reducing greenhouse gas (GHG)

emissions from energy and non-energy sources and at the enterprise-level, better environmental management and industrial chemical safety.

Even though, all four approaches - circular economy, industrial symbiosis, 3Rs and Cleaner production can be used for greening the industry, these approaches have different methodology and the target to achieve and require specific tool to assess the environmental impacts and generate opportunities or options to enhance the operation and productivity of the premise.

Meanwhile, Industrial symbiosis is still a very new concept and phrase, and is not recognized by most industry executives. Moreover, there are not many publications on the subject and it also requires an understanding of the basic principle of ecology, which is dynamic feedback systems. Most executives (and most people) do not think that way, and will not intuitively understand what the phrase industrial ecology is trying to say. Industrial symbiosis also require Life Cycle Assessment (LCA) because it involves a cradle to grave analysis of product systems, that is, of the total of processes which are involved in the provision of a certain function. This LCA requires extensive data and consumes lots of time to come out with enhancement options.

Circular economy represents a fundamental shift for businesses, away from a so called linear model where resources are extracted, made into products and disposed of, to a model where products are remade, repaired, resold or recycled. The concept focuses more on the products rather than the process which form a vital part of the manufacturing industry. For the purposes of this study, the approach adopted must be able to address most of the environmental issues associated with manufacturing industry starting from raw material selection, manufacturing processes, and product generation.

Meanwhile, CP almost combines all sustainability aspects that are needed for the greening of industry, since it implies pollution free measures, energy and natural resources conservation, efficient, economical, safe and healthy environment for workers, communities, and consumers, and socially rewarding outcomes at all production levels.

Cleaner production techniques are dynamic, and although the industry has improved its environmental performance over the last two decades, there is continuing room for improvement. Improvement, which, when implemented through cleaner production, leads both to improved economic efficiency and environmental protection.

From the review of the greening of industry case studies, it was shown that both case studies carried out by the Department of Environment Malaysia on the premises of MM Vita Oils and Dagang Batikraf adopted CP approach to identify and evaluate the improvement of opportunities in the premises through compilation of information on the process, operation and management of premise. Based on the gathered information, options to enhance the process and management of the factory were generated and evaluated on the feasibility and effectiveness. In both case studies - MM Vita Oils and Dagang Batikraf, no carbon reduction calculation was carried out before and after the implementation of CP options on the premises. Implementation of CP options was only evaluated on the aspect of process and productivity enhancement and also compliance with existing environmental regulations.

Meanwhile, the analysis carried out by Ecologic shown that all existing 10 indicators to measure the greening of industry are not perfect or outperformed the others on all assessment criteria. Some indicators do not take into account the impacts to the environment that caused by the consumption of resources such as raw material and electricity. The data needed to calculate the selected indicators also vary widely in their

amounts, accuracy, level of resolution and transferability, which might pose a problem to Small and Medium Enterprises that become targets in this study. CO2 emission reduction has been identified as the best indicator for measuring green industry because of its role as the main greenhouse gas that contribute to the global warming and climate change.

The printing industry in Malaysia is an industry that continues to grow with the investment increased from 2010 to 2013. From the aspect of the effects to the environment, printing industry generates pollution such as air emission, schedule waste such as solvent wastes, photographic chemical wastes, plate making waste and fountain solution waste. Besides that, it also generates solid waste such as paper, plates, pallets and contaminated rags.

Increase in compliance of printing industry with environmental regulations since 2008, are based on the compliance to discharge standards as required in the Industrial effluent regulations and do not indicate that the printing premises are exercising best environmental practices or in other word – green industry practices. Most of the printing premises are practicing environmental management based on end of pipe concept where the main focus was centered to complying with emission and discharge standards stipulated in the respective regulations.

The end of pipe approach does not take into account the sustainability of process, operation and management of the premise, while Cleaner production concept focus on material saving, water and utility saving, reduction of waste generation and energy saving. In other words, industrial premises are still behind in Cleaner production aspect that lead to establishment of green industry. CP also possesses similar characteristics as Green industry such as minimization of raw material, energy and fuel consumption,

reduction of waste generation, enhancement of safety and health, and increased of productivity.

It has been demonstrated through case studies that Cleaner Production is an effective environmental management strategy which bring about sustainable development for the industry. In this study, Cleaner production approach will be adopted to generate options in the process of greening the industrial premise. CP was chosen because of its practicality and easy to apply in the industry environment and it is proven as one of the approaches to greening the industry as approved by UNEP and UNIDO.

The printing premise has been chosen as the premise to be audited and generation of options as no printing premise being audited under the CP programme to date. This study will take into account, the amount of carbon that can be reduced for every CP option generated. This calculated carbon reduction is the indicator for greening the printing industry.

CHAPTER 3: METHODOLOGY

Based on the prescribed objectives, the methodology used in this study comprises of these components:

3.1 Selection of premise

An offset lithographic printing premise was chosen as a studied premise because it is the predominant printing process and commonly used in the printing industry. It accounts for approximately 47% of all printing done today (Dynodan.com, 2013). In this case, the offset lithographic printing premise was selected based on the following criteria:

- The premise is a printing company located in the Kelang valley area for easier logistic and access.
- Produce various printed media and operates 24 hours a day, not on occasionally operate on specific demand
- The premise is a medium size, industry with sales turnover from RM 15 million to not exceeding RM50 million, according to the Guideline for New SME Definition produced by SME Corp Malaysia
- Premise consumes electricity, water, raw materials that contribute to the waste generation.
- Full commitment from top management of the premise in assisting and providing information and supports before, during and after audit exercise.

3.2 Cleaner Production Audit

Cleaner Production Audit (CPA) is a data and information collection activity that helps in assessing the operational efficiency, providing information on whether the operating activities have positive or negative impacts on the environment. The collected information is used to evaluate the performance of a company to identify areas for

improvements. Such information helps in the identification of causes of problems, issues and potentials for improvement. In this study, the direct aspects covered were as follows:

a) Energy: electricity, fuel, loss of latent heat.
b) Material: raw materials, solid waste, liquid waste, waste gas, waste water.
c) The indirect aspects that covered were as follows:
d) Productivity
e) Safety and Health

Meanwhile, CP audit is also a management tool that manages, control and improves environmental performance of a company. It comprises of documented process flow and complete raw material data. The audit also provides information on a company's operations which are subject to environmental legislation or which may become a liability in the future.

CP audit was conducted with the following objectives:

a) Reducing the consumption of materials and energy
    - Identify the types of raw materials, chemicals and fuel used and the quantity/rate.
    - Identify the resource consumption of utilities (water, electricity) and measure the quantity/rate.
    - Identify the causes of wastage of materials and energy use.
b) Improving the quality and productivity;
    - Identify and measure the use of resources and processing time.
    - Identify factors that affect the quality of products and productivity.

c) Reducing risks to the environment;

- Identify the types of waste generated and waste generation sources.
- Measuring waste generation.
- Identify the characteristics of the resulting waste.
- Identify waste management methods available.

The scope of the audit was to cover the entire premises including the processing, administration and support parts available (e.g. Workshops, laundry, etc).Walk through audit was also conducted with an objective to obtain basic company background, such as information of workers, production hours, product details, plant layout showing the location of production area, administration building, storage area and process flow chart with detailed information on production processes and other activities related to the production. Visual inspection and observation were conducted to gather information and qualitatively identify issues in the premise. Hence, information obtained was used to identify the basis for determining the focus and depth of audit scopes

3.3 Data Collection

The collection of data and information during the audit process conducted by CP methodology organized as follows:

- Use a checklist or audit form that contains 17 components in terms of materials and energy use, waste and safety and health risks. Refer to Table 3.1.
- Interviews and discussions with the owners and employees on the premises to identify the issues faced by the premises and obtain information about each step of the manufacturing process, the use of materials, utilities, time and other factors that affect productivity and quality aspects of the product.
- Review the records, measurements and estimates of consumption of raw materials, chemicals, fuel, water and electricity.

- Assessment of the current state of the layout of the premises and a review of all activities carried out on the premises to identify the causes of wastage of materials and energy as well as the types of safety and health risks that exist, the level of employee exposure to these risks and the level of awareness of employees impact of risks to their health and safety.

Table 3.1: Components of Clean Production Audit Checklist

No. of component	
1. Basic information of premises 2. Main products 3. Products 4. Raw materials 5. The use of utilities 6. Flow chart 7. Description of the process 8. Other activities –Plant layout of the premise, MSDS, measurement., estimation	9. Other facilities - canteen, recycling area & product storage 10. Quantity of waste 11. Gas emissions 12. Loss of raw material 13. Loss of energy 14. Safety and Risk 15. Complaints received 16. Issues of housekeeping 17. Other observations

3.4 Estimation of Carbon dioxide Emission Reduction

The targeted entities or hotspots can be identified based on the CP audit findings. The typical target entities are raw materials, water, electricity and fuel consumption, as well as generation of solid wastes and wastewater. Besides, health risks and workplace safety are also always among the concerns. CP options can then be generated to mitigate or reduce the severity of the target entities. Target entities of a premise can be identified based on the quantity of carbon dioxide emitted from materials usage and waste generation. Six main entities should be considered for quantification purpose, which

include water, electricity and fuel usage; and generation of wastewater, solid wastes and hazardous wastes (Abdul Raman et al., 2014).

3.4.1 Entities and Carbon Emissions Factors

The concept of carbon dioxide emission reduction was chosen as the indicator that can be used to assess the returns in the context of the environment. In this study, only five relevant entities were considered for quantitative analysis subject to the audit findings. The quantity of consumption and generation entities and also emission factors are shown in Table 3.2 for the estimation of the carbon dioxide reduction of the premises.

Table 3.2: Emission factors of input and output (Razuana Rahim & Raman, 2015)

Resources and Wastes	Emission factor	Unit
Water	0.8	Kg CO_2/ m^3
Electricity	0.67	Kg CO_2/ kWh
Scheduled waste	3.7*	Kg CO_2/ kg
Solid waste	3.7*	Kg CO_2/ kg
Waste water	1	Kg CO_2/ kg COD (reduced)

* CO_2 emission of waste by incineration

3.4.2 Calculation Method

Overall of carbon dioxide emission of the premise (gate to gate analysis) was calculated using a formula that is based on the methodology developed by the Intergovernmental Panel on Climate Change (IPCC):

$$Emission\ of\ \ CO_2(kg\ CO_2) = \ Carbon\ Emission\ Factor\ \left(\frac{kg\ CO_2}{unit\ of\ entity}\right)$$

$$\times\ rate\ of\ entity\ consumption\ (unit\ of\ entity)$$

Or

$$Emisision\ of\ CO_2(kg\ CO_2) = \ Carbon\ Emission\ Factor\left(\frac{kg\ CO_2}{unit\ of\ entity}\right)$$

$$\times\ rate\ of\ entity\ generation\ \ (unit\ of\ entity)$$

Where the units are;

Emission of Carbon dioxide: kg CO_2

Carbon Emission Factor for entity: kg CO_2/ $unit_{entiti}$

Rate of consumption or generation: $unit_{entity}$

3.4.3 Identification of Hotspot

In this study, the results acquired from a systematic analysis of adaptive audit provide clues about the main issues in the premise. The main issues were identified as a hotspot for the premise. The solutions / improvements to these issues need to be given a priority due to its significant impact to the process of the premise. This identification method can be a reference to prioritizing the implementation of CP options. There are two main methods applied to identify hot spots in the premise:

a) Identify the largest contributor of Carbon dioxide (CO_2) components.

b) Identify the most negative aspects that excluded from the benchmarking value.

