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Analysis of energy-based carbon emission from landside operations of container terminal and its abatement strategies

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ANALYSIS OF ENERGY-BASED CARBON EMISSION FROM LANDSIDE OPERATION OF CONTAINER TERMINAL AND ITS ABATEMENT STRATEGIES

(CASE STUDY : BERLIAN CONTAINER TERMINAL, TANJUNG PERAK PORT, INDONESIA)

By

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A research paper submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The content of this dissertation reflect my own views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation : ***Analysis of Energy-Based Carbon Emission from Landside Operation of Container Terminal and Its Abatement Strategies. (Case Study : Berlian Terminal, Tanjung Perak Port, Indonesia)***

Degree : ***MSc in International Transport and Logistics***

Recently, global warming and climate change are the most significant issues in societies. United Nation – Intergovernmental Panel for Climate Change (UN-IPCC) identified that the main contributor of climate change is greenhouse gases such as CO_2, NH_4, aerosol, etc. The use of energy for human activities is considered as the biggest source of greenhouse gases. Because of that, container terminal as a one place which also need a huge amount of energy for its operation is expected to contribute in reducing CO_2 emission from its operation.

This research is focused to calculate the production of CO_2 emission from the use of diesel oil by cargo handling equipments in Berlian Terminal in 2013. Furthermore, forecasting of diesel demand and CO_2 emission in the future are conducted to give an insight to terminal management about fuel-cost expense which will be borne and CO_2 emission which will be emitted.

Electrification program which have been implemented by Berlian Terminal on 2 (two) units of Harbor Mobile Cranes in 2014 is analysed from the perspective of energy-cost saving and CO_2 emission. In addition, challenges / threats which limit the possibility of terminal management to continue the program of electrification are also explained. The use of biodiesel and LNG in Berlian Terminal are simulated and then followed by a comparative analysis between the use of diesel oil and biodiesel and LNG, in order to determine the appropriate alternative energy-source which can be used to substitute the use of diesel oil in Berlian Terminal. Comparison is conducted from the view of fuel-cost and CO_2 emission.

Trendline forecasting model and single regression model are used to calculate container throughput and diesel demand, while emission calculation formula tier 1 from United Nation - Intergovernmental Panel on Climate Change (UN-IPCC 2006) is used to estimate CO_2 emission.

Keywords : Cargo handling equipments, CO_2 emission, diesel demand, trendline forecasting model, single regression forecasting model, UN-IPCC 2006, biodiesel, LNG.

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LIST OF ABBREVIATIONS

CHEs	Cargo Handling Equipments
CY	Container Yard
GHG	Green House Gases
HMCs	Harbor Mobile Cranes
LNG	Liquid Natural Gas
RTGC	Rubber Tyred Gantry Cranes
UN - IPCC	United Nation - Intergovernmental Panel on Climate Change

CHAPTER 1
INTRODUCTION

1.1 Background

Recently, GHG emissions and climate change are becoming hot issue in global society. GHG emissions are believed as the cause of climate change. The Intergovernmental Panel on Climate Change (2007) noted that climate change has caused increase in global average air and ocean temperatures, widespread melting of snow and ice, extreme weather, and rising global average sea level. Global surface temperature increase by 0.74 ± 0.18 °C over the last 100 years. The IPCC has also concluded that the increase of global temperature is due to an increased concentration of GHG resulting from human activities. Global GHG emission from human activities have risen by 70% between 1970 and 2004, and CO_2 is the most important emission element which has grown by about 80%, from 21 to 38 gigatonnes (Gt).

International Energy Agency (2013) explains that among many human activities which produce GHG emission, the use of energy is the largest source of emission which takes approximately 83% of global GHG emissions. However, demand of energy will always increase due to the rapid development and global economic growth. Global total primary energy supply (TPES) was more than doubled between 1971 and 2011, mainly depending on fossil fuel. Despite the growth of non-fossil energy (such as nuclear, wind, and hydropower), the share of fossil fuels within the world energy supply is relatively unchanged over the past 40 years. In 2011, fossil sources accounted for 82% of the global TPES. Growing of world energy demand from fossil fuels plays a key role in the upward trend in GHG emission.

Due to the wake of energy shortages, higher energy cost, and increasing of GHG emission, pressure on governments and industries to take energy efficiency strategies and to come forward with (more) climate-friendly strategies is increasing. This new challenge requires new approaches that include a reconsideration of existing production and consumption processes, new policy initiatives and instruments, new data, and new supportive research activities (Geerling, et al., 2010).

Transportation sector is also expected to involve in the action of CO_2 emission reduction. It is because transportation sector yield for about 23 per cent of global CO_2 emission in 2010 (World Energy Council, 2011). In particular, maritime transport industry contributes for between 1.4 per cent and 4.5 per cent (IAPH, 2013). This percentage is believed to increase significantly in the future due to the rapid growth of maritime industries. Among maritime industries, container sector has been the fastest-growing market segment accounting for over 16 per cent of global seaborne trade by volume in 2012 (UNCTAD, 2012). As the gateway for container transport, container terminal operations are also a major source of air pollution, which emitted from ocean-going vessel (OGVs), harbor craft, cargo handling equipment, and port-inland transportation activities (locomotive and heavy-duty vehicle).

This research will be focused on the analysis of CO_2 emission emitted from the usage of energy in container terminal, especially from the operation of cargo handling equipments. Moreover, existing reduction strategies will be analyzed and further, new potential strategies will be analyzed. This research will take Tanjung Perak Port in Indonesia as an object study. Tanjung Perak Port plays significant role as a hub port for east region of Indonesia. Tanjung Perak Port has six terminal, which one of them is Berlian Terminal. Berlian Terminal is focused to serve either domestic or international container flow. The growth of container flow in Berlian Terminal can be seen in figure 1.1

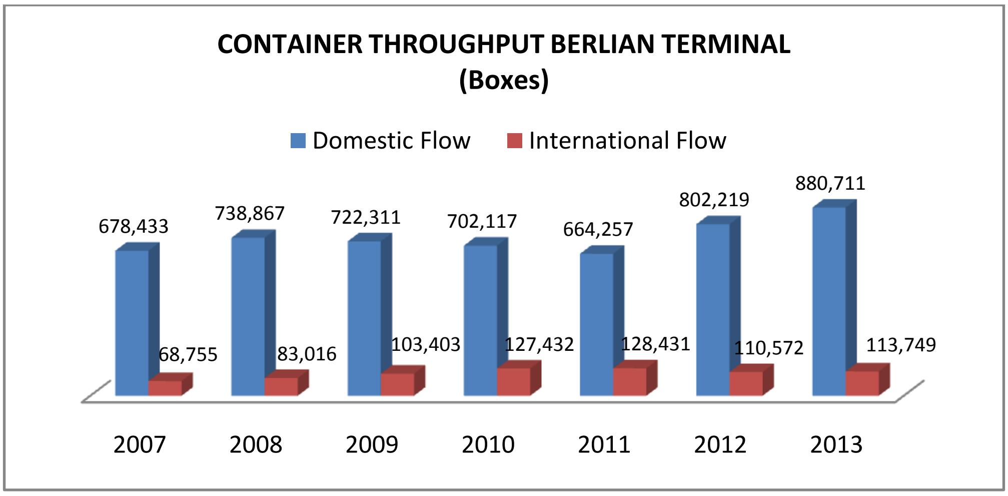

Figure 1.1 Container Throughput of Berlian Terminal

Source : Tanjung Perak Port Authority (2013)

As can be seen in figure 1.1, container flow in Berlian Terminal is increase year to year. In line with this condition, the number of cargo handling equipments and operation hours will also rise. It will lead to the huge demand of energy which further release big number of CO_2 emission. All of these situations and conditions are become the background for conducting this research..

1.2 Research Problem

In recent time, many of terminal managements still giving their attention on how to improve their productivity. A lot of efforts have been done such as by assigning more cargo handling equipments, land expansion, or non-stop terminal operation. Non-stop operation from big number of cargo handling equipments, of course, will need huge amount of energy. Generally, cargo handling equipments at container terminal still rely on fossil fuel such as diesel-fuel as energy source. Consumption of vast amount of energy will result in high operating cost and tremendous CO_2 emission.

In the era of green economy at present day, terminal management can not only focus on productivity, but is also expected to contribute to the environment and society. Contributions can be done by reducing CO_2 emission from its operation. Identification of energy consumption, followed by calculation of CO_2 emission can be conducted as the first step. Furthermore, forecasting of energy consumption and CO_2 emission in the future can give an insight to the terminal management on the amount of cost expense will be borne and the number of CO_2 released from its operation. Based on these identifications and insights, terminal management can arrange some reduction strategies. Many of abatement strategies have been developed in recent years and it gives many choices to terminal management. However, before deciding to implement some strategies, port management should consider many aspects, such as technical analysis, economic benefit, effectiveness in emission reduction, ease of implementation, etc. Moreover, abatement strategies should also correspond to the national energy and emission policies.

Berlian Terminal is one of the bussiest container terminal in Tanjung Perak Port which motivated to reduce CO_2 emission from its operation. Nowadays, most of cargo-handling equipments in Berlian Terminal still use diesel oil as energy source, therefore reduction strategies which will be taken are expected to not only decrease CO_2 emission but also can reduce operating cost from the use of diesel oil. At the end of 2013, Berlian Terminal has adopted electrification of Harbor Mobile Cranes as a pilot project for reducing emission. This strategy was tried on 2 (two) Harbor Mobile Crane and these electrified HMCs began to operate in 2014 . This research paper attempts to analyse and predict CO_2 emission from the use of energy in Berlian Terminal. Moreover, it will also analyse the electrification of Harbor Mobile Crane which is taken by terminal management. Afterward, potential alternative energy-source which are available will be analysed in order to select and propose the most reliable alternative energy-sources from the perspective of fuel-cost expense and CO_2 emission.

1.3 Research Purposes and Contributions

The purposes of the research about carbon emission in Berlian Terminal, Tanjung Perak Port are :

a. Identify cargo handling equipments and its energy consumption.
b. Estimating the number of CO_2 emission which is emitted from the operation of cargo handling equipments.
c. Forecasting future needs of diesel oil and CO_2 emission.
d. Identify energy consumption and the number of CO_2 emission per container throughput.
e. Gives an overview about diesel-cost expense which will be borne by terminal management if there is no energy saving program taken.
f. Analyse electrification of Harbor Mobile Cranes (HMCs) as a pilot project of emission abatement strategies from the perspective of energy-cost saving and emission reduction, together with its challenges/threads.
g. Simulate the use of biodiesel and LNG in Berlian Terminal as an alternative energy-sources, to determine its potential in substituting diesel oil.
h. Propose an appropriate strategies which can be taken from the perspective of energy-cost expense and CO_2 emission.

At current time, none of CO_2 emission identification is conducted in Tanjung Perak Port. Therefore, Tanjung Perak Port management can use this study as a reference in conducting inventory of CO_2 emission based on the energy consumption. Moreover, it can also be used as a reference to analyse its existing reduction policy and further, can take new potential abatement strategies which is appropriate with the port policies and condition.

1.4 Research Limitation

Due to the limitation of time and data, this research will be conducted under several limitation. Those limitation are :

a. The object study is Berlian Container Terminal in Tanjung Perak Port, Surabaya, East-Java Province, Indonesia.
b. Identification of energy consumption and calculation of CO_2 emission are only conducted for cargo handling equipments operation in 2013.
c. Forecasting of energy consumption and CO_2 emission will be performed for year 2014 – 2016 in montly basis.
d. Forecasting of energy consumption will be only conducted for diesel oil consumption.
e. Analysis of HMCs electrification, simulation of biodiesel and simulation of LNG are limited on cost benefit analysis and emission reduction.

1.5 Structure of Research Paper

This research paper is structured as follows :

Chapter 1 is an introduction which explains the background of the study, research problems, the expected contributions, problem limitations and structure of the research.

Chapter 2 is a literature review which contains of supporting theories which will be used as conceptual basis of the research. The theories consist of container terminal operation, GHG emission, emission abatement strategies, and also the concept of forecasting methods.

Chapter 3 is research methodology which presents detail explanation about the phases which will be done in the research, including data collection methods and data analysis methods.

Chapter 4 is analysis of Berlian Terminal operation which will overview the profile of Berlian Terminal, continued by the explanation of Berlian Terminal Operation, from its cargo handling equipments, container throughput, energy consumption, and its current carbon emission in terminal.

Chapter 5 is analysis of energy-based carbon emission which contains the calculation of CO_2 emission from the use of diesel by cargo handling equipments in 2013, and further followed by estimation of future needs of diesel oil and CO_2 emission.

Chapter 6 is analysis of emission abatement strategies which will explain about national and port management policies on emission, followed by the analysis of HMCs electrification which had been taken by terminal management as a pilot project at the end of 2013. Furthermore, biodiesel and LNG will be simulated and analyzed as an elternative energy-source, and later a comparative analysis will be done to know the appropriate alternative energy-source from the view of energy-cost saving and emission reduction.

Chapter 7 is conclusion and recommendation which presents some conclusions which can be drawn from this research and some recommendation for Berlian Terminal management.

CHAPTER 2
LITERATURE REVIEW

This chapter will present some literatures about container terminal operation, GHG emission, and also some overview of current energy and GHG emission abatement technologies. Other related previous researches about container terminal operation, GHG emission and also abatement strategies will also be used as a reference.

2.1 Container Terminal

2.1.1 Container Terminal Operation

Vacca, et al. (2007) described that a container terminal is a zone of the port where sea-freight dock on a berth and containers are loaded, unloaded and stored in a buffer area called yard. Vacca, et al. (2007), Steenken, et al. (2004), and Zhang, et al. (2003) devided container terminal into two main areas, the quayside and the yard / landside. Zhang, et al (2003) noted that the quayside is the area where vessel are berthed. Quay crane (QCs) discharge inbound (I/B) and transit containers from and load out-bound (O/B) and transit containers to vessels. The storage yard is typically made up of blocks of containers.

Meanwhile, Brinkmann (2011) devided container terminal into at least three operational area, operational area between quay wall and container yard (apron or the area just behind the berth front), container yard (terminal storage = stacking area), and terminal area of landside operations (including the gate, parking, office buildings, customs facilities, container freight station with an area for stuffing and stripping, empty container storage, container maintenance and repair area, etc.). Figure 2.1 shows the schematic lay out of container terminal.

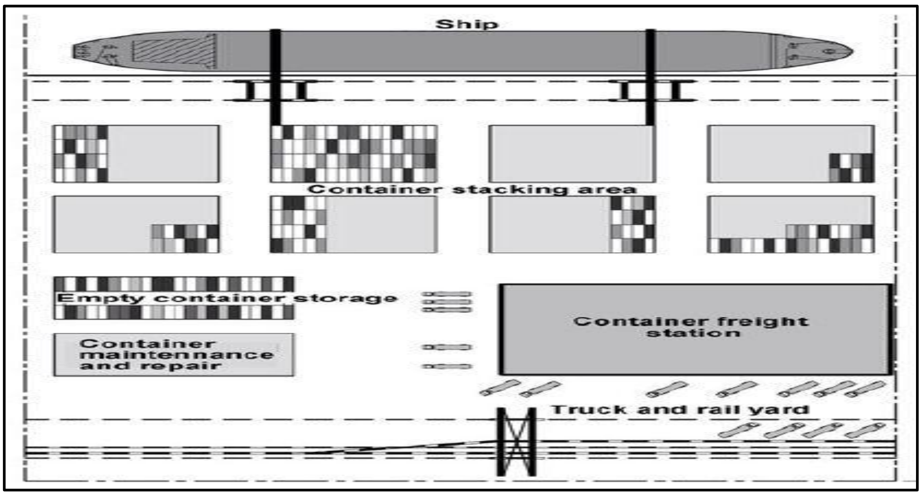

Figure 2.1 General Lay Out of Container Terminal

Source : Brinkmann (2011)

Kim, et al. (2012) described there are three types of handling operations. First is ship operations associated with containerships. During this operations, the containers are unloaded from a vessel by using a quay crane (QC) and moved to the yard by using a transporter (yard truck, straddle carrier, or automated guided vehicle). They are then located into a storage yard by a yard crane (YC). Second is hinterland operations, where the containers are delivered to a gate by over-the-road trucks and are inspected to check for damage. Beside that, all the documents are also checked. Third operation is yard operations involving the storage or retrieval of containers in the yard. Operation in this step includes remarshaling, which involves changing the positions of containers and managing empty containers. During the loading operation, containers are handled in the reverse direction. Figure 2.2 presents operation in container terminal.

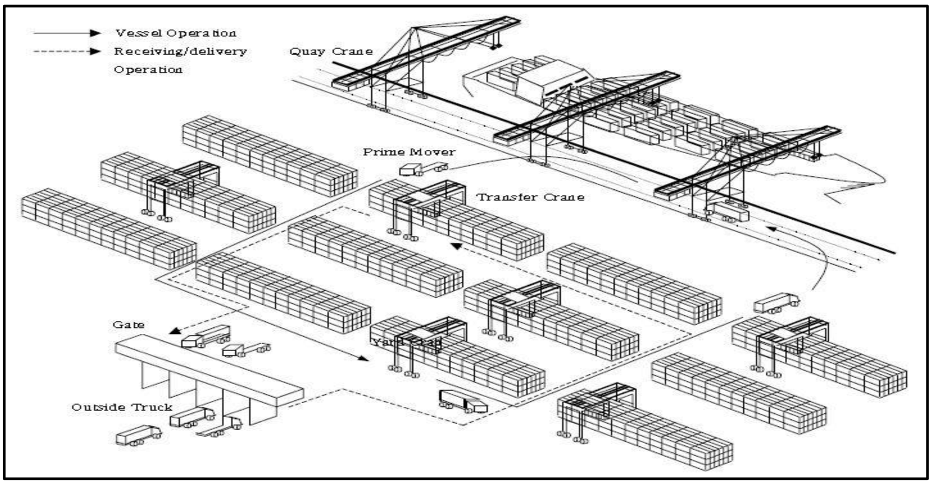

Figure 2.2 Operation in Container Terminal

Source : Park (2003)

2.1.2 Cargo Handling Equipment (CHE) and Energy Consumption

Kim, et al. (2012) noted that operations of container terminal involves numerous pieces of handling equipment. A container has to go through numerous handling steps after it enters a terminal until it loaded onto vessel or exit gate. Figure 2.3 shows process of unloading and loading of a ship.

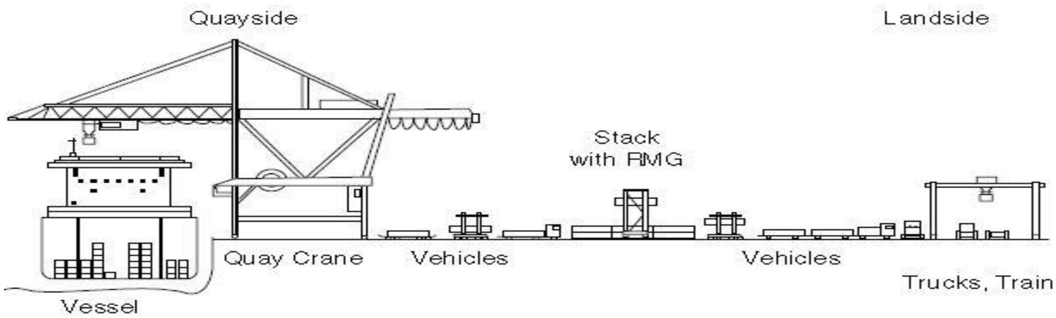

Figure 2.3 Process of Unloading and Loading of a Ship

Source : Steenken, et al. (2004)

CHEs are devided into three sectors, quay crane, horizontal transport, and stacking equipment. Common equipments for quay crane are gantry crane and mobile crane. Horizontal transports consist of straddle carriers (SC), AGV, reach stackers, and chassis. While stacking equipments include RTG (Rubber Tired Gantry), RMG (Rail Mounted Gantry), and OHBC (Over Head Bridge Cranes).

