

**CARBON EMISSION REDUCTION STRATEGIES THROUGH CLEANER PRODUCTION AT
MANUFACTURING INDUSTRY**

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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**A report submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering**

Faculty of Mechanical Engineering

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2021

DECLARATION

I declare that this project report entitled “Carbon Emission Reduction Strategies Through Cleaner Production at Manufacturing Industry” is the result of my own work except as cited in the references.

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Date :

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :

Supervisor's Name : Mr. Mohamed Hafiz bin Md Isa

Date :

DEDICATION

For my beloved family and friends

ABSTRACT

Manufacturing industry is generally reported as one of most the influential sector in contributing to uncontrolled greenhouse gas emission annually. As consequences, global warming, climate change and effects to human health are what must be taken seriously by any appropriate means such as green technology adaptations, cleaner production and strengthening current regulations and acts. Nowadays, as manufacturing industry striving to achieve their profit goal, most of them seems facing various circumstances to control the rising of carbon emissions, energy and raw material consumption and waste generations due to production activities. This research concentrates on evaluation on energy consumptions and waste generations by a coconut milk processing industry by using statistical approach. Aiming to estimate the trend of greenhouse gas emissions mainly Carbon Dioxide (CO₂), baseline models of energy consumptions and waste generations are constructed by using single and multiple linear regression methods. The performance of ultimate models of electrical consumption, water consumption, fuel consumption, solid waste generation and wastewater generations are investigated by a statistical analysis which involve coefficient of correlation, coefficient of determination, analysis of variance (ANOVA) etc. Hence, end of analysis reveals that in 2018, 10,474.94 tons CO₂ have successfully been reduced and the achievement continues in 2019 where 2,579.67 tons CO₂ have been reduced. This study is an aid for the management and engineers of the industry to investigate their accomplishment in reducing environmental impacts by production activities from any implementation made such as cleaner production (CP) and industry green practices.

ABSTRAK

Industri pembuatan umumnya dilaporkan sebagai salah satu sektor yang paling berpengaruh dalam menyumbang kepada pelepasan gas rumah hijau yang tidak terkawal setiap tahun. Sebagai akibatnya, pemanasan global, perubahan iklim dan kesan terhadap kesihatan manusia adalah perkara yang mesti dipandang serius dengan cara yang sesuai seperti penyesuaian teknologi hijau, pengeluaran yang lebih bersih serta pengukuhan peraturan dan akta. Pada masa kini, ketika industri pembuatan berusaha untuk mencapai matlamat keuntungan mereka, kebanyakan mereka menghadapi pelbagai masalah untuk mengawal kenaikan pelepasan karbon, penggunaan tenaga dan bahan mentah serta penjanaaan sisa akibat aktiviti pengeluaran. Penyelidikan ini bertumpu pada penilaian penggunaan tenaga dan penjanaaan sisa oleh industri pemprosesan santan dengan menggunakan pendekatan statistik. Bertujuan untuk menganggar tren pelepasan gas rumah hijau terutamanya Karbon Dioksida (CO₂), model asas penggunaan tenaga dan penjanaaan sisa dibina dengan menggunakan kaedah regresi linear tunggal dan berganda. Prestasi model utama penggunaan elektrik, penggunaan air, penggunaan bahan bakar, penjanaaan sisa pepejal dan air sisa disiasat oleh analisis statistik yang melibatkan pekali korelasi, pekali penentuan, analisis varians (ANOVA) dan lain-lain. Oleh itu, akhir analisis mendedahkan bahawa pada tahun 2018, sebanyak 10,474.94 tan CO₂ berjaya dikurangkan dan pencapaiannya berterusan pada tahun 2019 dimana 2,579.67 tan CO₂ telah dikurangkan. Kajian ini merupakan bantuan bagi pihak pengurusan dan jurutera industri untuk menyelidiki pencapaian mereka dalam mengurangkan kesan persekitaran oleh aktiviti pengeluaran daripada setiap pelaksanaan yang dibuat seperti pengeluaran bersih (CP) dan amalan hijau industri.