3.5 Options Generation Methodology

The process of generating CP options needs a systematic approach to ensure that all of the possibilities and opportunities are taken into account. In this study, four (4) measures were used to generate CP options. The first step focused on audit findings

where the findings were analysed to identify the relevant issues. The second step was to identify main targets that need to be resolved specifically. To ensure the scope is in focus, the targets were limited to the use of the term to prevent, reduce or improve the impacts that have been identified. The third step was to decide which implementation methods to be used to achieve the set targets. These methods were limited to the housekeeping, modification process, 3R, 5S, material substitution, abolition of process sequences, and the application of technology. The final step was the generation of CP options based on flow structures obtained. The options that are not relevant can be discarded after the initial assessment and the ranking process to prioritise the option to be implemented can also be carried out if the company has financial problems and resource constraints.

3.6 Carbon Emission Reduction Assessment

Carbon reduction will be assessed by comparing the amount of CO_2 reduced by the implementation of CP options with the existing amount of CO_2 produced by the premise before the implementation of the options. In this case, every option that previously identified went through the evaluation process and finally, the selected options were calculated in term of CO_2 reduction by using the emission factor published by the Intergovernmental Panel on Climate Change (IPCC) and other recognized international institutions.

3.7 Cleaner Production Audit in the premise

The audit involved five stages which are to identify studied premise and audit planning (objectives and scope), pre-audit preparation, on site CP audit, CP option generation and evaluation of audit data and reporting findings.

3.7.1 Identify Studied Premise and Audit Planning

Identifying suitable printing premise to become a studied premise was the first hurdle that needs to overcome. Besides the premise agreed to join in the audit programme, the commitment from the premise management was also crucial in ensuring the audit exercise was smoothly carried out.

Planning was made to ensure a smooth and effective Cleaner Production audit. Audit objectives, scopes and requirements were first defined at this stage. Full commitment from top management was really needed to support the audit activities from the beginning. In this study, different departments were involved in the audit formulation of the CP team in order to ensure successful implementation of the audit. At the studied premise, the company's Safety Manager developed a team to assist in the audit exercise. The team consisted the personnel from the human resources department, safety department and production department. These personnels were expert in their respective field in system managements, printing process and technical knowledge of the facilities in the premise.

Pre-audit preparation started after the audit plan had been agreed with the premise management. The pre-audit included obtaining pre-visit information from the printing premise such as audit plan, audit protocol and audit schedule. All these were done to ensure the on site audit runs smoothly.

The organization chart of the company's audit team comprised of two personnels from safety department, two from the human resource department and a representative of the production line. Meanwhile, a site layout plan showing the location of operational sites, raw materials store, production area, finished products warehouse, office administration building and waste storage area was obtained from the engineering department. Information on printing process flow, list of chemicals, gas emission and waste

generation were produced before the auditors to give a first insight of the premise activities. The auditor then prepared the set of questions regarding the focused topics such as type of hazardous waste used, wastewater quality, and type of facilities available in the printing industry.

Finally, the audit activity schedule was prepared to guide the auditor and ensure no audit requirement being left out. The whole process took three (3) months to complete before proper CP audit being carried out.

3.7.2 On-site Cleaner Production Audit

The main objective of the on-site audit was to gather data through reviewing documents, interviewing facility operators and observing all relevant operations in the printing premise, which involved the consumption of raw material, energy and utilities, productivity, premise layout, safety and health risk, waste and wastewater generation. Material balance in the printing process was taken into account during the audit. The indicator system proposed in this audit comprised of five indicators which were energy use, material use, water consumption, solid waste and scheduled waste. Data and documents pertaining to waste disposal, electricity and water consumption and carbon dioxide emission were obtained from the human resource department, operation department and safety department. Visual inspection and observation were conducted to acquire relevant information. Interview sessions were also held to inquire information related to printing processes and workers' understanding of pollution prevention.

Information on various characteristics of facilities and their operations such as plant layout, process flow chart, material and stock inventory was obtained from the engineering and production department. The on site CP audit took six (6) months to complete because of the audit schedule had to take into account the availability of

officer in charge, priority given to other important premise activities and other technical problems that could not be avoided.

3.7.3 Cleaner Production Audit Analysis

The audit findings were compiled for the preparation of the report. The six indicators were studied and analysed. Utility bills were translated into the required unit in order to calculate the carbon footprint. Cost and rate of consumption of raw materials, papers and waste generation were estimated.

The audit findings and the method to generate CP options were presented to the representative of the company to confirm the data and findings. This was to ensure that data obtained through the pre-audit and on-site CP audit were reliable and gave the true picture of the activities carried out in the premise. This process took three (3) months to complete in view of the need to compile and prepare a complete report that will be used to generate cleaner production options.

3.7.4 Cleaner Production Options Generation

CP options are generated after the audit and audit findings analysis. Examples of CP options include housekeeping, modification of design and operation, substitution of raw materials and change of technologies and operating procedures.

Table 3.3 gives a detailed explanation on the generation of CP options. Probing questions could help the auditors in generating CP options.

Table 3.3: Generation of CP options

Activity	:	Generation of CP options
Objectives	:	Generate ideas in identifying potential improvements in various aspects
Targeted areas	:	Target entity
Implementation	:	Brainstorming
References	:	Audit findings
Tools	:	Probing question
Outputs	:	GI options
Tips	:	Generate as many CP options as possible Note down all the CP options

In this study, options were generated based on the audit findings, feedback from the company personnel, especially the safety manager and various examples of good practices implemented by other premises. Other options were developed based on the literature review, personal knowledge and experience, best available techniques or technology and discussion with suppliers. The whole process took five (5) months to complete because of the amount of time and efforts that were spent to obtain the realistic and feasible cleaner production options.

3.7.5 Evaluation and Feasibility study

CP options should be assessed to make sure that they yield returns to the premise. The feasibility of CP options in various aspects were considered prior to implementation. Implementation cost, time and resource requirement were identified. In this topic, the relevant assessment criteria were discussed to assess the feasibility of CPI options. In this study, main CP options selected during the generation phase were evaluated according to their technical and environmental aspect. Most of the options generated for this premise will be simple and able to save material and energy consumption that will

be converted to the amount of carbon dioxide reduced. Economic analysis was also carried out to determine the viability of the options.

No evaluation being done on the aspects such as an increase in productivity, quality and image improvement, safer operating system, increased motivation, and etc. This is due to the objective of the study was to identify options that will contribute to the saving of raw material, energy and fuel, and reduction of carbon dioxide emission.

The evaluation of the CP options took another three (3) months to complete due to the economic analysis that required the consultation with the suppliers on the equipment proposed in the CP options. The simplified overall methodology adopted in this study is shown in Figure 3.1.

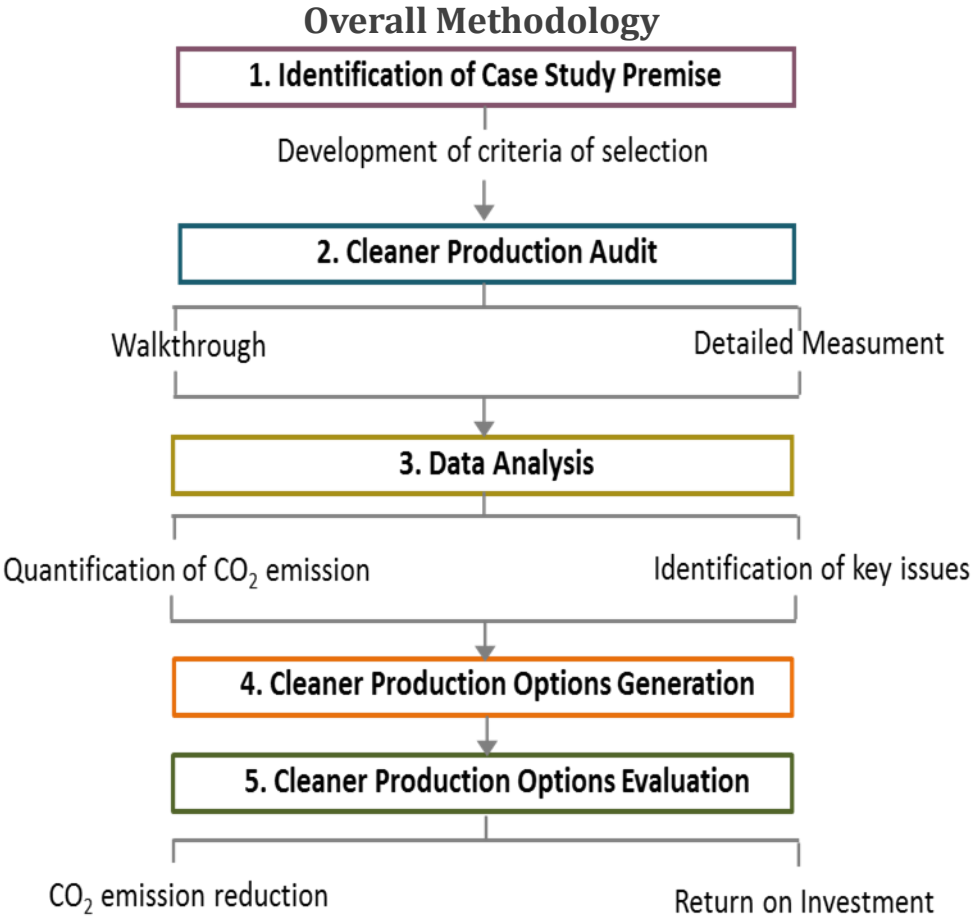

Figure 3.1 Simplified overall methodology of the study

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Preliminary Premise Assessment

A printing company which is located in an industrial zone in Klang Valley has been chosen as a studied premise. It has been in operation since 1988. It occupies a land area of 83,000 square feet, with 600 workers. The printing premise operates from 8 a.m. to 5 p.m. on weekdays and 8 a.m. to 12 p.m. on Saturday. The premise produces books, brochures, reports, government file, documents and other printed products for local market.

On average, this printing premise uses 300 tons of paper per month and provides a wide spectrum of services ranging from basic to advanced services in General Printing, Variable Data Printing, Security Printing, Digital Imaging and Archiving Solution. Besides that, it also provides Manage Print Services & Print Room Services, Information Products and A4 papers.

Based on the records of the Department of Environment, no complaints has been received or legal action has been taken against the company in terms of non-compliance with environmental regulations. Meanwhile, the highest recognition obtained by the premise in the quality management is ISO 9001: 2008 which shows the company's commitment to improving the services to the customer and maintain a good corporate image.

4.2 Process and Flow Diagram of the Premise

A production process of the premise consists of three phases which are pre-press or pre-printing, printing, post- printing and auxiliary process.

