BACHELOR THESIS PROPOSAL – ME184834

# *ANALYSIS OF GREEN HOUSE GAS (GHG) EMISSION REDUCTION FROM HEAD TRUCK BY USING ELECTRIFICATION METHOD AT TERMINAL PETIKEMAS*

**DWI BUDI HARDIKS DEWANTARA**

NRP 5019201066

Supervisor I
**PROF. DR. IR. AGOES SANTOSO, M.SC., M.PHIL., CENG, FIMAREST**
NIP 196809281991021001

Supervisor II
**TAUFIK FAJAR NUGROHO, S.T., M.SC.**
NIP 197603102000031001

**Undergraduate Study Program**

Department of Marine Systems Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Surabaya

2024

*(This page is intentionally left blank)*

BACHELOR THESIS PROPOSAL – ME184834

# ANALYSIS OF GREEN HOUSE GAS (GHG) EMISSION REDUCTION FROM HEAD TRUCK BY USING ELECTRIFICATION METHOD AT TERMINAL PETIKEMAS

**DWI BUDI HARDIKS DEWANTARA**

NRP 5019201066

Supervisor I
**PROF. DR. IR. AGOES SANTOSO, M.SC., M.PHIL., CENG, FIMAREST**
NIP 196809281991021001

Supervisor II
**TAUFIK FAJAR NUGROHO, S.T., M.SC.**
NIP 197603102000031001

**Undergraduate Study Program**

Department of Marine Systems Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Surabaya

2024

*(This page is intentionally left blank)*

TUGAS AKHIR – ME184834

# ANALISIS PENURUNAN EMISI GAS RUMAH KACA (GRK) DARI HEAD TRUCK DENGAN MENGGUNAKAN METODE ELEKTRIFIKASI DI TERMINAL PETIKEMAS


**DWI BUDI HARDIKS DEWANTARA**

NRP 5019201066

Dosen Pembimbing I
**PROF. DR. IR. AGOES SANTOSO, M.SC., M.PHIL., CENG, FIMAREST**
NIP 196809281991021001

Dosen Pembimbing II
**TAUFIK FAJAR NUGROHO, S.T., M.SC.**
NIP 197603102000031001

**Program Studi Sarjana**

Departemen Teknik Sistem Perkapalan

Fakultas Teknik Kelautan

Institut Teknologi Sepuluh Nopember

Surabaya


2024

*(This page is intentionally left blank)*

## VALIDITY SHEET

***ANALYSIS OF EMISSION REDUCTION IN HEAD TRUCK ELECTRIFICATION AT TANJUNG PERAK PORT***

**BACHELOR THESIS PROPOSAL**

Submitted to meet one of the conditions

Obtained a Bachelor of Engineering degree in

S-1 Marine Engineering Study Program

Department of Marine Engineering

Faculty of Marine Technology

Sepuluh Nopember Institute of Technology

By : **DWI BUDI HARDIKS DEWANTARA**

NRP. 5019201066

Approved by the Head of the Marine Engineering Department

Signature :

Head of Department : Beny Cahyono, S.T., M.T., Ph. D

NIP : 197903192008011008

Date :

**SURABAYA**

**Juli, 2024**

*(This page is intentionally left blank)*

## APPROVAL SHEET

***ANALYSIS OF GREENHOSE GAS EMISSION (GHG) REDUCTION FROM HEAD TRUCK BY USING ELECTRIFICATION METHOD AT TERMINAL PETIKEMAS***

**BACHELOR THESIS PROPOSAL**

Submitted to meet one of the conditions

Obtained a Bachelor of Engineering degree in

S-1 Marine Engineering Study Program

Department of Marine Engineering

Faculty of Marine Technology

Sepuluh Nopember Institute of Technology


by : **DWI BUDI HARDIKS DEWANTARA**

NRP. 5019201066


Approved by the Bachelor Thesis Proposal Supervisors Team

1. Prof. Dr. Ir. Agoes Santoso, M.SC., M.Phil., CEng, FIMarEST. NIP. 196809281991021001 — Supervisor ( )
2. Taufik Fajar Nugroho, S.T, M.Sc. NIP. 197603102000031001 — Co-Supervisor ( )
3. Sutopo Purwono Fitri, S.T ., M. Eng., Ph.D. NIP. 197510066200212100003 — Examiner ( )
4. Ede Mehta Wardhana. Dr. Eng., S.T., M.T. NIP. 1992201711048 — Examiner ( ) 02-08-2024
5. Prof. Semin, S.T., M.T., Ph.D. NIP. 197102101997021001 — Examiner ( )
6. Handi Rahmanuri, S.T., M.T. NIP. 198805042020121010 — Examiner ( )
7. Danang Jawara Ditya, S.T., M.T. NIP. 198601052024061001 — Examiner ( )

**SURABAYA**

**July, 2024**

*(This page is intentionally left blank)*

## STATEMENT OF ORIGINALITY

The undersigned below:

| | | |
|---|---|---|
| Student name / NRP | : | Dwi Budi Hardiks Dewantara / 5019201066 |
| Study Program | : | S-1 Teknik Sistem Perkapalan |
| Supervisor / NIP | : | Prof. Dr. Ir Agoes Santoso, M.SC., M.Phil., C.Eng, FIMarEST./ 196809281991021001 |
| | | Taufik Fajar Nugroho, S.T., M.Sc./ 197603102000031001 |

Hereby declare that the Final Project with the title "*ANALYSIS OF GREENHOSE GAS (GHG) EMISSION REDUCTION FROM HEAD TRUCK BY USING ELECTRIFICATION METHOD AT TERMINAL PETIKEMAS*" is the result of your own work, is original, and written following the rules of scientific writing.

If in the future there is a discrepancy with this statement, I am willing to accept sanctions in accordance with the provisions in force at the Institut Teknologi Sepuluh Nopember.

Surabaya, __________________

Student

Dwi Budi Hardiks Dewantara
NRP. 5019201066

Acknowledge
Supervisor 1

Prof. Dr. Ir. Agoes Santoso, M.Sc., M.Phil., C.eng, FIMarEST
NIP. 196809281991021001

Acknowledge
Supervisor 2

Taufik Fajar Nugroho, S.T., M.Sc.
NIP. 197603102000031001

*(This page is intentionally left blank)*

# LEMBAR ORISINALITAS

Yang bertanda tangan dibawah ini:

| | | |
|---|---|---|
| Nama Mahasiswa / NRP | : | Dwi Budi Hardiks Dewantara / 5019201066 |
| Program Studi | : | S-1 Teknik Sistem Perkapalan |
| Dosen Pembimbing / NIP | : | Prof. Dr. Ir Agoes Santoso, M.SC., M.Phil., CEng, FIMarEST./ 196809281991021001 |
| | | Taufik Fajar Nugroho, S.T., M.Sc./ 197603102000031001 |

dengan ini menyatakan bahwa Tugas Akhir dengan judul "*ANALYSIS OF GREENHOSE GAS (GHG) EMISSION REDUCTION FROM HEAD TRUCK BY USING ELECTRIFICATION METHOD AT TERMINAL PETIKEMAS*" adalah hasil karya sendiri, bersifat orisinal, dan ditulis dengan mengikuti kaidah penulisan ilmiah.

Bilamana di kemudian hari ditemukan ketidaksesuaian dengan pernyataan ini, maka saya bersedia menerima sanksi sesuai dengan ketentuan yang berlaku di Institut Teknologi Sepuluh Nopember.

Surabaya, ____________________

Mahasiswa

Dwi Budi Hardiks Dewantara
NRP. 5019201066

Mengetahui
Dosen Pembimbing 1

Prof. Dr. Ir. Agoes Santoso, M.Sc., M.Phil., C.eng, FIMarEST
NIP. 196809281991021001

Mengetahui
Dosen Pembimbing 2

Taufik Fajar Nugroho, S.T., M.Sc.
NIP. 197603102000031001

*(This page is intentionally left blank)*

# ABSTRACT

**ANALYSIS OF GREENHOUSE GAS (GHG) EMISSION REDUCTION FROM HEAD TRUCK BY USING ELECTRIFICATION METHOD AT TERMINAL PETIKEMAS**



| | | |
|---|---|---|
| **Student Name / NRP** | **:** | **Dwi Budi Hardiks Dewantara / 5019201066** |
| **Department** | **:** | **Teknik Sistem Perkapalan - ITS** |
| **Supervisor** | **:** | **Prof. Dr. Ir Agoes Santoso, M.SC., M.Phil., CEng, FIMarEST./ 196809281991021001**<br>**Fajar Taufik Nugraha, S.T., M.Sc./ 197603102000031001** |




**Abstract**

Indonesia occupies a key position in the world's important shipping routes. Geographically, Indonesia stands to gain significantly from investing in transitioning to lower carbon emissions. Port emits approximately 938 kilotons of $CO_2e$ annually, with annual emissions of about 5 kilotons of $SO_x$ and 12 kilotons of $NO_x$. These figures indicate that Port is the second-largest emitter of greenhouse gases after Tanjung Priok Port in Jakarta. In this study, it is to find out how much greenhouse gas emissions are produced from the combustion of fuel from head trucks and find out how much reduction can be done if the electrification method is carried out. The concept of electrification is to replace the head truck to become fully-electric. The calculation method follows IPCC 2006 and looks for other methods to calculate greenhouse gas emissions. It is known that $CO_2$ has decreased by 45%-50%, $CH_4$ and $N_2O$ have decreased by 75%-88%. Cost analysis was also carried out using the marginal abatement cost method and operational costs also decreased by up to 75%.



**Kata kunci: Port Emission, Head Truck, Greenhouse Gas**

*(This page is intentionally left blank)*

# ABSTRAK

**ANALISIS PENURUNAN EMISI GAS RUMAH KACA PADA HEADTRUCK DENGAN METOHDE ELEKTRIFIKASI DI TERMINAL PETIKEMAS**



| | | |
|---|---|---|
| **Nama Mahasiswa / NRP** | **:** | **Dwi Budi Hardiks Dewantara / 5019201066** |
| **Departemen** | **:** | **Teknik Sistem Perkapalan - ITS** |
| **Dosen Pembimbing** | **:** | **Prof. Dr. Ir Agoes Santoso, M.SC., M.Phil., CEng, FIMarEST./ 196809281991021001**<br>**Fajar Taufik Nugraha, S.T., M.Sc./ 197603102000031001** |




**Abstrak**

Indonesia menempati posisi kunci dalam jalur pelayaran penting dunia. Secara geografis, Indonesia akan memperoleh manfaat yang signifikan dari investasi dalam transisi ke emisi karbon yang lebih rendah. Pelabuhan mengeluarkan sekitar 938 kiloton CO2e setiap tahunnya, dengan emisi tahunan sekitar 5 kiloton SOx dan 12 kiloton NOx. Angka-angka tersebut menunjukkan bahwa Pelabuhan merupakan penghasil emisi gas rumah kaca terbesar kedua setelah Pelabuhan Tanjung Priok di Jakarta. Pada penelitian ini untuk mengetahui seberapa besar emisi gas rumah kaca yang dihasilkan dari pembakaran bahan bakar head truck dan mengetahui seberapa besar pengurangan yang dapat dilakukan jika dilakukan metode elektrifikasi. Konsep elektrifikasi adalah menggantikan kepala truk menjadi full listrik. Metode penghitungannya mengikuti IPCC 2006 dan mencari metode lain untuk menghitung emisi gas rumah kaca. Diketahui CO2 mengalami penurunan sebesar 45%-50%, CH4 dan N2O mengalami penurunan sebesar 75%-88%. Analisis biaya juga dilakukan dengan metode marginal abatement cost dan biaya operasional juga mengalami penurunan hingga 75%.



**Kata kunci: Emisi Pelabuhan, Head Truck, Gas Rumah Kaca**


.