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LIST OF ABBREVIATIONS

CP	Cleaner Production
CO ₂	Carbon Dioxide
GHG	Greenhouse Gas
SME	Small Medium Enterprise
SDG	Sustainable Development Goal
VIF	Variance inflation factor

CHAPTER 1

INTRODUCTION

1.1 Background

Generally, Carbon dioxide (CO₂) is generated from natural process called photosynthesis by the combination of oxygen and other organic substances. Normally, land use changes, industrial processes, the byproduct of fossil fuel combustion and biomass burning will eventually lead to CO₂ emissions. However, due to human activities, the atmospheric concentration of carbon dioxide has been rising in a vast scale by years. Nowadays, the issue of the statistical rising of the rate of global warming and anthropogenic climate change are largely due to the production activities by manufacturing industry. This is due to the fact that most of manufacturing industries have directly involved in growing of the concentrations of atmospheric carbon dioxide. Besides, CO₂ is known as greenhouse gas and also can be considered as a harmful gas is a major source rise of sea level and global warming. From annual research, global ice sheets and glaciers are actively melting and as a consequence, high volume of water are added to the current ocean.

Technically, a byproduct of chemical reactions is extremely needed in most manufacturing production process. Therefore, there are numerous industrial processes that generate significant amounts of carbon dioxide emissions to the atmosphere. From a study in 2011, industrial processes have influenced 4% of human carbon dioxide emissions and produced 1.7 billion tonnes of the gas of carbon dioxide emissions (C. Le Quer´e et al. 2011). Hence, without negatively affecting the industrial production, economy, and their net worth, reducing the amount of carbon dioxide emissions is very crucial as a healing process of the earth. Moreover, one of the wide human source of carbon dioxide emissions is contributed from the combustion of fossil fuels. By burning these fuels, energy will be released by mechanical and chemical processes which is most technically turned into electricity, heat or power used for transportation. Power plants, transportation and industrial facilities are some common example where this method is used.

Basically, electricity/heat, transportation and industry are the three main economic sectors that use fossil fuels. In recent study, the first two sectors which are electricity/heat and transportation, generated almost two-thirds of global carbon dioxide emissions each year. However, the economic sector that produces the largest amount of man-made carbon dioxide emissions are electricity and heat generation plant. Based on research from International Energy Agency, this sector relies extremely on coal, the most carbon-intensive of fossil fuels. Thus, a giant carbon footprint is majorly contributed by this sector. In addition, according to International Energy Statistics Database, 60% to 90% electricity source in industry are contributed from the combustion of fossil fuels.

In this research, a study is conducted to reduce carbon dioxide emission in manufacturing industry by using cleaner production approach. Cleaner production is an integrated preventative environmental strategy applied to manufacturing process and activities through conserving raw energy and material, reducing toxicity of emission, removing toxic material, and minimizing wastes at the source of generation. Since most of carbon emission that are generated in manufacturing industry are contributed by energy consumption and waste generations, this research will focus on the study of energy, wastes and cleaner production option evaluation in order to reduce the emission of CO₂. This is due to the fact that CP is an effective approach as its focuses on preventive strategies to minimize environmental impact of manufacturing sector (Razuana and Rahim 2017).

In identifying CP options, a methodology is developed based on the main purpose to reduce the sources of carbon emission from manufacturing processes and activities. Through consumption of electrical, fuel and water, the gas of carbon dioxide can be generated from any production processes and activities. The source of carbon emission also involves two more factors which are the generation of wastewater and solid waste. Hence, it completes the five entities that influence the fluctuation of carbon emission in manufacturing industry. Based on the studied manufacturing industry, carbon emission is measured by evaluating and analyzing the inputs and outputs of five main entities, which are water, wastewater and solid waste generation, electricity, and fuel consumption. In order to evaluate these variables, a statistical analysis is proposed by measuring and modelling single and multiple linear regression technique in statistical software. In a past research of petroleum products consumption, this statistical technique was used for similar purpose which is to evaluate the independent and dependent variables. To generate regression equations for measuring the CO₂ emissions in Malaysia, multiple linear regression modelling is implemented (Sim

Chong Keat, 2015). The input data was collected annually from 1980 to 2010 which is 31 years period.