4.2.1 Pre-press

Pre-press is the first process in producing the printed products and consists of a series of tasks required to obtain the printing plate or printing form, which transfers the image to the support. These tasks are carried out in different phases as described below:

1) Design

   Constitutes the first phase of the pre-press process. It is a creative phase in which the graphic designer tries to reflect his/her ideas or those of the client so that the product may appropriately fulfil the function for which it was developed.

2) Film preparation

   This second phase includes the necessary operations for obtaining the films. The design that has been made by the graphic designer is prepared so that it can be printed and subsequently manipulated. This main part of the pre-press process is presently carried out on the PC, so that the image is scanned, inserted on the screen with the text, edited and sent to the printer to view the test images, or it is filmed in order to obtain films.

3) Film processing

   This is done once the films with the texts and the images have been obtained. The processor is the machine used for automatically carrying out a series of operations required for processing the films. The film is passed through a series of baths, successively carrying out the developing, fixing, rinsing and drying processes. These operations are carried out under certain specific conditions, and at all times the developing liquids and their pH, are controlled. Working in non-ideal conditions leads to faulty films with excessive or inadequate developing.

4) Typesetting and composition

   Is the phase where the photographic material of the text and the photographic material of the illustrations are combined to obtain an original to be reproduced.

5) Making plates or printing forms

This is the last phase before printing. In this phase the image carrier is prepared, which consists of plates made of different materials and printing forms. The principle used to transfer the ink to the support is what differentiates the type of printing. In the description of the plate making processes, the offset printing plates are described first and subsequently the remaining printing plate types.

One of the latest technology used in this process is Computer-to-Plate (CTP) system. With CTP the printing plate is obtained directly from the order given by the computer, in other words, it saves all the intermediate steps that make up the pre-press procedures of less technologically advanced systems. The CTP system can be used for making offset, flexography and rotogravure plates.

4.2.2 Printing

Once the printing form has been obtained, it can be used for transferring the image onto the desired graphic support, it is at this time that the printing stage starts. Before that, the printing machines are pre-programmed based on the required paper size to minimize the wastage of paper. In this process, the petroleum based ink that contains xylene, ketones, alcohol andaliphatic with high VOC content is usually used. During printing, fountain (dampening) solution, which consists primarily of water with small quantities of isopropyl alcohol and other additives to lower surface tension and control pH, is first applied in a thin layer to the printing plate and migrates to the hydrophilic non-image areas of the printing plate. Ink is then applied to the plate and migrates to the oleophilic image areas. Since the ink and water essentially do not mix, the fountain solution prevents ink from migrating to the non-image areas of the plate.

4.2.3 Post press or finishing

The finishing process normally includes the operations of cutting, folding, milling, gluing, sewing, making the covers, binding, and finally packaging.

- Cutting: the operation to give the printed product the required size.
- Folding: the obtaining of a folded signature with a marked edged obtained by pressure, in order to eliminate the recovery properties inherent to the paper.
- Stacking: the placing of the signatures that form the book one beside the other until they form the complete block.
- Milling: the operation for grinding down the surface of the spine of the book, to prepare it for the gluing operation.
- Gluing: The operation of joining the different elements that have to be glued together (spine of the book).
- Stamping: consists in adding metallic embossed elements as a highlight to the covers of the book or any printed matter.
- Binding: the joining of the signatures of a printed work, in an organised manner, to form a compact volume by means of a solid seam, and add a consistent cover to protect the book and facilitate its use.

In addition, production processes are operated in a 20°C fully air-conditioned rooms. At the end of each production day, printing rollers are cleaned with solvent based reagents. Wastewater generated from the roller cleaning activities is collected and stored in 10 litre containers before being collected by schedule waste contractors. Remaining wastewater discharges into public drains without any pretreatment. The Process flow chart of the studied printing premise is shown in Figure 4.1.

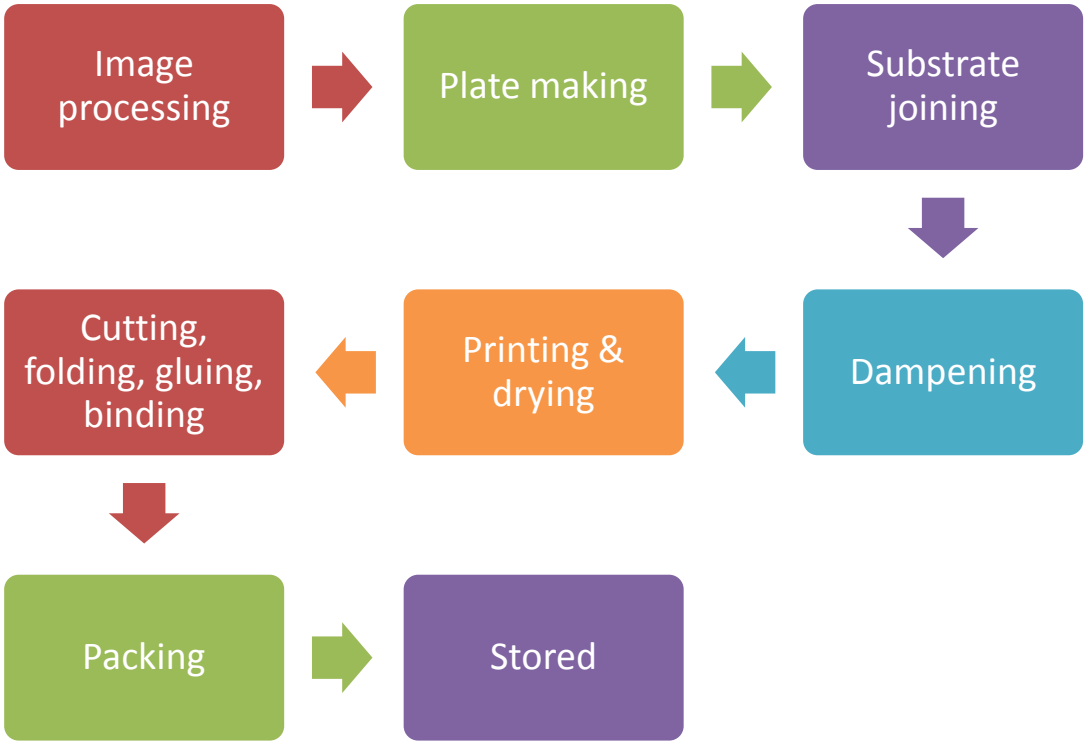

Figure 4.1: Process flowchart of printing media processes

4.3 Audit findings

a) Raw Material consumption

List of raw material and rate of consumption in the premise excluding paper is as shown in Table 4.1.

Table 4.1: Raw material consumption

No	Raw material	Area of consumption	Rate of consumption per month	Rate of consumption (per ton of paper/ month)
Pre-printing (offset)				
1	Plate	Basic material	3,930 pieces	13.1 pieces
2	Film material	CTP machine	212 rolls	0.71 rolls
3	Chemicals	Chemical for CTP machine	699 litres	2.33 litre
Printing				
1	Ink	Basic material	409 kg	1.36 kg
2	Fountain solution	Retaining ink on the image	758 litre	2.53 litre
3	Lubricating oil	Machine performance	1.4 litre	0.005 litre
4	Cleaning Agent	Cleaning of machines	12,518 litre	41.7 litre
Post- printing				
1	Plastic Fastener	Packaging	75 units	0.25 units
2	Tape	Packaging	58 units	0.19 units
3	Box	Packaging	25 units	0.08 units

b) Utility consumption

A list of utilities and rate of consumption in the premise as shown in Table 4.2.

Table 4.2: Utilities used

No.	Utilities	Rate of utilization per month	Rate of utilization per month / ton of paper
1	Electricity	312,226 kWh	1,040.75 kWh
2	Water	2886m^3	9.62 m^3

c) Details of water consumption

A total of 2886 m^3 of water is consumed monthly on the premise. Washing activities such as hands, face and body cleaning constitute the highest consumption of water which is 2,092 m^3, followed by domestic usage, such as drinking and toilet, which amounting to 756 m^3 and roller cleaning processes that take up 38 m^3 of water consumption.

Details of water consumption and rates of consumption per month in the premise are shown in Figure 4.2.

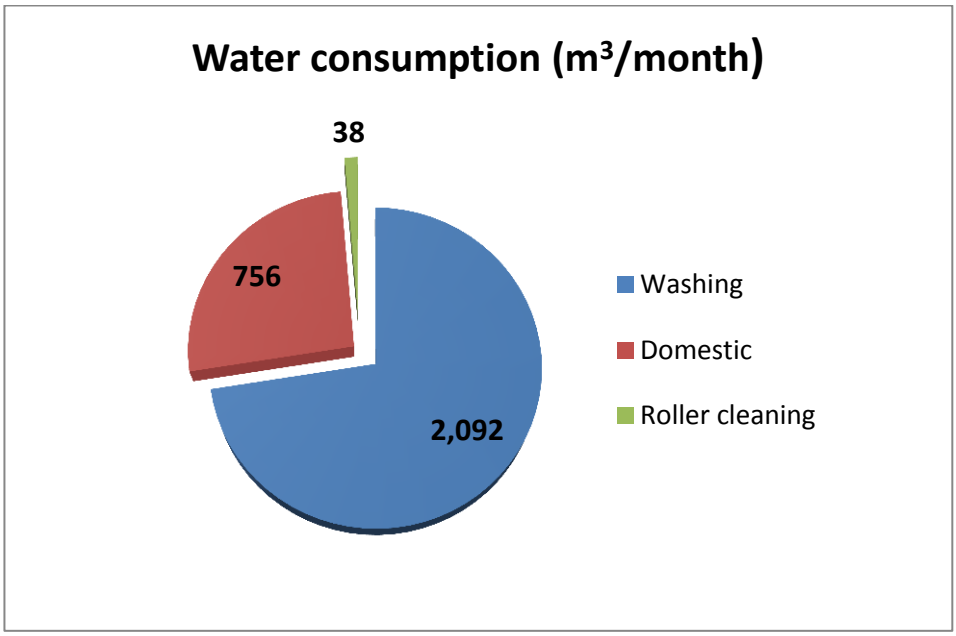

Figure 4.2: Details of water consumption

d) Details of electricity consumption

A total of 312,226 kWh is consumed per month in the premise, which comprise of the electrical components such as air conditioning, machines, lighting and computer. The amount of electricity consumption of each of the components was calculated based on the power (kW) of the component multiplied by the average usage hour. The calculations are shown in Table 4.3.

Table 4.3: Calculation of electricity consumption for each electrical component.

No.	Types of consumption	Power (kW)	Average Usage (hour/ month)	Rate of consumption (kWh/month)
1	Air Conditioning	2591.9	160	212,174
2	Machines	758	110	83,380
3	Lighting	101	160	16,160
4	Computer	3198	160	512
Total				312,226

From the Table 4.3, it is found that the air conditioning in the premise consumes the highest amount of electricity, which is 212,174 kWh/ month, followed by the printing machines and CTP which is 83,380 kWh/month and lightings which is 16, 160 kWh/month. Meanwhile, computer usage constitutes the least amount of electricity consumption, which is only 512 kWh/month.