*(This page is intentionally left blank)*

# FOREWORD

Praise be to the presence of Allah SWT who has bestowed His grace and guidance so that the author can complete the thesis entitled "Analysis of Emission Reduction in Head Truck Electrification At Terminal Petikemas". This thesis was prepared as a requirement to obtain a bachelor's degree in the Department of Shipping Systems Engineering. The preparation of this thesis could not be separated from the support of various parties. Therefore, the author would also like to thank:

1. Allah SWT has given His grace and guidance to make it easier for me to carry out every process of this thesis;
2. Dr. Eng. Dhimas Widhi Handani, S.T., M.Sc. as my guardian lecturer who always support and always giving advces during my study;
3. Prof. Dr. Ir. Agoes Santoso, M.SC., M.Phil., CEng, FIMarEST as supervisor and Mr. Taufik Fajar Nugraha, S.T, M.Sc as Co-Supervisor who has helped and provided assistance to me during the process of working on this thesis;
4. My Parent Mr. Budi Utomo and Mrs. Kukuh Catur Marhaenis, was my motivation to complete my studies well and my motivation;
5. My brother Eko Budi and his family have supported me and provided facilities for me all this time;
6. Revina Hani Rahmadilla, S.Kom who always encourages, accompanies and motivates me;
7. Bryan, Ryo and Marco as my friend in the decarbonisation team;
8. My friends, whom I cannot mention one by one, have accompanied me in the process of this thesis;
9. My self have been strong and survived every process so far.

(This page is intentionally left blank)

**TABLE OF CONTENTS**

VALIDITY SHEET ..... vi
STATEMENT OF ORIGINALITY ..... xi
LEMBAR ORISINALITAS ..... xiii
ABSTRACT ..... xv
ABSTRAK ..... xvii
FOREWORD ..... xix
TABLE OF CONTENTS ..... xxi
LIST OF TABLE ..... xxiii
LIST OF IMAGES ..... xxiv
LIST OF SYMBOL ..... xxvi
CHAPTER 1 INTRODUCTION ..... 1
1.1 Background ..... 1
1.2 Problem Statement ..... 2
1.3 Research Purpose ..... 2
1.4 Problem Boundaries ..... 2
1.5 Research Benefit ..... 3
CHAPTER 2 LITERATURE REVIEW ..... 4
2.1 Bibliometric Analysis ..... 4
2.2 Related Study ..... 4
2.3 Green House Gas (GHG) ..... 7
2.4 Method 1 Green House Gasses Inventory ..... 7
2.5 Method 2 Calculating Greenhouse Gas ..... 10
2.6 Intergovernmental Panel on Climate Change (IPCC) ..... 11
2.7 Difference of Common Air Contaminant and Green House Gas ..... 11
2.8 Green House Gas Effect and Source ..... 12
2.9 Carbon Dioxide (CO2) ..... 13
2.10 Methane (CH4) ..... 13
2.11 Nitrous Oxide (N2O) ..... 14
2.12 Green House Gas Effect ..... 14
2.13 Green House Gas Mitigation ..... 15
2.14 Port **Error! Bookmark not defined.**
2.15 Head Truck ..... 18
2.16 Operation Pattern of Head Truck ..... 18
2.17 Greenhouse Gas from Electrification of Head Truck ..... 18
2.18 Marginal Abatement Cost Curve ..... 20
CHAPTER 3 RESEARCH METHODOLOGY ..... 22
3.1 Research Flowchart ..... 22
3.1.1 Problem Identification ..... 23
3.1.2 Literature Review ..... 23
3.1.3 Data Gathering ..... 23
3.1.4 Data Review ..... 23
3.1.5 Emission Estimation and Operational Cost from Head Truck ..... 23
3.1.6 Emission Estimation, Investment & Operational Cost from Electrical Head Truck ..... 23
3.1.7 Result Analysis ..... 24
3.1.8 Conclusion ..... 24
3.2 Research Schedule ..... 24
CHAPTER 4 RESULT AND DISCUSSION ..... 26

4.1 Head Truck Fuel Consumption Data........................................................26
4.2 GHG Estimation Calculation Results from Head Truck............................27
4.2.1 GHG Estimation Calculation of Head Truck using Method 1.........27
4.2.2 GHG Estimation Calculation of Head Truck using Method 2.........29
4.2.3 GHG Estimation Calculation of Electrical Head Truck...................30
4.3 Investment and Operational Cost..............................................................31
4.3.1 Operational Cost of Head Truck.....................................................31
4.3.2 Investment Cost for Electrification of Head Truck..........................31
4.3.3 Operational Cost of Electric Head Truck.........................................31
4.4 Analysis of Results....................................................................................32
4.4.1 GHG Analysis based on Calculation method 1 of Head Truck with Electrification...................................................................................32
4.4.2 GHG Analysis based on Calculation method 2 of Head Truck with Electrification...................................................................................34
4.4.3 Overview Emission Production.......................................................36
4.4.4 Operational Cost Comparison..........................................................38
4.4.5 Marginal Abatement Cost................................................................38
CHAPTER 5..............................................................................................................40
BLIBIOGRAPHY.......................................................................................................41
ATTACHMENT.........................................................................................................43
AUTHOR BIODATA..................................................................................................46

## LIST OF TABLE

Table 2.1 Related study ........................................................................................................ 5
Table 2.2 Category of Emission Sources from Energy Activities...................................................... 8
Table 2.3 Emission Sources from Fuel Combustion ........................................................................... 8
Table 2.4 GHG Emission Factors of Mobile and Immobile Equipment. ........................................... 9
Table 2.5 Calorific Value of Indonesian Fuel .................................................................................. 10
Table 2.6 Emission Factor from Electricity Consumption ............................................................... 19
Table 4.1 Head Truck Fuel Consumption ........................................................................................ 26
Table 4.2 GHG Estimation Calculation of Head Truck ................................................................... 28
Table 4.3 Emission Total Using Method 2 ....................................................................................... 29
Table 4.4 GHG Estimation from Electrical Head Truck per Day per Truck.................................... 30
Table 4.5 GHG Estimation from Electrical Head Truck per Year ................................................... 30
Table 4.6 Opeartional Cost of Head Truck ...................................................................................... 31
Table 4.7 Investment Cost for Electrification of Head Truck .......................................................... 31
Table 4.8 Operational Cost of Head Truck ...................................................................................... 32
Table 4.9 Operational Cost Comparison .......................................................................................... 38

*(This page is intentionally left blank)*

## LIST OF IMAGES

Figure 2.1 Related Study Regarding to Electrification and Greenhouse Gas Emission Reduction ... 4
Figure 2.2 Polygon representing Indonesia’s EEZ polygon and the shipping activity .................... 17
Figure 4.1 Comparission of CO2 Production in energy Transition................................................ 32
Figure 4.2 Comparission of CH4 Production in energy Transition................................................ 33
Figure 4.3 Comparission of N2O Production in energy Transition ................................................ 34
Figure 4.4 Comparission of CO2 Production in energy Transition................................................ 34
Figure 4.5 Comparission of CH4 Production in energy Transition................................................ 35
Figure 4.6 Comparission of N2O Production in energy Transition ................................................ 36
Figure 4.7 Overview Result of CO2 Total Production.................................................................... 36
Figure 4.8 Overview Result of CH4 Total Production.................................................................... 37
Figure 4.9 Overview Result of N2O Total Production ................................................................... 37
Figure 4.10 Marginal Abatement Cost Detail Calculation.............................................................. 38
Figure 4.11 Marginal Abatement Cost Graph of Electrification Head Truck................................. 39

*(This page is intentionally left blank)*

# LIST OF SYMBOL

| | |
|---|---|
| $CO2$ | Carbon Dioxide |
| $NH4$ | Ammonium |
| $N2O$ | Nitrous Oxide |
| $SFOC$ | Specific Fuel Oil Consumption |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Indonesia is in the strategic shipping lanes in the world. Indonesia geographically has a huge opportunity to investing on transition to lower carbon intensity (Global Maritime Forum; University College London, 2022). Indonesia itself has almost 17,000 island and There are 126 ports under PT. Pelindo as the main-state owner of these ports. This port serves almost 28.000 ships mainly in general cargo, tankers, bulk carriers and other. Port plays big role because, in addition to being a connecting gate for eastern Indonesia, it is also due to increasing economic growth in the East Java Province. This situation has an impact on the increasing flow of goods distribution from and to the East Java region both for domestic goods and international trade.

Port is included in the largest and second busiest port after Tanjung Priok port (Syarifuddin et al., 2016). In supporting services at the port, various aspects are needed, one of which is the service of Head Trucks. As the 5th largest contributor to emissions in the world (Global Maritime Forum; University College London, 2022), Indonesia must take steps to reduce greenhouse gas emissions. The high operational activity at Port is one of the factors contributing to emissions in Indonesia. Port operations which include loading and unloding goods from or to ships, the majority of the tools used are tools that still use combustion engines and still use fossil fuels. One of the things that can be done to reduce these emissions is the use of renewable fuels, the use of low carbon fuel or also using additives that are incorporated into the combustion engine. The IPCC suggest that avoiding the wors scenario by limiting the rise of global temperature to around 1,5˚C. To do so, human -caused emission would need to fall by about 45% from 2010 levels by 2030, reaching at least ‘net-zero’ emissions around 2050 (Allen et al., 2018).

Through the Coordinating Minister for Maritime Affairs and Investment, Luhut Binsar Pandjaitan, Indonesia has the ambition to achieve the net zero emission target by 2060 or sooner. This target can be achieved if its implementation can be done as soon as possible, especially in the maritime sector. The port itself is one of the contributors to emissions. Based on Shipping Energy Transition (2022), Port had a total annual greenhouse gasses emission of 938 kt $CO_2e$ and an annual emission of $SO_x$ of about 5 kt and 12 kt $NO_x$. The data shows that Port is the largest contributor to emissions after Tanjung Priok Port, Jakarta. Greenhouse gases are gases in the atmosphere that absorb and emit infrared radiation. The effects of greenhouse gas accumulation can cause extreme climate change that affect land productivity. The emissions of interest in this study are $CO_2$, $CH_4$, and $N_2O$ (Jatmiko et al., 2019). There needs to be an application of alternative energy that must be applied to achieve the 2050 net-zero emission and green port targets.

Electrification based on renewable energy is widely known as decarbonization method that can only be utilized to power at berth, directly reducing port emission (Global Maritime Forum; University College London, 2022). Switching to electrification can reduce greenhouse gasses emission production and reduce fuel consumption. Switching port activities to rely on electrical energy from renewable sources can reduce GHG emissions. Electrification also can reduce the local air pollution emissions, maintenance, and energy cost. Efforts such as those by PT. PELINDO Regional 3 in Port, have already installed the electric container crane in the port area to operate. One asset that has a lot of quantity is the head truck. Based on data obtained from PT. PELINDO has a total of 105 head trucks operated. The head truck unit contained in the Petikemas Terminal is the most unit compared to other terminals at Port. The electrification of the head truck at the Container terminal, is expected to have a significant impact in reducing emissions in the Port area.

Electrical energy production in Indonesia, 60% still uses coal as fuel (BPS-Statistic, 2020). Especially in the Java-Bali region is supplied by a powerplant located in Paiton, Probolinggo. Paiton Powerplant uses coal as fuel to produce electricity (PLTU, 2018). This has led to polarization that electrical energy is environmentally friendly energy. So, that electrification in Indonesia still cannot be said to be emission free. Further proof is needed whether electrification is proven to reduce emissions.

## 1.2 Problem Statement

The formulation of the problem in this research is:

1. How much electrical energy is needed for Electric Head Trucks at Petikemas Terminal ?
2. How much is the estimation of greenhouse gasses emission from electrification of head trucks at the Petikemas Terminal ?
3. How is the cost analysis with Marginal Abatement Cost for electrification of head truck at the Petikemas Terminal ?

## 1.3 Research Purpose

The objectives of the research to be carried out are:

1. Calculate the estimated electrical energy required untuk Electric Head Trucks at at the Petikemas Terminal.
2. Calculate estimated greenhouse gas emissions from electrification of head trucks at the Petikemas Terminal.
3. Find The cost analysis with Marginal Abatement Cost for electrifiaction of head truck at the Petikemas Terminal.

## 1.4 Problem Boundaries

The limitations of the problem in this research are:

1. The equipment that will be examined is only Head Truck.
2. Research object only at Petikemas Terminal
3. Report greenhouse gas emissions on by identifying equipment included in scope 1 (Direct Emission), especially from Head Truck
4. Based on IPCC 2006 and Guide book of Ministry of Environment of Indonesia, greenhouse gas emission calculation only consist of CO2, CH4 and N2O

## 1.5 Research Benefit

The benefits of this research are:

1. For Port

   Can find out the number of energy audits produced by the Head Truck, as well as considerations in the form of planning to reduce greenhouse gas emissions at Port.