1.2 Problem Statement

In this age, manufacturing industry is under serious pressure to improve its environmental performance in terms of production operations and activities, waste minimization and prevention of end-of-pipe treatment. In addition, carbon dioxide can be considered as hazardous gas waste that is rapidly emitted from production activities in most of manufacturing industry. Hence, composting and recycling can minimize the emission of greenhouse gases, reducing carbon dioxide or other harmful gasses, and enhance energy savings (Rafael Mattos Deus et al. 2017). Moreover, there are more strategic ways which is by evaluating of cleaner production options that can help reducing production wastes, costs, and most importantly reduce the environmental risks. Besides, high energy consumption and waste generations is one of the factors that lead to carbon emission by manufacturing as their production activities involve the use of various kind of machine with high voltage consumption. Related to this matter, some problem statements are identified which are:

1. Rise of carbon dioxide percentage in air from production activities by manufacturing industry. Example of case study of a cement plant in UK, 5% of hazardous greenhouse gas emissions to surroundings is generally considered as cement industry responsibility (Daniel L. Summerbell et al. 2016).
2. The impact of various independent variables in contributing the elevation of carbon concentration in air depend on difference circumstances. For example, in the past study in China, the relationship between CO₂ emissions, economic scale, technology, income and population was analyzed by establishing regression model (Guo Hang, 2011). As a discussion, the regression result showed that economic scale, income, and population have a strong effect on carbon emission to the surroundings.

1.3 Objectives

The objectives of this research are as follows:

1. To measure and evaluate energy consumption, waste generations and carbon emission in industrial sector which focused on manufacturing industry.
2. To perform a statistical study on independent and dependent variables based on a specific manufacturing industry for further analysis and discussion.

1.4 Research Scopes

In order to meet the objectives, the scopes of this research are as follows:

1. Identifying and evaluating waste generations and energy consumption in manufacturing industry comprehensively.
2. Performing statistical analysis by using gathered independent and dependent variables data sets in a manufacturing industry.

CHAPTER 2

LITERATURE REVIEW

2.1 Cleaner Production

Cleaner production (CP) is defined as a preventative method and approach to control and reduce the environmental impacts normally from production process by manufacturing industry in pursuing their profit target. In fact, cleaner production strategy has been accepted in various kind of industrial sectors and acknowledge as one of sustainable development, and already has been promoted and implemented in most country and region all over the world since 1989 (Yunwei Liu et al. 2011). Today, the theory and application of Cleaner Production has been considered as the key to success of achieving and facing sustainability challenge in this rapid industrial growth period especially in industry economical management. Besides, according to Basappaji K M and N Nageshab (2014), Cleaner Production is also known as strategic policy that is planned meticulously and aim to achieve sustainable production, minimize wastes and harmful emissions at the original source and is difference from end-of-pipe technologies. Hence, this preventive strategy has already proved its capability as there are numerous of success implementation achieved with remarkable result as it gives better condition not only to environment but economy and society as well.

In viewing Cleaner Production concept in general study, the purpose is usually involving thorough research on energy consumption and environmental management to estimate and analyze possibility to implement a continuous cleaner production strategy and consequently enhance company or industry's performance. As explained by Edvins Terehovics et al. (2019), cleaner production is a continuous and preventive application that is applied to the energy and environmental management. In addition, CP is also approved to provide services and continue various production activities with a minimum negative result on the human well-being and environmental aspect using economic and technology opportunities.