Details of electricity consumption and rates of consumption per month in the premise are shown in Figure 4.3.

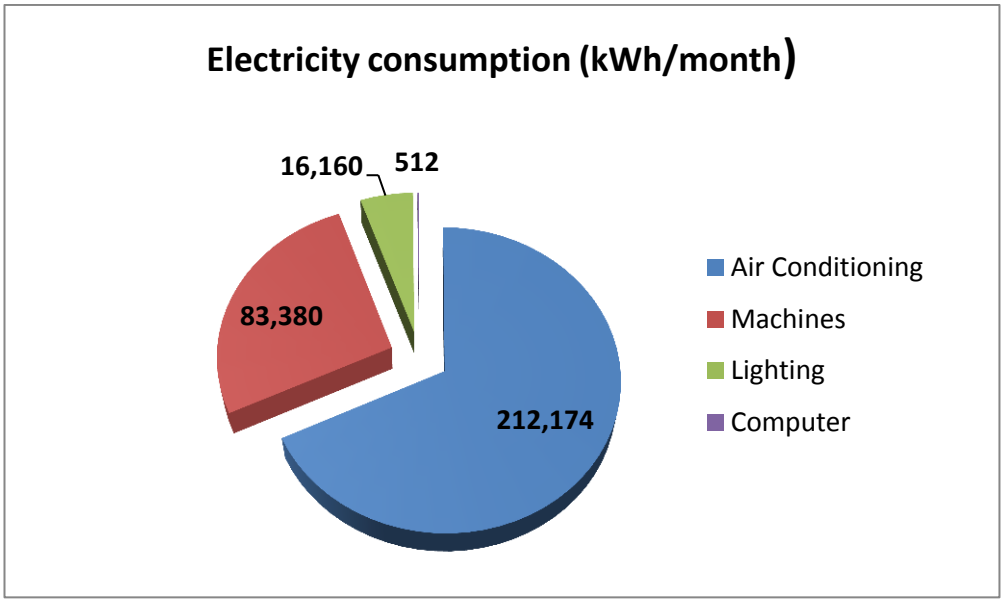

Figure 4.3: Details of electricity consumption

e) Quantity of Wastewater

Source of wastewater and rate of generation per month are as shown in Table 4.4.

Table 4.4: Detailed generation of wastewater

No	Source	Rate of generation (m^3/month)	Wastewater characteristics	
			COD (mg/l)	BOD (mg/l)
1	Washing	2,092	96	25
2	Roller cleaning	38		
3	Domestic	756		

f) Quantity of solid waste (Non Scheduled Waste)

Source of solid waste (non scheduled waste) and rate of generation per month are as shown in Table 4.5.

Table 4.5: Detailed generations of solid waste (non scheduled waste)

No.	Types of waste	Location	Rate of generation
1	Paper (i.e. Off spec printing, waste, cut and etc)	Production	6 tons/month
2	Wood Pallet	Production	4 tons/month

g) Quantity of Scheduled Waste

All wastes which are categorised as scheduled waste come from the printing process of the premise. These wastes are kept in the store and managed according to the Schedule Waste Regulations 2005. The wastes are either sold to recyclers or disposed in a licenced waste disposal premise. The rate of generation per month is shown in Table 4.6.

Table 4.6: Detailed generation of Scheduled waste (SW)

No.	Type	Location	Rate of generation
1	SW 305 (Spent oil)	Store	20 litre (16 kg)
2	SW 409 (Disposed paint containers)	Store	500 kg
3	SW 410 (Rags)	Store	500 kg
4	SW 416 (Sludges of inks)	Store	50 kg
5	SW 423 (Chemical solvent)	Store	2,000 kg
6	SW 418 (Pigments of organic solvent)	Store	50 kg

4.4 Summary of Audit Findings

Analysis of audit findings shows that a total of 2886 m^3 of water is used monthly. Approximately 38 m^3 of wastewater are generated from the roller cleaning activities, while 2,092 m^3 are generated from overall washing activities, with a COD value of 96 mg/litre. In addition to water, electricity is also used in the printing processes with hourly operation consumption is approximately 312,226 kWh/month. Air conditioning consumes a large chunk of electricity, which is 212,174 kWh/month, followed by machines (83,380 kWh/month,), lightings (16,160 kWh/month) and computer (512 kWh/month).

In addition, solid waste generated from overall production activities was identified to be mainly the waste paper, which include trimmed papers, off spec products and quantified as 6 tons/month, with approximately 72 tons generated annually. Wood pallet became the second solid waste generated in the premise. The scheduled wastes mainly spent oil, solvents, scrapped ink from rollers and cleaning cloths are estimated to be 3,116 kg/month, were stored in specific containers before being collected by waste

contractors. The results of mass and energy balance study conducted are shown in Figure 4.4.

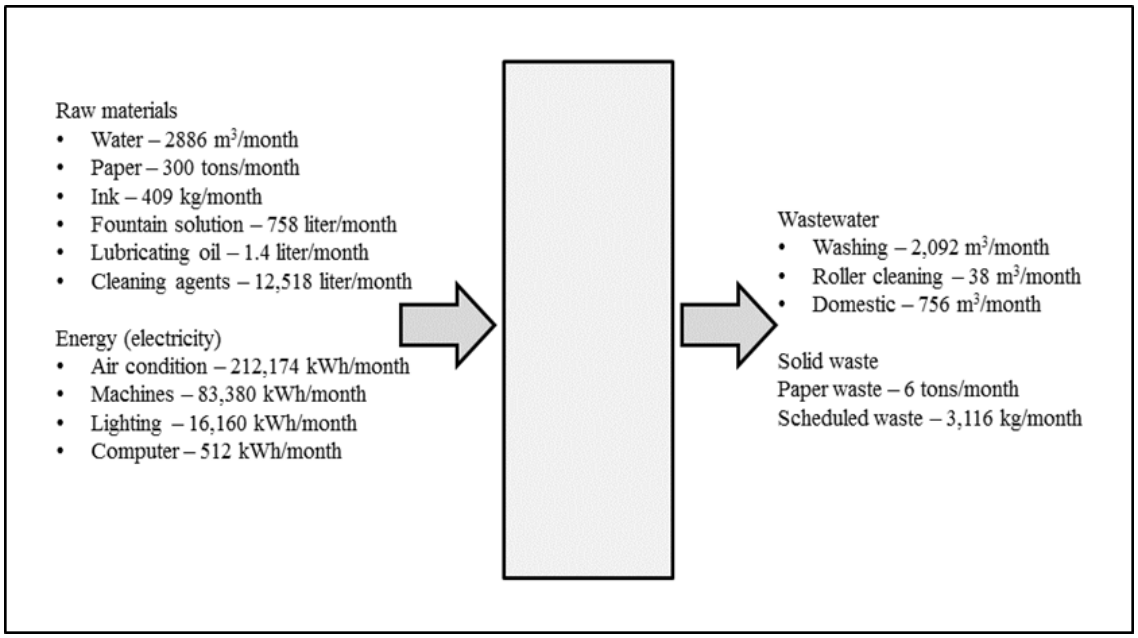

Figure 4.4: Summary on analysis of input-output streams

The breakdown of CO_2 emission sources and respective percentage are summarized in Table 4.8. From the CO_2 quantification obtained in Table 4.7, the total emission of the premise is approximately 244.6 tons on a monthly basis, resulting in 2,940 tons per annum or can be presented as 0.8 tons CO_2/ton of paper processed. Further, electricity consumption is the major contributor of CO_2 emission, which constituting about 85% of total percentage, with quantitative values of 209 tons CO_2/kWh in a monthly basis or 0.7 ton CO_2/ton of paper processed. Thus, electricity can be considered as the main problem that the premise is facing and become a targeted entity as well as focus areas for major improvement potential, in terms of cleaner production opportunities.

Table 4.7: Ecological profiles

Entities	CO_2 emission (ton)/month	Ton CO_2/ton paper processed
2,886 m3 of water	2.3[a]	0.007
312,226 kWh of electricity	209[b]	0.7
6,000 kg of solid waste	22[c]	0.07
3,000 kg of Scheduled waste	11[d]	0.04
2,886 m3 of waste water	0.3[e]	0.001
Total	244.6	0.818

[a] Greenhouse gas emission kg equivalent (in CO_2/m_3) = 0.8; CO_2 mass = 0.8 x 2,886 = 2,309

[b] Greenhouse gas emission kg equivalent (in CO_2/kWh) = 0.67; CO_2 mass = 0.67 x 312,226 = 209,191

[c] Greenhouse gas emission kg equivalent (in CO_2/kg) = 3.7; CO_2 mass = 3.7 x 6,000 = 22,200

[d] Greenhouse gas emission kg equivalent (in CO_2/litre) = 3.7; CO_2 mass = 3.7 x 3,000 = 11,100

[e] Greenhouse gas emission kg equivalent (in kg CO_2/ kg COD (removed)) = 1; CO_2 mass = 1 x 2886 x 96 x 1, 000 / 1, 000, 000 = 277

4.5 CP Option Generation and Evaluation

From Figure 4.4, it is shown that the plant is facing with the problem of high consumption of electricity, which comprised of three major components – air conditioning, machines and lighting. This is followed by generation of solid waste and scheduled waste respectively. Even though, the premise also generates waste water, but the contribution to the CO_2 emission is low compared to other entities. So, the CP option was not generated for this problem as the CO_2 emission generated was not significant. Instead, the CP options were generated to tackle the problems of high electricity consumption and solid & scheduled waste generation.

In this study, more than 100 options were identified ranging from the options to reduce electricity consumption, options to reduce the wastewater, options to reduce Scheduled wastes, options to reduce solid wastes, options to reduce air pollutions to good housekeeping practices. The details of the options are shown in **Appendix B**. From the options, nine (9) options have been selected based on the Cleaner production category which are the change of operating procedure, process modification and raw material/ chemical substitution. These options were assessed based on the impacts on the following aspects:

a) Saving of Materials

   Each option was assessed on the ability to reduce solid waste or wastewater generation, as well as reducing the fuel consumption.

b) Saving of Energy (electricity and heat)

   The option was also assessed in the aspect of the reduction of electricity or heat consumption.

c) Reduction of Carbon dioxide (CO_2)

   Another important aspect of the assessment was the CO_2 reduction. The option that can reduce the CO_2 emission will contribute to the greening of the premise.

d) Ease of implementation of CP options

   Under the aspect of ease of implementation, the options were given the scale from 1 to 4 based on the readiness of the options to be implemented without a cost, or either low or high cost, and also the need for further study to assess the feasibility and the viability of the options in the market. The initial assessment of the options is shown in Table 4.8.