Picture 2.4 shows common ship to shore crane and Picture 2.5 presents common in yard cargo handling equipment.

Figure 2.4 Ship-to-Shore Crane

Source : Morais and Lord (2006)

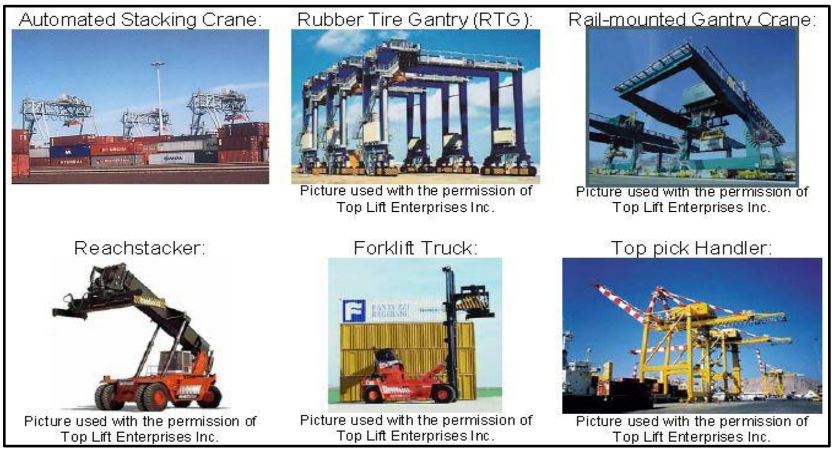

Figure 2.5 Common-in-Yard Cargo Handling Equipments

Source : Morais and Lord (2006)

Whitaker, et al (2003) described much researches and discussions are needed in choosing the equipment to handle containers. There is no single system can be applicable to every terminal and situation. There are various methods of handling containers using different types of equipment. Geerlings and Duin (2010) explained the type of equipment and the operation of equipment determine the energy consumption, and consequently the amount of emission.

Conventionally, CHEs are powered by internal combustion engines that are powered by diesel-fuel engines. Therefore, CHEs are often considered to be one of the most significant sources of air pollution caused by terminal operations

(Vujicic, et al (2013). However, at current times, there are also big number of CHEs which powered by alternative fuels / energy sources such as biofuel, LNG, and electrically-powered engine.

At the port industry, consumption of fuel is one of the most expensive resources, along with maintenance, tyres and IT system. The total fuel consumption cost is between 15% and 25% of the total cost operations, and any variability of fuel will bring financial benefits in operations and transport (Rentokil Initial, 2006). In order to reduce operating costs, strengthen business competitiveness, and mitigate environmental pollution, container terminal operators should formulate appropriate strategies to achieve the goal of energy efficiency and reduced carbon emissions (Yang and Chang, 2013).

2.2 GHG Emissions

2.2.1 Scope of GHG Emissions

IPCC (2007) described that greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wave-length within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by cloud. United Nation (1998) in Kyoto Protocol dealt that greenhouse gases contains six emissions, which are Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6).

Some explanations about 6 main GHG emissions (based on Kyoto Protocol) are :

1. Carbon dioxide (CO_2)
   Reay, D. (2013) explained that Carbon dioxide is a colorless, odorless gas at atmospheric pressure and temperature, and it exists naturally as a trace gas in the Earth's atmosphere. CO_2 enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (.e.g., manufacture of cement) (EPA, 2013). European commission (2011) noted that since 1800, the concentration of CO_2 have risen by about 30% as massive amounts of fossil

fuels are burned to produce energy, mostly in developed countries. Currently, more than 25 billion tones of CO_2 are emitting into the atmosphere each year.

2. Methane (CH_4)

   Methane is the principal component of natural gas (Reay D., 2003). Methane is the second - most abundant and emitted from a number of sources. The most significant are agriculture (both animal digestive systems and manure management); landfills; oil and gas production, refining, and distribution; and coal mining. Methane traps heat in the atmosphere and is 23 times more effective at than that CO_2. However, its lifetime is shorter, between 10 and 15 years (European commission, 2011).

3. Nitrous Oxide (N_2O)

   Nitrous oxide is produced during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste (EPA, 2013). N_2O is 310 times more effective than CO_2 absorbing heat. Concentration of nitrous oxide in the atmosphere have increased by approximately 16 per cent and contributed 4 to 6 per cent to the enhancement of the greenhouse effect since the beginning of the industrial revolution (European Commissin, 2011).

4. Fluorinated greenhouse gases

   Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and Sulphur Hexafluoride (SF_6) are included to fluorinated greenhouse gases. There are produced by man for industrial purposes. For example, Hydrofluorocarbons (HFCs) which are used in cooling and refrigeration, including air conditioning. Sulphur Hexafluoride (SF6) is used, for example, in the electronic industry, and Perfluorocarbons (PFCs) are produced during the manufacture of aluminium and also used in the electronic industry (European Commission, 2011).

2.2.2 Impact of GHG Emissions to Global Warming

EPA (2013) explained that impact of GHG emission depends on three main factors. There are concentration of GHG emission in the atmosphere, how long GHG emission stay in the atmosphere, and how strongly it impact global temperatures. Uherek, E. (2008) noted that the impact of a particular greenhouse gas on global warming depends not only on its concentration, but also on how efficiently it can trap infra-red radiation. Therefore, the concept of Global Warming Potential (GWPs) was then developed.

Gillenwater (2010) noted that Global Warming Potential (GWPs) are a quantified measure of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. Carbon dioxide (CO_2) was chosen as the reference gas (GWP = 1). Gases with a higher GWP absorb more energy, per pound, than gases with lower GWP, and thus contribute more to warming Earth (EPA, 2013). Table 2.1 shows some of the GWPs value of the most important greenhouse gases.

Table 2.1 GWP Value of The Most Important Greenhouses Gases

Greenhouses Gases	**Lifetime (Year)**	**GWP 100 Year**
Carbon dioxide	variable	1
Methane	12	25
Nitrous oxide	114	298

Source : IPCC AR4, 2007

According to table 2.1, it is clearly showed that Nitrous Oxide has the highest GWP, which means that this gas is approximately 298 times more heat-absorptive than Carbon Dioxide per unit of weight. While, Methane absorb heat by 25 times more than Carbon Dioxide. The atmospheric lifetime of Nitrous Oxide is also longer than the other gases.

2.2.3 Emission Factor

Emission factor is the average amount of a specific emission released into the athmosphere by a certain activities. It can be expressed in the weight of the pollutant per unit of volume or weight of the source substance, or per unit of distance or time associated with the activity (Steenwijk, 2011). Port of Immingham (2010) explained that emission factors are standard values that express the mass of emissions in term of a unit of activity.

According to Zadek & Schulz (2010), there are two common type of emission factors to calculate CO_2 emission for mobile combustion sources :

- Fuel – based : Kg CO_2 / litre
- Distance – based : Kg CO_2 / km

The latter type is often adapted to include the cargo quantity, in which case also called activity – based :

- Distance – based (alternative) : Kg CO_2 / quantity * km, with quantity as e.g. weight in ton kgs.

However, some institution such as IPCC and Environmental Protection Agency (EPA) has provided default value of emission factors for general use.

2.2.4 IPCC Methodology for Emission Calculation

Theoretically, there are two different approaches to calculate GHG emission, sectoral approach and reference approach. Sectoral approach is known as bottom-up approach, while reference approach is known as top-down approach. In sectoral approach, calculation of emission is conducted according to the sectoral of activity, such as energy production, manufacturing, transportation, etc. It calculates emission from fuel combustion in each sector and fugitive emission. While in reference approach, emission is calculated based on the consumption of fuel, ignoring the sectoral where the fuel are consumed (Ministry of Environmental Republic of Indonesia, 2012).

The Intergovernmental Panel on Climate Change (IPCC) is a body established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). Its goal is to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences. In 2006, IPCC had released The 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The methodology provides a calculation method for all sectors causing emissions (Vaccari and Vitali, 2011).

Based on the IPCC (2006), emission from mobile-combustion can be calculated in three tiers, as follow :

Tier 1 : emission calculation is conducted based on activity data and default emission factor released by IPCC

Tier 2 : based on more accurate activity dta and IPCC's default emission factor or country / plant specific emission factor

Tier 3 : calculation is conducted based on country specific method with more accurate activity data (direct calculation) and country / plant specific emission factor

The equation formula are :

Tier 1 :

$$\text{Emission} = \Sigma_a \left[\text{Fuel}_a \times \text{EF}_a\right] \quad (1)$$

Tier 2 :

$$\text{Emission} = \Sigma_{a,b,c} \left[\text{Fuel}_{a,b,c} \times \text{EF}_{a,b,c}\right] \quad (2)$$

Tier 3 :

$$\text{Emission} = \Sigma_{a,b,c,d} \left[\text{Distance}_{a,b,c,d} \times \text{EF}_{a,b,c,d}\right] + \Sigma_{a,b,c,d}\, C_{a,b,c,d} \quad (3)$$

Where :

Emission : Emission (Kg)

Fuel_a : Fuel Consumption (TJ)

EF_a : Emission factor (Kg/TJ)

a : Type of fuel (e.g. petrol, diesel, natural gas, LPG, etc.)

b : Vehicle type

c : Emission control technology (such as catalytic converter, etc.)

d : Operating conditions (e.g., urban or rural road type, climate, or other environmental factors)

The IPCC Guidelines methodology is internationally accepted as the basis for inventory development. In particular, IPCC also provides default values of the various parameters and emission factors, so that, at its simplest, a country only needs to supply national activity data (Jiang, et al, 2012).

2.2.5 GHG Emissions from Port Activities

Port activities are the source of huge amount of GHG emissions. Emissions come from ocean-going vessel (OGVs), harbor craft, cargo handling equipments, and port-inland transportation activities. IAPH (2013) described that the emission sources which are directly controlled by port authority are an even smaller fraction of overall port-related emissions, which also include emission sources under control of port tenants (i.e., ships, harbor craft, trucks, rail, and cargo handling equipment). GHG emissions for port are often categorized in term of “scopes” that indicate how directly (or indirectly) the emissions are generated. Such categorization is a common element of emissions models and different protocols may define the boundaries of the scopes in a variety of ways. Figure 2.6 illustrates scopes of port operation related to GHG emissions.

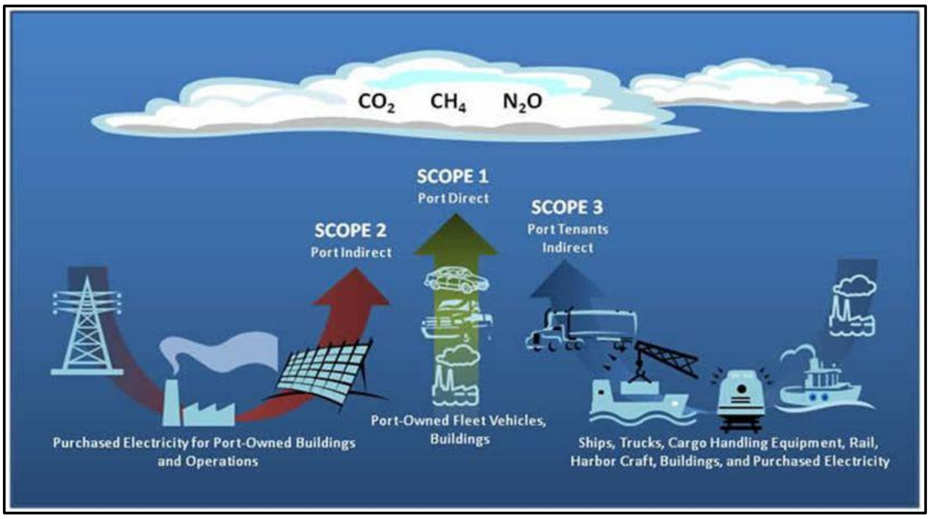

Figure 2.6 Scopes of Port Operation Related to GHG Emissions

Source : IAPH (2013)

Scope 1 and 2 emission categories will likely represent a very small fraction of the port’s overall emissions, while Scope 3 emissions will likely account for the vast majority of the port-wide emissions. However, GHG emission reductions from all port-related sources are necessary to minimize the overall impact of the port-related operations on climate change.

There are several studies and researches which have already conducted to assess emissions emitted from port activities. Some researchers focused on the operation of container handling equipments, such as Yang and Lin (2013) which analysed the performance of cargo handling equipment from a green container terminal perpective. They compare the performance of four types of cargo handling equipment used in container yards (automatic rail, rail, electric tire, and tire transtainer) from the view of working efficiency, energy saving, and carbon reduction performances.

Geerlings and Duin (2010) assessed CO_2-footprints of container handling equipments in Netherland's container terminal. Their study provides insight into the processes of container handling and transshipment at the terminals and calculates the contribution of the processes to the CO_2 emission. Yang and Chang (2013) compared the performance of Rubber Tired Gantry (RTGs) and electric-Rubber Tired Gantry (e-RTG) from the perspective of energy saving and CO_2 reduction.

Moreover, many researchers also tried to assess and explain air emission from either OGVs (Ocean Going Vessels) or inland transportation. There are Khan (2013), Wines (2010), Wahab (2009), Ho (2013), Medin & Mo (2005), Liao, et al (2009), Jiang et al. (2013). Although port related emission inventories are still relatively new, there are several ports in the world which are already conducted air emission inventory from their operations. The report of inventory are also published, and therefore can also be used as a reference. Emission inventories are already conducted by The Port of San Diego for emissions year 2006, South Carolina Port for year 2011, Port of Immingham for emission year 2008.

2.3 Energy and GHG Emissions Abatement Technologies

Strategies and methodologies to reduce energy consumption and emission already have been developed by experts in recent years. There are many either researchers or institutions who focusing their study on the assessment of energy and emission abatement strategies.

BP Australia Limited (2005) briefly outlined current strategies for reducing diesel engine exhaust emissions as summarized in the table 2.2 below :

Table 2.2 Reducing Strategies for Diesel Engine Exhaust Emission

Emission	Reduction
Carbon dioxide	- Substitute with biodiesel - Substitute with ethanol at 10 % - Substitute with gas - Engine modification to reduce fuel consumption
NOx	- PuriNOX - Exhaust gas recirculation - DeNOX Catalyst
HC and CO particulate matter	- Refining to reduce density, distillation and sulphur and to increase cetane number - Fuel substitution - Engine maintenance

Source : BP Australia Limited (2005)

Geerling and Duin (2010) proposed and analyzed three reduction strategies, with the case of Rotterdam Port. They proposed the adaptation of the terminal layout, replacement of obsolete equipment with new electric-equipment, and to use alternative fuels (mixing of 30 per cent bio fuel with the presently used diesel). Corzo (2012) analyzed the sustainable reduction of CO_2 emissions as well as particle and NO_2 emissions by using LNG (liquefied methane and bio methane) for the Danube inland navigation.

Yang and Chang (2013), Morais and Lord (2006), Yang and Lin (2013) concluded that automated and electric-powered equipment can be used as an effective strategies to reduce energy consumption and emission. Fiadomor (2009), Zanetti (2013) studied about the cold ironing strategies which is used to reduce energy and emission from ships during berthing in the terminal.

Moreover, there are several researches about the usage of biodiesel as an alternative fuels in order to reduce emission. Although those researches took road transportation as an object study, it can also be implemented as reference in port industries system as many of CHEs also used diesel as power-source. Those researches are Xue, et al. (2011), Ribeiro, et al. (2009), Mandil and Eldin (2010), Wirawan, et al. (2008), Wirawan and Tambunan (2006).

2.4 Forecasting Method

Forecasting method is devided into two methods, qualitative method and quantitative method. Quantitative method consist of time series analysis and regression. Time series analysis can be moving average method, weight moving average method, exponential smoothing model, and trend prediction model. While regression method includes single regression and multiple regreesion method (Yuan, 2013).

Winston and Albright (1998) described the principle of determining the best forecasting methods is forecast error. One method to forecast error is to measure the value of MSE (mean square error). MSE is one of way to quantify the difference between values implied by an estimator and the true values of the quantity being estimated. Forecasting method which have smallest value of MSE is the best method to forecast. Equation for Mean Square Error is :

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(\mathrm{\hat{Y}i} - \mathrm{Yi})^2 \qquad (4)$$

In recent years, forecasting method has been developed. Hwang, et al. (2007) used fuzzy group method data handling type (GMDH) neural network and its application to forecast container terminal demand. Gosasang, et al. (2010) applied neural network for forecasting container throughput at Bangkok Port, by using world GDP, exchange rate, population, inflation rate, interest rate and fuel price. Chou, et al. (2007) used modified regression model to forecast the volume of Taiwan’s import containers.

In other side, Zheng (2007) compared some modeling system to forecast the demand for petrol in the Australian road transport sector, emphasizing the effects of national income and petrol price. He used linear regression model, Autoregressive Integrated Moving Average (ARIMA), and TRESIS for policy scenario model. Sakauchi (2011) apllied Bayesian forecasting method to predict heating oil demand for individual new customer.

CHAPTER 3
RESEARCH METHODOLOGY

This chapter will explain the systematic research, data collection methods, and also data analysis methods.

3.1 Systematic Research

This research consists of three main objectives. First is to calculate CO_2 emission based on the usage of energy in 2013 by using emission calculation formula tier 1 supplied by United Nations - Intergovernmental Panel for Climate Change (UN – IPCC 2006). Second is to forecast the use of diesel and further to forecast CO_2 emission under the assumption that there is no reduction strategies taken in the future. And third is to study and analyse some emission reduction strategies which has being taken or can be taken by terminal management. Systematic research can be seen in figure 3.1 below :

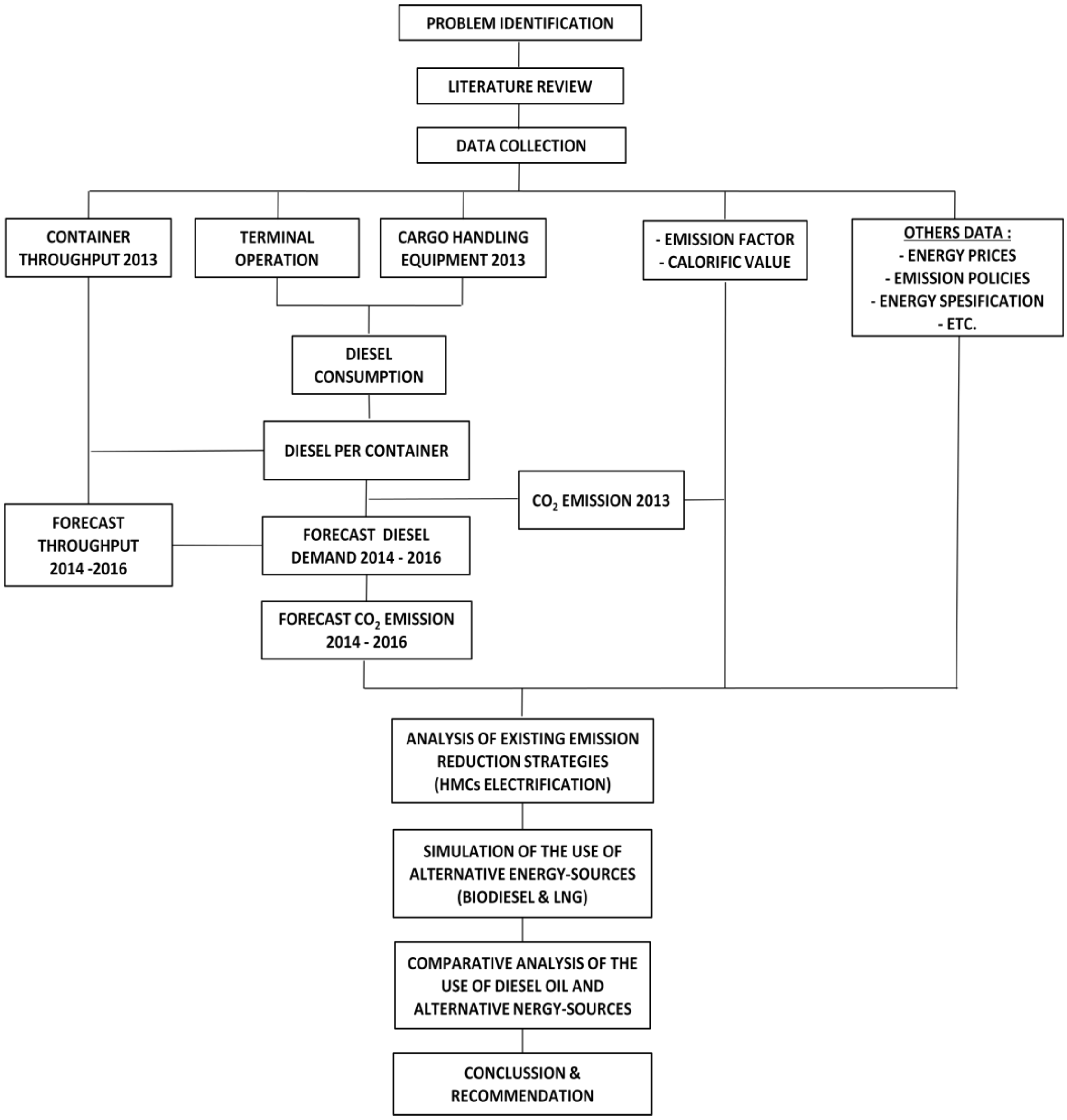

Figure 3.1 Research Syctematics

Source : Author

3.2 Data Collection Method

Data requirements and its collection methods are described as follows:

1. Container throughput

   Container throughput is collected in the unit of box. Data of container throughput are collected from PT. Berlian Jasa Terminal Indonesia and also Port Authority of Tanjung Perak from January 2013 until December 2013.