2. For Authors

   Can train skills and apply knowledge in lectures in the Shipping Systems Engineering study program to help the Port authority.

3. For Education

   This research can be used as reference material for another research, especially for emission reduction in port area.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Bibliometric Analysis

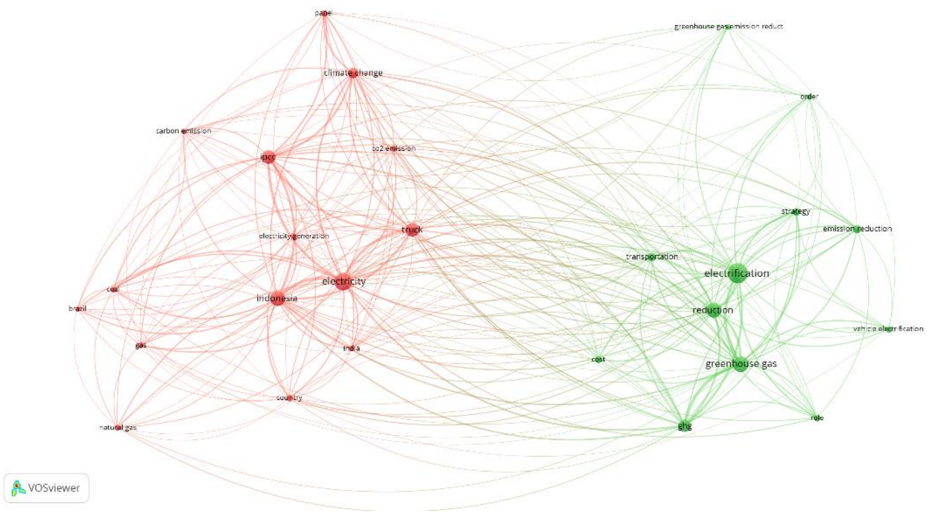



Figure 2.1 Related Study Regarding to Electrification and Greenhouse Gas Emission Reduction

Bibliometrics is the study or measurement of formal aspects of texts, documents, books and information It is a titative study as reflected in the bibliography. Bibliography is the application of mathematical and statistical methods to publications, books, and other communication media. It is an analytical method that uses statistical and mathematical techniques to measure and analyze books or literature. The purpose of bibliometrics is to explain the process of written communication as well as the nature and direction of development of various aspects of communication. Bibliometrics can be used to map research trends and analyze the impact of publications. The main components of bibliometric analysis are citation analysis, co-citation analysis, and paragraphs with bibliographies.

In this study, the author raised topics related to electrification. The focus on research is related to reducing greenhouse gas emissions at PT PELINDO. From this idea, the author will calculate the amount of fuel oil consumption and the amount of emissions produced by Port. From the topic of this final project, the focus that the author will analyze is on the comparison of emissions of fuel-oil-powered equipment and equipment with electrical energy.

## 2.2 Related Study

Here are some supporting studies related to electrification that are good steps to reduce GHG emissions in a company.

Table 2.1 Related study

| Title | Author | Year | Description |
|---|---|---|---|
| Air Emission from In-Land Activities of Chittagong Port of Bangladesh | A.Dey, M.A. Amin, A. Akhter | 2019 | • This study only calculated all equipment operating at Chittagong Port, Bangladesh.<br>• Based on the study, it is said that the largest contributor to emissions is Head Truck.<br>• This is due to the high hours of operation and the number of areas covered. This makes the head truck the highest contributor to emissions at the port.<br>• It is also known that 95.57% is produced from the head truck during running conditions with a total emission of 4,851,317.09 ton. (A. Dey, M. A. Amin, 2019) |
| Study on the Carbon Emission Evaluation in a Container Port Based on Energy Consumption Data | Muhammad Hanzalah Huzaifi, etc | 2019 | • This study took place in Belawan Port, Medan, North Sumatra.<br>• Based on the study, it is said that truck terminals are the 3rd largest contributor to emissions after Diesel Container Crane and Rubber tired gantry crane in the port asset category. The study also showed that docked ships are the largest contributor to emissions in the port area<br>• This study only carried out calculations on tools operating in the Belawan port area, International Terminal. (Huzaifi et al., 2020) |
| Calculating the Carbon Footprint in ports by using a standardized tool | Sahar Azarkamand, etc. | 2020 | • Stating that international calculation standards use the IPCC issued in 2006 and the latest update in 2019.<br>• Each port or government concerned has its own methodology in calculating GHG emissions.<br>• Furthermore, the new tool incorporates the three primary greenhouse gases (carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). The total quantity is shown as a $CO_2eq$ |

| Title | Author | Year | Description |
|---|---|---|---|
| | | | since it contains emissions of all three GHGs. Furthermore, the tool offers choices for choosing scopes that are better suited and appropriate to each port.<br>• This journal is about the creation of a GHG emission calculation application using software designed on a computer. |
| Pollutant Emission at Port: Comprehensive Review | Salvatore Barberi, etc. | 2021 | • If we were to simplify, we could say that there are two primary categories of emissions that pollute the sea: greenhouse gases (GHG) and common air contaminants (CAC). If we want to include other less aggressive pollutants like dust, smoke, odors, and even noise, we could add another category.<br>• Based on this journal, green house gas consist of 3 main gas there are $CO_2$, $CH_4$ and $N_2O$<br>• According to this journal and refer to the (Psaraftis & Kontovas, 2021), The overall amount of greenhouse gas emissions from the marine sector, which include $CO_2$, $CH_4$, $N_2O$, and are measured in $CO_2$ equivalent emissions, or $CO_2e$, grew from 977 million tonnes in 2012 to 1076 million tonnes in 2018 (9.6%), with $CO_2$ accounting for about 98% of these emissions. Reducing greenhouse gas emissions has economical benefits in addition to environmental ones. |
| Review of Initiatives and Methodologies to Reduce CO2 Emissions and Climate Change Effect in Ports | Sahar Azarkamand, etc. | 2020 | • According to the Parliamentary Office of Science and Technology, a process or product's carbon footprint is the total quantity of greenhouse gas emissions, including $CO_2$, that are released over its entire life cycle. The $CO_2$ equivalent ($CO_2eq$) is used to express the other GHGs. |

| Title | Author | Year | Description |
|---|---|---|---|
| | | | • Whereas a few GHGs are radiated actually, there's understanding among climate researchers universally that human action has altogether increased the GHGs within the Earth's climate, driving to accelerating global warming |

## 2.3 Green House Gas (GHG)

The term GHG reflects the function of the earth's atmosphere similar to the effect of glass on greenhouse structures in the context of agricultural practices. The atmosphere allows sunlight to pass through and reach the earth's surface, warming it and thus supporting the existence of living things. This phenomenon is caused by the presence of gases in the atmosphere that can absorb and re-emit infrared radiation, as explained in Illustration 2.2. These gases are referred to as Greenhouse Gases (GHG) because their characteristics resemble those of a greenhouse (KLHK, 2012)

Increasing concentrations of Green House Gases (GHG) are one of the factors causing global warming because they result in an increase in the earth's surface temperature. This GHG has the property of absorbing heat energy from the sun, which produces a greenhouse effect. The rise in temperature on the earth's surface has caused global climate change, such as the emergence of colder winters and very extreme summer temperatures in the northern and southern hemispheres. In tropical countries, climate change is also affecting rainfall patterns, causing an increase in extreme rainfall. The impact of climate change is also seen in agricultural patterns, ecosystems, and the emergence of certain disease outbreaks (Ministry of Energy and Mineral Resources, 2012).

There are six varieties of Greenhouse Gases (GHG), namely: CO2 (carbon dioxide), CH4 (methane), N2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), and SF6 (sulfur hexafluoride). The unit used to describe the amount of emission reduction is t-CO2. Thus, if we reduce 1 ton of emissions from GHG types other than CO2, the reduction will be multiplied by the power ratio compared to CO2. CO2 emissions account for the majority of total GHG emissions (UNFCCC, 2010). Furthermore, the new tool incorporates the three primary greenhouse gases (carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). The total quantity is shown as CO2eq since it contains emissions of all three GHGs. Furthermore, the tool offers choices for choosing scopes that are better suited and appropriate to each port (Azarkamand et al., 2020).

## 2.4 Method 1 Green House Gasses Inventory

Emission inventory refers to the collection of quantitative data that includes all information about air pollution from all sources in a geographic area over a certain period of time. The emissions inventory process provides comprehensive information on all emission sources, including location, magnitude, frequency, duration and relative contribution of emissions. The results of this emissions inventory can be a reference basis for preventive measures against air pollution in the future, as well as assist in analyzing activities that play a role in increasing pollution in a geographic area. In addition, according to (KLHK, 2012), emissions inventory has the following benefits:

1. Assess the air pollution load.
2. Monitor development or changes air quality.
3. Become the basis for data for planning and managing cleaner air.
4. Support the creation of environmental regulations.
5. Becomes the basis of data for air quality modeling, especially air dispersion models.
6. In the context of long-distance transportation, emission inventory studies are useful for understanding the spread of air pollutants across regional boundaries (transboundary).

In the GHG inventory of the energy sector in Indonesia, the categories of emission sources are grouped into 2 main categories, namely emissions from fuel combustion and fugitive emissions. In each category there are several sub-categories grouped by type of activity. Table 2.1 presents the grouping of emission sources for the categories of fuel combustion and fugitive emissions (IPCC, 2006).

Table 2.2 Category of Emission Sources from Energy Activities

| **IPCC Code (2006)** | **Category** |
|---|---|
| **1A** | **Industrial Combustion Activities** |
| 1 A 1 | Industry Produciing Industry |
| 1 A 2 | Industry of Manufacture and Construction |
| 1 A 3 | Transportation |
| 1 A 4 | Other Energy Consument (Houses, Comercial, etc) |
| 1 A 5 | Other Exclude from 1A1 to 1A4 |
| **1 B** | Fugitive Emission |
| 1 B 1 | Solid Fuels |
| 1 B 2 | Natural Oil and Natural Gas |
| 1 B 3 | Other Emission fromteh provision of energy |

Based on the book "Guidelines for Organizing the National Greenhouse Gas Inventory" issued by the Ministry of Environment of the Republic of Indonesia, GHG emission sources from fuel combustion are grouped into 2 main categories, namely stationary sources and mobile sources. As shown in the following table 2.2.

Table 2.3 Emission Sources from Fuel Combustion

| **Code** | **Category** | **Type of Activity** | **Note** |
|---|---|---|---|
| 1 A 1 | Energy Producer Industry | Power plant | Stationer |
| | | Oil Refineries | Stationer |
| | | Production of Solid Fuel Fuel and Other Energy Industries | Stationer |
| 1 A 2 | Manufacturing and Construction Industry | Iron and Steel | Stationer |
| | | Nonferrous Metals | Stationer |
| | | Chemicals | Stationer |
| | | Pupl, Paper and Printed Materials | Stationer |

| Code | Category | Type of Activity | Note |
|---|---|---|---|
| | | Food, Beverage and Tobacco Processing | Stationer |
| | | Non-Metallic Minerals | Stationer |
| | | Transportation Equipment | Stationer |
| | | Machinery | Stationer |
| | | Non-Fuel and Quarry Mining | Stationer |
| | | Wood and Wood Products | Stationer |
| | | Construction | Stationer |
| | | Textile and Leather Industry | Stationer |
| | | Other Industries | Stationer |
| 1 A 3 | Transportation | Civil Aviation | Mobile |
| | | Ground Transportation | Mobile |
| | | Train | Mobile |
| | | Water Freight | Mobile |
| | | Other Transportation | Mobile |
| 1 A 4 | Other Sectors | Commercial and office | Stationer |
| | | Housing | Stationer |
| | | Agriculture/Forestry/Fishermen/Fisheries | Stationer |
| 1 A 5 | Miscellaneous | Emissions from Stationer Equipment, Mobile Equipment | Mobile/ Stationer |

Stationary emission sources are distinguished from mobile emission sources because GHG emission factors, especially non-CO2 GHGs, depend on the type of fuel and technology used for the fuel. Table 2.3 shows the different emission factors of several types of fuel for mobile and stationary equipment.