Table 4.8: Evaluation of CP options for Studied Printing Premise

No.	Main issues	Potential CP Options	Effects			Effects Ease of Implementation (1-4)
			Materials saving	Energy Saving	Reduction of CO2 Emission	
1.	Electricity consumption					
	a) Air Conditioning	Fitting the existing air conditioning with energy saver		√	√	3
		Increase temperature from 20°C to 25°C		√	√	1
	b) Machineries	Installation of inverter unit of motorized equipment.		√	√	3
		Turn off air compressor during one-hour rest time.		√	√	1
	c) Lightings	Turn off lights during one-hour rest time.		√	√	1
		Installation of T5 fluorescent lamp.		√	√	3
		Installation of LED lightings		√	√	3
2.	Generation of solid waste (none scheduled)	Optimizing the size of papers for printed media by adopting print management capabilities.	√		√	2
		Expose the client on the strategy to optimize paper usage.	√		√	1
3.	Generation of Scheduled Waste	Optimize the usage of inks (Use soy based ink)	√		√	3
		Use environmentally friendly cleaning solvents. (Use biochemical solvents)	√		√	3

Indicators: 1: No cost involved 2: Low cost 3: High cost 4: Need further study

Based on the analysis of initial assessment, it is found that all options are either saving material or energy, are also contributing to carbon dioxide reduction. The options that do not involve any cost such as increase the temperature from 20°C to 25°C, turn off air compressor during one-hour rest time and turn off lights during one-hour rest time can be implemented immediately by the premise, compared to other options that require a financial budget and time. These options will reduce the electricity consumption and will result in the reduction of CO_2.

Meanwhile, options that involve cost, whether low or high cost will require time to implement as the company will have to look into the economic aspects of the options such as the financial budget and Return of Investment (ROI). These options will also result either in energy saving or material saving and the reduction of carbon dioxide.

Further analysis to calculate the amount of material and energy saving and also the CO_2 reduction for each option is carried out in quantitative assessment. In this assessment, the return of investment for each of the options that require financial budget is also calculated

4.6 CP Options and Energy / Material Saving

For each of CP options proposed to reduce the consumption of electricity and generation of solid waste and scheduled waste, the percentage of energy and material saving was identified as shown in Table 4.9.

Table 4.9: CP options and percentage of energy / material savings

Area	CP options	% of energy /material saving	References
Electricity consumption			
a) Air Conditioning	Fitting of existing air conditioning with energy saver, (Aircosaver)	30	(Bodacious Group, 2015)
	Increase temperature from 20°C to 25°C	50	(Abhishek Jain, 2015)
b) Machineries	Installation of inverter unit of motorized equipment.	70	(Honeywell, 2011)
	Turn off air compressor during one hour rest time	35	(Nkechi Chieke, Elbert Jaquess Jr., & Vance Willis, 2006)
c) Lightings	Turn off lights during one-hour rest time.	13	% Saving = One hour off / normal working hours x 100
	Installation of T5 fluorescent lamps.	55	(Hygrow, 2015)
	Installation of LED lighting	70	(Koninklijke Philips Electronics NV, 2012)
Generation of solid waste (none scheduled)	Optimizing the size of papers for printed media through N-up function and Duplex printing	20	(Preton Ltd, 2010) (Simpson, Tazik, Miller, & Randall, 1994)
	Expose the client on the strategy to optimize paper usage. Eliminate unwanted printing that usually ends up as waste		
Generation of Scheduled Waste	Optimize the usage of inks (use soy based ink)	10	(Cartensen, 1997)
	Use environmentally friendly cleaning solvents. (Use bio - chemical solvents)	75	(Joseph Lucas, 1995.)

The saving in terms of electricity and materials will be discussed further in detail in the section 4.7, Economic evaluation of CP options (Quantitative) and Carbon dioxide (CO_2) reduction.

4.7 Economic Evaluation of CP Options (Quantitative) and Carbon dioxide (CO_2) Reduction

The concept of carbon dioxide (CO_2) reduction is one of the indicators that can be used to assess the returns in the context of the environment. The assessment of the carbon dioxide (CO_2) reduction can be done if there is a quantitative reduction in water consumption, raw materials, fuel, electricity and waste.

For each option proposed, the assessment was carried out to evaluate the reduction of electricity or material consumption by comparing the value before and after option being implemented. Then, the value is converted to monetary return in term of RM. The CO_2 reduction was calculated by multiplying the value obtained with the respective emission factor for electricity or material. Other indirect returns such as quality improvement, image improvement, safer operating system, less risk operation, increased motivation and more comfortable working environment were not evaluated.

The quantitative assessment of CP options, which calculated the saving of material or energy, including the Return of investment (ROI) and also an estimated reduction in the CO_2 emissions of the premises are shown in Appendix A

Based on the quantitative assessment, the detailed evaluation of the nine CP options are discussed as follows:

4.7.1 Energy

Improving energy efficiency can benefit the business and the environment by (Australian Industry Group, 2014):

- Reducing energy costs through actions such as purchasing more efficient equipment
- Reducing the environmental impact of your business through minimising energy-related greenhouse gas emissions
- Extending equipment life, reducing operating costs and avoiding own time through increased energy efficiency and improved maintenance regimes
- Improving the business' reputation and providing a safer and more comfortable workplace

As shown in Figure 4.3, air conditioning system contributes as the major electrical consumer with approximate percentage of 68%, followed by machinery operation. However, as a not much initiative can be done in improving efficiencies on the machinery design due to limitation in economic and technological aspect, hence cleaner production options suggested focusing on the efficient operation of air conditioners, lighting system and machineries which are air compressor and motorized equipment. Efficient energy use may be achieved through implementation of options that require low monetary investment.

4.7.1.1 Lightings

For the lightings, options that do not require monetary investment should be implemented immediately such as turning off lights during the 1-hour rest time can reduce electricity consumption by 2,101 kWh/month or 1.35 tons of CO_2 emission a month, which is equivalent to a cost reduction of RM777.00/ month. Detail calculations of the saving of energy and reduction of CO_2 are shown in Table A5, Appendix A

Meanwhile, there are two options that can be implemented that can further reduce the electricity consumption that caused by lighting. The options include the installation of T5 fluorescent lighting and LED lighting to replace the existing conventional lighting in the premise. The installation of T5 lighting can reduce the consumption of electricity up to 78% depend on the technology provided by the supplier (General Energy Efficiency, 2013).

In this study, a proposal from Hygrow (2015) was obtained to replace the existing conventional lighting in the process area of the premise. The proposal comprised of the installation of T5 fluorescent, 188W RSB447 with 252 units which can save electricity up to 55 %. The electricity consumption for the T5 fluorescent lighting was calculated based on the total monthly electricity consumption of 16,160 kWh for the lighting purposes. The result showed that the saving of electricity by 8,888 kWh/ month, which translated to RM 3,289.00 per month can be achieved excluding the maintenance cost of the existing lighting. Meanwhile, the CO_2 emission can also be reduced by 5.95 tons/ month. Meanwhile, the calculated Return of Investment (ROI) for this option which is 3.3 years, is quite acceptable when taking into account the amount of saving that can be obtained monthly in terms of electricity cost and CO_2 emission. Detailed calculations of the saving of energy, reduction of CO_2 and ROI are shown in Table A6, Appendix A

Figure 4.5: Example of T5 fluorescent lamp

The saving of electricity by installing T5 fluorescent lamp was proven by the study undertaken by Hitachi Air Conditioning Products (M) Sdn. Bhd. in its factory in Bandar Baru Bangi, Selangor. A total of 450 pieces of T5 fluorescent lighting (28 W x 1) was installed to replace the existing fluorescent lighting (40Wx2) on the ground floor, factory no.2. By doing that, the company has managed to save the energy usage of 38 %, which translated to the saving of RM6, 000.00 per year (Hitachi Air Conditioning Products (M) Sdn Bhd, 2015) Apart from that, economically the T5 lighting also increases the power factor which prevents penalty imposed because of the low power factor (The Electrical and Mechanical Services Department (EMSD), 2014).

Lastly, by installing the LED lighting in the process area of the printing premise could result in the saving of RM 4,185.00 per month, even though the cost of LED lighting is higher compared to other types of lighting. LED lighting can save electricity up to 70%, which is a reduction of 11,312 kWh per month or 7.60 tons of CO_2 emission. Detailed calculations of the saving of energy and reduction of CO_2 are shown in Table A7, Appendix A

Figure 4.6: Example of LED lighting

A study by Philips, one of the leading manufactures in LED lighting has shown that old factories using old lighting technologies can save up to 70% by switching to energy saving alternatives, combining lighting, luminaires and controls. The investment will pay for itself in just 2-5 years' time (Koninklijke Philips Electronics NV, 2012). The study showed that lighting energy can be reduced by up to 70 % from a pre-existing baseline. The premises desiring further energy reductions may be able to realize savings beyond 70% through the application of best practices and more aggressive dimming levels.

(a) ***Comparison between T5 fluorescent lighting and LED Lighting***

The study by the Institute of Electrical Engineers (IEEE) in 2009 found that T5 bulbs perform significantly better than LED bulbs in term of heat dissipation and thermal degradation efficacy. The measured efficacy of a 14 Watt T5 fluorescent lamp was 96.7 lm/W, while the measured efficacy for the best performing LED lamp was only78.5 lm/W. The study concluded that T5 bulbs produce more light (lumens) compared to the amount of power they consumed in Watts (Sydney Sanchez & Sweeney, 2010).

The IEEE's case study also demonstrated that T5 lighting is a more cost effective lighting solution. The study records the source cost of both T5 lighting and a T8 sized LED bulb using the measurement of $/1000 lm. Study results show that T5 bulbs performed at a source cost of approximately $3 per 1000 lm, whereas the best comparison rival single LED bulb cost more than $70 per 1000 lm (Pioneer Lighting 2014).

The Color Rendering Index ("CRI") measures a bulb's ability to reveal small shade variations between colours on a scale ranging from zero to one hundred. A report written by Measurement Science and Technology showed that T5 fluorescent lights have a significantly higher CRI rating than LED lights.T5 lights obtained a CRI rating

of 85, while the single LED received a CRI rating of 70. This study also suggested that T5 bulbs may produce a higher quality light than LED bulbs (Sydney Sanchez & Sweeney, 2010).

According to the U.S. Department of Energy, high powered LED bulbs can have anywhere between 35,000 - 50,000 useful life hours, while linear fluorescent bulbs maintain anywhere between 20,000 -30,000 useful life hours xi. However, when comparing the costs of LED and T5 bulbs, the longer life hours can appear trivial (KL Gordon & Gilbride, 2008). Today, LED bulbs cost nearly 24 times more than T5 bulbs. This significant cost differential is due to the high cost associated with the complexity of LED bulb technology, while T5 technology simply consists of efficient bulbs without integrated electronics (Sydney Sanchez & Sweeney, 2010).

(b) ***Summary***

LEDs have proven to be extremely effective due to their long lifespan and increased efficiency. However, T5 fluorescent bulbs have performed significantly better in multiple studies that are critical to commercial and residential usage. In this case, T5 lighting was chosen as suitable lighting technology to replace the existing lighting in the printing premiums by taking into account the crucial factors such as heat dissipation, the CRI rating, efficacy, overall cost, and life span of lighting technology.