2. List of cargo handling equipments

   Data of cargo handling equipments that are collected in this research are all equipments which are used to handle container from berth side until container yard and vice versa in 2013. Data of cargo handling equipments include its equipments ID, type, number, production year, and load capacity. Data are collected from PT. Berlian Jasa Terminal Indonesia.

3. Terminal Operation

   Terminal direct observation will be conducted to obtain information and data about how the daily operation of container terminal. These informations include on how the equipments operated, equipments assignment, etc. Information about daily terminal operation will be used to support the analysis of energy consumption and emission in container terminal.

4. Energy consumption

   Data of energy consumption which are collected are the amount of diesel oil and electricity consumed by each type of cargo handling equipment. Data of diesel are collected from January 2013 – December 2013. While the electrical data are collected from January 2014 until March 2014,because electricity is just started to be used from January 2014. Data are collected PT. Berlian Jasa Terminal Indonesia.

5. Data of emission factor and calorific value.

   Data of CO_2 emission factor and calorific value are collected from Ministry of Environment Republic of Indonesia. Data which will be gathered are emission factor for diesel, electric power, biodiesel, and LNG. While data of calorific value is only for diesel.

6. Data of energy prices

   Data of energy prices include the price of diesel per Litre, the electric price per kWh, the price of biodiesel per Litre, and the price of LNG per Litre. These data are collected from PT. Pertamina Indonesia and also PT. PLN Indonesia.

3.3 Data Analysis Method

Methodology which will be used to analyse the data can be explained as follow :

1. Emission of CO_2

   Emission of CO_2 is calculated by using energy-based emission formula Tier 1 which is supplied by United Nation – Intergovernmental Panel on Climate Change (UN – IPCC 2006) :

$$\textbf{\textit{Emission}} = \boldsymbol{\Sigma_a [Fuel_a \times EF_a]} \text{..............................(5)}$$

   Where :

Emission	: Emission (Kg CO_2)
$Fuel_a$	: Fuel Consumption (TJ)
EF_a	: Emission factor (Kg/TJ)

   Generally, consumption of diesel is expressed in the unit of Litre, whereas formula (5) states that fuel consumption is revealed in the unit of Tetra Joule (TJ). Therefore, the unit of Litre (L) should be converted to Tetra Joule (TJ) by using formula as follow :

   Diesel cons. (TJ) = Diesel Cons. (Litre) x Calorific Value (TJ / Litre)……(6)

   Calorific value is the amount of heat produced by the complete combustion of a material or fuel.

2. Energy and CO_2 emission per container

   To get the data of energy and emission per container, the amount of energy used and emission emitted are devided by the number of container throughput.

3. Forecasting of container throughput

   Container throughput will be forecasted by using trendline prediction model. Data of container throughput in 2013 will be plotted by using excel program, and further linear and exponential trendline are drawn to get the formula and the value of R^2. The formula is used to forecast container throughput in 2013, and afterward the value of Mean Square Error (MSE) can be calculated. Linear trendline model will be compared to exponential trendline prediction model, to know which model has the lowest Mean Square Error (MSE). Model with the smallest MSE will be used to forecast container throughput. Mean Square Error (MSE) can be calculated with formula (7) :

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(\hat{\mathrm{Y}}\mathrm{i} - \mathrm{Yi})^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(7)$$

Where :

MSE : Mean Square Error

n : Number of data

$\hat{\mathrm{Y}}\mathrm{i}$: Forecasted of dependent variable

Yi : Actual value of dependent variable

4. Forecasting of diesel needs

Prediction of diesel needs will be performed by using single regression model. Container throughput will be an independent variable, while diesel needs will be dependent variable. Generally, single regression has a formula as below :

$$\mathbf{Y_t = \alpha + \beta.\ X_t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

Where :

Y = Dependent variable

α = Constanta

β = Coeffisient of independent variable

X = Independent variable

While, the value of **α** and **β** can be calculated by using formula as follow :

$$\beta = \frac{\Sigma(\mathrm{Xt}-\mathrm{x}*)(\mathrm{Yt}-\mathrm{y}*)}{\Sigma(\mathrm{Xt}-\mathrm{x}*)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$\alpha = y^* - \beta . x^* \text{...(10)}$$

Where :

X_t = Independent Variable

Yt = Dependent Variable

x* = The Average Value of X_t

y* = The Average Value of Y_t

5. Forecasting of CO_2 emission

   CO_2 emission will be predicted based on the projection result of diesel demand in the future, and it will also be forecasted by using emission calculation formula tier 1 by United Nation – Intergovernmental Panel on Climate Change (UN – IPCC 2006).

6. Analysis of existing reduction strategy.

   Berlian Terminal has started to electrify their 2 (unit) of HMCs on Nopember 2013, and began to be operated on January 2014. Electrification of HMCs will be explained from the perspective of cost benefit and emission reduction. To describe it, the average usage of diesel in 2013 will be compared to the average usage of electricity on January until March 2014 for each HMC.

7. Simulation of the use of alternative energy-sources.

   Biodiesel (B5, B20, and B100) and LNG will be simulated and assumed to be used by all equipments in Berlian Terminal. Data of diesel demand in the future (the result from diesel demand forecasting) will be used as the basis for the simulation. Furthermore, comparative analysis will be used to compare the use of diesel, biodiesel, and also LNG, to know the best appropriate energy-source from the perspective of fuel-cost expense and CO_2 emission.

CHAPTER 4
ANALYSIS OF BERLIAN TERMINAL OPERATION

Number of cargo handling equipments, how the equipments operated, and number of container handled are some part of terminal operation data which will affect the amount of energy used and CO_2 emission emitted. Chapter 4 will explain about profile of Berlian Terminal, and continued with the analysis of Berlian Terminal operation. Analysis of Berlian Terminal operation is focused on the operation data in 2013.

4.1 Profile of Berlian Terminal

Berlian Terminal is one of six terminal at Tanjung Perak Port. The other terminals are Kalimas Terminal, Jamrud Terminal, Nilam Terminal, Mirah Terminal, and Surabaya International Container Terminal. As one of the major port in Indonesia, Tanjung Perak Port has a strategic role and function in economic development of East Java in particular, and also eastern region of Indonesia in general. Geographically, Tanjung Perak Port is located at Longitude 112º 44'100” - 112º32'40” East and Latitude 7º11'50” - 70º13'20” South. Location of Tanjung Perak Port in Indonesia can be seen in figure 4.1, while its layout is presented in figure 4.2.

Figure 4.1 Location of Tanjung Perak Port

Source : Indonesia Port Corporation III

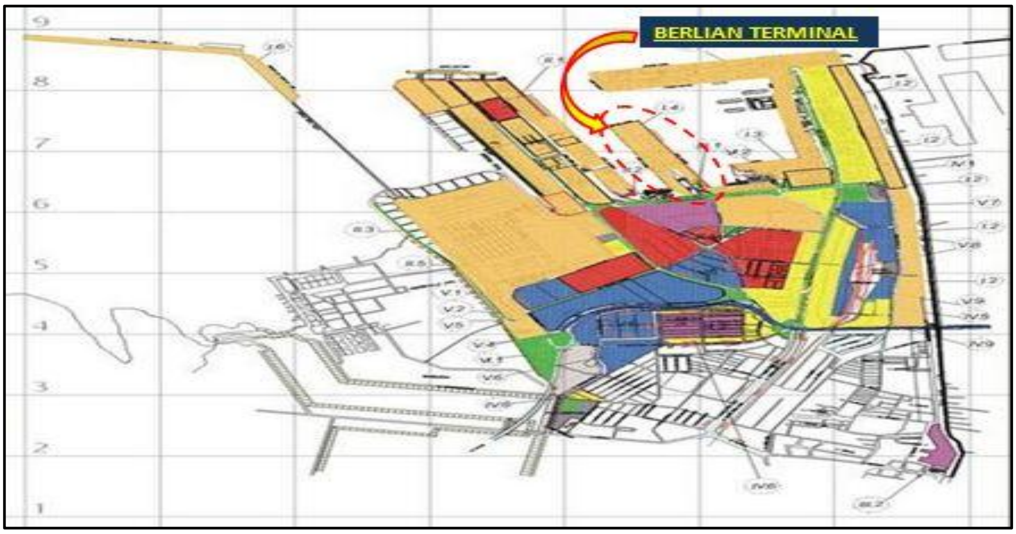

Figure 4.2 Lay Out of Tanjung Perak Port

Source : Indonesia Port Corporation III

Berlian Terminal is focused to serve domestic container flows, but due to the fast growing of international freight, it then also serves international container flows, even though in small quantities. Berlian Terminal consists of three quays: East Berlian, North Berlian, and West Berlian. Berlian Terminal is managed by PT. Berlian Jasa Terminal Indonesia which is a subsidiary of Indonesia Port Corporation III. Layout of Berlian Terminal is presented in figure 4.3, while table 4.1 shows the facilities in 2013.

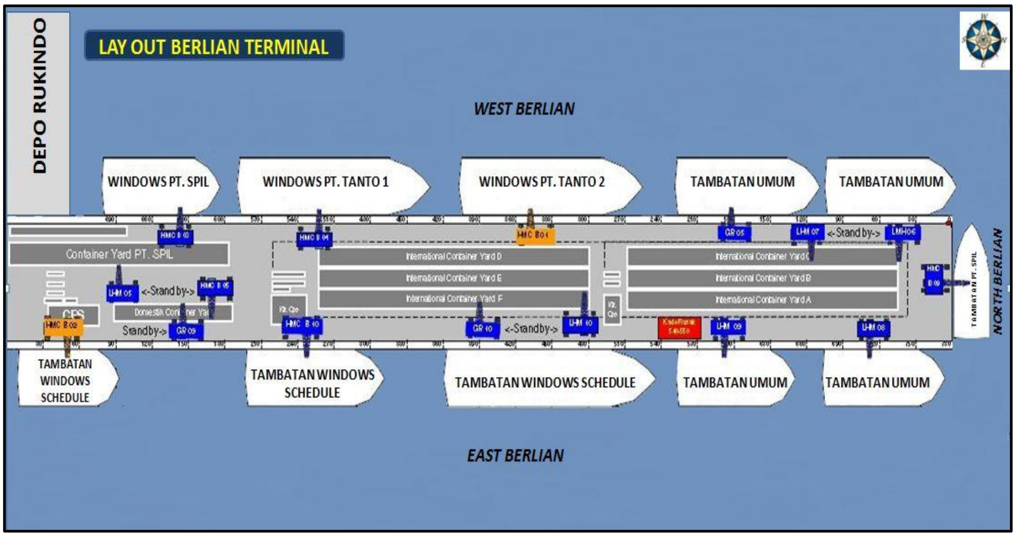

Figure 4.3 Lay Out of Berlian Terminal

Source : PT. Berlian Jasa Terminal Indonesia

Table 4.1 Facilities of Berlian Terminal 2013

Description	Area	Length (m)	Width (m)	Depth (m.LWS)
Quay				
East Berlian	1.2 Ha	785	15	-9.7
North Berlian	0.2 Ha	140	15	-9.0
West Berlian	1.2 Ha	700	15	-8.2
Yard				
International Container Yard	4.3 Ha	-	-	-
Domestic Container Yard	1.2 Ha	-	-	-
Container Freight Station (CFS)	800 m2	-	-	-
Consolidation	1.755 m2	-	-	-
Stripping & Stuffing	625 m2	-	-	-

Source : PT. Berlian Jasa Terminal Indonesia (2013)

4.2 Analysis of Berlian Terminal Operation

4.2.1 General Overview of Terminal Operation

Generally, container handling process consists of 2 (two) activities, loading and unloading operations. The process of unloading container from ship to the container yard in Berlian Terminal can be explained as follows :

a. Container is unloaded from ship by using Harbour Mobile Cranes (HMCs) and or ship's cranes. Container is then put onto the head trucks.
b. Container is transferred from quay side to container yard by head trucks.
c. In container yard, container is lifted off from trailer using RTGCs and then be grounded at the stacking yard for temporary storage. RTGCs are also used in receiving and delivery area.
d. Top loaders and reach stackers are also used in container yard to move / arrange the container. While, forklifts is used to move either container or other things in terminal.

The principle of container loading activity is similar with unloading operation where container is transferred from container yard to the ship.

Average operation hours of Berlian Terminal was 20 hours per day. In a year, official holiday was only in Eid Festival Holiday, therefore operation day of Berlian Terminal in 2013 was 362 days.

4.2.2 Container Handling Equipments

Berlian Terminal is equipped with wide range of cargo handling equipments to ensure the smooth operation of loading and unloading process. Summarized data of cargo handling equipments in Berlian Terminal for year 2013 is presented in table 4.2, while detailed data which include equipment's ID, type / brand, year, capacity, and status of belonging for each equipment can be seen in the apendix page.

Table 4.2 Summarized Data of Cargo Handling Equipments in 2013

Description	Model Year Range	Capacity Range (Ton)	Belonging Status		Count (Unit)
			Owned	Leased	
Harbor Mobile Crane	1978 - 2013	40 - 120	7	9	16
Forklift	1991 - 2011	2 - 33	10	-	10
Reach Staker	2010 - 2013	45	5	1	6
Rubber Tyred Gantry Crane	1979 - 2013	35 - 45	3	6	9
Top Loader	1991	42	1	-	1
Head Truck	2000 - *	40	6	32	38
TOTAL					***80***

*Note : * data are not available*

Source : PT. Berlian Jasa Terminal Indonesis (2013)

According to table 4.2, Berlian Terminal had 80 unit of cargo handling equipments which consist of 6 (six) types : harbor mobile crane (HMC), forklift, reach stacker, rubber tyred gantry crane (RTGC), top loader, and head truck. Some of cargo handling equipments are belong to terminal operator itself, but the others are leased from the other parties. Distribution of cargo handling equipments can be seen in figure 4.4.

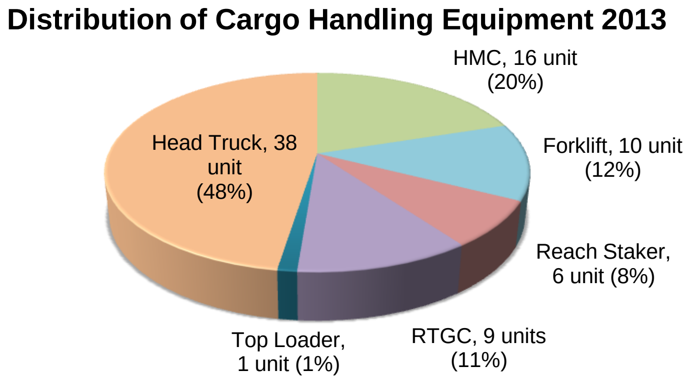

Figure 4.4 Distribution of Cargo Handling Equipments in Berlian Terminal 2013

Source : Author

Head truck took the biggest proportion of CHEs in Berlian Terminal in 2013. There were 38 unit of head trucks or approximately 48% of all CHEs. Proportion of HMC was about 20% of all unit of CHEs. HMCs are used in Berlian Terminal, because the structure of quay is appropriate for this type of equipment. The rest of CHEs are equipments which are used in container yard such as RTGCs, reach stackers, top loaders, and forklifts.

The number of cargo handling equipments in a container terminal is very important in influencing terminal performance and capacity. Sufficient amount with proper capacity is needed to ensure loading / unloading process. According to the information from PT. Berlian Jasa Terminal Indonesia, the number of cargo handling equipments in Berlian Terminal is not sufficient yet. As can be seen in figure 4.4, Berlian Terminal only had 38 unit of head trucks in 2013, and those were not sufficient, compared to the high activity of loading and unloading. Similar condition happened to HMC, where in its daily operation, these were only 14 unit of HMCs operated, while the rest (2 units) were in standby condition. Based on the author's observation, it was only 1 unit of HMC assigned to serve 1 vessel during its berthing time.

Basically, lack of cargo handling equipments will reduce loading and unloading capacity. Low capacity of loading and unloading process will further lead to the increase either berthing time or waiting time in a port. The high berthing time and waiting time could lead to the inefficiency of shipping line whose ships berthed in Berlian Terminal. According to this condition, terminal management need to increase their loading / unloading capacity which one of the way is by adding the number of handling equipments.

4.2.3 Container Throughput 2013

The growth of container throughput in 2013 is presented in figure 4.5.

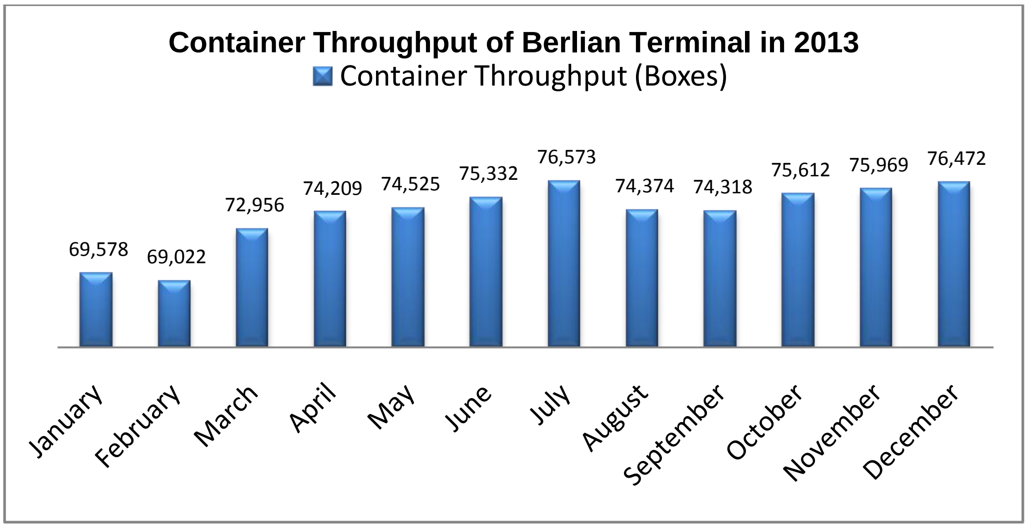

Figure 4.5 Container Throughput of Berlian Terminal 2013

Source : Tanjung Perak Port Authority (2013)

Container throughput of Berlian Terminal was fluctuate but generally had an increase trend from January until December 2013. Total container throughput in 2013 was 888,940 Boxes. Container throughput of Berlian Terminal is very influenced by the development of East Java Province and eastern region of Indonesia. As broadly known, most of the needs of eastern Indonesian region are supplied by Java Island, and Tanjung Perak Port plays as a main hub port to link eastern region to either Java Island, western Indonesian regions, or overseas countries.