Table 2.4 GHG Emission Factors of Mobile and Immobile Equipment.

| **Fuel Type** | **Emission Factor for Not Moving Equipment, Ton/Gj (IPCC 2006)** | | | **Emission Factor for Mobile Equipment, Ton/Gj (IPCC 2006)** | | |
|---|---|---|---|---|---|---|
| | **CO2** | **CH4** | **N20** | **CO2** | **CH4** | **N20** |
| **Gas** | 56100 | 1 | 0,1 | 56100 | 92 | 3 |
| **Premium** | - | - | - | 69300 | 33 | 3,2 |
| **Diesel** | 74100 | 3 | 0,6 | 74100 | 3,9 | 3,9 |
| **Industrial/Residual Fuel Oil** | 77400 | 3 | 0,6 | - | - | - |
| **Marine Fuel** | - | - | - | 77400 | 7±50% | 2 |
| **Coal** | 96100 | 10 | 1,5 | - | - | - |

GHG emissions from burning fuel in mobile sources are GHG emissions from transportation activities, including land transportation (road, off road, rail), transportation by water (river or sea) and transportation by air (aircraft). GHGs emitted by fuel combustion in the transportation sector are CO2, CH4 and N2O (KLHK, 2012). Where the calculation of CO2, CH4 and N20 emissions can be done using separate calculations. The calculation of estimated CO2 emissions based on the book of the Ministry of Environment of the Republic of Indonesia can be calculated using the equation (2.1),

$$E = \sum FC \ x \ EF \tag{2.1}$$

where,

Emissions = $CO_2$, $CH_4$ and $N_2O$ Emission

FC = Fuel Consumption

EF = $CO_2$, $CH_4$ and N20 Emission Factor, Based on IPCC 2006 Fuel Type

On the other hand, the available energy consumption data is generally in physical units (tons of coal, kilo liters of diesel oil etc.). Therefore before being used in Equation (2.2), energy consumption data must first be converted into units of energy TJ (Terra Joule) Using the formula,

$$E = \sum Enegrgy\ Consumption\ \ x\ Calorific\ Value\ (Terra\ Joule) \tag{2.2}$$

The various types of fuel used in Indonesia and the calorific value of each fuel are shown in the Table

Table 2.5 Calorific Value of Indonesian Fuel

| Fuel | Calorific Value | Use |
|---|---|---|
| Premium | 33 x $10^{-6}$ TJ/liter | Motor Vehicle |
| Diesel Oil (HSD, ADO) | 36 x $10^{-6}$ TJ/liter | Motor vehicles, Power Plants |
| Industrial Diesel | 38 x $10^{-6}$ TJ/liter | Industrial Boilers, Power Plants |
| MFO | 40 x $10^{-6}$ TJ/liter<br>4,04 x $10^{-2}$ TJ/ton | Power plant |
| Gas | 1,055 x $10^{-6}$ TJ/SCF<br>38,5 x $10^{-6}$ TJ/$Nm^3$ | Industrial, house, restaurant |
| LPG | 47,3 x $10^{-6}$ TJ/kg | House, restaurant |
| Coal | 18,9 x $10^{-3}$ TJ/ton | Power Plant, Industrial |
| Note: *) Include Pertamax, Pertamax Plus | | |

## 2.5 Method 2 Calculating Greenhouse Gas

This method uses for the operation pattern and specifications of the machine. The calculation method used as a comparison of IPCC 2006 and KLHK 2017 is to use the specifications of the engine and operating hours of the truck. It is known that the operational hours of the truck are 16 hours with a system for dividing working hours into 2 work shifts. So it is assumed that the operating hours of the trucks are assumed by generalizing all trucks operating for 8 hours a day. Then, for the specifications of this engine, what is needed is the specific oil consumption of the Volvo FM400 truck engine, which is 10,8 g/kwh. The formula of method 2 is a combination of the IPCC with some modifications by adding calculation elements such as SFOC and operating hours. Here is a formula that can be used to calculate emissions by the following method,

$$E = (SFOC\ x\ Operate\ Hour\ x\ Terra\ Joule\ Convertion)\ x\ Emission\ Factor \tag{2.3}$$

where,

Emissions = $CO_2$, $CH_4$ and $N_2O$ Emission

SFOC = Specific Fuel Oil Consumption (Engine Specification, 10,8 g/kWh)

EF = $CO_2$, $CH_4$ and N20 Emission Factor, Based on IPCC 2006 Fuel Type

The use of method 2 in emission calculation is carried out as a form of one of the methods in emission calculation that can be carried out by PT. Pelindo and indeed allowed by the IPCC to find its own training method and enter the tier 3 category.

## 2.6 Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) is an independent organization founded by the UN in 1998. This organization scientifically and technically carries out surveys related to climate change throughout the world. The IPCC guidelines provide methods for estimating anthropogenic emissions nationally, including emissions from sources and absorption by Greenhouse Gases (GHGs) (Lundie et al., 2009). In compiling an inventory of GHG emissions in Indonesia, the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories were used. Two additional guidelines, namely the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories 2000 and the Good Practice Guidance on Land Use, Land-Use Change and Forestry (GPG for LULUCF) 2003, are also being considered. Along with advances in knowledge about GHG emissions inventory, the IPCC then prepared new guidelines in 2006 which have improved and accommodated the methods contained in the three previous guidelines, namely the 2006 IPCC Guidelines for National Greenhouse Gas Inventories which consists of five volumes (KLHK, 2012).

According to IPCC (2006), the level of accuracy in estimating Green House Gas (GHG) emissions is grouped into three levels known as "Tier" in GHG emissions inventory activities. This level of accuracy includes:

1. Tier 1: Estimates are based on activity data and IPCC default emission factors.
2. Tier 2: Estimates are based on more accurate activity data, as well as IPCC default emissions factors or country or plant specific emissions factors.
3. Tier 3: Estimates are based on country-specific methods with more accurate activity data (direct measurements), and country- or plant-specific emission factors.

Determining tiers in the GHG emissions inventory is very dependent on the availability of data and the level of progress of a country in terms of research to formulate a methodology or determine emission factors that are specific and applicable to that country.

## 2.7 Difference of Common Air Contaminant and Green House Gas

Common air contaminants and greenhouse gases are two different concepts, although they are related. Here are the main differences (Barberi et al., 2021):

1. Definition:

a) Common Air Contaminants: These are pollutants that are present in the air and can have negative impacts on human health and the environment. Examples NOx, Sox Particulate Matter (PM10 and PM2,5), Carbon Monoxide (CO), Ozone (O3), Volatile Organic Compound (VOC).
b) Greenhouse Gases: These are gases that trap heat in the atmosphere, contributing to the greenhouse effect and global warming. Examples include carbon dioxide, methane, and water vapor, N2O, O3 dan CFC

2. Sources:
   a) Common Air Contaminants: These can come from various sources, including natural and human-made activities. Examples include industrial processes, transportation, and agricultural activities.
   b) Greenhouse Gases: These can also come from various sources, including natural and human-made activities. Examples include fossil fuel combustion, land-use changes, and agricultural activities.

3. Effects:
   a) Common Air Contaminants: These can have negative impacts on human health and the environment, such as respiratory problems, cardiovascular disease, and ecosystem damage.
   b) Greenhouse Gases: These can contribute to global warming and climate change, leading to more frequent and severe weather events, sea-level rise, and ecosystem disruption.

## 2.8 Green House Gas Effect and Source

Green House Gas is a gas produced from various macacm factors that cause the appearance of this gas. GHGs are gases trapped in the atmosphere and these gases are able to absorb heat. Geothermal heat that should be emitted is well and only absorbs a small amount of the heat, but the GHG produced makes the infrared emission absorbed more. The ability to absorb heat causes an increase in the earth's temperature and causes the earth's temperature to be hotter. In this case, there are 3 types of gases that can be calculated using the formula contained in the Greenhouse Gas Inventory guidebook issued by the Ministry of Environment. These gases are CO2, CH4 and N2O.

The cause of the emergence of these gases is from many factors such as the burning of fossil fuels, land clearing, industrial activities, transportation, heat production and land use diversion. According to National Planning and Development/Bappenas, transportation is the largest contributor to greenhouse gas emissions after the energy sector. The causes of the appearance of 3 gases identified by the Ministry of Environment include, (Iberdlola, 2024).

1. CO2 (Carbon Dioxide)

   65 percent of the greenhouse impact is contributed. Effect on global temperature: For every doubling of CO2 concentrations, the global temperature rises by around 1°C. Deforestation, changes in land use, and the burning of fossil fuels are the sources.

2. CH4 (Methane)

Contribution to the greenhouse effect: 20%. Effect on global temperature: For every doubling of methane concentrations, there is an approximate 0.5°C increase in global temperature. Landfills, natural gas production and transportation, and agriculture are the sources.

3. Nitrous Oxide ($N_2O$)

   Contribution to the greenhouse effect: 5%. Effect on global temperature increasing global temperature by approximately 0.3°C for every doubling of nitrous oxide concentrations. The source is agriculture, industrial processes, and the burning of fossil fuels.

## 2.9 Carbon Dioxide ($CO_2$)

Fossil energy is concentrated in solar energy with carbon compounds. When carbon is burned, it produces $CO_2$ particles that extend through the entire atmosphere. Fossil fuels began to be known during the first industrial revolution and until now it continues to be used to a very wide scale (Jatmiko et al., 2019). However, excessive fossil energy consumption from large-scale carbon dioxide ($CO_2$) emissions. It is known that $CO_2$ is the root of environmental problems such as global warming, sea level, and frequent extreme weather. But in addition to the greenhouse effect, $CO_2$ also plays a very important role for plant life. Carbon dioxide is absorbed by plants with the help of sunlight and is used for plant growth in a process known as photosynthesis. The same process occurs in the oceans where carbon dioxide is absorbed by algae (Pratama & Kunci, 2019).

The impact of increasing $CO_2$ in the atmosphere includes increasing the earth's surface temperature, rising sea levels, climate anomalies, the emergence of various diseases in humans and animals. Various efforts are made to reduce the effects of $CO_2$. $CO_2$ is the most important greenhouse gas that causes global warming that is being stockpiled in the atmosphere due to human activities. The main contribution of humans to the amount of carbon dioxide in the atmosphere comes from the combustion of fossil fuels, namely petroleum, coal, and natural gas (Pratama & Kunci, 2019).

## 2.10 Methane ($CH_4$)

$CH_4$ is produced by the decomposition of anaerobic organic matter. Organic and water regimes are two important factors that control $CH_4$ emissions. Emissions of methane gas ($CH_4$) into the atmosphere come from natural sources, natural sources affected by human activities, and sources caused by human activities. Methane is a compound that has no color or odor. Methane is one of the gases that causes the greenhouse effect with the potential for global warming 23 times in 100 years (Jatmiko et al., 2019).

Methane ($CH_4$) is the second ranking anthropogenic greenhouse gas (GHGs), with a global warming potential (GWP) 86 times greater than that of $CO_2$ over a 20-year time horizon(Gao et al., 2020). $CH_4$ gas can contribute 15% of total GHGs and has the potential to cause 21 times greater global warming than $CO_2$ gas. Anthropogenic factors (human activities), known to contribute 70% of $CH_4$ gas emissions (Azmi & Arif, 2018). As one of the factors of global warming, there needs to be an effort to reduce the level of $CH_4$ production to reduce global warming and environmental damage.

Diesel fuel is a refined product made from crude oil that also includes other hydrocarbons and trace amounts of methane. The precise amount of methane included in diesel fuel might change based on the type of crude oil used and the particular refining method. Diesel fuel is described as a refined product from crude oil, which contains several hydrocarbons, including methane, in the context of the sources that are given. Diesel fuel may include methane, according to the search results, however it is unclear how much (Jun et al., 2001).