4.7.1.2 Air conditioning

One of the shortcoming of typical Air Conditioning Systems is when switched on, typical air conditioning systems operate continuously until the room thermostat senses the desired temperature and turns the system off. As the room warms up, the thermostat switches the air conditioner back on and the cycle repeats. Air conditioning systems are usually dimensioned to cope with the extreme cooling demands of the few hottest days of the year (plus a safety margin) (Airco Saver, 2015).

There is a cost effective and environmentally friendly alternative to spending a lot of money on expensive new systems and that is by upgrading existing units with air conditioning energy saver. One of the air conditioning energy saver available in the market is AircoSaver. The AircoSaver compensates for the shortcoming of a typical AC system. Its sensor-driven software algorithms are designed to detect thermodynamic saturation and to optimize the compressor accordingly. When overcapacity is detected, the AircoSaver switches the compressor off and avoids inefficient overcooking (Bodacious Group, 2015). The independent tests and reference installations have demonstrated that average energy savings between 20% and 30% and payback period for most applications is well below two years (AirCo Saver, 2010).

Figure 4.7: Airco Saver

Bodacious Energy has conducted a pilot study to determine the amount of energy that can be saved by installation of Airco Energy Saver on air condition unit. In this study, the energy consumption data of Airco Saver air condition were compared with Air Conditioner without Airco Unit for the period of 16 February 2010 to 02 March 2010. The result showed that the energy saving of 24% could be accomplished by installing the Airco Saver on air condition. The installation of this product will reduce the monthly energy charges and will therefore increase the company's profitability (Madeleen Wienand, 2010).

In this study, the installation of air conditioning energy saver could achieve a monthly reduction in electricity consumption by 63,652 kWh, or can be translated into RM23,551.00. Thus, reduction in CO_2 emission can be achieved by 43.7 tons/month. For the purpose of calculating the Return of Investment (ROI), the number of Airco Saver proposed to suit the needs for 2592 kW or 8,849,088 BTU/hr of existing air conditioning is 147 and the calculated ROI is only 3 months. However, detailed requirements of air conditioners at the premise should be revised. Detailed calculations of the saving of energy, reduction of CO_2 and ROI are shown in Table A3, Appendix A

Besides that, it is also recommended that this printing company ensures the correct temperature setting for air conditioners, where low temperature setting causes high cooling load, thus increase electricity consumption. Based on the calculation according to the Formula of Ideal Air Conditioner Temperature, by increasing the inner temperature from 20°C to 25°C, with an outside temperature of 30°C, approximately 50% of energy savings can be achieved. Hence, implementation of this option should be able to achieve monthly electricity savings of RM39,252.00 as well as reductions of 71.1 tons of CO_2 emission. Detailed calculations of the saving of energy and reduction of CO_2 are shown in Table A4, Appendix A

Companies like Google and Sun Microsystems have advocated raising the temperature to reduce the power required for cooling server-packed racks. The trend has also received a boost from ASHRAE, the industry group for heating and air conditioning professionals, which increased the top end of its recommended temperature range from 77 to 80 degrees (Rich Miller, 2009).

In one case study, Cisco Systems (CSCO) managed to realize savings of $2 million a year by raising the temperature in its research labs. The proof-of-concept project has been carried out in three research labs on Cisco's San Jose campus. Most of the

increases were implemented gradually, but in one lab the team hiked the temperature by two degrees per day for four consecutive days (Rich Miller, 2009).

4.7.1.3 Machineries

Inverters are known by many names, such as variable frequency drives (VFD), variable speed drives (VSD), frequency converters and AC drives. All mean essentially the same thing: an electronic device that provides step-less speed control for an electric motor. Step less speed control of three-phase motors is very important for the productivity and the durability of electric drive. With the help of frequency inverters, one achieves a constant uniform quality of the drive train. The inverter generates a voltage of alternating current, which can be adjusted in amplitude and frequency (Stefan Fassbinder, 2009).

The three-phase motor is driven by means of this "re-targeted" voltage. Depending on the area of application, there are different types of frequency inverters. For example, for use in pump and fan applications in building technologies or in servo drives in industrial robots and production machines. With the aid of frequency inverters, all these engines can stand strong speed and torque alternations without getting damaged (Rebecca Pahmeyer, 2014)

As a result of the ratification of the Kyoto Protocol, an international accord to thwart global warming, the energy-saving effect of inverters has been attracting attention, and even small capacity inverters are being provided with energy-saving functions Because of this, simple torque vector control was developed to enhance the torque characteristics of small-capacity general-purpose inverters, and to provide automatic energy-saving, stall prevention and other functions that are demanded by the market (e-front runners, 2003).

Inverters can be applied to printing, to meet the requirements of the production process. The motorized equipment such as a printing machine requires an electric motor through a belt drive, gear drive, chain drive to drive the machine, which includes roller and tooth row, by a mechanical connection to coordinate the movements between components so the main drive motor on control of the whole running process.

In this study, the installation of an inverter unit of the motorized equipment of the printing process could reduce the energy consumed by 70%, or can be translated into 58,366 kWh monthly, resulting in the monthly estimated reduction of CO2 emission of 39.1 tons. For the purpose of calculating the Return on Investment (ROI), the number of inverters proposed to suit the needs for 758 kW of the motorized equipment is 13 unit and the calculated ROI is only 10 months. Detail calculations of the saving of energy, reduction of CO2 and ROI are shown in Table A1, Appendix A

Meanwhile, air compressors can account for 10% or more of the electricity use in the average industrial facility. For example, a 50-horsepower (HP) modulating compressor running 4,000 hours per year can consume almost US$12,000 per year in energy. Opportunities for saving money exist in almost every compressed air system. Savings can be realized by detecting leaks, adjusting controls, and upgrading inefficient equipment, on both the supply and demand sides. In addition to saving energy and reducing energy costs, a properly working, efficient compressed air system can (Efficiency Vermont, 2000-2015):

- Improve manufacturing processes, resulting in better quality control.
- Reduce plant noise due to less leaking air in an open blow.
- Improve overall system reliability by reducing or eliminating the need for a secondary compressor through enhanced performance and improved air usage.

There are 168 hours in a week, but most compressed air systems only run between 60-100 hours at anything near full capacity. In view of this, for electricity savings, turning off air compressor during the one-hour rest time can potentially reduce monthly electricity consumption by 29,183 kWh or 19.6 tons of CO_2 emitted, with the monetary savings of RM10,798.00.Further, leakages could be a significant source of energy wasted in industrial compressed air system. Hence, maintaining and regular monitoring of compressed air system able to reduce electricity consumption without any cost investment. Detail calculations of the saving of energy and reduction of CO_2 are shown in Table A2, **Appendix A.**

4.7.2 Solid Waste

As for the reduction of solid waste generated in the premise, the cleaner production options focuses on the strategy to reduce the amount of waste trimmed paper generated. No option is proposed for the wood pallet because the waste is either sold to the third party or reused in the premise. For the excess paper, it is recommended that the waste be used for printing notepad or calendar. Further, the waste paper generation can be reduced by optimizing the size of papers for the production of certain types of printed media. The strategy can be done through the dissemination of knowledge to the clients on the need of paper optimization.

To reduce the paper waste in the premise, the CP options that make use of the print management capabilities, can also be implemented by the printing premise:

a) Eliminating unwanted printing that usually ends up as waste can be achieved by determining page quotas for users, keeping track of user print volumes, omitting pictures and other unneeded elements, reducing the number of pages needed per print job etc.

b) Duplex printing, an attributes seldom used by employees, even in a duplex enabled printer environment, can be defined as the default for all or specific users in the organization. This results in potentially reducing demand for paper by up to 50%. Duplex printing is a relatively new phenomenon in the printer technology industry, but double sided printing is both eco-friendly and can save money at the same time. Duplex printing is basically just printing on both sides of the paper (Martin Larsson, 2013).

c) N-up function compresses more than one page into a single sheet and serves as a more economical use of paper. For example, 2-up compression will reduce print volume by 50%.

If implemented, the total paper demands of the printing industry can be cut by up to 20 % (Preton Ltd, 2010). In this premise, the paper waste generated from the printing activities is 6 tons out of 300 tons of paper used which is only 2%. This spoilage rate is very small and good compared to the rates published by the Printing Industries of America (PIA) which is 10%. The study carried out by The Printing Industries Association in conjunction with the Australian Environment Business Network reported that average spoilage rate of the printing industry in New South Wales is 7.53% (Australian Environment Business Network, 2003).

By implementing the proposed options, the studied premise can cut the paper demand by 20%, to only 240 tons per month. By taking the 2% of the paper consumption turn into waste, the paper waste generated is 4.8 tons per month. This result in cost saving of RM 5,760.00 per month which is equal to 4.4 tons of CO_2 emission reduction. Detail calculations of the saving of raw material and reduction of CO_2 are shown in Table A8, **Appendix A.**

Besides that, good housekeeping should be also implemented to avoid excessive waste. Maintaining sharp cutter for post printing processes can avoid damage to printed products, thus lowering product rejection rate and waste eventually. Clear guidelines and training should be provided to workers in handling materials and machines. In addition, proper loading of papers into the printing machine could reduce paper damage as well as save in production time by reducing faulty machine operation.

4.7.3 Scheduled wastes

As for the reduction of scheduled wastes generated in the premise, the cleaner production options focuses on the strategy to reduce the amount of waste ink and solvent produced at the end of the printing process.

4.7.3.1 Soy based ink

The first option is to replace the petroleum based ink with the natural soybean oil. Natural soybean oil was established as the best replacement to petroleum oil because of the following technical superiorities (Richter, 2011):

1) Soy ink used in lithographic printing processes has the ability to remain stable throughout the entire printing cycle. Thus, the press operator performs fewer adjustments, which enables him to attend more closely to the process, thus reducing the number of rejected copies.
2) Soybean oil allows the pigments to reach full vibrancy of colours in order to deliver high-quality print outcomes. This ability, likewise entails additional cost-efficiency because of the reduced demand for ink application.
3) Printers have experienced more ease in changing dark colours to lighter colours, compared to the difficulty level posed by petroleum-based ink.
4) Another benefit of soy-based ink is its low-rub-off resistance as opposed to the prints produced by petroleum-based ink.

5) The de-inking of soy-based ink for purposes of pulp recovery results in less stress and damage to the paper fibre.
6) Wastes from soy-based ink could be reduced by recycling black ink with unused colour inks, which also results in cost-efficiency.
7) The use of soy-based ink in industrial laser printers poses less detriment to the machine, since soy-ink responds rapidly to laser heat. That way, faster ink-absorption takes place on the paper, which results in a less likely chance of build-up on the machine's plate.

In relation to the environmental effects of the printing ink, the speed at which chemical solutions dry (vaporize) can be used to give a rough approximation of the chemicals' VOC potential. Faster drying compounds tend to have high VOC counts, while slower drying ones are typically rated low. In the press room, chemicals contributing to this effect include the ink vehicle and nearly all of the solutions associated with cleaning the press. The VOCs, which are most often reduced by using soy ink are those resulting from the use vehicle that transfers the ink pigment. In traditional petroleum-based inks, the level of VOCs can range from 20-30%. By using soy-based inks, this percentage can be reduced to a range of 5-20%, which is especially noteworthy in large, long-run jobs, as the savings will compound over time. VOCs can be further reduced, as soy and vegetable-based inks can be cleaned with solutions that have lower VOC potentials themselves. This leads to a double reduction in the VOCs released (Paulsen, 2007).