According to figure 4.5, during a whole year, the peak of container throughput was on July 2013, where total container moved was 76,573 boxes. July 2013 was ahead of the long feast Eid holiday, where most of Indonesian peoples increased their consumptions. Therefore, it contributed to the significant development of container throughput in July. After long holiday, the number of container throughput decreased as can be seen in August and September 2013. However, it began to rise again in October 2013.

4.2.4 Energy Consumption

All of cargo handling equipments in Berlian Terminal still using diesel as its energy source in 2013. Diesel consumption in 2013 is presented in table 4.3.

Table 4.3 Diesel Consumption 2013

Month	Diesel Consumption 2013 (Litre)						*Total*
	HMC	Forklift	RTGC	Reach Staker	Top Loader	Head Truck	
January	190,000	4,415	51,380	18,735	5,870	163,360	**433,760**
February	172,000	6,865	51,725	18,425	5,800	161,275	**416,090**
March	200,000	8,030	56,265	15,271	6,210	165,220	**450,996**
April	220,000	7,895	54,870	18,166	5,960	163,810	**470,701**
May	210,000	6,110	52,770	20,170	5,980	164,070	**459,100**
June	215,000	5,480	54,300	22,696	5,700	166,270	**469,446**
July	213,000	7,260	52,235	20,328	6,040	164,640	**463,503**
August	210,000	5,550	57,665	23,095	6,245	166,225	**468,780**
September	220,000	7,935	58,110	28,895	5,980	164,550	**485,470**
October	220,000	6,925	60,060	27,195	6,125	164,785	**485,090**
November	225,000	7,605	63,310	25,345	6,350	167,320	**494,930**
December	201,000	7,070	65,175	26,090	6,455	168,140	**473,930**
TOTAL	**2,496,000**	**81,140**	**677,865**	**264,411**	**72,715**	**1,979,665**	**5,571,796**

Source : PT. Berlian Jasa Terminal Indonesia (2013)

Diesel consumption grew fluctuate and totally, cargo handling equipments needed 5,571,796 Litre of diesel in 2013. Distribution of diesel consumption by equipment type is presented in figure 4.6. The total of diesel consumption is indicated by red colour, while blue colour indicates consumption by type of equipment.

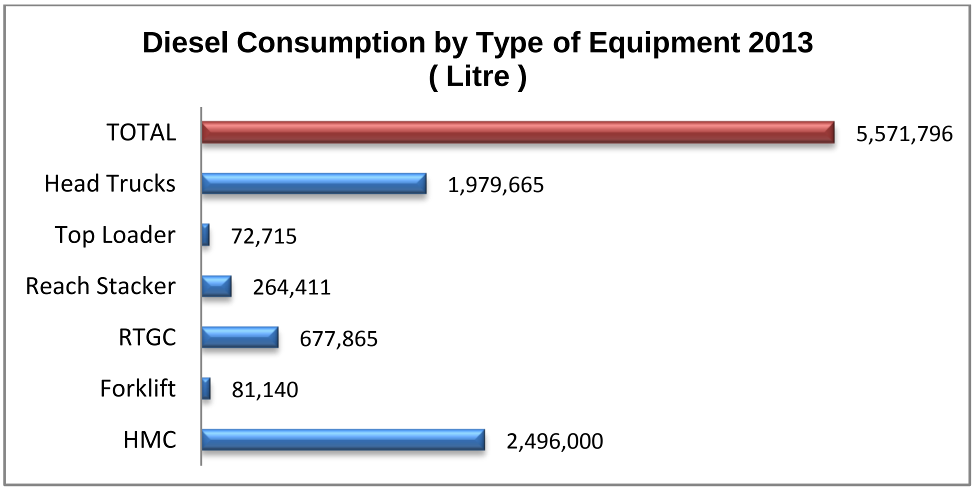

Figure 4.6 Diesel Consumption by Equipment Type

Source : Author

HMCs took the biggest proportion with more than 2 million Litre or about 44.8% of all diesel consumption. HMCs are the main equipment in handling loaded and unloaded containers in terminal, but the process of loading / unloading container can also be assisted by ship's crane, therefore the consumption of diesel by HMCs can also be fluctuated.

The second place were head trucks where needed more than 35% of diesel. Beside as the biggest number of equipment in Berlian Terminal, head truck also need to travel from quay side to container yard and vice versa in handling a container. From the author's observation, in its operation, head trucks usually also need to queue in a long line with the engine still running on. All of these will affect the consumption of diesel by head trucks. The rest of diesel was consumed by equipments which operated in container yard such as RTGCs, forklifts, reach stackers, and top loaders.

By knowing the factors which influence the big consumption of diesel oil, terminal management can take several step to reduce it. It can be summarized, that the consumption of diesel by an equipments will be affected by several factors such as :

a. Work Load

   Work load usually measured by the amount of container that should be handled by an equipment. More container to be moved means more diesel used.

b. Distance to be travelled by an equipment

   Some equipments need to travel a long distance in performing their work, such as head truck, RTGC, forklift, reach stacker, and top loader. Longer distance which should be travelled, means more diesel will be used.

c. Condition of the machine

   Condition of the machine will affect how efficient it in using energy source. An old and unwell maintenanced machine will consume more energy source than well maintenanced one. Therefore, machine maintenance is an important thing to keep machine's efficiency.

d. Driving operation

   "stop and go operation" will lead to the bigger diesel consumption, compared to continuous operation. This condition usually happens in Berlian Terminal, especially on head trucks operation, where head truck have to queue in a long traffic jam and practice "stop and go operation".

4.2.5 Energy Consumption per Container

Data of diesel consumption per container can be used to estimate the average use of diesel to handle 1 (one) unit container in a terminal. Calculation can be done based on the data of diesel consumption in table 4.3 and container throughput in figure 4.5. Calculation will be conducted on the total of energy usage in monthly basis and diesel consumption by type of equipment in 2013.

Based on the calculation, about 6.27 Litre of diesel was used to handle 1 (one) unit container in 2013. Complete result of calculation can be seen in table 4.4, while figure 4.7 presents diesel consumption per container by type of equipment.

Table 4.4 Consumption of Diesel per Container by Month 2013

No.	Month	Diesel Cons. / Cont. (Litre / Boxes)
1	January	6.23
2	February	6.03
3	March	6.18
4	April	6.34
5	May	6.16
6	June	6.23
7	July	6.05
8	August	6.30
9	September	6.53
10	October	6.42
11	November	6.51
12	December	6.20
TOTAL		6.27

Source : Author's calculation

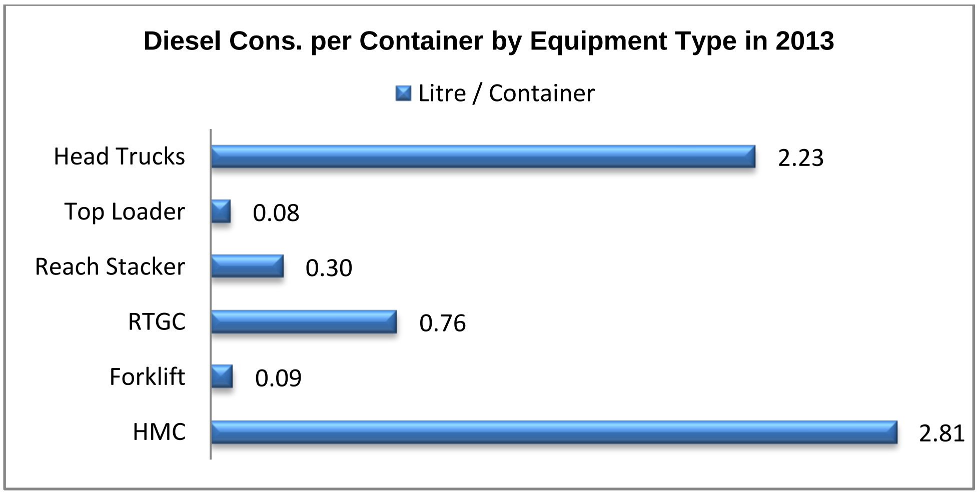

Figure 4.7 Diesel Consumption per Container by Equipment Type in 2013

Source : Author's calculation

From the total of 6.27 Litre of diesel needed to handle 1 (one) container, more than 44% of them was consumed by HMCs. It then followed by head truck (2.23 Litre/Box or 35.53%) and the rest of 19.67% was used by equipments in CY.

4.3 Analysis of Current Situation of Carbon Emission from Terminal Operation

Basically, the main focus of terminal management is still about terminal productivity. But, by the increasing of environmental awareness on society, terminal management begins to implement the concept of green port in Berlian Terminal. The concept of green port is implemented by several actions, such as planting many trees around the terminal and building garbage disposal place. Air emission problem from the activities in terminal also starts to be concerned. It is proved by the pilot project of HMCs electrification which was done at the end of 2013, even though it was only implemented on 2 (two) units of HMCs.

Berlian Terminal management has never conducted air emission inventory, therefore there is no data about the amount of CO_2 emission which was emitted from the operation of container terminal. Because of that, this research is very significant to give an insight to terminal management on how to estimate CO2 emission, particularly from the operation of cargo handling equipments, together its potential reduction strategies from the view of energy-cost saving and emission reduction.

CHAPTER 5
ANALYSIS OF ENERGY - BASED CARBON EMISSION

Chapter 4 will analyse CO_2 emission from the use of energy in 2013. Furthermore, demand of diesel in the future will be estimated under an assumption there is no reduction strategies taken. The result of diesel projection can be used to estimate the CO_2 emission. All the analysis will be based on the data which have been collected.

5.1 Data Collection

Required data for the analysis of CO_2 emission and future needs of diesel are :

a. Diesel consumption 2013

   Data of diesel consumption in 2013 has been already presented in table 4.3.

b. Container throughput 2013

   Data of container throughput 2013 in the unit of boxes has already been presented in figure 4.5.

c. CO_2 emission factors and calorific value

   Data of CO_2 emission factors is gathered from the book of Indonesia's National GHG Emission Inventory Guideline which is published by Ministry of Environment Republic of Indonesia. Basically, this guideline is based on the UN-IPCC 2006. Data of CO_2 emission factors for some energy-source are presented in table 5.1.

Table 5.1 CO_2 Emission Factor

Energy-Source	Emission Factor	Unit
Diesel oil	74000	Kg CO_2 / TJ
Electric power	0.725	Kg CO_2 / kWh
Biodiesel B5	2.6	Kg CO_2 / Litre
Biodiesel B20	2.32	Kg CO_2 / Litre
Biodiesel B100	0.81	Kg CO_2 / Litre
LNG	1.18	Kg CO_2 / Litre

Source : Indonesia's National GHG Emission Inventory Guideline

CO_2 emission factor of diesel oil is stipulated in the unit of Kg CO_2/TJ, while data of diesel consumption is generally expressed in Litre. Therefore, data of calorific value is needed to convert the unit of diesel used from Litre to Tetra Joule (TJ). Calorific value of diesel oil in Indonesia is 36 x 10^{-6} TJ/Litre.

d. Energy price and currency rate

Energy-price which should be borne by terminal management can be predicted by multiplying energy need with energy prices. List of energy prices for some energy-source in Indonesia is presented in table 5.2.

Table 5.2 Energy-Prices

Energy-Source	Price	Unit
Diesel oil	11,700	IDR / Litre
Electric power	803	IDR / kWh
Biodiesel B5	5,600	IDR / Litre
Biodiesel B20	7,400	IDR / Litre
Biodiesel B100	9,250	IDR / Litre
LNG	3,600	IDR / Litre

Source : PT. Pertamina

In Indonesia, energy price is a sensitive issue and government seldom taking a policy to increase energy-price. Because of that, the price of energy-source is predicted to remain same in the next two year. Currency rate of Indonesian Rupiah (IDR) to US Dollar (USD) is fluctuate, but the average is USD 1 equal to IDR 11,200.

5.2 Calculation of CO_2 Emission in 2013

CO_2 emission can be estimated by using formula UN-IPCC Tier 1 (equation 5). Based on this formula, the amount of CO_2 emission depends on the number of energy used and emission factor for each energy source. In 2013, CO_2 emission was only produced from the use of diesel. Before conducting the calculation of CO_2 emission, the unit of diesel has to be converted from Litre (L) to Tetra Joule (TJ). Conversion from Litre to Tetra Joule (TJ) depends on calorific value of diesel and the calculation can be done based on the equation (6).

Based on the data of diesel consumption in table 4.3, and calorific value of diesel, the unit of diesel consumption can be converted from Litre (L) to Tetra Joule (TJ). The example of conversion for total diesel consumption in January 2013 is presented below :

Diesel cons. (TJ) ***= Diesel Cons. (Litre) x Calorific Value (TJ / Litre)***

= 433,760 Litre x 36 * 10^{-6} TJ / Litre

= 15,615 TJ

After converting the unit of diesel from Litre (L) to Tetra Joule (TJ), CO_2 emission can be calculated. The example of CO_2 emission calculation from the use of diesel in January 2013 is presented as follow :

Emission (Kg CO_2) ***= Diesel cons. (TJ) x Emission Factor (Kg CO_2 / TJ-diesel)***

= 15,615 TJ x 74,000 Kg CO_2 / TJ

= 1,157,098 Kg CO_2

Furthermore, total emission will be divided by container throughput, to know the amount of CO_2 emission per container. The result of calculation for total CO_2 emission and CO_2 emission per container are presented in table 5.3. While, Figure 5.1 shows the proportion of CO_2 emission by type of equipment in 2013. The annual CO_2 emissions are shown in blue, indicating the proportion of the total emission and it is shown in the unit of kilo tonnes CO_2. The CO_2 emission per container are shown in red.

Table 5.3 Total CO_2 Emission and CO_2 Emission per Container Box

No.	Month	CO_2 Emission (Kg CO_2)	CO_2 Emission / Cont. (Kg CO_2 / Box)
1	January	1,157,098	16.630
2	February	1,109,962	16.081
3	March	1,203,077	16.490
4	April	1,255,642	16.920
5	May	1,224,695	16.433
6	June	1,252,294	16.624
7	July	1,236,441	16.147
8	August	1,250,518	16.814
9	September	1,295,040	17.426
10	October	1,294,026	17.114
11	November	1,320,275	17.379
12	December	1,264,256	16.532
TOTAL		**14,863,323**	**16.720**

Source : Author's Calculation

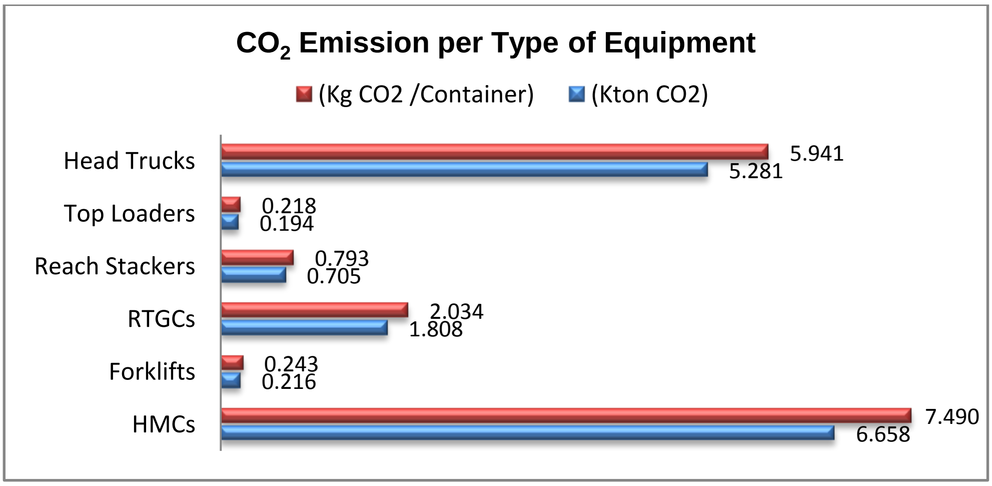

Figure 5.1 CO_2 Emission per Type of Equipment in 2013

Source : Author's Calculation

During 2013, CO_2 emission fluctuated inline with the number of energy use. Totally, CO_2 emission in 2013 was 14,863,323 Kg CO_2. Handling 1 (one) container produced approximately 16.720 Kg CO_2 / box. Most of carbon emission was contributed by

HMCs, where emitted about 6.658 Kilo Tonnes CO_2 or approximately 7.490 CO_2 / box. Head trucks were the second biggest emission producer, following by RTGCs, reach stackers, forklifts, and top loader.

5.3 Forecasting of Diesel Demand and CO_2 Emission (2014 – 2016)

Diesel is still the main source of energy in Berlian Terminal. The use of diesel will lead to the higher cost expenses, because the price of diesel is expensive and the price in the future is likely to rise again due to the lack of supply. In addition, the use of diesel will also emit large CO_2 emissions. In its operation, terminal management need to make projection to give an idea of what to expect in the future. One of it is the projection of energy needs. These projections can help terminal management to set up the budget for energy cost. Moreover, it can also be used to estimate the emission.

Container throughput will be used as the basis for predicting the future needs of diesel. It is based on the idea that container throughput has strong relation with energy use. It has been revealed previously that a growing number of containers handled, work load of equipments will increase, thus energy consumption will also rise.

5.3.1 Forecasting of Container Throughput

Before performing a forecast of diesel demand, container throughput of Berlian Terminal in the future has to be known. Due to the availability of data, forecasting of container throughput will be conducted in monthly basis. Real data which will be used is container throughput in 2013 which has already presented in figure 4.5. In other researches, forecasting of container throughput usually were done by using regression model with GDP of hinterland area as an independent variable. However, in this research, forecasting will be performed by using trendline forecasting model (due to the condition, that data of GDP is not available on monthly basis). Linear trendline model and exponential trendline model will be compared each other, and the value of Mean Square Error (MSE) will be used as the basis to determine the most appropriate method.

5.3.1.1 Linear Trendline Prediction Model

Data of container throughput in 2013 is plotted by using excel program and graph of linear trendline is obtained. Figure 5.2 shows the graph of linear trendline model with its formula and R^2 value.