Small quantities of methane can be produced when the hydrocarbons in fuels are not completely combusted. Methane emissions are influenced by the fuel's methane content, the kind of engine, the volume of non-combusted hydrocarbons going through the engine, and post-combustion emission controls. Methane emissions from uncontrolled engines are typically greatest at low speeds and during engine idle. Methane emission from engines that are not adjusted properly may be exceptionally high (Jun et al., 2001).

### 2.11 Nitrous Oxide (N2O)

In the upper stratosphere, N2O is oxidized to NO by the action of UV light, and NO destroys the ozone layer which protects living things against UV-sun radiation. It is estimated that N2O has an infrared absorption capacity of around 300 times more than CO2 (IPCC, 2013). The ability to absorb infrared, coupled with the effects of CO2 that can erode the earth's ozone layer can increase the temperature on earth.

Nitrous oxide is created during the combustion of fossil fuels when fuel or airborne nitrogen oxidizes in the engine's high temperature environment. The amount of emissions from boats, ships, and other vessels is unknown, however it is believed to be negligible. Engine type and fuel type are likely to have an impact on emissions. Although it is anticipated that ships, boats, and other navigational vessels would emit very little N2O, the installation of post-combustion catalytic controls may cause emissions to rise. However, these restrictions are not widely used currently (Jun et al., 2001).

### 2.12 Green House Gas Effect

Earth's temperature is controlled by a natural phenomenon known as the "greenhouse effect." A portion of the solar energy that strikes the planet is reflected back into space. The land, water, and atmosphere absorb the remaining radiation. The globe becomes warmed by this absorbed energy, some of which is reflected as longwave or infrared radiation, most of which escapes into space(Change, 2020). Climate change poses a threat to environment and way of life both now and in the future, regardless of were. But not everyone will be negatively impacted by climate change in the same way. Nevertheless, combating climate change is something we should all be doing. The following are some of the main dangers posed by climate change:

1. Rising Sea Levels – Rising sea levels in wealthy and developing places, like New York City and Dhaka, Bangladesh, respectively, present a dangerous threat to millions of people. As ocean waters warm and glaciers melt, sea-levels will rise. This will affect nearly half of the world’s population as 44% of people live within 150 kilometers (93 miles) of the ocean.8 Places as diverse as Canada, India, Denmark, Nigeria, and Indonesia will be tremendously impacted, with long term effects on population, economics, and energy.
2. Extreme Weather – In the Caribbean and Southeast Asia, as well as other places around the world, hurricanes, tsunamis, and other forms of extreme weather have increased in severity and frequency in the past decade. This can result in more flooding, destroyed infrastructure, damaged crops, and the loss of human life.

3. Changing Precipitation Patterns – Climate change will likely result in an increase in the number of droughts and floods. For countries in sub-Saharan Africa and the Middle East, unpredictable precipitation patterns will have a great impact on agriculture and farming, disrupting millions of lives and livelihoods.
4. Higher Temperatures – A warmer earth will impact many aspects of life, especially with population growth and urbanization. Higher temperatures will increase the number of forest fires and lead to greater food insecurity and water scarcity.

The UNFCCC established a framework to address the complexity and difficulties brought on by a shift in rising global temperatures because it recognized that the Earth's climate is a common resource that necessitates international collaboration. The UNFCCC specifically named greenhouse gas emissions from industry and other sources as the main causes of climate instability and urged countries to implement best practices and regulations to cut back on these pollutants. It also demanded that the richer, industrialized nations and the less developed nations have "common but differentiated responsibilities," and that the industrialized nations share their financial resources, technology, and expertise with the developing nations.

This strategy is a result of the reality that every nation has a unique incentive to combat climate change. Large fossil fuel-producing nations may have distinct policy preferences than do developing nations. Developed countries will need to cut their carbon footprint more drastically, especially the United States and Japan, whose economies rely heavily on fossil fuels and other systems that contribute to global warming. Many people would oppose the necessary changes to achieve this since they might have an impact on their financial security. Furthermore, the nations that would be most negatively impacted by climate change such as Bangladesh, Haiti, Sierra Leone, South Sudan, and the Philippines may demand financial compensation from the nations that will be least impacted and those that have produced the most greenhouse gases. The strategies to address climate change are difficult to implement because of these political complications. As countries pursue their own interests, getting each one to execute universally agreed goals will look different elsewhere.

## 2.13 Green House Gas Mitigation

In 2016, a lion's share of the world's governments concurred on an yearning arrange to handle climate alter, known as the Paris Agreement. This understanding set out a worldwide activity arrange to put the world on track to maintain a strategic distance from unsafe climate alter by restricting worldwide warming to well underneath 2°C (3.6°F). The agreement is due to enter into drive in 2020. Those who have confirmed the agreement here concurred to:

1. a long-term goal of keeping the increase in global average temperature to well below 2°C above pre-industrial levels; and,
2. To limit the increase to 1.5°C, since this would significantly reduce risks and the impacts of climate change.

To achieve this, each nation must presently sign and demonstrate their assent to be bound by the Agreement. The Paris Understanding will be in full lawful drive and impact when at least 55 Parties to the UNFCCC that account for at least 55 percent of the whole worldwide greenhouse gas outflows have kept their rebellious of confirmation, acknowledgment, endorsement or promotion. This implies that the United States, China, and India must concur, as these nations together make up more than 50% of all greenhouse gas emissions (Change, 2020).

Today, the fight against greenhouse gas emissions is at the international level. World summits devoted to this problem are being held, documents are being created aimed at organizing a global solution to the problem. Many scientists of the world are engaged in finding ways to reduce the greenhouse effect, maintaining balance and life on Earth. It is desirable to invent ways to combat the greenhouse effect. For example, in the United Kingdom and the United States, groups of scientists have already created a device of active molecules that decompose greenhouse gases, and then turn them into useful aerosols. In those years there was not enough technically developed equipment that would allocate these molecules in a free form.

GHG mitigation is a form of human intervention that aims to reduce emissions or improve the ability to absorb and convert GHG. In addition to being beneficial in environmental aspects, GHG mitigation usually has a positive impact on social and economic aspects. According to Simpson et al. (2008), there are 4 main strategies for implementing GHG emission mitigation:

1. Elimination, avoiding activities and the use of tools that can produce GHG emissions, for example turning off lights when not in use. The obstacle to this strategy is public awareness of energy-saving behavior. A study in London, England showed that electricity consumption in household samples decreased drastically when they learned that electricity consumption in their homes was monitored and became a sample of energy-saving behavior research by the government (Levermore, 1985).
2. Reduction, carried out by energy efficiency in each activity, for example the selection of electronic equipment that is more energy-efficient. Studies in China show that if every used refrigerator is replaced with an energy-efficient refrigerator, energy savings of 20% will be achieved in the next 15 years. But the obstacle is that energy-efficient products are not the main reason for consumers in China to buy electronic products. Consumers more consider well-known brand factors and price as the first and second reasons when buying electronic products (Ma et al, 2011).
3. Substitution, which is a strategy to replace technology or change behavior that causes the emergence of large GHG emissions with technology or change behavior with low emissions. For example, the use of biogas to replace fossil energy or energy from biomass. The switch to the use of firewood, charcoal, kerosene and LPG to the use of biogas in Tanzania was able to prevent GHG emissions of 5,825 kg CO2-eq/year/family (Laramee & Davis, 2013).

Offset, which is a strategy to absorb GHG concentrations so that GHG emissions that appear can be reduced. An example of an offset strategy is reforestation to absorb carbon dioxide emissions caused by human activities. A study conducted by Putri and Wulandari (2015) showed that the cat's eye resin plant (Shorea javanica) was able to absorb CO2 emissions of 124.86 tons/hectare.

## 2.14 Port

Port is a place consisting of land and / or waters with certain limits as a place of government activities and business activities used as a place for ships to dock, get on and off passengers, and / or loading and unloading goods, in the form of terminals and berths of ships equipped with shipping safety and security facilities and port support activities as well as places for intra- and intermodal transportation movements (PERPRES No.74 Th.2021). One of the biggest in Indonesia is  in Surabaya.  is the second busiest port after Tanjung Priok, Jakarta

(Syarifuddin et al., 2016). Port is one of the gateway ports in Indonesia, which is the center of collectors and distributors of goods to Eastern Indonesia, especially for East Java Province. Because of its strategic location and supported by the potential hinterland area of East Java, Port is also the center of interinsular shipping in Eastern Indonesia.

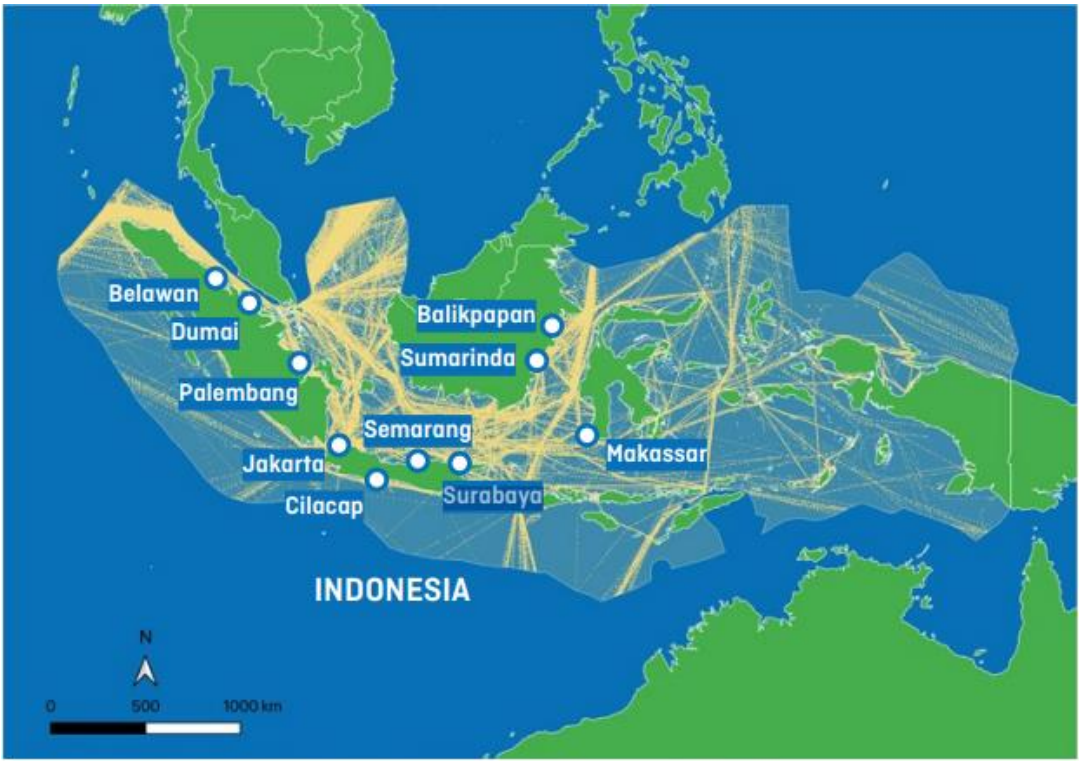



Figure 2.2 Polygon representing Indonesia's EEZ polygon and the shipping activity

(Source: Global Maritime Forum; University College London, 2022)

As one of the busiest ports in Indonesia, Port certainly has tools that can accommodate goods in and out of the port. Recorded based on data obtained from PT. PELINDO, there are 104 head trucks operating at the Surabaya container terminal. The use of a head truck is usually paired with a trailer that is sized according to the size of the container. The size consists of 20 feet and 40 feet, adjusting to the size of the container to be transported. The busyness of this port indicates a long and busy operation pattern of trucks there. This can be seen from the number of containers coming to the port, at least in 2023 yesterday there were 134,652 TEUs and in 2024 there were 136,074 TEUs coming to the port. This is also an indication that the high operation of trucks operating at the port. This can be a sign that the high operating hours of the truck also cause GHG production from the combustion of the fuel used by the truck. There needs to be clear exponential data from the operational data of PT. PELINDO which operates in the port area.

There are at least 110 units of trucks owned by PT. PELINDO which operates in the port area. This is an indication of the emergence of GHG production in the Port area. There needs to be an in-depth analysis of the amount of GHG production produced by the trucks themselves and ways to reduce that production. Based on data on the official website of PT. TPS, at least 1 month there are around 11,000 TEUs coming to the port of . The high arrival of containers arriving at this port indicates the high operational hours of trucks owned by PT. PELINDO. This shows that there is also a high GHG production in the port area. The operational hours at this time also need to be examined again whether there are empty hours but the truck is still alive or idle. This idle condition also continues to burn fuel and also continues to produce greenhouse gases.