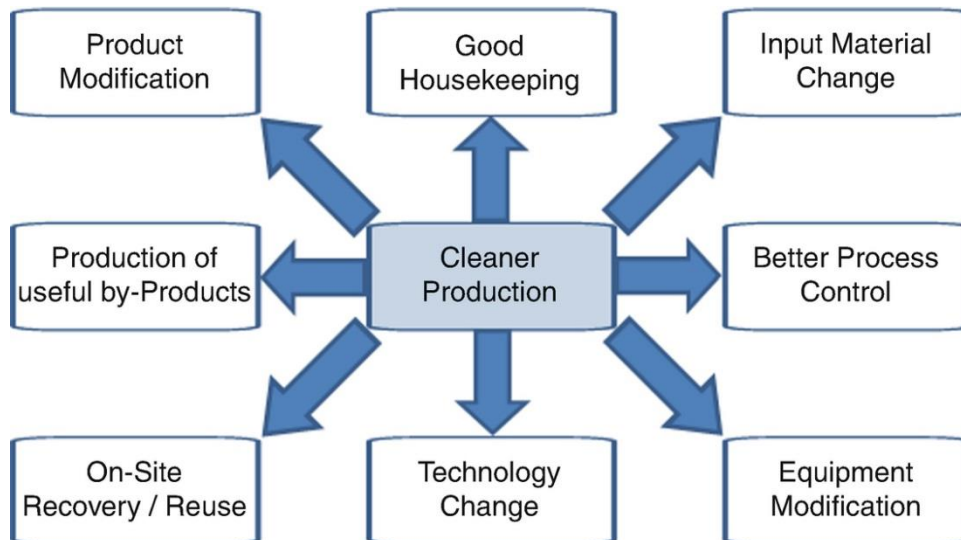


Figure 2. 1: Concept of CP (Duflou J., Kellens K. 2014)

Based on a research by L. Hens et al. (2018), they stated that Cleaner Production is about the quantity of the better use of valuable energy and materials or substances and the substitution of numerous harmful products to the environment and human healthiness by low dangerous products. Moreover, according to Nafis Khuriyati et al. (2015), CP implementation is accomplished through minimizing the use of resources and useful energy, recycling any possible material, and reducing various kind of emission and wastes. However, in considering to all environmental problem, CP is not the solution that could settle them all, but it helps less harmful wastes generated and most importantly it reduces the dependence on end of pipe solutions which is widely used nowadays.

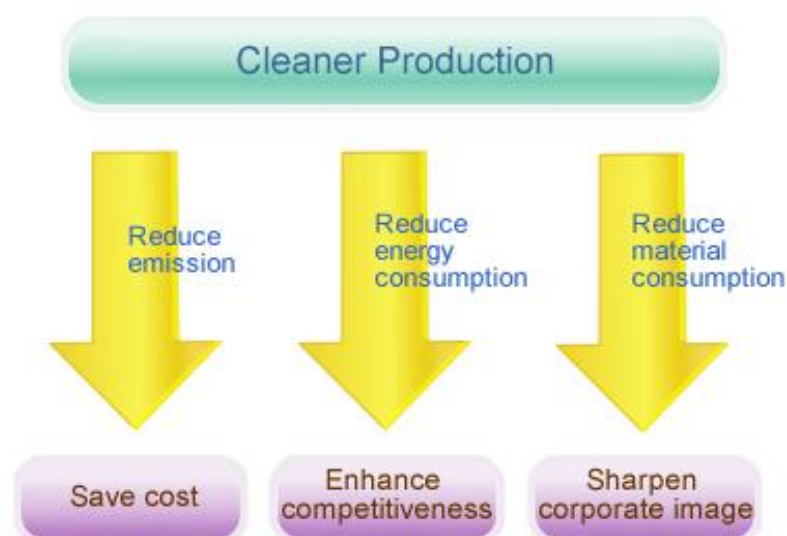


Figure 2. 2: Benefits of Cleaner Production by World Environmental Services Pakistan.

The feasible techniques of cleaner production which includes changes in technology, input materials, operating practices, product design, waste usage and maintenance activities have provided numerous advantages to industrial sector mainly manufacturing industry. As referring to Basappaji K Ma and N Nagesha (2014), they mentioned that products output that are redesigned and reproduced with CP techniques as main strategy are less dangerous or harmful for consumers to use, and their leftover output are usually not give too much negative impact to waste disposal activities. Another positive outcome stated by Jeniffer Gracia et al. (2018), by performing the cleaner production program developed for a medium-sized rubber soles manufacturing company, Mezcauchos S.A.S, in order to give an optimal solution to the environmental problems, the company have gained the precious profitable alternatives and mechanism to enhance the quality of the industrial environment.