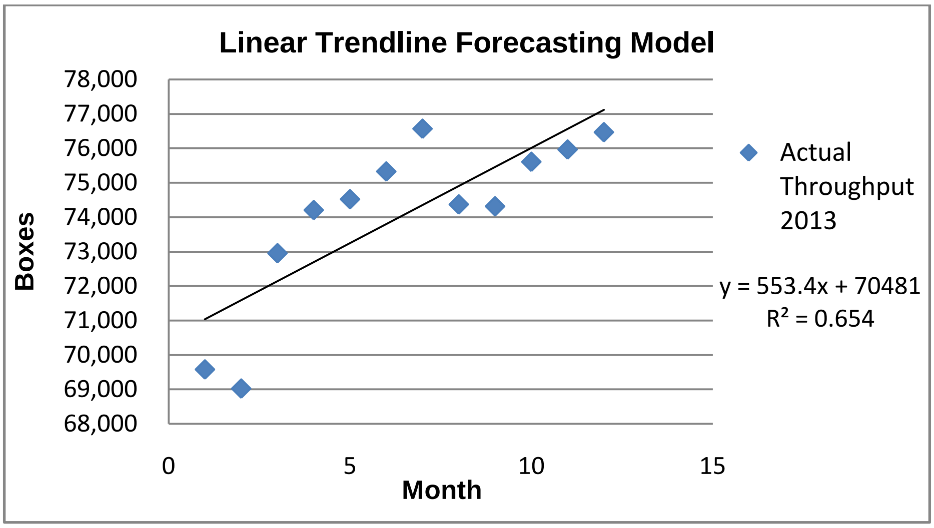

Figure 5.2 Linear Trendline Forecasting Model

Source : Author's Calculation

It is revealed that formula for linear trendline model is **:**

$$Y = 553.4x + 70481$$

Where :

y = Container throughput

x = The sequence of month (x = 1,2,3,…).

This formula will be used to forecast container throughput in 2013, and furthermore Mean Square Error (MSE) could be calculated. The result of container throughput prediction in 2013 is presented in table 5.4.

Table 5.4 Result of Container Throughput Estimation by Linear Trendline Model

No.	Month	Actual Throughput 2013 (Boxes)	Prediction Throughput (Boxes)	(Ŷi-Yi)	(Ŷi-Yi)^2
1	January	69,578	71,034	1,456	2,121,101
2	February	69,022	71,588	2,566	6,583,330
3	March	72,956	72,141	-815	663,899
4	April	74,209	72,695	-1,514	2,293,407
5	May	74,525	73,248	-1,277	1,630,729
6	June	75,332	73,801	-1,531	2,342,736
7	July	76,573	74,355	-2,218	4,920,411
8	August	74,374	74,908	534	285,370
9	September	74,318	75,462	1,144	1,307,821
10	October	75,612	76,015	403	162,409
11	November	75,969	76,568	599	359,280
12	December	76,472	77,122	650	422,240
TOTAL		**888,940**	**888,937**	**-2.800**	**23,092,734**

Source : Author's Calculation

In table 5.4 it is also presented the result of calculation for $(\hat{Y}i - Yi)^2$. It will be used to calculate Mean Squre Error (MSE). The calculation of Mean Square Error (MSE) is conducted by using formula (7) and presented below :

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}(\hat{Y}i - Yi)^2$$

$$= \frac{1}{12}\, X\ 23{,}092{,}734$$

$$= 1{,}924{,}394$$

5.3.1.2 Exponential Trendline Prediction Model

Graph of exponential trendline model is presented in figure 5.3.

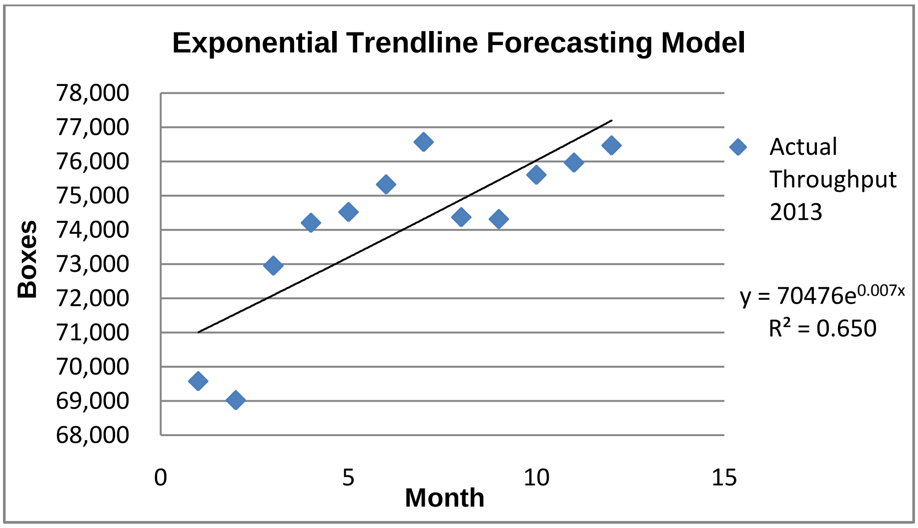

Figure 5.3 Exponential Trendline Forecasting Model

Source : Author's Calculation

Formula for exponential trendline forecasting model is :

$$\mathbf{Y = 70476e^{0.007x}},$$

By using this formula container throughput of Berlian Terminal in 2013 can be projected, and the result is showed in table 5.5.

Table 5.5 Projection Result of Container Throughput by Exponential Trendline Model

No.	Month	Actual Throughput 2013 (Boxes)	Prediction Throughput (Boxes)	(Ŷi-Yi)	(Ŷi-Yi)^2
1	January	69,578	70,971	1,393	1,940,624
2	February	69,022	71,470	2,448	5,990,760
3	March	72,956	71,972	-984	968,954
4	April	74,209	72,477	-1,732	2,999,082
5	May	74,525	72,986	-1,539	2,367,491
6	June	75,332	73,499	-1,833	3,359,774
7	July	76,573	74,015	-2,558	6,541,679
8	August	74,374	74,535	161	26,003
9	September	74,318	75,059	741	548,831
10	October	75,612	75,586	-26	672
11	November	75,969	76,117	148	21,917
12	December	76,472	76,652	180	32,304
TOTAL		**888,940**	**885,339**	**-3,601**	**24,798,092**

Source : Author's Calculation

Mean square error (MSE) from exponential trendline forecasting model is :

$$\text{MSE} \quad = \frac{1}{n}\sum_{i=1}^{n}(\hat{\text{Y}}\text{i} - \text{Yi})^2$$

$$= \frac{1}{12}\ X\ 24{,}798{,}092$$

$$= 2{,}066{,}508$$

5.3.1.3 Container Throughput Forecasting

The most appropriate forecasting formula is defined by the value of Mean Square Error (MSE). The model whose Mean Square Error (MSE) is the smallest will be used. Mean Square Error (MSE) of linear trendline model is **1,924,324**, while exponential trendline model is **2,066,508**. It means linear trendline forecasting model will be used to forecast container throughput three years ahead. The result of container throughput estimation is presented in table 5.6

Table 5.6 The Result of Container Throughput Estimation (2014 – 2016)

No.	Month	Container Throughput (Boxes)		
		2014	2015	2016
1	January	77,675	84,316	90,957
2	February	78,229	84,869	91,510
3	March	78,782	85,423	92,064
4	April	79,335	85,976	92,617
5	May	79,889	86,530	93,170
6	June	80,442	87,083	93,724
7	July	80,996	87,636	94,277
8	August	81,549	88,190	94,831
9	September	82,102	88,743	95,384
10	October	82,656	89,297	95,937
11	November	83,209	89,850	96,491
12	December	83,763	90,403	97,044
TOTAL		**968,627**	**1,048,316**	**1,128,006**

Source : Author's Calculation

Based on forecasting result, container throughput in 2014 will increase by approximately 8,96% from container throughput in 2013, and it will exceed 1 million boxes in 2015 and 2016.

5.3.2 Forecasting of Diesel Demand

Diesel demand by all CHEs will be forecasted under an assumption that there is no reduction strategies taken by terminal management in 2014 until 2016. Diesel demand will be forecasted by using single regression model, where container throughput as an independent variable and diesel demand as a dependent variable.

5.3.2.1 Building Single Regression Forecasting Model

Data of diesel consumption and container throughput in 2013 have already been presented in table 4.3 and figure 4.5. Data of container throughput and diesel demand are presented again as an worksheet for regression calculation in the table 5.7 below :

Table 5.7 Worksheet for Regression Calculation

	Y_t	X_t	X_t-x*	Y_t-y*	(X_t-x*)(Y_t-y*)	(X_t-x*)^2
January	433,760	69,578	-4,500	-30,556	137,513,685	20,253,000
February	416,090	69,022	-5,056	-48,226	243,848,417	25,566,507
March	450,996	72,956	-1,122	-13,320	14,949,854	1,259,632
April	470,701	74,209	131	6,385	834,263	17,074
May	459,100	74,525	447	-5,216	-2,329,962	199,511
June	469,446	75,332	1,254	5,130	6,430,892	1,571,680
July	463,503	76,573	2,495	-813	-2,028,996	6,223,362
August	468,780	74,374	296	4,464	1,319,757	87,419
September	485,470	74,318	240	21,154	5,069,829	57,440
October	485,090	75,612	1,534	20,774	31,859,880	2,352,133
November	494,930	75,969	1,891	30,614	57,880,239	3,574,620
December	473,930	76,472	2,394	9,614	23,011,913	5,729,640
Total	**5,571,796**	**888,940**	**0**	**0**	**518,359,773**	**66,892,019**

Source : Author's Calculation

According to table 5.7, some variable for calculation of regression can be formulated as follows :

a. The average value of diesel demand (y*)

$$y^* = \frac{5{,}571{,}796}{12} = 464{,}316.33$$

b. The average value of container throughput (x*)

$$x^* = \frac{888{,}940}{12} = 74{,}078.33$$

c. The value of β is calculated by using formula (9)

$$\beta = \frac{\Sigma(Xt - x*)(Yt - y*)}{\Sigma(Xt - x*)^2} = \frac{518{,}359{,}773}{66{,}892{,}019} = 7.7492$$

d. The value of αis calculated by using formula (10)

$\alpha = y^* - \beta . x^*$ = 464,316.33 – (7.7492 * 74,078.33) = -109,731.64

From the calculation to buid single linear regression model, it is obtained that the formula which will be used to forecast future diesel needs is :

Y = -109,731.64 + 7.7492. X

5.3.2.2 Diesel Demand Forecasting

Single regression forecasting formula is used to forecast future needs of diesel from 2014 until 2016 in monthly basis, and moreover, the amount of diesel consumption per container can be predicted. The result of projection is presented in table 5.8. While, Figure 5.4 and 5.5 present the growth trend of diesel demand and diesel demand per container from 2013 to 2016. Data in 2013 is real data, while data in 2014 until 2016 is based on the result of projection which have been done.

Table 5.8 The Result of Diesel Demand Estimation

No.	Month	Diesel Demand Estimation (Litre)			Diesel / Container Box (Litre / Box)		
		2014	2015	2016	2014	2015	2016
1	January	492,189	543,650	595,111	6.337	6.448	6.543
2	February	496,477	547,938	599,399	6.346	6.456	6.550
3	March	500,766	552,227	603,688	6.356	6.465	6.557
4	April	505,054	556,515	607,976	6.366	6.473	6.564
5	May	509,343	560,804	612,264	6.376	6.481	6.571
6	June	513,631	565,092	616,553	6.385	6.489	6.578
7	July	517,919	569,380	620,841	6.394	6.497	6.585
8	August	522,208	573,669	625,130	6.404	6.505	6.592
9	September	526,496	577,957	629,418	6.413	6.513	6.599
10	October	530,785	582,246	633,706	6.422	6.520	6.605
11	November	535,073	586,534	637,995	6.430	6.528	6.612
12	December	539,361	590,822	642,283	6.439	6.535	6.618
TOTAL		**6,189,303**	**6,806,834**	**7,424,364**	**6.390**	**6.493**	**6.582**

Source : Author's Calculation

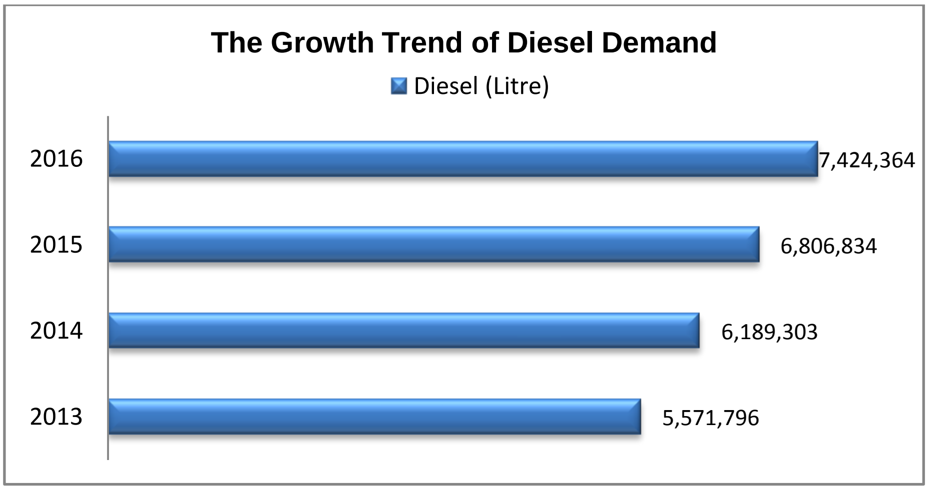

Figure 5.4 The Growth Trend of Diesel Demand (2013 – 2016)

Source : Author's Calculation

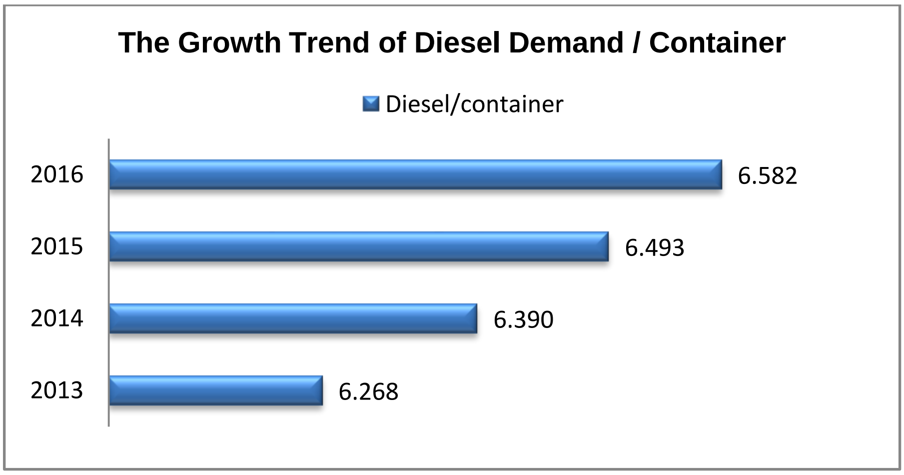

Figure 5.5 The Growth Trend of Diesel Demand per Container (2013 – 2016)

Source : Author's Calculation

As stated previously, one of benefit from diesel demand prediction is to provide an overview of energy cost which will be incurred. Energy cost will be estimated under assumption that diesel price in 2014 until 2016 will be same to the price in 2013. Based on the result of diesel demand projection and the price of diesel, estimation of energy cost which will be borne by terminal management is calculated and the result is shown in table 5.9

Table 5.9 Estimation of Energy Cost

Year	Energy Cost (IDR)
2014	72,414,845,926
2015	79,639,954,511
2016	86,865,063,096

Source : Author's Calculation

In 2013, Berlian Terminal bore IDR 65,190,013,200 or equal to USD 5,820,536.89 (currency rate USD 1 = IDR 11,200). Expense of energy cost has been estimated to rise in the next years, where in 2014, it will be more than IDR 72 billion or increase about 11.08% from cost expense in 2013.

5.3.3 Forecasting of CO_2 Emission

Based on the result of diesel demand projection, the number of CO_2 emission can also be predicted. Calculation of emission is conducted with the same way as already explained in sub-chapter 5.2. The result of emission prediction is presented in table 5.10. Whereas, figure 5.6 and 5.7 shows the growth trend of emission and emission per container from 2013 until 2016. Data in 2013 is real data, while data in 2014 until 2016 is the result of projection.

Table 5.10 Prediction Result of CO_2 Emission

No.	Month	Emission Estimated (Kg CO2)			Emission per Cont. (Kg CO2 / Box)		
		2014	**2015**	**2016**	**2014**	**2015**	**2016**
1	January	1,312,963	1,450,240	1,587,518	16.903	17.200	17.454
2	February	1,324,403	1,461,680	1,598,957	16.930	17.223	17.473
3	March	1,335,843	1,473,120	1,610,397	16.956	17.245	17.492
4	April	1,347,283	1,484,560	1,621,837	16.982	17.267	17.511
5	May	1,358,722	1,496,000	1,633,277	17.008	17.289	17.530
6	June	1,370,162	1,507,439	1,644,716	17.033	17.310	17.549
7	July	1,381,602	1,518,879	1,656,156	17.058	17.332	17.567
8	August	1,393,042	1,530,319	1,667,596	17.082	17.353	17.585
9	September	1,404,481	1,541,759	1,679,036	17.106	17.373	17.603
10	October	1,415,921	1,553,198	1,690,475	17.130	17.394	17.621
11	November	1,427,361	1,564,638	1,701,915	17.154	17.414	17.638
12	December	1,438,801	1,576,078	1,713,355	17.177	17.434	17.655
TOTAL		**16,510,585**	**18,157,910**	**19,805,234**	**17.045**	**17.321**	**17.558**

Source : Author's Calculation

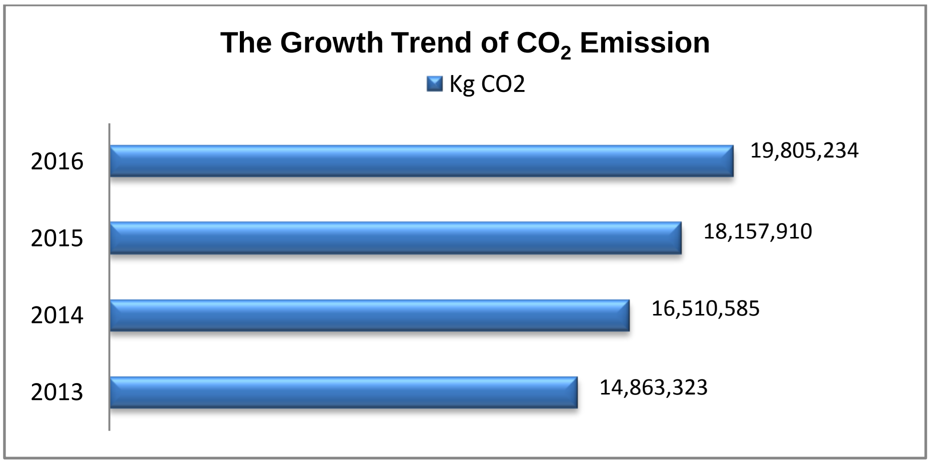

Figure 5.6 The Growth Trend of CO_2 Emission (2013 – 2016)

Source : Author's Calculation

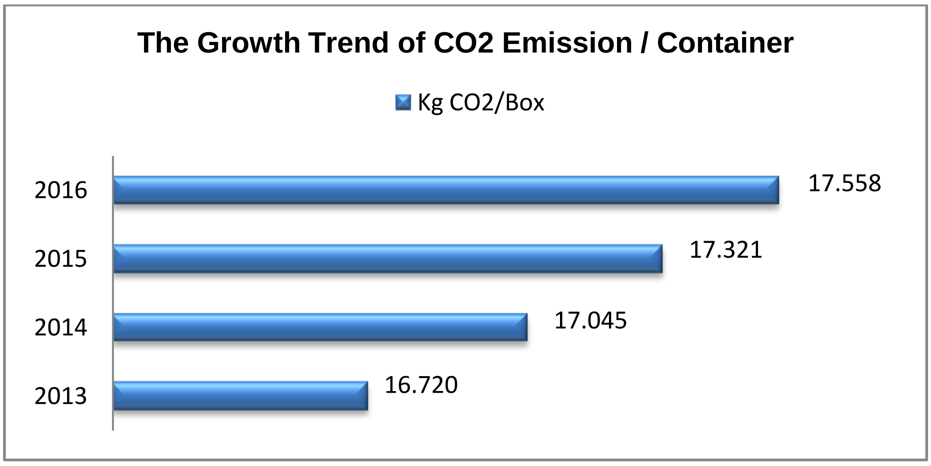

Figure 5.7 The Growth Trend of CO_2 Emission (2013 – 2016)

Source : Author's Calculation

The growth trend of CO_2 emission is similar to the growth trend of diesel demand. Production of CO_2 emission will always increase in the future due to the fast growth of terminal productivity. Diesel cost will always be the main cost which has to be borne by management, unless terminal management considers to implement the program of energy saving. In addition, diesel will also emit numerous GHG emission which can affect the environment. Therefore, program of energy saving which should be taken by terminal management should be also directed to reduce GHG emission from the activity of container terminal.