## 2.15 Head Truck

Head Truck is a tool used to transport goods with heavy weights with a certain capacity. This head is only the front part which is generally seen on the road to pull containers or chassis to add to the back. This truck generally requires a large torque to be able to pull the item. Head trucks generally use diesel engines that are fueled by diesel. In the Port area itself, the head truck used is a Volvo FM400.

Based on the brochure or roduct guide issued by Volvo with the FM400 series, this engine uses a diesel engine with a specific fuel oil consumption of 10 g/kwh with the same asusmi load at work. In the port area itself, there are 55 units that are always operating with a division of 2 work shifts with 1 work shift being 8 working hours. These operational working hours can be used as a reference to calculate how long this unit runs the engine and how many emissions are produced when the truck is operating.

## 2.16 Operation Pattern of Head Truck

An operational pattern is a pattern or schedule that has been created and arranged based on needs and schedules that have been planned. This pattern follows the busyness or needs of the ships that will come and depart. Trucks that have transported containers from the gantry area will be dispatched to the stacking area and vice versa. This also affects the productivity of each truck and the amount of greenhouse gas produced by it. Operating patterns also affect greenhouse gas production per time period. By including the operating pattern in the calculation of greenhouse gases, it will clarify the number of greenhouse gases produced at a certain time.

Based on inventory data from PT. PELINDO has at least 55 units that operate regularly in the port area of PT. PELINDO. In 2023, there will also be at least 140,000 containers going in and out of the Container Terminal. If analyzed, there are at least 12,000 containers per month assuming that 1 unit of truck transports 218 containers per month. This can be a reference to clarify the production of greenhouse gases from 1 truck transporting 1 container. Then, it also helps to estimate how much reduction can be done in reducing greenhouse gas production if electrification is carried out in the truck. A clear operating pattern starting from idling time and operational time will be very helpful for PT. PELINDO to estimate the number of greenhouse gases with the method that will be used later.

## 2.17 Greenhouse Gas from Electrification of Head Truck

A head truck is a device paired with a trailer to move containers. The size of the trailer that is paired is adjusted to the size of the container to be transported, which is 20-feet or 40-feet. Head truck is one of the crucial tools in the Container Terminal. This is because the head truck is the main component of the trailer truck that transports containers for transfer. This is shown by data obtained from PT. PELINDO, that there are 105 head trucks operating at the Petikemas Terminal.

The high utilization value is accompanied by the high fuel consumption of the head truck. It can be assumed that the high fuel consumption of the head truck also produces high greenhouse gasses emissions. From this, it is necessary to use technology that can reduce greenhouse gasses emissions. One of the efforts that can be done is the electrification of the head truck. Although, 60% of electricity production in Indonesia still uses coal as its main fuel (BPS-Statistic, 2020). However, electrification is an effort that can be done to reduce the production of greenhouse gas emissions in the port area.

60% of electricity production in Indonesia still uses coal fuel (BPS-Statistic, 2020). Especially in the Java-Bali region is supplied by a powerplant located in Paiton, Probolinggo. Paiton Powerplant uses coal as fuel to produce electricity (PLTU, 2018). The results of burning coal certainly also produce similar greenhouse gasses that are also produced by head trucks. There needs to be further evidence regarding the comparison of greenhouse gasses resulting from the use of direct fuel for head trucks and also the use of fossil fuels to produce electricity as an energy source from electric head trucks. The calculation to determine the emissions produced by powerplant using equation (2.4),

$$E = \sum EC \ x \ EF \tag{2.4}$$

where,

Emission = CO2, CH4 and N2O Emission

EC = Electrical Consumption (kWh)

EF = CO2, CH4 and N20 Emission Factor based on Ecometrica

For emission factors of electrical energy consumption for power plants in Indonesia

Table 2.6 Emission Factor from Electricity Consumption

(Source: Brander et al., 2011)

| FE CO2 ton/year | FE CH4 ton/year | FE N20 ton/year |
|---|---|---|
| 0,00084 | 0,0000000141 | 0,00000000775 |

For the calculation of operational costs of the head truck there are several things that need to be known, namely,

1. Types of PLN customer groups, there are 13 types of customers mentioned by PT. PLN. The type of customer affects the price per kWh of electricity usage.
2. Then it can be calculated using equation (2.5),

$$E = \sum Baterry \ Capacity \ needed \ (kWh) \ x \ Electricity \ Cost \tag{2.5}$$

## 2.18 Marginal Abatement Cost Curve

Emission reduction is also inseparable from the implementation of an innovative idea and technology. Cost considerations are one of the things that make an institution or company consider many things that affect the business or services being carried out. Therefore, there needs to be a tool that can provide an overview that reducing emissions in an area does need to make an investment in the implementation of emission reduction technology. Marginal abatement cost is an analysis tool used to analyze how much costs must be incurred and how many emissions are deducted from the costs that have been incurred.

A popular tool for policymakers to show the potential for emission reduction and the associated costs of abatement is the MAC curve. Three factors may be used to sum up the benefits and utility of the MAC curve (Wang et al., 2020). First, by raising public knowledge and transparency of the emission reduction order and related abatement costs, the MAC curve may pinpoint a win-win situation for the abatement units and the environment. Second, certain potentially highly expensive pollution abatement strategies can be selected based on the total cost. These possibilities, which you would otherwise miss, are highlighted by the MAC curve. Thirdly, the MAC curve tells very clearly which is the next abatement unit with greater costs to accomplish one extra emission abatement based on the aggregation level of the amounts of emissions abated. When choosing an emission abatement strategy, the MAC curve may be considered as a guide for determining abatement units.

$$E = \frac{Initial\ Cost\ Investment + Operational\ Cost\ Difference}{Total\ CO2\ Emission\ (Based\ on\ Productivity)} \quad (2.5)$$

The opportunity costs of switching from current to alternative technologies are the basis for market participants' decisions to invest in abatement technologies. The cost (in Cost/t CO2e) related to the final unit of emission abatement for a specific amount of emission reduction is known as the marginal abatement cost (MAC) of a particular abatement measure, and it determines the opportunity costs. As a result, MAC estimations can offer important insights into the economics of reducing carbon emissions and the potential economic benefits of such initiatives industry (Rekker et al., 2023). Furthermore, the utilization of MAC estimations might aid in the economic development and execution of carbon reduction strategies that are particularly aimed at the chemical sector. These strategies could include tax breaks or subsidies for certain low-carbon technology.

*(This page is intentionally left blank)*

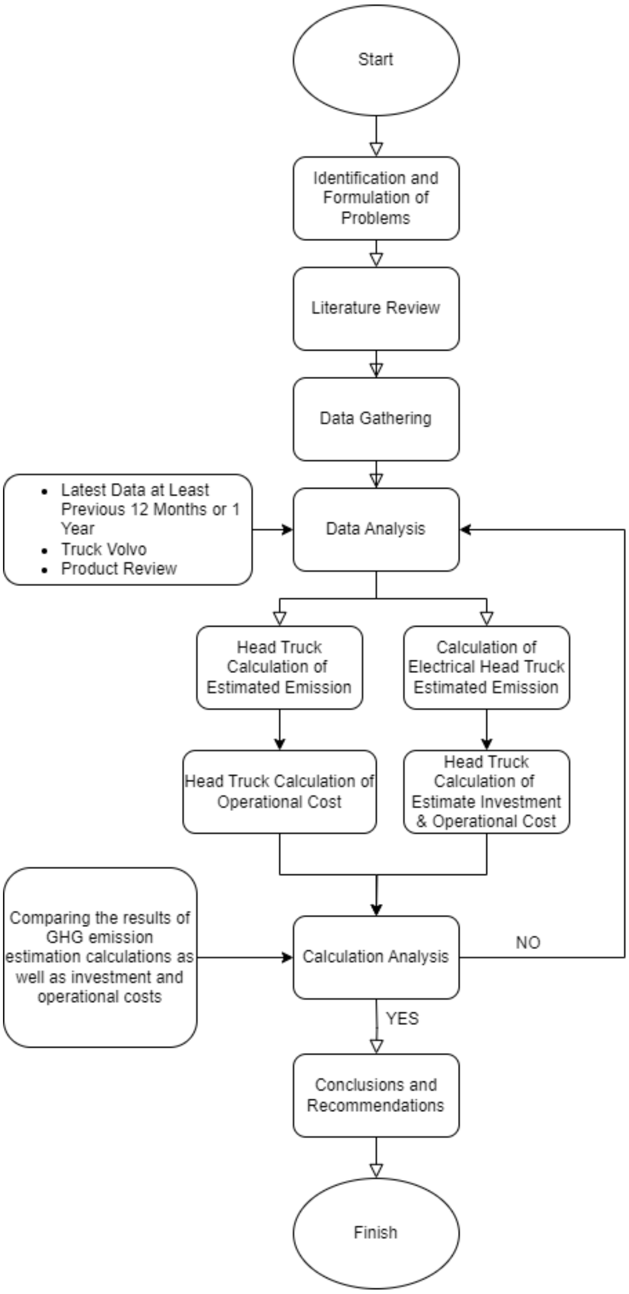
**CHAPTER 3**

**RESEARCH METHODOLOGY**

In this research, author using IPCC method to categorize emissions and calculate the number of emissions per year. After the calculation, there will be analyses to identify the chance to reduce the Emission by Head Truck electrification.

## 3.1 Research Flowchart

This is the Research Flowchart



### 3.1.1 Problem Identification

The initial stage in doing the final project is to formulate a problem that later needs to be solved. In this final project, the main problem that needs to be solved is air pollution produced by exhaust gases due to loading and unloading activities at Indonesian ports. The number of shipments of goods by sea has increased so that the contribution of pollution due to loading and unloading activities at ports is also getting bigger. Therefore, an analysis of emissions produced by exhaust gases due to loading and unloading activities at the port is needed.

### 3.1.2 Literature Review

Literature study is any attempt to collect relevant information related to the topic or problem to be researched. Information can be obtained from scientific books, research reports, scientific essays, theses, dissertations, regulations, statutes, and others related to the theme or topic of this final project.

### 3.1.3 Data Gathering

Data collection is carried out by collecting data used as input needed in calculating emissions to be carried out. The data covered are data on the type of equipment, fuel consumption and type of fuel used at the Port.

### 3.1.4 Data Review

Data review is carried out to find out whether the data that has been received from PT. PELINDO is complete and is in accordance with what is expected. This is done to assist in the input of emission protection from the port. It is expected that the known data is the latest data at least the last 12 months or 1 year earlier.

### 3.1.5 Emission Estimation and Operational Cost from Head Truck

This emission calculation is carried out to determine the emission of greenhouse gases produced by work tools in Port. The calculation of emissions uses calculations used in a book issued by the Ministry of Environment, Greenhouse Gas Inventory, 2012. Not only calculated but whether it is still within the safe threshold set by the Ministry of Environment, Ministry of Health, etc. using equation (2.1) and adjusted to fuel type and calorific value from the fuel used.

### 3.1.6 Emission Estimation, Investment & Operational Cost from Electrical Head Truck

The next calculation is carried out when the equipment at the port uses type of electrical Head Truck operating at the port of . Not only calculated but whether it is still within the safe threshold set by the Ministry of Environment, Ministry of Health, etc. using equation (2.3) and adjusted to fuel type and calorific value from the fuel used.

### 3.1.7 Result Analysis

Analysis of the results regarding the calculation of emissions from Head Trucks before electrification and after electrification. From these results, conclusions will be drawn from the calculation. Also, there is an investment and operational cost of head truck electrification.

### 3.1.8 Conclusion

By analyzing the results of emission calculations, conclusions can be drawn about the emissions produced by the activities of PT. Pelindo in Port, Surabaya. Conclusions include all research results, calculations, etc. This conclusion will answer the points that have been formulated in the objectives and then also provide suggestions based on research results for further research development.