Besides the technical superiorities and positive environmental effects of the soy based ink, the usage of the ink also reduce the waste ink generated in the printing process by 10 % (Simpson et al., 1994). In this study, by replacing petroleum based ink with soy based ink, about 5 kg of waste ink can be reduced per month with result in the reduction of 18.5 kg CO_2/month (0.018 ton/month). Even though, the amount is small compared

to other savings, the reduction of waste ink, SW 416 will further reduce the cost of disposal to a licensed scheduled waste collector. Detail calculations of the saving of raw material and reduction of CO_2 are shown in Table A9, Appendix A

4.7.3.2 Biochemical solvent

Press chemicals are by far the greatest contributors to the release of VOCs from printing establishments. Press washes outnumber fountain solutions three to one in a typical press-room. The main reason press washes are considered to be the large generators of VOCs is that the vast majority of the chemicals are formulated with petroleum-derived solvents, resulting in products that adversely affect the environment and the press room workers. Solvents used to clean the printing equipment include toluene, xylene, methanol, and methyl ethyl ketone (MEK).

In addition, blankets used to transfer the ink-filled image to sheets of paper are cleaned with washes that contain glycol ethers and 1,1,1-trichloroethane (TCA). The type of solvent used depends largely on the equipment to be cleaned. For example, a blanket wash must dissolve ink quickly and dry rapidly with minimal wiping. The low toxicity and high biodegradability of biochemical offers benefits to workers and the natural environment alike. The use of biochemical also avoids a significant amount of the "upstream" pollution generated from the extraction and processing of crude oil into chemicals. Manufacturing Advantages: Biochemicals save the private sector money in three ways by reducing environmental compliance costs, improving worker safety and reducing disposal and liability costs (Cartensen, 1997).

The study by Inland Technologies (Tacoma, WA) has shown that the use of biochemical solvent can reduce the waste solvent by 75 %. Inland Technologies formulates alternative cleaning solvents tailored to its clients' cleaning needs. Inland's solvent line, based on the terpene d-limonene (derived from citrus fruits), has

successfully replaced press cleaners containing TCA, MEK, acetone, toluene and methylene chloride. The solvent, Citra-Safe™, is an excellent cleaner of ink rollers and press blankets. It is literally a biodegradable solvent replacement for mineral spirits, thinners, and chlorinated solvents that reduces the risk of hazardous chemical spills, eliminates most hazardous waste disposal costs, and eliminates the health hazards associated with traditional solvents (Inland Technology, 2009).

In this study, the use of biochemical solvent to clean the roller and other machineries, will reduce the waste solvent by 1500 kg/ month. This will also contribute to the reduction of 5550 kg CO_2/month (5.5 tons/ month). Detail calculations of the saving of chemical and reduction of CO_2 are shown in Table A10, Appendix A

The discussion of the economic returns and CO_2 reduction of the nine options can be summarized in Table 4.10.

The proposed options can also be grouped according to Cleaner production category – process modification, change of operating procedure and raw material/chemical substitution as shown in Table 4.11.

Table 4.10: Details of Suggested Cleaner Production Options

Area	CP Option	Saving (RM/ month)	Energy saving (kWh/month)	Reduction of CO_2 Emission (tons/month)	Return of investment (ROI)
Air conditioning	Increase temperature of air conditioning from 20°C to 25°C	39, 252.00	106,087	71.1	Immediate
	Fitting the existing air conditioning with energy saver	23,551.00	63,652	43.7	2 years
Machineries	Turn off air compressor during one-hour rest time.	10, 798.00	29,183	19.6	Immediate
	Installation of inverter unit of motorized equipment	21,595.00	58,366	39.1	10 months
Lightings	Turn off lights during one-hour rest time.	777.00	2,101	1.35	Immediate
	Installation of T5 fluorescent lamp	3,289.00	8,888	5.95	3.3 years
Solid waste	Implement print management capabilities - Eliminate unwanted printing, adopting Duplex printing and N- up function	5,760.00	--	4.4	Immediate
Scheduled waste	Optimize the usage of inks (use soy based ink)	100.00	--	0.018	
	Use environmentally friendly cleaning solvents. (Use biochemical solvents)	11,400.00	--	5.5	
	Total	116,522.00		190.718	

Table 4.11: Options based on Process Modification, Change of Operating Procedure and Raw Material/ Chemical Substitution

No	CP Option	Category	Saving (RM/month)	Energy saving (kWh/month)	Estimated Reduction of CO_2 Emission (tons/month)	Estimated CO_2emission reduction (per ton of paper/month)
1	Fitting the existing air conditioning with energy saver	Process Modification	23,551.00	63,652	43.7	0.146
2	Installation of inverter unit of motorized equipment		21,595.00	58,366	39.1	0.130
3	Installation of T5 fluorescent lamp.		3,289.00	8,888	5.95	0.020
4	Increase temperature of air conditioning from 20°C to 25°C	Change of operating procedure	39,252.00	106,087	71.1	0.237
5	Turn off air compressor during one-hour rest time.		10,798.00	29,183	19.6	0.065
6	Turn off lights during one-hour rest time.		777.00	2,101	1.4	0.0047
7	Implement print management capabilities		5,760.00	-	4.4	0.0147
8	Optimize the usage of inks (Use soy based ink)	Raw material/ chemical substitution	100.00	-	0.018 (18.5 kg)	0.00006
9	Use environmentally friendly cleaning solvents. (Use biochemical solvents)		11,400.00	-	5.5	0.018
Total			116,522.00	268,277.00	190.768	0.635

From the Table 4.11 above, there are four options that can be implemented immediately by the premise and do not involve any cost. The options are shown in Table 4.12

Table 4.12: Simple CP options that do not involve any cost

Area	CP options	Estimated monthly savings in RM	Estimated monthly CO_2 emission reduction in tons	Estimated CO_2 emission reduction (per ton of paper/month)
Air conditioning	Increase temperature from 20°C to 25°C.	39,252.00	71.1	0.237
Machineries	Turn off air compressor during one-hour rest time.	10,798.00	19.6	0.065
Lightings	Turn off lights during one-hour rest time.	777.00	1.4	0.0047
Solid waste	Implement print management capabilities- Eliminate unwanted printing, adopting Duplex printing and N- up function	5,760.00	4.4	0.0147
Total		56,587.00	96.5	0.321

By implementing these four options, the premise will be able to reduce 96.5 tons of CO_2 emission and saving of RM 56,587.00 per month. In one year, the reduction of CO_2 emission is 1158.12 tons and the saving is RM 679,047.00.

Besides that, there are 1000 active printing premises in Malaysia that use the same raw materials and utilities in their processes. By assuming that these premises are using the same amount of paper as raw material and consume the same amount of electricity per month, this will result in the reduction of CO_2 emission of 96,510 tons and the savings of RM 56.6 million per month.

This approach can be applied to greening other industries as well by using CP as a tool to identify options for improvement of the process and operation that result in CO_2 reduction. There are more than 600,000 SMEs in Malaysia. These companies more or less are printing their documents in their daily business, whether by in house printing or commercial printing. By assuming, 15 % of the SMEs are implementing these four options, the amount of CO_2 that can be reduced are 8.7 million tons per month and the saving of RM 5.09 billion per month can be realized. Thus, it is shown that by adopting CP, SMEs will be able to reduce significance amount of CO_2 that resulted from their daily businesses.

4.8 Other Benefits

Besides reducing the energy consumption, and the generation of wastes, the implementation of CP options will also result in the saving of production and waste management costs. This will increase the productivity and the ability to compete in the open market. The options will also enhance the good image of the company as a printing premise that adopts the green industry practices.

The good image plays an important role in securing work contracts and financial support from clients, relevant authorities and financial institutions. The green printing premise can become a model and reference for other premises in the same category that want to adopt green industry practices.

4.9 Implementation and Performance Monitoring suggested for Implementation of CP Options

To ensure the successful implementation of CP options, a couple of things need to be done by the management of the premise during the implementation phase and performance monitoring.

a) Implementation phase

   During this phase, CP options should be evaluated to identify and prioritize the options that need to be implemented first based on the factors such as finance, implementation periods and return of capital. After these options have been prioritized, the implementation schedule should be prepared and in place to ensure smooth implementation of the options and completed on schedule.

b) Performance monitoring

   For the purpose of performance monitoring, Key Performance Indicator (KPI) should be developed in advance to measure the effectiveness of the options implemented. The effectiveness will be evaluated on the energy-saving aspects of the electricity used by checking the electric bills every month. For the generation of waste, the savings are tracked through the quantity of waste generated. For this purpose, the inventory record of wastes generated per month, including scheduled wastes is examined to detect the changes in terms of reduction of waste materials. The savings can also be detected through waste disposal costs, particularly wastes sent for disposal at a licensed facility Apart from the aspect of energy saving and waste reduction, the performance of the CP option's exercise will also be evaluated for reduction of water consumption, raw materials and utilities such as gas and diesel.

c) Continuous improvement

CP Practices is a continuous improvement process where the effectiveness of the CP options implementation will be assessed after a few months of the implementation. The options that do not meet Key Performance Indicator (KPI), will be further studied for the purpose of improvement. Then, the new or improved options will be implemented and evaluation of its effectiveness will be carried out after a few months. For this printing premise, the implementation of CP options can be evaluated after 3 months for the reduction of electricity and 6 months for the reduction of waste and other options.

d) Benchmarking

The printing industry is increasingly adopting the use of benchmarking to measure how well sites are performing compared with previous years. Benchmarking involves gathering data and calculating various performance indicators.

i. To compare one printer with other printers, it‘s best to use a comparable indicator, such as ‘amount of make-ready waste on a four-colour lithographic press’. Other examples of comparable indicators include spoilage, ink use and amount of waste generated. Some suggestions for benchmarking:

ii. Calculate indicators weekly or monthly.

iii. Use a common measurement, based on published benchmarks for the type of printing process.

iv. Present the results graphically each week or month, according to each shift, in a way that will identify improvements and goals to be reached.

v. For each type of waste generated, measure quantities generated, recycled and disposed of, to better identify trends.

vi. Measure overall efficiency, such as the amount of paper, board or substrate converted to the final product.

4.10 Wider implications of the case

This case study can be used as a model for green industry practice or implementing CP strategy for the printing industry and other industries that have similar characteristics. Furthermore, this case can also be used as a reference for the development of policies by the relevant authorities to improve the wellbeing of the industry itself. For example, the Department of Environment (DOE) can develop policies regarding the greening of printing industry through CP implementation and increasing the carbon emissions reduction. In addition to the policies, the new and specific regulations to increase the compliance of the printing industry with environmental requirements can also be formulated based on the findings of this case study.

As far as the whole industry is concerned, DOE should also embark on the new regulations to increase the uptake of green industry practices or CP among Malaysia industries. For example, The EQA 1974 should be reviewed to include the green industry practices as part of the best practice that adopted or implemented by the industries especially SMEs. This is also in line with DOE's policy to encourage self-regulations and self-performance monitoring by the industries to inculcate the self-conscious environmental culture and enable them to compete with other country in the international market.