CHAPTER 6
ANALYSIS OF EMISSION ABATEMENT STRATEGIES

This chapter will be commenced by an introduction of several emission reduction strategies which are available. The next explanation is about national and port management policies on emission, and then followed by analysis of HMCs electrification which has been chosen as a pilot project in Berlian Terminal. Simulation for the use of biodiesel and LNG, and its comparison with the use of diesel will then be conducted as the basis to know the appropriate energy-source which can further be implemented by terminal management.

6.1 Introduction of Emission Reduction Strategies

Principally, there are two main approaches to reduce emission from the use of energy (schwientek and Jahn, 2012). There are :

1. Reduction the consumption of fossil fuel

Consumption of fossil fuel in container terminal can be reduced by several ways as follow :

a. Minimizing distance travelled.
   As explained initially in chapter 4, that one of influence factor in the amount of diesel consumption is the distance that should be travelled by equipments such as head truck, reach stacker, top loader, etc. To reduce the distance travelled, terminal lay out should be arranged compactly, in order to shorten the distance that have to be travelled by equipments.

b. The use of equipment economically and efficiently.
   Driving techniques have great impact on the use of fuel. Therefore simultaneously training on how to drive economically and efficiently have to be given to equipment operators.

c. Conversion of diesel-powered to electric-powered
   Carbon emission factor and price per unit of electric power is lower than diesel. This condition lead to the widely implementation of diesel to electric conversion program in container terminal. Beside gaining benefit of low

carbon emission, it also can reduce energy-cost expense.

2. The usage of energy sources which contain less carbon.

Some less carbon energy-sources can be used to substitute the use of diesel oil in container terminal. Some of them are :

a. Gaseous Fuels.

Gaseous fuels such as Butane, Propane, Natural gas have less carbon and more hydrogen than diesel fuels and therefore produce less carbon dioxide. However there is an increase in fuel consumption and special tanks are needed to store the gases. The gaseous fuels are cheaper than normal diesel but require expensive modifications to engines and storage. Examples are LPG, CNG, and LNG (BP Australia Limited, 2005)

b. Biodiesel

Biodiesel is a compound of methyl ester derived from the esterification/trans-esterification process of various types of vegetable oils or animal fats (Wirawan and Tambunan, 2006). Biodiesel has similar properties to diesel and can be used in normal diesel engines. It can be used as a diesel (B100) or as a blend with normal diesel, normally at 20% (B20) (BP Australia Limited, 2005).

c. Diesel – ethanol blends.

Ethanol is produced from plants and it can be blended with diesel using stabilizing additives to produce a diesel fuel. The normal ethanol component in a blend is 10%. Both ethanol and biodiesel can reduce diesel carbon dioxide emissions by the approximate proportion in which they are used as substitutes. There can be an increase in fuel consumption proportional to the amount of oxygen present (BP Australia Limited, 2005).

6.2 National and Port Management Policies on Emission

Emission policies will affect the decision of terminal management on implementing emission reduction strategies. Sea ports in Indonesia are operated by state-owned company, therefore its policies are very affected by national policies.

6.2.1 National Emission Policies

Indonesian government has expressed a strong commitment to address climate change. National Medium Term of Development Plan for year 2009 – 2014 has stipulated a priority in environmental management which directed at “ conservation and utilization of natural environment that supports economic growth and sustained prosperity, along with the control and disaster risk management to address climate change ". Moreover, government has a target to reduce GHG emissions by 26% of business as usual in 2020.

Government has set Law No. 32 Year 2009 on the Protection and Management of the Environment. This law mandated that efforts of atmospheric conservation through mitigation and adaptation to climate change are needed in maintaining environment. Furthermore, government also has issued Presidential Regulation No. 61 Year 2011 on National Action Plan for Greenhouse Gas Emission Reduction and Presidential Decree No. 71 Year 2011 on the Implementation of the National Greenhouse Gas Inventory. In essence, government encourages all sector in Indonesia to commit in the effort of emission reduction. One of effort that is driven by government is to shift the use of fossil fuel to renewable energy sources such as biodiesel and gas.

In the author's view, Indonesia already has good and complete regulations on emission policies, eventhough those regulations and laws are still relatively new which just regulated in the years around 2010 and 2011. However, those regulations still need to be widely disseminated and a strong system on environmental laws still need to be built, to guarantee that the regulations will be implemented properly.

6.2.2 Port Management Emission Policies

Tanjung Perak Port is operated by Indonesia Port Corporation III which is one of Indonesia state-owned company. As a state-owned company, Indonesia Port Corporation III should be in the first raw in implementing national regulation, includes of emission policy regulation. Basically, port management is still focusing on how to increase profits by increasing productivity and reducing cost expenses. However, with the increasing of awareness on environmental protection and to comply with government regulations, port management began to make more stringent policy on environmental protection efforts in the port area.

Policies considered by port management are directed at two targets, emission reduction and energy cost reduction. However, energy-cost reduction is still the main objective of port management. Factually, there are several ways which can be taken to either reduce emission and energy cost expense. However, terminal management decided to applicate HMCs electrification as a pilot project at the end of 2013, and commenced to be fully operated from January 2014. This decision was taken based on the consideration that HMCs consumed the biggest proportion of diesel.

6.3 Analysis of Emission Reduction Pilot Project : HMCs Electrification

The pilot project of HMCs electrification in Berlian Terminal will be explained, includes its process and investment cost, energy saving analysis, emission reduction, and also its future challenges / threats.

6.3.1 Electrification Process and Investment Cost

Management of Tanjung Perak Port has determined to conduct the pilot project of HMCs electrification in order to save diesel used and reduce carbon emission. HMCs electrification was commenced in November 2013 and finished at the end of December 2013. The project was implemented on 2 (two) unit of HMCs and those HMCs have a same type. Description about electrified HMCs is presented in table 6.1.

Table 6.1 Technical Data of Electrified HMCs

Description	Data
ID Number	- 05/HMK/BJTI - 06/HMK/BJTI
Type	Gottwald HMK 4406
Capacity / Build Year	100 T / 2010
Output of Diesel Engine	765 kW / 1800 rpm
Generator Type	MJB 400/LA4 440 V / 60 HZ

Source : PT. Berlian Jasa Terminal Indonesia

Crane's diesel generator power unit provides the crane with 765 kW / 440 V / 60 Hz. Crane's diesel generator can be switched off and the crane can be switched over for external electric power supply from the quay mains. In Berlian Terminal, electricity is supplied by Indonesia's National Electric Company (PT. PLN), and the main supply for HMC electrification is 3 MW / 20 KV / 50 Hz. Because external power supply has higher voltage system, the crane must be equipped with a transformer to reduce the voltage to 440 V and converter to increase the frequency to 60 Hz.

HMCs electrification in Berlian Terminal has 2 (two) element of investment cost, which are substation installation and electric line installation cost. Investment cost for the project of HMC electrification in Berlian Terminal is presented in table 6.2.

Table 6.2 HMC Electrification Investment Cost

No.	Description	Expenses (IDR)
I	**Installation of Electric Line**	
A	Installation of medium voltage line 20 KV & administration cost for installation of electric power 2500 kVA (2 units)	2,586,673,500
B	Installation of low voltage line 440 Volt (2 units)	6,626,130,000
C	Installation of electric line for substation lightening	92,430,000
D	Others (labour wages, etc.)	358,050,000
II	**Installation of Electric Substation**	336,097,477
	Total	9,999,380,977
	Tax (10%)	999,938,098
	Grand Total	10,999,319,075

Source : PT. Berlian Jasa Terminal Indonesia

Total cost for the project of HMC electrification was IDR 10,999,319,075 or equal to USD 982,082.06 (currency rate USD 1 = IDR 11,200). The biggest proportion of electrification cost is for the installation of low voltage line 440 Volt, which 1 (one) unit HMC needed more than 3 billion Indonesia's Rupiah.

HMCs Electrification was only conducted to 2 (two) unit of HMCs, eventhough Berlian Terminal actually has 3 unit of Gottwald HMK 4406 and main supply from PT. PLN is enough for all of those. The decision was taken because terminal management will firstly analyse and evaluate the impact of electrification to energy cost saving and also emission reduction, before it is continued.

6.3.2 Analysis of Energy-Cost Saving

In order to analyse the differences between the use of diesel and electric on HMC no. 05 and 06, data of diesel which was consumed by those HMCs before it were electrified is needed. Beside that, it is also needed the data of electric usage on January 2014 – March 2014. Data of diesel consumption in 2013 is presented in table 6.3, while data of electric used is showed in table 6.4.

Table 6.3 Diesel Consumption (Litre) of Electrified HMCs in 2013

No.	Month	05/HMK/BJTI	06/HMK/BJTI	Total
1	January	15,000	15,000	30,000
2	February	17,000	10,000	27,000
3	March	15,000	15,000	30,000
4	April	20,000	10,000	30,000
5	May	15,000	15,000	30,000
6	June	15,000	15,000	30,000
7	July	20,000	15,000	35,000
8	August	15,000	15,000	30,000
9	September	20,000	10,000	30,000
10	October	20,000	10,000	30,000
11	November	15,000	15,000	30,000
12	December	8,000	5,000	13,000
TOTAL		195,000	150,000	345,000

Source : PT. Berlian Jasa Terminal Indonesia

Table 6.4 Electric Consumption (kWh) of Electrified HMCs in 2014

No.	Month	05/HMK/BJTI	06/HMK/BJTI	Total
1	January	25,653	23,575	49,228
2	February	27,528	25,765	53,293
3	March	28,432	24,126	52,558
TOTAL		81,613	73,466	155,079

Source : PT. Berlian Jasa Terminal Indonesia

Energy cost saving will be analysed by comparing cost expense from the average use of diesel before it were electrified with cost expense from the use of electric. Calculation will be done for each HMC.

Calculation of energy-cost saving for ***HMC no. 05/HMK/BJTI*** is presented as follow :

Average diesel cost expense :

Average diesel use / month (L) $= \frac{Total\ diesel\ consumption\ \ (L)}{Number\ \ of\ data}$

$= \frac{195{,}000\ L}{12}$

= 16,250 L

According to table 5.2, diesel price is IDR 11,700, therefore, average diesel cost expense per month is :

Diesel cost expense (IDR) = Average diesel cons. x Diesel price

= 16,250 L x IDR 11,700

= IDR 190,125,000 (USD 16,975.45)

Average electric cost expense :

Data of electric used by HMC No. 05/HMK/BJTI from January 2014 – March 2014 have been presented in table 6.4. Average usage of electric and cost expense can then be calculated as follow :

Average electric used (kWh) $= \frac{Total\ \ electric\ \ consumption\ \ \ (L)}{Number\ \ of\ \ data}$

$= \frac{81{,}613 \text{ kWh}}{3}$

= 27,204 kWh

Price of electricity per kWh is IDR 803 (stipulated in table 5.2)

Cost expense (IDR) = Average electric cons. (kWh) x price (IDR / kWh)

= 27,204 kWh x IDR 803

= IDR 21,845,080 or equal to USD 1,950.45

Energy-cost saving

After obtaining data of average diesel cost expense and electric cost expense, energy cost saving can then be calculated as follow :

Average cost saving (IDR) = Diesel cost (IDR) – Electric cost (IDR)

= IDR190,125,000 - IDR 21,845,080

= IDR 168,279,920 or equal to USD 15,024.99

% of energy saving $= \frac{(\text{Diesel cost} - \text{Electric cost})}{\text{Diesel cost}}$ x 100%

$= \frac{(190{,}125{,}000 - 21{,}845{,}080)}{190{,}125{,}000}$ x 100%

= 88.51 %

The same formula and calculation are conducted for HMC No. 06/HMK/BJTI, and the result of energy-cost saving calculation on HMC No. 05/HMK/BJTI and 06/HMK/BJTI as an impact of electrification is summarized in table 6.5.

Table 6.5 Summarized Result of Energy-Cost Saving Calculation

Description	05/HMC/BJTI	06/HMC/BJTI
Average diesel used (L) / month	16,250	12,500
Average electric used (kWh) / month	27,204	24,489
Average diesel cost (IDR) / month	190,125,000	146,250,000
Average electric cost (IDR) / month	21,845,080	19,664,399
Energy-cost saving (IDR) / month	168,279,920	126,585,601
% Energy-cost saving	88.51%	86.55%

Source : Author Calculation

It is clearly showed that conversion of diesel-powered to electric-powered gives a significant impact on reducing energy-cost expense which should be borne by terminal management. Total average energy-cost saving per month from 2 (two) unit of HMCs is about IDR 294,865,521 (USD 26,327.28) or approximately 87.66% of diesel cost expense. Annually, from 2 unit of HMCs, energy-cost expense can be saved by approximately more than 3,5 billion Indonesia's Rupiah.

6.3.3 Analysis of Emission Reduction

Average carbon emission from the use of diesel will be compared to average emission from electricity use. Calculation will also use the average data of diesel and electric consumption.

Calculation of emission reduction on ***HMC No. 05/HMK/BJTI*** is conducted as follow :

<u>Emission from diesel usage</u>

Average diesel used (Litre) = 16,250 L

Diesel used in TJ = Diesel Used (L) x Calorific Value (TJ/L)

= 16,250 L x 36 * 10^{-6} TJ/L

= 0.59 TJ

Emission (Kg CO_2) = Diesel used (TJ) x Emission Factor (Kg CO_2 / TJ)

= 0.59 TJ x 74,000 Kg CO_2 / TJ

= 43,290 Kg CO_2

Emission from electric

Average electric used (kWh) = 27,204 kWh

Emission factor for electric has been stipulated in table 5.1, where the value is 0.725 Kg CO_2 / kWh.

Emission = Electric used (kWh) x Emission Factor (Kg CO_2 / kWh)

= 27,204 kWh x 0.725 Kg CO_2 / kWh

= 19,723 Kg CO_2

Emission reduction

Emission reduction from diesel to electric conversion on HMC No. 05/HMK/BJTI can be calculated as follow :

Emission reduction (Kg CO_2) = Diesel emission – Electric emission

= 43,290 Kg CO_2 – 19,723 Kg CO_2

= 23,567 Kg CO_2

% of emission reduction $= \frac{(\text{Diesel emission} - \text{Electric emission})}{\text{Diesel emission}}$ x 100%

$= \frac{(43{,}290 - 19{,}723)}{43{,}290}$ x 100%

= 54.44%

The same formula and calculation method are also conducted on HMC No. 06/HMK/BJTI, and the result of emission reduction calculation is summarized and presented in table 6.6.

Table 6.6 Summarized Result of Emission Reduction Calculation

Description	05/HMC/BJTI	06/HMC/BJTI
Average diesel used (L) / month	16,250	12,500
Average electric used (kWh) / month	27,204	24,489
Average diesel emission (Kg CO_2) / month	43,290	33,300
Average electric emission (Kg CO_2) / month	19,723	17,754
Emission reduction (Kg CO_2) / month	23,567	15,546
% Emission reduction	54.44%	46.68%

Source : Author Calculation

According to table 6.6, total average emission reduction from 2 (two) unit of electrified HMCs per month is 39,113 Kg CO2 or about 51.07% from diesel emission. Annually, it will reduce emission by approximately 469,350.90 Kg CO2.

6.3.4 Challenges / Threats for Electrification Program

Beside giving some benefits such as energy-cost saving and emission reduction, equipments electrification program also left some challenges / threats that should be faced by Berlian Terminal management. The main challenges / threats is related to the stability supply of electric power from external source (PT. PLN). Indonesia (especially Java Island) is still shortage of electric power supply, and therefore, terminal management has to allocate electric generator to anticipate power black-out. Allocation of electric generator and diesel oil for energy-source will add investment cost for this project. Unstable and limitation supply of electric power will make terminal management difficult to continue the program of equipments electrification.

Another challenge is about the mobility of electrified equipments. Before to be electrified, equipments such as Harbor Mobile Cranes (HMCs) can be moved from one place to another place, to anticipate the ships / container arrival flow. But, after to be electrified, HMCs should stay on a certain place or can be moved as far as the power cord is still be connected.

6.4 Analysis of The Potential Use of Alternative Energy-Sources

Pilot project of HMCs electrification which was taken by terminal management to reduce either energy-cost and carbon emission has a serious challenge related to sustainability supply of electric power. This condition make terminal management difficult to expand the electrification program to the other equipments.

As stated previously, there are several abatement strategies which are available and can be chosen by terminal management. Alternative fuels which have less price and less carbon content can be considered to be used in Berlian Terminal, such as biodiesel and LNG. This sub-chapter will analyse the potential of Biodiesel and LNG to be used in Berlian Terminal from the perspective of energy-cost expense and CO_2 emission.

6.4.1 Analysis Of The Potential Use of Biodiesel

6.4.1.1 General Overview

As one of the biggest producer of palm oil in the world, Indonesia has a big potential in using biodiesel as an alternative energy source. National Energy Policy stated that biofuels as a part of renewable energy sources targeted to contribute at least 5% of the total national energy consumption in 2025. Recently, PT. Perkebunan Nusantara IV (Indonesia's National Plantation Corporation) and other private companies are continuously developing production and the use of biodiesel. PT. Pertamina as national oil and gas company also has sold biodiesel commercially for public.

Physical and chemical properties of biodiesel are similar to diesel, therefore it can be used directly in diesel engines (B100) without engine modification or blended with diesel. Other researches which have been done stated that total fuel consumed, horse power, and torsion from the use of biodiesel is similar to the use of diesel oil.

6.4.1.2 Simulation of The Use of Biodiesel

Biodiesel will be simulated to be used on the all of equipments in Berlian Terminal for 3 (three) year ahead. Data of diesel demand in 2014 until 2016 from the diesel demand forecasting are needed for the basis of simulation. Simulation is conducted to know the biodiesel-cost expense and CO_2 emission from the use of biodiesel.

Data and assumption which will be used in this simulation are :

- Simulation will be done to B5, B20, and B100
  B5 is blending between 5% biodiesel and 95% diesel oil
  B20 is blending between 20% biodiesel and 80% diesel oil
  B100 is 100% biodiesel
- Consumption of biodiesel is assumed to be same with the needs of diesel oil. It is based on the previous research that the use of biodiesel will not increase the consumption of fuel (Wirawan and Tambunan, 2006). Forecasted diesel needs for year 2014 until 2016 is already been presented in table 5.8.
- Simulation will be conducted in yearly basis.
- Data of CO_2 emission factor of biodiesel have already been revealed in table 5.1.
- Data of biodiesel price is already been stipulated in table 5.2.

The result of biodiesel simulation are presented in table 6.7, while figure 6.1 and figure 6.2 shows the graph of biodiesel-cost expense and CO_2 emission. Complete calculation of biodiesel simulation can be seen in appendix pages.