## 3.2 Research Schedule

| No. | Activity | Week | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | Identification Problem | | | | | | | | | | | | | | | | |
| 2 | Literature Review | | | | | | | | | | | | | | | | |
| 3 | Data Gathering | | | | | | | | | | | | | | | | |
| 4 | Data Review | | | | | | | | | | | | | | | | |
| 5 | Emission Calculation | | | | | | | | | | | | | | | | |
| 6 | Emission Calculation from Electrical Usage | | | | | | | | | | | | | | | | |
| 7 | Calculation Result Analysis | | | | | | | | | | | | | | | | |
| 8 | Conclusion | | | | | | | | | | | | | | | | |

*(This page is intentionally left blank)*

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Head Truck Fuel Consumption Data

There are 55 units of head trucks operating at Port, Container Terminal. This data is fuel consumption data for 2023. This data is obtained directly from PT. PELINDO Regional 2. The following is the data obtained from PT. PELINDO,

Table 4.1 Head Truck Fuel Consumption

| No | Code | Utility | Productivity (Box/Year) | Fuel Consumption (Litre/Year) |
|---|---|---|---|---|
| 1 | *212 / VL* | *22%* | *325* | 10.065 |
| 2 | *236 / VL* | *23%* | *554* | 14.070 |
| 3 | *242 / VL* | *13%* | *323* | 8.060 |
| 4 | *243 / VL* | *50%* | *1130* | 30.321 |
| 5 | *261 / VL* | *57%* | *1284* | 33.556 |
| 6 | *262 / VL* | *60%* | *1456* | 35.413 |
| 7 | *263 / VL* | *55%* | *1252* | 32.330 |
| 8 | *264 / VL* | *50%* | *1195* | 31.547 |
| 9 | *265 / VL* | *48%* | *1025* | 28.167 |
| 10 | *266 / VL* | *60%* | *1329* | 35.475 |
| 11 | *267 / VL* | *63%* | *1554* | 37.114 |
| 12 | *268 / VL* | *62%* | *1431* | 36.614 |
| 13 | *269 / VL* | *62%* | *1445* | 33.949 |
| 14 | *270 / VL* | *58%* | *1343* | 31.773 |
| 15 | *271 / VL* | *62%* | *1452* | 35.573 |
| 16 | *272 / VL* | *57%* | *1333* | 32.250 |
| 17 | *273 / VL* | *62%* | *1436* | 38.063 |
| 18 | *274 / VL* | *67%* | *1569* | 38.421 |
| 19 | *275 / VL* | *57%* | *1336* | 33.493 |
| 20 | *276 / VL* | *54%* | *1208* | 32.803 |
| 21 | *277 / VL* | *65%* | *1580* | 36.732 |
| 22 | *278 / VL* | *62%* | *1450* | 36.391 |
| 23 | *279 / VL* | *60%* | *1412* | 34.257 |
| 24 | *280 / VL* | *61%* | *1378* | 35.481 |
| 25 | *281 / VL* | *44%* | *1001* | 25.099 |
| 26 | *282 / VL* | *59%* | *1404* | 35.326 |
| 27 | *283 / VL* | *58%* | *1329* | 33.837 |
| 28 | *284 / VL* | *63%* | *1476* | 38.632 |
| 29 | *285 / VL* | *61%* | *1365* | 37.282 |
| 30 | *286 / VL* | *68%* | *1573* | 38.678 |
| 31 | *287 / VL* | *63%* | *1380* | 36.505 |
| 32 | *288 / VL* | *49%* | *1158* | 28.815 |
| 33 | *289 / VL* | *62%* | *1435* | 34.866 |
| 34 | *290 / VL* | *61%* | *1458* | 37.058 |
| 35 | *291 / VL* | *54%* | *1221* | 32.576 |
| 36 | *292 / VL* | *65%* | *1521* | 39.291 |
| 37 | *293 / VL* | *55%* | *1283* | 33.035 |
| 38 | *294 / VL* | *72%* | *1851* | 44.979 |
| 39 | *295 / VL* | *64%* | *1644* | 41.658 |
| 40 | *296 / VL* | *60%* | *1457* | 37.028 |
| 41 | *297 / VL* | *63%* | *1404* | 36.622 |
| 42 | *298 / VL* | *71%* | *1816* | 45.160 |
| 43 | *299 / VL* | *72%* | *1823* | 46.130 |

| No | Code | Utility | Productivity (Box/Year) | Fuel Consumption (Litre/Year) |
|---|---|---|---|---|
| 44 | *300 / VL* | *63%* | *1592* | 40.987 |
| 45 | *301 / VL* | *66%* | *1626* | 39.483 |
| 46 | *302 / VL* | *69%* | *1671* | 42.175 |
| 47 | *303 / VL* | *70%* | *1613* | 38.625 |
| 48 | *304 / VL* | *66%* | *1493* | 35.264 |
| 49 | *305 / VL* | *66%* | *1519* | 37.383 |
| 50 | *306 / VL* | *62%* | *1519* | 35.912 |
| 51 | *307 / VL* | *71%* | *1718* | 40.556 |
| 52 | *308 / VL* | *63%* | *1474* | 35.624 |
| 53 | *309 / VL* | *66%* | *1533* | 37.560 |
| 54 | *310 / VL* | *66%* | *1511* | 36.866 |
| 55 | *311 / VL* | *66%* | *1506* | 37.536 |
| **TOTAL** | | | | **1.912.463** |

## 4.2 GHG Estimation Calculation Results from Head Truck

### 4.2.1 GHG Estimation Calculation of Head Truck using Method 1

Greenhouse gas calculations can be done by making calculations following calculations from IPCC 2006 and MoEF 2017.Examples of greenhouse gas calculations can be done in the following way

$$CO2 = (Fuel\ Consumption\ x\ Terra\ Joule\ Converstion\ Factor) x\ Emission\ Factor$$

$$CO2 = (1.912{,}463\ x\ 0{,}000036)\ x\ 74{,}1$$

$$CO2 = 5.101{,}687\ Ton/Year$$

$$CH4 = (Fuel\ Consumption\ x\ Terra\ Joule\ Converstion\ Factor) x\ Emission\ Factor$$

$$CH4 = (1.912{,}463\ x\ 0{,}000036)\ x\ 0{,}0039$$

$$CH4 = 0{,}269\ Ton/Year$$

$$N2O = (Fuel\ Consumption\ x\ Terra\ Joule\ Converstion\ Factor) x\ Emission\ Factor$$

$$N2O = (1.912{,}463\ x\ 0{,}000036)\ x\ 0{,}0039$$

$$N2O = 0{,}269\ Ton/Year$$

Likewise for the calculation of CH4 and N2O, what is different is the emission factor used. Based on the existing guidebook, the emission factor used is 0.0039. The calculation of GHG emissions produced follows the Greenhouse Gas Inventory Guidebook issued by the Ministry of Environment in 2012. The calculation follows equation (2.1) to calculate CO2, CH4 and N2O emissions. The following are the results of the calculation of estimated emissions produced from Head Trucks that use B30 Solar fuel,

Table 4.2 GHG Estimation Calculation of Head Truck

| No | Code | Fuel Consumption (Litre/Year) | EMISI | | |
|---|---|---|---|---|---|
| | | | CO2 | CH4 | N2O |
| 1 | *212 / VL* | 10065 | 26,850 | 0,001 | 0,001 |
| 2 | *236 / VL* | 14070 | 37,533 | 0,002 | 0,002 |
| 3 | *242 / VL* | 8060 | 21,500 | 0,001 | 0,001 |
| 4 | *243 / VL* | 30321 | 80,884 | 0,004 | 0,004 |
| 5 | *261 / VL* | 33556 | 89,515 | 0,005 | 0,005 |
| 6 | *262 / VL* | 35413 | 94,467 | 0,005 | 0,005 |
| 7 | *263 / VL* | 32330 | 86,244 | 0,005 | 0,005 |
| 8 | *264 / VL* | 31547 | 84,155 | 0,004 | 0,004 |
| 9 | *265 / VL* | 28167 | 75,139 | 0,004 | 0,004 |
| 10 | *266 / VL* | 35475 | 94,633 | 0,005 | 0,005 |
| 11 | *267 / VL* | 37114 | 99,004 | 0,005 | 0,005 |
| 12 | *268 / VL* | 36614 | 97,671 | 0,005 | 0,005 |
| 13 | *269 / VL* | 33949 | 90,561 | 0,005 | 0,005 |
| 14 | *270 / VL* | 31773 | 84,757 | 0,004 | 0,004 |
| 15 | *271 / VL* | 35573 | 94,893 | 0,005 | 0,005 |
| 16 | *272 / VL* | 32250 | 86,029 | 0,005 | 0,005 |
| 17 | *273 / VL* | 38063 | 101,537 | 0,005 | 0,005 |
| 18 | *274 / VL* | 38421 | 102,491 | 0,005 | 0,005 |
| 19 | *275 / VL* | 33493 | 89,347 | 0,005 | 0,005 |
| 20 | *276 / VL* | 32803 | 87,507 | 0,005 | 0,005 |
| 21 | *277 / VL* | 36732 | 97,987 | 0,005 | 0,005 |
| 22 | *278 / VL* | 36391 | 97,076 | 0,005 | 0,005 |
| 23 | *279 / VL* | 34257 | 91,383 | 0,005 | 0,005 |
| 24 | *280 / VL* | 35481 | 94,650 | 0,005 | 0,005 |
| 25 | *281 / VL* | 25099 | 66,954 | 0,004 | 0,004 |
| 26 | *282 / VL* | 35326 | 94,235 | 0,005 | 0,005 |
| 27 | *283 / VL* | 33837 | 90,264 | 0,005 | 0,005 |
| 28 | *284 / VL* | 38632 | 103,054 | 0,005 | 0,005 |
| 29 | *285 / VL* | 37282 | 99,454 | 0,005 | 0,005 |
| 30 | *286 / VL* | 38678 | 103,179 | 0,005 | 0,005 |
| 31 | *287 / VL* | 36505 | 97,380 | 0,005 | 0,005 |
| 32 | *288 / VL* | 28815 | 76,867 | 0,004 | 0,004 |
| 33 | *289 / VL* | 34866 | 93,008 | 0,005 | 0,005 |
| 34 | *290 / VL* | 37058 | 98,856 | 0,005 | 0,005 |
| 35 | *291 / VL* | 32576 | 86,900 | 0,005 | 0,005 |
| 36 | *292 / VL* | 39291 | 104,812 | 0,006 | 0,006 |
| 37 | *293 / VL* | 33035 | 88,124 | 0,005 | 0,005 |
| 38 | *294 / VL* | 44979 | 119,985 | 0,006 | 0,006 |
| 39 | *295 / VL* | 41658 | 111,127 | 0,006 | 0,006 |
| 40 | *296 / VL* | 37028 | 98,775 | 0,005 | 0,005 |
| 41 | *297 / VL* | 36622 | 97,692 | 0,005 | 0,005 |
| 42 | *298 / VL* | 45160 | 120,468 | 0,006 | 0,006 |
| 43 | *299 / VL* | 46130 | 123,057 | 0,006 | 0,006 |
| 44 | *300 / VL* | 40987 | 109,338 | 0,006 | 0,006 |
| 45 | *301 / VL* | 39483 | 105,324 | 0,006 | 0,006 |
| 46 | *302 / VL* | 42175 | 112,505 | 0,006 | 0,006 |
| 47 | *303 / VL* | 38625 | 103,037 | 0,005 | 0,005 |
| 48 | *304 / VL* | 35264 | 94,070 | 0,005 | 0,005 |
| 49 | *305 / VL* | 37383 | 99,723 | 0,005 | 0,005 |
| 50 | *306 / VL* | 35912 | 95,799 | 0,005 | 0,005 |
| 51 | *307 / VL* | 40556 | 108,187 | 0,006 | 0,006 |
| 52 | *308 / VL* | 35624 | 95,031 | 0,005 | 0,005 |
| 53 | *309 / VL* | 37560 | 100,195 | 0,005 | 0,005 |
| 54 | *309 / VL* | 36866 | 98,344 | 0,005 | 0,005 |
| 55 | *311 / VL* | 37536 | 100,132 | 0,005 | 0,005 |

| No | Code | Fuel Consumption (Litre/Year) | EMISI | | |
|---|---|---|---|---|---|
| | | | CO2 | CH4 | N2O |
| | | **1.912.463** | **5.101,687** | **0,269** | **0,269** |