In acquiring the benefits of CP to industry, environment and mankind, this preventive strategy and implementation techniques should be highlighted. There are a few main steps to apply CP to a particular industry. They include identifying the input of consumption and source of emission in the plant, applying CP inspecting methodology, quantifying waste or emission generated, proposing possible CP options and finally, evaluating the economic and environment impact corresponding to the chosen CP options (Razuana Rahim and Abdul Aziz Abdul Raman 2017). In addition, as stated by M Sirait (2018), the method of CP is mainly involving five steps which are planning and organizing, qualitative review, quantitative review, feasibility analysis, and implementation and continuation.

In implementing the cleaner production strategy to a particular organization especially in manufacturing industry, there exists various constraints that appear behind the success of the implementation. Based on a study on implementing cleaner production in Zambia by Levy Siaminwe et al. (2005), they stated that the main constraints that obstructed the implementation of cleaner production in the industry were identified based on a direct observations and consultations. From the thorough consultation and observation, financial issues, environmental laws with poor enforcement, lack of knowledge to the implementation strategy, awareness and the most obvious issue was lack of technical manpower. Besides, they also identify comprehensively about the potential constraints in most of industries which include lack of environmental standards, low of realization the importance of cleaner production, limited knowledge of production and economic advantages of applying cleaner production strategy, and insufficient organizational arrangements for promoting the implementation of cleaner production. In addition, from a research in Small Medium

Enterprises (SMEs) of batik industry in Indonesia, the barriers that affect the limitation of implementing cleaner production are lack of awareness of the jeopardy of hazardous and chemicals wastes and narrow-minded thinking of awareness of the economic and environmental advantages (Darminto Pujotomo). However, all these constraints can be eliminated by proper introduction of cleaner production concept, organized training, proper implementation of wastewater and solid waste treatment plan, and scheduled wastes level checking.

2.2 Energy Consumption and Carbon Emission Relations

Technically, in order to produce energy, energy is needed. From a recent research, 8 % of carbon emissions are produced by collecting, processing, and delivery of fossil fuels. Meanwhile, 20 % of global carbon emissions were caused by the production of cement, steel, automobiles, and other manufactured products. However, the use of electrical and heat energy seems become the main contributor to the global carbon emission in many years. According to Rida Waheed et al. (2019), the main culprit for carbon emission have been reported and they are due to higher energy consumption in both developing and developed countries. To protect the global effect from this issue, the non-renewable energy sources need to be replaced by the governments and industries with renewable sources to generate electrical energy, run the industrial activities and for transportation aspect. In fact, most of developed country are directly affected by this issue. According to a research in China, energy consumption significantly contributed carbon emissions direct and indirectly in the three regions. As the consequence, the impact in the western region was significant with the highest amount of carbon emission (Haitao Wu et al. 2020).

In pursuing globalization era, with the rapid growth of manufacturing industry production, the amount of CO₂ emissions per kWh is also instantly rising as the consumption of electricity is going high. This trend also goes for household that use electrical energy in their daily life. Based on a research by Vishnu Bajpai et al. (2012), residential carbon dioxide emissions are usually generated by the energy consumption in various activities such as heating, cooking, hot water etc. Thus, restoration of energy and minimization in emissions require the proper implementation of low-carbon economic development and most importantly the changes in energy consumption behavior by the household in a particular residential. Besides, in a study of plastic resin manufacturing plant by Razuana Rahim et al.

(2017), high CO₂ emission is directly come from high energy consumption. Normally, CO₂ generated from a plastic production industry is contributed by electricity consumption and other additional activities, which involve heating, cooling, chilling, drying, granulating and other related processes.