4.11 Challenges in Greening of Printing Industry and SMEs in Malaysia and the way forward

There are five main challenges in greening of industry faced by the relevant stakeholders which include the industry and government. The need to overcome the challenges faced by the SMEs and other stakeholders, especially the government is very

crucial in view of the pressing need to reduce the emission of carbon dioxide and tackle the problems of climate change. The challenges are :

4.11.1 Access to information, knowledge and technology

The capacity of SMEs to reduce their carbon dioxide emission, mostly depends on their ability to access the information about environmental impacts of their activities as well as on the availability of clean or green alternatives. Moreover, improving environmental performance of SMEs would require a substantial change in focus, from end-of-pipe technical solutions that has been practiced nowadays, to a new concept of integrated environmental strategies and management systems. However, the large majority of SMEs, have little knowledge about how to reduce the environmental impact of their products, from raw material acquisition, through production and finally to recycling and disposal (OECD, 2009b).

So, increasing SMEs' and entrepreneurs' awareness and connecting them to knowledge networks is crucial for favoring adaptation to or anticipation of green-led changes, as well as for enhancing their active role in the low-carbon economy, as producers, users, integrators of skills and technologies, innovators and trainers. Local ecosystems of firms, institutions and organizations constitute important players for the implementation of strategies that better link the different stakeholders at the local level (OECD, 2010).

4.11.2 Access to finance

One of the most significant challenges for the survival and growth of SMEs, especially innovative ones is an access to financing (OECD, 2009a). Easing SME access to finance is crucial for their adoption of greener technology and investment in sustainable business practices in order to achieve the green industry status. The government has to provide access to appropriate types of financing structures and facilities that are especially required to allow SMEs and entrepreneurs to respond to the investment needs

implied by the transition to a green, low-carbon economy and to take advantage of the opportunities provided by innovation. Enhancing venture capital markets is key to the entry of new firms, particularly high-growth ones, in the emerging green markets (OECD, 2010).

4.11.3 Incentives

To address the pressing issue of climate change, the Malaysian Government has given greater focus to green developments in recent years and is making concerted efforts to encourage Malaysians to embrace green industry practices and technology. This is evident through some of the measures implemented by the Malaysian Government, which reveals the Government's intention to stimulate the adoption of green industry practices and technology. These measures include the introduction of a series of tax incentives to encourage the public and private sectors to invest in green technology. Prior to Budget 2010, tax incentives were given to companies which generate energy from renewable sources and for energy conservation activities. Together with the launch of GBI, the Government introduced tax incentives for GBI-certified buildings in Budget 2010 to encourage the construction of buildings using green technology (Pricewaterhouse Coopers, 2010).

Generally, the current tax incentives for green industry practices and technology in Malaysia may not be sufficiently attractive to the public and private sectors as compared to those given in our neighbouring countries The scope of the tax incentives should be widened and cover not only industries that generate and conserve energy but also the industries that consume electricity such as printing industry. Tax incentives should be given to this industry for purchasing machines that are energy efficient and pollution control equipment and treatment facility that are environmentally friendly.

This will ensure more SMEs premises to adopt and implement green industry practices and technology in their manufacturing processes and premise management

4.11.4 Skills and qualified personnel

Greening the economy and seizing available opportunities to build a low-carbon society requires transforming jobs, occupational profiles and business operations in ways yet quite uncertain. New skills are required not just for innovation and competitiveness but also for adjusting to climate change related policies and regulations. Evidence from a number of countries how's that traditional training institutions cannot provide appropriate skill that was needed in certain sectors or occupations (OECD/Martinez-Fernandez C, C. Hinojosa, & Miranda, 2010).

In this case, the government can play a major role in the transition process towards a low carbon economy demands by educating new generations to take-up appropriate skills to meet the changing demand. Labour markets and training policies can play a key role in facilitating the structural adjustment required by the transition to green growth, while, at the same time, minimizing the associated social costs. Flexibility in the delivery of training and skills development programs is crucial to educate SMEs (OECD, 2010).

4.11.5 Technology

a) 3D printing

   3D printing is also known as desktop fabrication, it can form any material that can be obtained as a powder. For creating an object you need a digital 3D-model. A set of 3D images can be scanned, or drawn by using computer assisted design or CAD software. The image can also be downloaded from the internet. The digital 3D-model is usually saved in STL format and then sent to the printer. The process of

"printing" a three-dimensional object layer-by-layer with equipment, which is quite similar with ink-jet printers (Gaurav Tyagi, 2015).

One of the most important applications of 3D printing is in the medical industry. With 3D printing, surgeons can produce mock-ups of parts of their patient's body which need to be operated upon. 3D printing makes it possible to make a part from scratch in just hours. It allows designers and developers to go from flat screen to exact part. Nowadays almost everything from aerospace components to toys are getting built with the help of 3D printers.

3D printing can provide great savings on assembly costs because it can print already assembled products. With 3D printing, companies can now experiment with new ideas and numerous design iterations with no extensive time or tooling expense. 3D printing could even challenge mass production method in the future and going to impact so many industries, such as automotive, medical, business & industrial equipment, education, architecture, and consumer-product industries (3ders.org, 2013).

b) Waterless printing

Simply put, waterless printing is an offset printing process that prints without water. Offset printing is the most common production printing method in use today as much as 40% of all printed material is produced using offset printing. Waterless printing eliminates the need for water in the printing process by using a special printing plate that has only two surface properties which are ink-resistant and ink-attractive. By working with only one fluid (ink) as opposed to two fundamentally different fluids (ink and water), the printing process is greatly simplified and some very unique benefits can be realized (International Waterless Printing Association, 2015).

In waterless printing, instead of press operators managing a chemical process in which water and ink are carefully balanced to control the application of ink to plates and paper, an alternate mechanical process that uses no fountain solution is employed. The printing is usually accomplished on conventional printing presses retrofitted with ink heating and cooling mechanisms that maintain a narrow range of temperatures on the surface of the plate (Litho Inc, 2005).

The advantages of waterless printing lie in the elimination of the fountain solution (Brancher, 2015):

- Qualitative advantages: Print quality is significantly improved by eliminating the fount solution which are constant reproducibility, better colour, density, and dot sharpness (low dot gain).
- Production advantages: The absence of water eliminates the need to adjust the water/ink balance, which reduces the startup and setting times and cuts waste. The elimination of the fountain solution also enables other related drawbacks to be avoided: no need for a fountain additive or need to maintain the fountain solution tanks, elimination of the problems of misting and piling, etc.
- Ecological advantages: The absence of isopropyl alcohol in the process eliminates any production of VOCs and ensures it is compliant with the objectives of the EPA (Environmental Protection Agency).

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIION

5.1 Conclusion

The first objective of the study is to conduct CP audit on the selected offset lithographic printing premise. In this case, the CP audit was conducted on the premise based on five (5) entities which are water, electricity, solid waste, scheduled waste and wastewater. The CP audit findings showed that the premise is faced with the issue of high electricity consumption followed by solid waste and scheduled waste generation.

The second objective requires the carbon emission equivalent generated from the premise is estimated in the current and internationally accepted form. The total carbon dioxide emission of the premise based on the "gate to gate" assessment was estimated at 244.6 tons of CO_2 per month, which produced 0.818 ton CO_2 per ton of processed paper. It was also found that energy consumption mostly electricity, which contribute to the high percentage of CO_2 emissions consist of three major sources, which are air conditionings, machineries, and lightings.

Meanwhile the third or the last objective is to generate and evaluate the feasibility of CP options to reduce CO_2 emission and the operating costs of the premise. In this case, in order to reduce energy consumption in the premise, the main CP options for each of the major sources which are air conditionings, machineries, and lightings were generated and evaluated. This resulted in the estimated total electricity savings of RM 99,262.00 per month and reduction in the generation of CO_2 emission by 180.80 tons of CO_2 per month. As for the solid waste, even though the premise generated 6 tons of paper waste as a result of its printing activities, the amount of waste paper was only 2% of the total paper used. This value is still below the normal standard of the printing industry and can be used as a benchmark for the premise to further reduce the amount of paper waste generated from the printing process. However, a saving of RM 5,760.00/month is

expected to be achieved by implementing the print management capability options. This also results in 4.4 tons of CO_2 reduction per month.

Furthermore, by implementing the options to reduce the scheduled waste generation will reduce the CO_2 emission by 5.518 tons/month and the saving of RM 11,500.00. Even though, CO_2 reduction is small compared to the reduction by the implementation of energy options, the reduction proves that proper CP options are contributing to the reduction of CO_2 as a whole.

In total, the implementation of all proposed CP options is expected to reduce 190.8 tons/month of CO_2 emission, which is equivalent to 0.635 tons of CO_2 per ton of processed paper. Meanwhile, the total cost savings of RM 116,522.00 per month. The total carbon emission reduction of the premise after the implementation of these nine options is estimated at 53.8 tons of CO_2 per month, which is equivalent to 0.180 tons of CO_2 per ton of processed paper.

Based on the findings, it shows that cleaner production concept can be applied in the printing industry to identify the options that can be implemented to reduce the CO_2 emission as a result of the printing activities.

Even by implementing four (4) simple CP options that do not involve any cost, the premise manages to reduce the amount of CO_2 emission of 96.5 tons per month and save RM 56,587.00 of operating cost. This is further followed by the reduction of CO_2 by 96,510 tons per month when these simple options are implemented by 1000 active printing companies in Malaysia. These simple CP options if implemented by 15% of the 600, 000 SMEs in Malaysia will produce the reduction of CO_2 emission by 8.7 million tons and the saving of RM 5.09 billion per month.

In other words, it shows that CP is the best approach to greening the industry by taking the printing premise as an example and this approach can be adopted to greening other industries as well.

This ‘gate to gate’ assessment of Carbon footprint serves as a first step for the industry to establish the procedure and methodology for comprehensive carbon foot printing of the printing industry. In addition, similar concept can be introduced to other types of industry, which can contribute to reduce CO_2 emission.

Lastly, this concludes that the aim of the study, which is to demonstrate the greening of the offset lithography printing industry through the implementation of CP practices is achieved. The CP options proposed are feasible in terms of economic and environmental aspects and can be implemented by the industry successfully especially the cost free options.

5.2 Recommendations for further research

Further research on the greening of printing industry can be carried out. The first recommendation is in depth quantitative analysis of carbon emission reduction of all CP options that were suggested in this report. This will help the development of sustainability index.

The second recommendation is a study on the correlation between the printed product size and the generation of waste. A life cycle analysis of the printing process is also suggested to generate more CP options for the printing industry by understanding the life cycle of the relevant materials, equipment and process.

A study of material flow and cost analysis of the printing industry is also recommended as this study can provide information on detailed loss in the printing process in order to develop better operational procedure to avoid wastage.

Last but not least, a study on energy saving in printing industry should be carried out to look into the options to further reduce the consumption of energy in the printing process in line with the Malaysia commitment to reduce the carbon dioxide emission by 40 % by the year of 2020.

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