Table 6.7 Simulation Result of The Use of Biodiesel

		2014	2015	2016
Cost Expense (,000 IDR)	B5	34,660,097.20	38,118,268.83	41,576,440.46
	B20	45,800,842.72	50,370,569.52	54,940,296.32
	B100	57,251,053.40	62,963,211.90	68,675,370.40
CO2 Emission (Kg CO2)	B5	16,092,187.98	17,697,767.67	19,303,347.35
	B20	14,359,183.12	15,791,854.23	17,224,525.33
	B100	5,013,335.49	5,513,535.31	6,013,735.14

Source : Author's Calculation

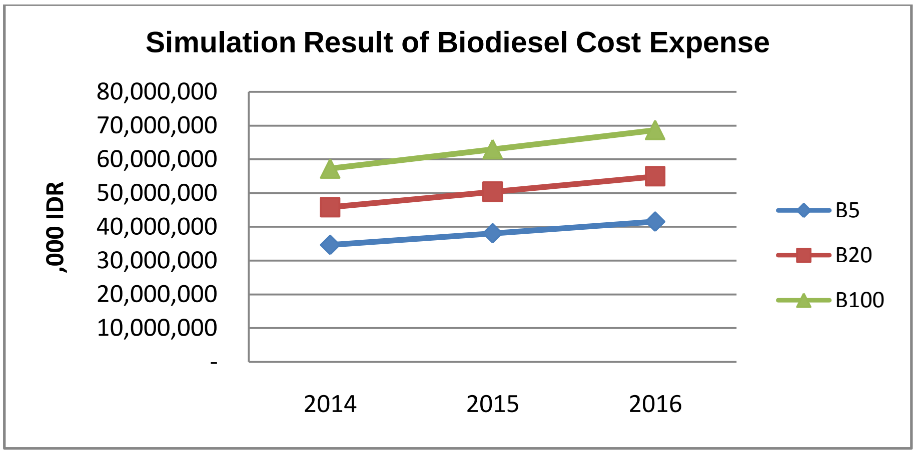

Figure 6.1 Simulation Result of Biodiesel-Cost Expense

Source : Author's Calculation

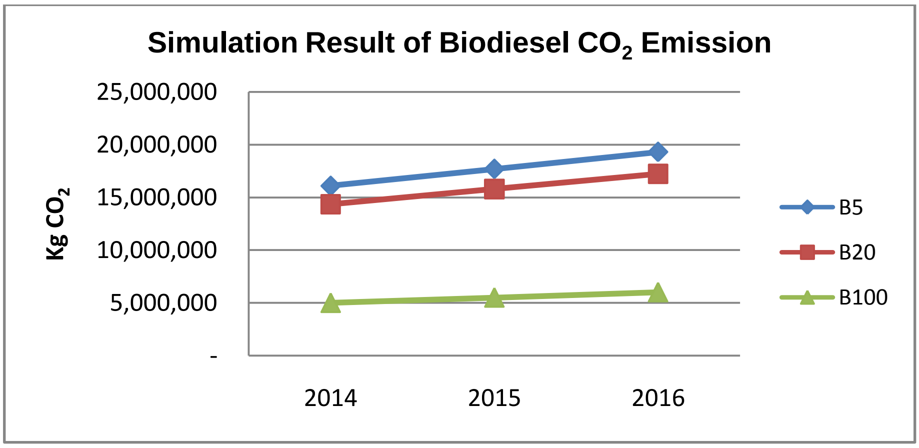

Figure 6.2 Simulation Result of Biodiesel CO_2 Emission

Source : Author's Calculation

According to table 6.7, figure 6.1, and figure 6.2, it is clearly showed that the use of biodiesel B5 will incur the lowest energy cost expense. But, in other hand, biodiesel B5 will emit the highest CO_2 emission. It is because biodiesel B5 contains 95% of diesel oil. The lowest CO_2 emission producer is biodiesel B100, but the price per Litre of biodiesel B100 is close to the price of diesel oil, therefore the use of pure biodiesel will need high cost.

6.4.2 Analysis of The Potential Use of Gaseous Fuel

6.4.2.1 General Overview

Beside biodiesel, another alternative fuel which is developed and driven by government is natural gas. Indonesia has abundant natural gas resources, therefore government set a target to shift the use of natural gas from 22% in 2005 to be 30% in 2025 of all national energy use. One form of natural gas which is widely promoted by government is LNG (Liquid Natural Gas).

All diesel engine can be converted to natural gas. Diesel engines converted to natural gas generally require added components as well as some mechanical changes to the engine. Beside that, special tank also needed for storage. The use of LNG to substitute the use of diesel oil will lead to increase fuel consumption up to 30% (*BP Limited Australia, 2005*).

6.4.2.2 Simulation of The Use of LNG

Assumption which will be used in the simulation are :

- Data of diesel demand in 2014 until 2016 will be used as the basis.
- Consumption of LNG is assumed 30% higher than diesel demand (it is based on the research of BP Australia Limited in 2005, that converting diesel oil to natural gas will increase fuel consumption up to 30%).
- Simulation will be done in yearly basis.

Data of CO_2 emission factor and price of LNG have been stipulated in table 5.1 and table 5.2. Simulation result of energy-cost expense and CO_2

emission from the use of LNG are presented table 6.8, figure 6.3 and figure 6.4. Complete calculation of LNG simulation can be seen in appendix page.

Table 6.8 Simulation Result of The Use of LNG

Year	Cost Expense (,000 IDR)	CO2 Emissin (Kg CO2)
2014	28,965,938	9,494,390.91
2015	31,855,982	10,441,682.92
2016	34,746,025	11,388,974.94

Source : Author's Calculation

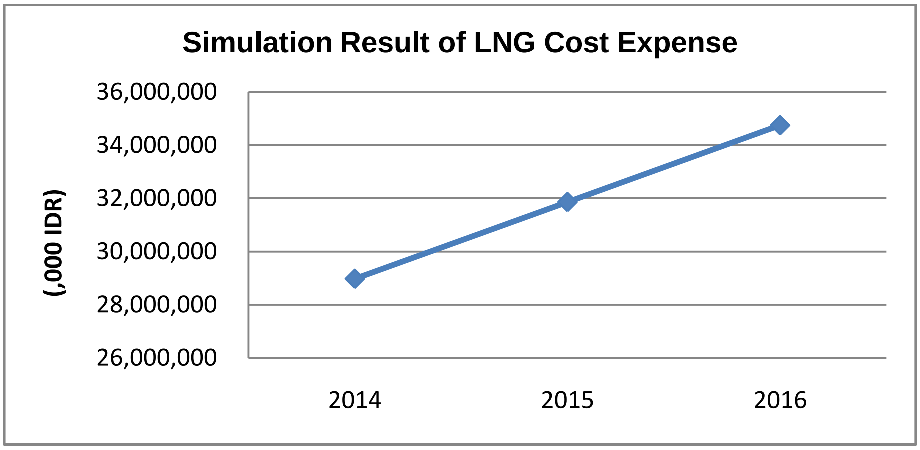

Figure 6.3 Simulation Result of LNG-Cost Expense

Source : Author's Calculation

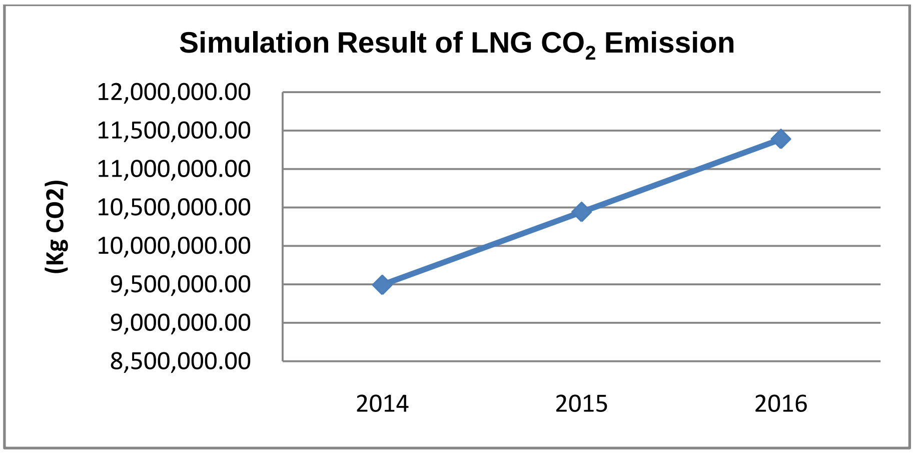

Figure 6.4 Simulation Result of LNG CO_2 Emission

Source : Author's Calculation

6.5 Comparative Analysis of The Use of Diesel Oil and Alternative Fuel

The use of diesel oil and alternative fuel will be compared to know which energy source will give the lowest energy-cost expense and CO_2 emission. Comparison of energy-cost expense and CO_2 emission between diesel oil and alternative fuel are presented below :

6.5.1 Comparison of Fuel-Cost Expense

Based on the result of diesel demand forecasting and simulation of the use of LNG and biodiesel, comparison of fuel-cost expense between the use of diesel oil and alternative energy in Berlian Terminal is presented in table 6.9 and figure 6.5 below :

Table 6.9 Comparison of Fuel-Cost Expense

Year	Cost-Expense (,000 IDR)				
	B5	B20	B100	LNG	Diesel
2014	34,660,097.20	45,800,842.72	57,251,053.40	28,965,938.37	72,414,845.93
2015	38,118,268.83	50,370,569.52	62,963,211.90	31,855,981.80	79,639,954.51
2016	41,576,440.46	54,940,296.32	68,675,370.40	34,746,025.24	86,865,063.10

Source : Author's calculation

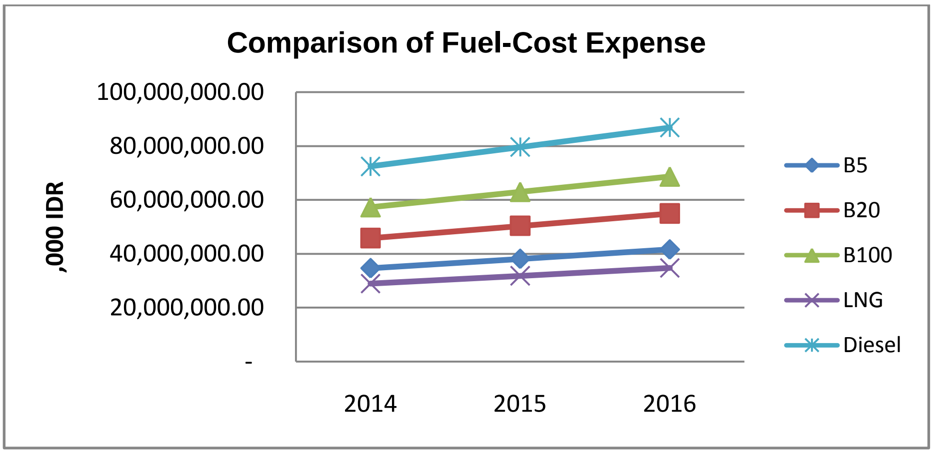

Figure 6.5 Comparison of Fuel-Cost Expense

Source : Author's calculation

According to table 6.9 and figure 6.5, it is clearly noticed that the use of LNG will incur the lowest cost expense than the other energy-sources. The substitution of diesel oil by LNG will yield the highest energy-cost saving, which is by approximately 60% of diesel cost. From the calculation, it is obtained that the use of LNG will save energy-cost by approximately more than 43,45 billion IDR in 2014; 47,78 billion IDR in 2015; and 52,12 billion IDR in 2016.

6.5.2 Comparison of CO_2 emission

Comparison of CO_2 emission from the use of diesel oil and alternative energy is presented in table 6.10 and figure 6.6. The comparison is based on the result of CO_2 emission forecasting and simulation of LNG and biodiesel.

Table 6.10 Comparison of CO_2 Emission

	CO2 Emission (Kg CO2)				
	B5	**B20**	**B100**	**LNG**	**Diesel**
2014	16,092,187.98	14,359,183.12	5,013,335.49	9,494,390.91	16,510,584.87
2015	17,697,767.67	15,791,854.23	5,513,535.31	10,441,682.92	18,157,909.63
2016	19,303,347.35	17,224,525.33	6,013,735.14	11,388,974.94	19,805,234.39

Source : Author's calculation

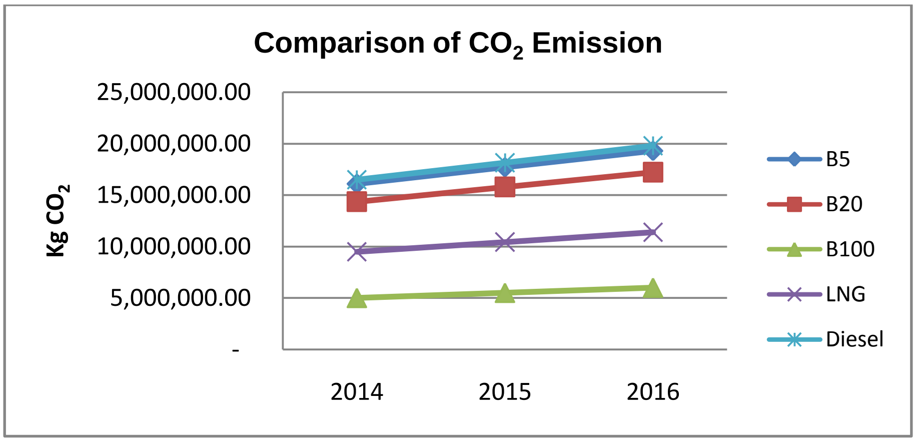

Figure 6.6 Comparison of CO_2 Emission

Source : Author's calculation

According to table 6.10 and figure 6.6, the use of biodiesel B100 will produce the lowest CO_2 emission than the other energy-sources. The substitution of diesel oil by biodiesel B100 will reduce CO_2 emission by about 69.64%. The use of LNG will emit CO_2 emission higher than biodiesel B100, because carbon content of LNG is bigger than biodiesel B100. However, the substitution of diesel oil by LNG will reduce CO_2 emission by approximately 42.50%.

The decision of terminal management in taking emission reduction strategies is depend on several consideration, such as energy-cost benefit, emission reduction, investment cost, pay back period, technology availability, sustainability supply of new energy-source, etc. Moreover, terminal management should also review the main target which they want to achieve, whether energy-cost saving or emission reduction. From this research, it can only be seen which strategy give the best result from the perspective of energy-cost saving and emission reduction. It is clearly indicated that LNG give the biggest energy-cost saving, but the emission reduction is only on the second place. While, the biggest emission reduction is achieved by the use of biodiesel B100, but the price per litre of B100 is more expensive than another alternative fuel. However, next research on investation cost and pay back time, sustainability supply, etc. should be done to define which the best strategy can be applicated in container terminal.

CHAPTER 7

CONCLUSSION AND RECOMMENDATION

6.3 Conclussion

Based on the analysis that have been done, conclusion can be made as follow :

a. Berlian Terminal had totally 80 unit of cargo handling equipments in 2013, which consist of 6 (six) types : Harbor Mobile Cranes (HMCs), head trucks, Rubber Tyred Gantry Cranes (RTGC), reach stackers, and forklift.

b. All cargo handling equipments consumed diesel oil as its energy source in 2013. Total diesel consumption in 2013 was 5,571,796 Litre. It was needed by approximately 6.27 Litre of diesel to handle 1 (one) container from ships to container yard or vice versa.

c. CO_2 emission in 2013 was calculated by using emission estimation formula which is supplied by UN-IPCC 2006. Totally, the operation of cargo handling equipments in 2013 emitted approximately 14,863,323 Kg CO_2. It is about 16.720 Kg CO_2 / Box.

d. Forecasting of future need of diesel oil gives a result that diesel consumption will increase to be 6,189,303 Litre in 2014; 6,806,834 Litre in 2015; and 7,424,364 Litre in 2016 if there is no fuel-saving program taken by terminal management. Diesel consumption per container will also increase to be 6.390 Litre / Box in 2014; 6.493 Litre / Box in 2015; and 6.582 Litre / Box in 2016

e. By assuming that diesel price for the next 3 years are still same with the current price, diesel cost expense which should be borne by terminal management is calculated. Diesel cost expense in 2014 is estimated to be IDR 72,414,845,926; IDR 79,639,954,511 for 2015; and IDR 86,865,063,096 for 2016.

f. Based on the result of diesel demand forecasting, the amount of CO_2 emission which will be emitted from the use of diesel in the future can be forecasted. CO_2 emission from the operation of cargo handling equipments in Berlian Terminal will increase to be 16,510,585 Kg CO_2 in 2014; 18,157,910 Kg CO_2 in 2015; and 19,805,234 Kg CO_2 in 2016 if there is no fuel-saving program and emission reduction program taken by terminal management. CO_2 emission per container will be 17.045 CO_2 / Box in 2014; 17.321 CO_2 / Box in 2015: and 17.558 CO_2 / Box in 2016.

g. Berlian Terminal implemented HMCs electrification on 2 (two) units of Harbor Mobile Cranes (HMCs) on January 2014. Annually, the use of electricity will reduce energy-cost expense of those 2 (two) unit of HMCs by more than 3.5 billion IDR while the reduction of CO_2 emission on those HMCs was approximately 469,350.90 Kg CO2.

h. The use of electric power as energy source in Berlian Terminal has a serious challenge / thread. The supply of electric power from Indonesia's Power Company is not stable, which then lead terminal management to provide electric genset to anticipate power black-out. This circumstance limits the possibility to expand electrification program to other equipments.

i. Other alternative fuel can be considered to be used in Berlian Terminal to substitute the use of diesel oil. Based on the simulation and comparative analysis of the use of biodiesel (B5, B20, B100) and LNG, it is obtained that the substitution of diesel oil by LNG will give the highest energy-cost saving. But, from the perspective of emission reduction, the use of biodiesel B100 will yield the biggest CO_2 emission reduction..

6.4 Recommendation

Some recommendation that can be suggested to Berlian Terminal management are :

a. Energy consumption should be recorded properly, in order to give an appropriate data for not only GHG emission inventory but also the calculation of operational cost expenses.

b. In order to reduce energy-consumption and CO_2 emission, terminal management can take several steps, such as :
   - Conducted routine maintenance to all cargo handling equipments in order to keep the efficiency of the machine.
   - Conducted continuous "driving skill training", in order to teach the equipment's operators how to drive the equipments economically and efficiently.
   - Arranged the lay out of container terminal properly, in order to shorten the distance which should be travelled by equipments.
   - Considered for using alternative energy-source for cargo handling equipments.

LNG and biodiesel can be the alternative of energy-source due to its abundant resources in Indonesia. Based on the main goal of terminal management which still focus in reducing fuel-cost expense, LNG can be considered to be used as it will give the highest energy-cost saving compared to biodiesel. However, other analysis on investment cost, pay back period, technology avaibility, sustainability supply, and etc. should be conducted to determine the most appropriate alternative energy-source for Berlian Terminal.

References :

BP Australia Limited. (2013). *Diesel Engine Emission Reduction*. Retrieved February 6, 2014 from the World Wide Web : http://www.bp.com/liveassets/bp_internet/australia/corporate_australia/STAGING/local_assets/downloads_pdfs/f/Diesel_EmissionReduction.pdf

Brinkmann, B. (2011). Operation Systems of Container Terminal: A Compendious Overview. *Operation Research/Computer Science Interface Series 49*

Chou, C. C., Chu, C. W., and Liang, G. S. (2007). A Modified Regression Models for Forecasting the Volumes of Taiwan's Import Containers. *Mathematical and Computer Modeling, 47,* 797-807.