Moreover, global demand for various kind of energy is predicted to rise in the coming years. This followed with higher electricity demand that is considered as the main reason for more than half of the growth in energy required. Increasing in new power plant generation for industrial uses also become the factor that enhance the growth in carbon emission percentage. High electrical demand usually for the purpose of uses in industry such as power for running industrial machinery, equipment for facility include heating, cooling, ventilation, lights, computers, and office equipment. Therefore, reducing and controlling the rise of energy needs seems very crucial as it effect the growth of global carbon emission. According to a last year research in in an iron & steel sector with the objective to control industrial energy demand and carbon dioxide emissions, a blast furnace that used in production process is the largest energy user and consequently is a priority target to propose alternative for energy demand reduction (Paul W.Griffina, 2019). Besides, based on a study in energy supply in the plastics industry, one of the methods to reduce the energy demand and rise the energy efficiency in the industry is to combine intelligent linkage of the consumer of energy, energy distribution, storage, and how it is supplied (HeikoDunkelberg, 2018).

2.3 Feasibility of Cleaner Production Approach Towards Sustainable Development Goals

Sustainable development is an idea that initially created by Brundtland Report in 1987 that encourages human societies to live and meet their needs without affecting the ability of future human life to meet their needs. Precisely, sustainable development is defined as a way of ensuring the long term exist of a society by organizing them strategically. This means it must be considered for both the present and upcoming generation in terms of preservation of the natural source, environment health and social and economic fairness. This definition is in parallel ways to the cleaner production approach which to minimize the utilization of production resource and minimize the environmental impact by a particular industry. Hence, it seems has a robust potential to confirm and help the achievement of sustainable development goals as it contributes in various ways in chasing the targets.

Cleaner production implementation contributes to a success of sustainable development through the development of new and smart technologies, efficient management of resources and energy, providing alternatives of assisting the development of policies, and organizing sectors, supply chains and companies' activity (B.F. Giannetti, 2020). Besides, by introducing proper knowledge and discussions for identifying and highlighting the ways cleaner production, sustainable development goal can be seen its path through the growth of present and future industry. Cleaner production is also showing its potential as a practical approach of moving towards sustainable development by ensuring industries and service providers to enhance their production with less raw materials and energy consumption, low solid and gas waste emissions, and most importantly, much better sustainability and low environmental impact (A. Basel Al-Yousfi, 2004). Therefore, cleaner production has been applied widely to develop more environmentally friendly and efficient development processes, services, products, and reducing its impacts.

According to United Nation (UN) in September 2015 when sustainable development goals were initially introduced, there are 17 SDG which include no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water, and sanitation etc. Cleaner production has contributed various benefits to each of the SDG in terms of their specification and relation to the environment. For example, related to SDG 6, a proper decision-making system was introduced to evaluate and propose the productivity of the drinking water treatment flow sustainability (Garcia-Caceres, 2019). In the research, the support system uses a mathematical and statistical programming model and an advanced solution to increase the profit and reduce the emission of various kinds of wastes. Moreover, from a research related to SDG 11, in order to combine public resources, human and social capitals, and information or communication technologies to encourage sustainable development, the researcher introduced a smart city as a best and efficient solution (Guimarães, 2019). From the perspective of smart cities, they analyzed and evaluated the guidance of smart governance on the life quality in the city. A survey was conducted to 829 residents of a Brazilian city, and the data were analyzed by using structural equation modeling method and multivariate data techniques.

In addition, cleaner production approach also emphasizes the achievements of multiple sustainable development targets which is not only focus on a particular or single SDG. In chasing the UN agenda, some of the experienced researchers are committed to explore and find the methods to achieve multiple SDGs or to control actions and strategies toward

multiple goals. In preserving the environmental impact from industrial activity, lowering waste generation, recycling, and reuse is very essential. To reach these targets, landfill mining was implemented as an effective plan that can surely contribute multiple sustainability development goals (Márquez, 2019). Based on the authors, they had explored and study numerous projects in the world comprehensively. They also stated that according to their relation to a related SDG, economy, social and environmental benefits could be classified. Therefore, the results of landfill mining can approximately fulfill at least 11 of the 17 SDGs and it is a must do project that needs to be seen by government or other sustainability organization as a great potential to enhance the environmental quality.