Corzo, F. (2011). *Sustainable Reduction of CO2 Emissions and Pollutants Using LNG for The Danube Inland Navigation*. Bachelor Thesis. Vienna University of Technology, Vienna, Austria

European Commission. (2011). *Understanding Greenhouse Gases*. Retrieved on February 5, 2014, from Worldwide Web : http://www.ec.europa.au/clima/sites/campaign/pdf/gases_en.pdf

Fiadomor, R. (2009). *Assessment of Alternative Maritime Power (Cold Ironing) and Its Impact on Port Management and Operations*. Master Thesis. World Maritime University, Malmo, Sweden

Geerling, H. & Van Duin, R. (2010). A New Method for Assessing CO2-Emission from Container Terminal : A Promising Approach Applied in Rotterdam. *Journal of Cleaner Production, 19*, 657-666

Gillenwater, M. (2010). *What is a Global Warming Potential ? And Which One Do I Use ?*. Retrieved on February 5, 2014, from Worldwide Web : http://ghginstitute.org/2010/06/28/what-is-a-global-warming-potential/

Gosasang, V., Chandraprakaikul, W. and Kiattisin, S. (2010). An Application of Neural Network for Forecasting Container Throughput at Bangkok Port. *Proceedings of the World Congress on Engineering 2010, Vol. 1*, WCE 2010, June 30-Jul 2, 2010, London, U.K.

Ho, B. Q. (2013). Air Emission Inventories Methodology for Port and Air Quality Simulation. *Modern Transportation, 2*, 1, 1-9

Hwang, H. S., Bae, S. T. and Cho, G. S. (2007). *Container Terminal Demand Forecasting Framework Using Fuzzy-GMDH and Neural Network Method*. College of Port & Logistic System, TonMyong University, South Korea

International Association of Port and Harbors. (2013). *Greenhouse Gases (GHG's) and Ports : An Overview*. Retrieved January 20, 2014 from the World Wide Web : http://wpci.iaphworldports.org/iaphtoolbox/GreenG_strategies.html

International Energy Agency. (2013). *CO_2 Emissions from Fuel Combustion : Highlights*. International Energy Agency, France

Jiang, B., Li, J., and Mao, X. (2012). Container Ports Multimodal Transport in China from The View of Low Carbon. *The Asian Journal of Shipping and Logistics*, *28*, 3, 321-344

Kim, K. H, Phan, M. H. T., and Woo, Y. J., (2012). New Conceptual Handling System in Container Terminals. *Industrial Engineering & Management Systems, 11* (4), 299-309

Khan, M. Y. (2013). *Strategies & Technologies for Improving Air Quality Around Port*. Phd Dissertation. University of California Riverside, California, USA

Kontovas, C. & Psaraftis, H. N. (2011). Reduction of Emission Along The Maritime Intermodal Container Chain : Operational Models and Policies. *Maritime Policy & Management Journal, 38* , 4

Liao, C-H., Tseng, P-H., and Lu, C. S. (2009). Comparing Carbon Dioxide Emissions of Trucking and Intermodal Transport in Taiwan. *Transportation Research D, 14*, 493-496

Mandil, C. & Eldin, A-S. (2010). *Assessment of Biofuels : Potential and Limitations*. International Energy Forum

Medin, E. & Mo, Z. (2005). *Environmental Performance Calculations for The Port of Gothenburg – Emissions to The Air from Road Transports*. Master Thesis. Goteborg university, Gothenburg, Sweden

Ministry of Environmental Republik of Indonesia (2012). *Guidline of National Greenhouse Gases Emission Inventories*. Jakarta, Indonesia

Morais, P. & Lord, E. (2006). *Terminal Appointment System Study*. Assessment report prepared for Transportation Development Centre of Transport Canada, Montreal, Canada

Park, Y-M. (2003), *Berth and crane scheduling of container Terminals.* PhD Thesis. Pusan National University, Pusan, South Korea

Port of Immingham. (2010). Port of Immingham – Inventory of Air Emmissions. London, UK

Reay, D. (2013).*Carbon Dioxide*. Retrieved on February 6, 2014 from Worlwide Web : http://eoearth.org/view/article/150925

Rentokil Initial. (2010). *Environmental Good Procedures Efficient Road Transport*, Rentokil Initial plc : West Sussex

Ribeiro, et al. (2012). The Impact of Biodiesel on Air Pollutant Emissions : Northern Portugal Case Study. *In Proceeding of IAIA12 Conference, The 32nd Annual Meeting of The International Association for Impact Assessment*. Porto, Portugal

Sakauchi, T. (2011). *Applying Bayesian Forecasting to Predict Customers' Heating Oil Demand*. Master Thesis. Marquette University, Wisconsin, USA

South Carolina Ports. (2013). 2011 Air Emission Inventory Update. South Carolina, USA

Steenken, D., Vob, S., and Stahlbock, R. (2004). Container Terminal Operation and Operations Research – A Classification and Literature Review. *OR – Spectrum*, *26*, 3-49

Steenwijk, M. (2011). *A Reference Architecture for Fuel-Based Carbon Management Information Systems in The Logistics Industry*. Master Thesis. University of Twente

The Port of San Diego. (2008). *The Port of San Diego 2006 Emission Inventory*. Starcrest Consulting Group, LLC., USA

Transport Canada Quebec Region. (2009). *Emissiions Inventory of Landside and Marine Sources at The Port of Montreal*. Canada

Uherek, E. (2008). *The Greenhouse Gases – Carbon Dioxide & Methane*. Retrieved on February 5th, 2014, from Worldwide Web : http://athmosphere.mpg.de/enid/253.html

UNCTAD. (2012). *Review of Maritime Transport 2012*. The UNCTAD Secretariat, New York and Geneva

UN-Intergovernmental Panel on Climate Change. (2006). I*PCC Guidelines for National Greenhouse Gas Inventories, Volume 2 Energy*. Retrieved January 10, 2014 from the World Wide Web : http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

UN-Intergovernmental Panel on Climate Change. (2007). *IPCC Fourth Assessment Report, Climate Change 2007 : Synthesis Report*. Retrieved January 10, 2014 from the World Wide Web : http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

UN-Intergovernmental Panel on Climate Change (2007). *Kyoto Protocol to The United Nations Framework Convention on Climate Change*. Retrieved February 5, 2014 from the World Wide Web : http://unfccc.int/resource/docs/convkp/kpeng.pdf.

US – Environmental Protection Agency. (2013). *Overview of Greenhouse Gases*. Retrieved on February 5, 2014, from Worldwide Web : http://epa.gov/climatechange/ghgemissions/gases/html

Vacca, I., Bierlaire, M., and Salani, M. (2007). *Optimization at Container Terminal : Status, Trends and Perpectives*. Paper presented at The 7th Swiss Transport Research Conference, 2007. Monte Verita / Ascona, Swizerland

Vaccari, M., & Vitali, F. (2011). *A Methodology for The Calculation of Greenhouse Gases Emissions from Office-Based Projects*. Unpublish Research Paper. University of Brescia, Brescia, Italy

Vujicic, A., Zrnic, N., and Jerman, B. (2013). Port Sustainability : A Life Cycle Assessment of Zero Emission Cargo Handling Equipment. *Journal of Mechanical Engineering, 59*, 9, 547-555

Wahab, M. H. (2009). *Emission of Gaseous and Particulate Pollutants of Ocean-Going Vessels in Johor Port*. Master Thesis. University Technology of Malaysia, Kuala Lumpur, Malaysia

Wines, H. (2010). *Air Pollution from Ship – Emission Measurements and Impact Assessment*. Phd Dissertation. Chalmers University of Technology, Gothenburg, Sweden

Winston W.L. & Albright S.C. (1998). *Practical management science*. Wadsworth Publishing Company, A Division of International Thomson Publishing inc.

Wirawan, S.S. & Tambunan, A.H. (2006). *The Current Status and Prospects of Biodiesel Development in Indonesia : A Review*. Paper presented on the Third Asia Biomass Workshop. Tsukuba, Japan

Wirawan et al. (2008). Study The Impact of Biodiesel On The Emissions of Transportation Sector at Jakarta. *Environmental Engineering Journal, 9*,2, 211-219 (In Indonesia)

Whitaker, D., & Francou, B. (2004). *Terminal Operations and Performance Indicators*. Retrieved February 5, 2014 from the World Wide Web : http://www.scribd.com/doc/3475439/46/CONTAINER-TERMINAL-EQUIPMENT

World Energy Council. (2011, December 8). *Press Release : The World Energy Council Scenarios Envision a Radically Different Transport Sector by 2050*. Retrieved January 19, 2014 from the World Wide Web : http://www.worldenergy.org/wec_news/press_releases/3807.asp

Xue, J. L., Grift, T. E., and Hansen, A. C. (2011). Journal of Renewable and Sustainable Energy Review. *Renewable and Sustainable Energy Reviews, 15*, 1098-1116

Yang, Y. C. & Chang, W. M. (2013). Performance Analysis of Electric – Rubber Tired Gantries from a Green Container Terminal Perpective. *Eastern Asia Society for Transportation Studies, 9*

Yang, Y. C. & Lin, C. L. (2013). Performance Analysis of Cargo – Handling Equipment from A Green Container Terminal Perpesctive. *Transportation Research Part D , 23*, 9-11

Yuan, Q. (2013). *ITL01DMT-Decision making techniques*. Unpublish lecture handout, World Maritime University-Shanghai Maritime University, Shanghai, China

Zadek, H., & Schulz, R. (2010). Methods for the Calculation of CO2 Emissions in Logistics Activities. *Advanced Manufacturing and Sustainable Logistics. Lecture Notes in Business Information Processing, 2010, Volume 46, Part 3* (pp. 263-268). Berlin, Germany: Springer

Zaneti, S. L. (2013). *Is Cold Ironing Hot Enough? An Actor Focus Perspective of On Shore Power Supply (OPS) at Copenhagen's Harbour.* Master Thesis. Lund University, Sweden

Zhang, C., Liu, J. Wan, Y. W., and Murty, K. G., (2003). Storage Space Allocation in Container Terminals. *Transportation Research Journal Part B, 37*, 883-903

Zheng, L. (2007). *Modelling and Forecasting the Demand for Automobile Petrol in Australia, and Its Policy Implications*. Paper Research. University of Sydney, Sydney, Australia

Appendix 1 List of Cargo Handling Equipments of Berlian Terminal

Description	Equipment's ID	Type / Brand	Year	Capacity (Tonne)	Status
Harbor Mobile Crane (HMC)	03/HMK/BJTI	G.HMC 280	1978	40	Owned
	04/HMK/BJTI	G.HMC 260	1984	40	Owned
	05/HMK/BJTI	G.HMK 4406	2010	100	Owned
	06/HMK/BJTI	G.HMK 4406	2010	100	Owned
	07/HMK/BJTI	G.HMK 4406	2011	100	Owned
	08/HMK/BJTI	G.HMK 4407	2012	100	Rent
	09/HMK/BJTI	G.HMK 4407	2012	100	Rent
	10/HMK/BJTI	L.HMK 400	2005	100	Rent
	13/HMK/BJTI	L.HMK 400	2005	100	Rent
	14/HMK/BJTI	L.HMK 400	2005	100	Rent
	15/HMK/BJTI	L.HMC 420	2012	120	Rent
	16/HMK/BJTI	L.HMC 420	2012	120	Rent
	17/HMK/BJTI	L.HMC 420	2013	120	Owned
	18/HMK/BJTI	G.HMC 4406	2013	100	Owned
	19/HMK/BJTI	G.HMC 4406	2013	100	Rent
	20/HMK/BJTI	G.HMC 4406	2013	100	Rent

Source : PT. Berlian Jasa Terminal Indonesia (2013)

Description	Equipment's ID	Type / Brand	Year	Capacity (Tonne)	Status
Forklift	01/FL/BJTI	Mitsubishi	1991	7	Owned
	03/FL/BJTI	Patria	1994	3	Owned
	04/FL/BJTI	Mitsubishi	2000	7	Owned
	05/FL/BJTI	Mitsubishi	2003	10	Owned
	06/FL/BJTI	Mitsubishi	2008	7	Owned
	07/FL/BJTI	Mitsubishi	2008	3	Owned
	08/FL/BJTI	Kalmar	2009	33	Owned
	09/FL/BJTI	Mitsubishi	2010	3	Owned
	10/FL/BJTI	Mitsubishi	2010	3	Owned
	11/FL/BJTI	Mitsubishi	2011	10	Owned

Source : PT. Berlian Jasa Terminal Indonesia (2013)

Description	Equipment's ID	Type / Brand	Year	Capacity (Tonne)	Status
Reach Staker	01/RS/BJTI	Kalmar	2010	45	Owned
	02/RS/BJTI	Kalmar	2011	45	Owned
	03/RS/BJTI	Kalmar	2012	45	Owned
	04/RS/BJTI	Kalmar	2012	45	Owned
	05/RS/BJTI	Kalmar	2012	45	Rent
	06/RS/BJTI	Kalmar	2013	45	Owned
Rubber Tyred Gantry Crane	01/RTG/BJTI	Mitsui-Paceco	1979	35	Owned
(RTGC)	02/RTG/BJTI	Mitsui-Paceco	1979	35	owned
	03/RTG/BJTI	Kalmar	2012	41	Rent
	04/RTG/BJTI	Kalmar	2012	45	Rent
	05/RTG/BJTI	Kalmar	2012	45	Rent
	06/RTG/BJTI	Kalmar	2012	45	Rent
	07/RTG/BJTI	Kalmar	2012	45	Rent
	08/RTG/BJTI	Kalmar	2012	45	Rent
	09/RTG/BJTI	Kalmar	2013	45	Owned
Top Loader	01/TL/BJTI	Mitsubishi	1991	42	Owned

Source : PT. Berlian Jasa Terminal Indonesia (2013)

Description	Equipment's ID	Type / Brand	Year	Capacity (Tonne)	Status
Head Truck	01/HT/BJTI	Nissan	2000	40	Owned
	02/HT/BJTI	Nissan	2000	40	Owned
	03/HT/BJTI	Nissan	2001	40	Owned
	04/HT/BJTI	Nissan	2001	40	Owned
	05/HT/BJTI	Nissan	2001	40	Owned
	06/HT/BJTI	Nissan	2003	40	Owned
	07/HT/BJTI until 38/HT/BJTI	*	*	*	Rent

*Note : * = Data are not available*

Source : PT. Berlian Jasa Terminal Indonesia (2013)

Appendix 2 : Simulation of The Use of Biodiesel (B5, B20, B100)

a. Data of diesel needs in 2014 until 2016 (Based on diesel demand forecasting).

No.	Month	Diesel Demand Estimation (Litre)		
		2014	2015	2016
1	January	492,189.02	543,649.90	595,110.79
2	February	496,477.42	547,938.31	599,399.20
3	March	500,765.83	552,226.72	603,687.61
4	April	505,054.24	556,515.13	607,976.01
5	May	509,342.64	560,803.53	612,264.42
6	June	513,631.05	565,091.94	616,552.83
7	July	517,919.46	569,380.35	620,841.23
8	August	522,207.87	573,668.75	625,129.64
9	September	526,496.27	577,957.16	629,418.05
10	October	530,784.68	582,245.57	633,706.46
11	November	535,073.09	586,533.98	637,994.86
12	December	539,361.50	590,822.38	642,283.27
TOTAL		**6,189,303.07**	**6,806,833.72**	**7,424,364.37**

Source : Author's Calculation

b. The use of biodiesel (B5, B20, B100) is assumed to be same with the demand of diesel in 2014 – 2016.

c. Calculation of biodiesel-cost expense and CO_2 emission is conducted in yearly basis.

d. Data of biodiesel prices and CO_2 emission factors :

	B5	B20	B100
Prices	5,600	7,400	9,250
CO2 Emission Factor	2.60	2.32	0.81

e. Calculation of biodiesel cost expense is conducted by using formula :

Biodiesel-cost expense : Biodiesel Demand (Litre) x Biodiesel Price (IDR)

Example of Calculation for B5-cost expense in 2014 :

B5-cost expense 2014 = 6,189,303.07 x IDR 5,600

= IDR 34,660,097,195.14

The same formula is used to calculate cost expense of B20 and B100 in 2014 until 2016, and the result is summarized below :

Year	Cost Expense (,000 IDR)		
	B5	B20	B100
2014	34,660,097.20	45,800,842.72	57,251,053.40
2015	38,118,268.83	50,370,569.52	62,963,211.90
2016	41,576,440.46	54,940,296.32	68,675,370.40

Source : Author's Calculation

f. Calculation of Biodiesel CO_2 emission is conducted by using formula :

Biodiesel - CO_2 emission = Biodiesel Used (Litre) x Biodiesel Emission Factor

The example of calculation for B5-CO_2 emission in 2014 :

B5-CO_2 emission 2014 = 6,189,303.07 x 2,60 Kg CO_2 / L

= 16,092,187.98 Kg CO_2

The same formula is used to calculate CO_2 emission of B20 and B100 in 2014 until 2016 and the result is summarized as follow:

Year	CO_2 Emission (Kg CO_2)		
	B5	B20	B100
2014	16,092,187.98	14,359,183.12	5,013,335.49
2015	17,697,767.67	15,791,854.23	5,513,535.31
2016	19,303,347.35	17,224,525.33	6,013,735.14

Appendix 3 : Simulation of The Use of LNG

a. Data of diesel needs in 2014 until 2016 (Based on diesel demand forecasting).

No.	Month	Diesel Demand Estimation (Litre)		
		2014	2015	2016
1	January	492,189.02	543,649.90	595,110.79
2	February	496,477.42	547,938.31	599,399.20
3	March	500,765.83	552,226.72	603,687.61
4	April	505,054.24	556,515.13	607,976.01
5	May	509,342.64	560,803.53	612,264.42
6	June	513,631.05	565,091.94	616,552.83
7	July	517,919.46	569,380.35	620,841.23
8	August	522,207.87	573,668.75	625,129.64
9	September	526,496.27	577,957.16	629,418.05
10	October	530,784.68	582,245.57	633,706.46
11	November	535,073.09	586,533.98	637,994.86
12	December	539,361.50	590,822.38	642,283.27
TOTAL		**6,189,303.07**	**6,806,833.72**	**7,424,364.37**

Source : Author's Calculation

b. The use of LNG is assumed to be 30% higher than the demand of diesel oil. It is based on the research which have been conducted by BP Australia Limited in 2005. Therefore the demand of LNG is :

No.	Month	LNG Demand Estimation (Litre)		
		2014	2015	2016
1	January	639,846	706,745	773,644
2	February	645,421	712,320	779,219
3	March	650,996	717,895	784,794
4	April	656,571	723,470	790,369
5	May	662,145	729,045	795,944
6	June	667,720	734,620	801,519
7	July	673,295	740,194	807,094
8	August	678,870	745,769	812,669
9	September	684,445	751,344	818,243
10	October	690,020	756,919	823,818
11	November	695,595	762,494	829,393
12	December	701,170	768,069	834,968
Total		8,046,094	8,848,884	9,651,674

Source : Author's Calculation

c. Calculation of LNG-cost expense and CO_2 emission is conducted in yearly basis.
d. Price per Litre of LNG is IDR 3,600, while CO_2 emission factor of LNG is 1.18
e. Calculation of LNG-cost expense is conducted by using formula :

LNG-cost expense : LNG Demand (Litre) x Biodiesel Price (IDR)

Example of Calculation for B5-cost expense in 2014 :

LNG-cost expense 2014 = 8,046,094 x IDR 3,600

= IDR 28,965,938,370

f. Calculation of LNG CO_2 emission is conducted by using formula :

LNG - CO_2 emission = Biodiesel Used (Litre) x Biodiesel Emission Factor

The example of calculation for LNG-CO_2 emission in 2014 :

LNG-CO_2 emission 2014 = 8.046.094 x 1.18 Kg CO_2 / L

= 9,494,390.91 Kg CO_2

The same formula is used to calculate cost expense in 2015 and 2016, and the summarized result is presented below :

Year	Cost Expense (,000 IDR)	CO2 Emissin (Kg CO2)
2014	28,965,938	9,494,390.91
2015	31,855,982	10,441,682.92
2016	34,746,025	11,388,974.94

Source : Author's Calculation