### 4.2.2 GHG Estimation Calculation of Head Truck using Method 2

The emissions produced by the head truck are also calculated using the 2nd method. Greenhouse gas calculations can be done by making calculations following calculations,

$$CO2 = (SFOC\ x \text{ Operate Hour x } Terra\ Joule\ Converstion\ Factor)x\ Emission\ Factor$$

$$CO2 = \left(11\,\frac{\text{g}}{\text{kWh}}\text{x 8 hours } x\ 0{,}000036\right)\ x\ 74{,}1$$

$$CO2 = 0{,}235\ Ton/day$$

$$CO2 = 4712{,}582\ Ton/year$$

$$CH4 = (SFOC\ x \text{ Operate Hour x } Terra\ Joule\ Converstion\ Factor)x\ Emission\ Factor$$

$$CH4 = \left(11\,\frac{\text{g}}{\text{kWh}}\text{x 8 hours } x\ 0{,}000036\right)\ x\ 0{,}0039$$

$$CH4 = 0{,}0000124\ Ton/day$$

$$CH4 = 0{,}248\ Ton/day$$

$$N2O\ = (SFOC\ x \text{ Operate Hour x } Terra\ Joule\ Converstion\ Factor)x\ Emission\ Factor$$

$$N2O\ = \left(11\,\frac{\text{g}}{\text{kWh}}\text{x 8 hours } x\ 0{,}000036\right)\ x\ 0{,}0039$$

$$N2O\ = 0{,}0000124\ Ton/day$$

$$N2O\ = 0{,}248\ Ton/day$$

The results of the total calculation are as follows

Table 4.3 Emission Total Using Method 2

| Emission Total | |
|---|---|
| 4712,582 | Ton CO2/year |
| 0,248 | Ton CH4/year |
| 0,248 | Ton N2O/year |

The calculation above is by generalizing the specific fuel oil consumption of head trucks operating at the port.

### 4.2.3 GHG Estimation Calculation of Electrical Head Truck

The calculation of this estimated emission follows the calculation on the official website of PT. PLN by using the formula in equation (2.4). In the Electric Head Truck production TERBERG YT 200 EV with a battery capacity of 350kWh is assumed for use in 2 days. From the available battery capacity then multiplied by the emission factor taken from the journal ecometrica, 2011. So, it can be known that the emissions produced are as follows,

$$CO2 = Electrical\ Consumption\ x\ Emission\ Factor$$

$$CO2 = 350\ x\ 0{,}00068$$

$$CO2 = 43{,}855\ Ton/Year$$

$$CH4 = Electrical\ Consumption\ x\ Emission\ Factor$$

$$CH4 = 350\ x\ 0{,}000000014$$

$$CH4 = 0{,}0001\ Ton/Year$$

$$N2O = Electrical\ Consumption\ x\ Emission\ Factor$$

$$N2O = 350\ x\ 0{,}00000000775254$$

$$N2O = 0{,}0005\ Ton/Year$$

Table 4.4 GHG Estimation from Electrical Head Truck per Day per Truck

| **Emission** | **Ton/Day** |
|---|---|
| CO2 | 43,855 |
| CH4 | 0,001 |
| N2O | 0,0005 |

If calculated in a period of time per year, the following results will be obtained,

Table 4.5 GHG Estimation from Electrical Head Truck per Year

| **Emission** | **Ton/Year** |
|---|---|
| CO2 | 219 |
| CH4 | 0,005 |
| N2O | 0,002 |

The estimated emission calculation above can be multiplied by how many trucks will be electrified. Electrification can be done by transitional or directly changing all conventional trucks with electrical trucks

## 4.3 Investment and Operational Cost

### 4.3.1 Operational Cost of Head Truck

Head Truck operating at Port, Container Terminal, there are 110 units. The type of fuel used in the head truck is B30 diesel. It is known that the price of B30 diesel fuel has a price of IDR 15,500 / liter. Overall, the total consumption of this fuel is 2,484,205 liters / year. The following is the calculation of the operational cost of the head truck,

Table 4.6 Opeartional Cost of Head Truck

| | |
|---|---|
| Total Consumption | 2.484.205 liter/year |
| Solar B30 price | 15.500 / liter |
| Total Operational Cost | IDR 38.505.169.750 |

### 4.3.2 Investment Cost for Electrification of Head Truck

Based on the information obtained, 1 unit of TERBERG YT 200 EV costs around Rp. 4,000,000,000 excluding taxes and shipping costs. Based on the information obtained, this unit was shipped from Malaysia, branch offices and warehouses from TERBERG. The price can fluctuate following other exchange rates and fees. As for the energy transition from an economical point of view by electrifying the head truck partially with the following estimates,

Table 4.7 Investment Cost for Electrification of Head Truck

| **Truck Terberg Price** | **Rp 4.000.000.000 (Prices do not include Taxes and billing fees)** | | | | |
|---|---|---|---|---|---|
| **Percentage** | 10% | 25% | 50% | 75% | 100% |
| **Total Head Truck** | 5 | 15 | 30 | 45 | 55 |
| **Investment Cost** | Rp 20.000.000.000 | Rp 60.000.000.000 | Rp 120.000.000.000 | Rp 180.000.000.000 | Rp 220.000.000.000 |

The investment cost will also be affected by how many electric vehicle charging installations can be installed. The factor that affects this booking is the area of land that can be used. It cannot be ascertained how much land can be used, because from the staff of PT. PELINDO itself has not been able to provide certainty about the land that can be used as an electric vehicle charging station.

### 4.3.3 Operational Cost of Electric Head Truck

The operational cost of electric vehicles is influenced by the type of customer category of PT. PELINDO set by PT. PLN. Based on the information obtained, the electricity usage tariff charged is around Rp. 1,500.00.

Table 4.8 Operational Cost of Head Truck

| Operational Cost EV truck | |
|---|---|
| Cost/kwh | Rp 1.500 |
| Consumption | 350 kWh/Day |
| Per Day | Rp 525.000 |
| per Month | Rp 15.750.000 |
| per year | Rp 189.000.000 |

## 4.4 Analysis of Results

### 4.4.1 GHG Analysis based on Calculation method 1 of Head Truck with Electrification

Based on the calculation of CO2 emissions that have been done, if analyzed it is found that the decrease in CO2 emission production has decreased by 41%. The value is obtained through a comparison of CO2 production when the vehicle in operation is still fully fossil fuel compared to when the vehicle is 100% electrified. The calculation results of 10% electrification produce emissions of 219,273 Tons / Year, 25% electrification produces emissions of 657,820 Tons / Year, 50% electrification produces emissions of 1315,639 Tons / Year, 75% electrification produces 1973,459 Tons / Year, 100% electrification produces 2994,338 Tons / Year emissions. Based on these results, it was found that the decrease in CO2 production from conventional trucks can experience a decrease of up to 50% when electrified trucks are 50% or around 30 units.

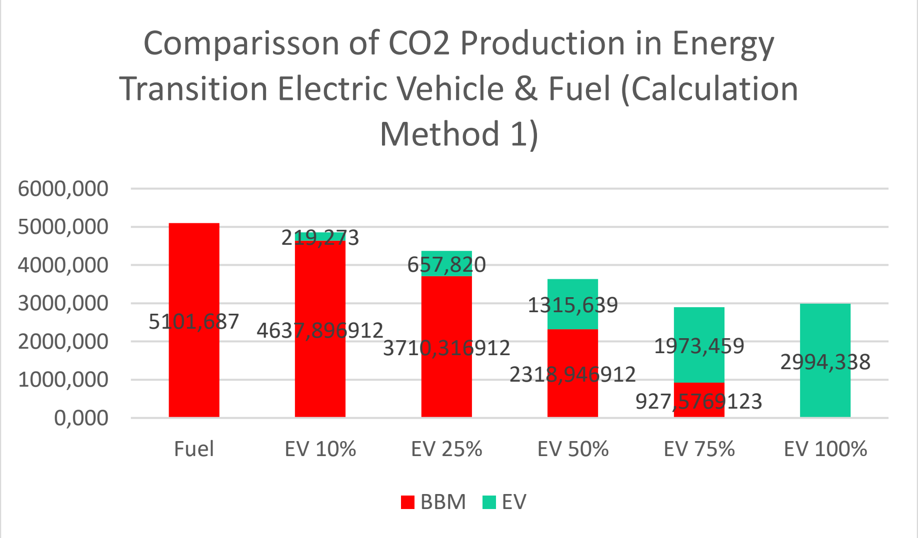



Figure 4.1 Comparission of CO2 Production in energy Transition

If electrification is 100% or equivalent to 55 units of head trucks, then the decrease is up to 42%. The decrease was from a value of 5101.87 tons CO2/year to 2994.388 tons CO2/year.

According to the analysis conducted on methane (CH4) emissions, it was observed that the reduction in carbon dioxide (CO2) emissions has reached 82%. This percentage was determined by comparing the CO2 emissions from vehicles running entirely on fossil fuels to those fully electrified. The calculations revealed that with 10% electrification, emissions were measured at 0.005 tons per year, increasing to 0.014 tons per year at 25% electrification, 0.027

tons per year at 50% electrification, 0.041 tons per year at 75% electrification, and 0.050 tons per year at 100% electrification. These findings indicate that the CO2 emissions from traditional trucks could potentially decrease by up to 50% if half of the fleet were electrified, roughly equivalent to 30 units.

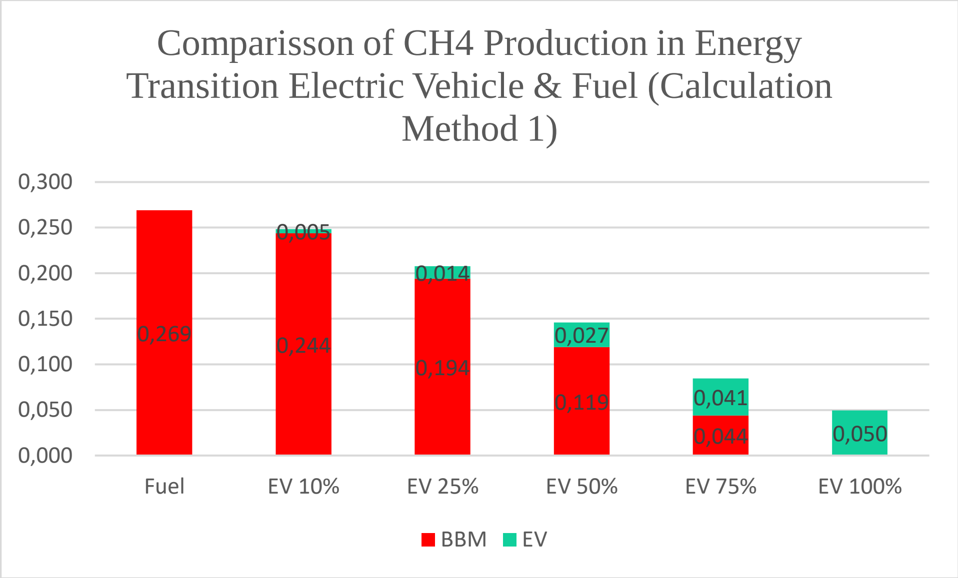



Figure 4.2 Comparission of CH4 Production in energy Transition

Pada figure 4.2 can be seen that the reduction in CH4 is very significant if 100% electrification is carried out on the unit or the equivalent of 55 units. The reduction was up to 82%.

Then the N2O emissions, it has been determined that the reduction in N2O emission production amounts to 90%. This figure 4.3 is derived from comparing the N2O emissions generated by vehicles operating solely on fossil fuels with those operating on 100% electricity. The calculations show that with 10% electrification, emissions are recorded at 0.002 tons per year, increasing to 0.007 tons per year at 25% electrification, 0.015 tons per year at 50% electrification, 0.022 tons per year at 75% electrification, and 0.027 tons per year at full electrification. These findings suggest that the CO2 emissions from conventional trucks could potentially decrease by up to 50% if half of the fleet were electrified, approximately equivalent to 30 units.

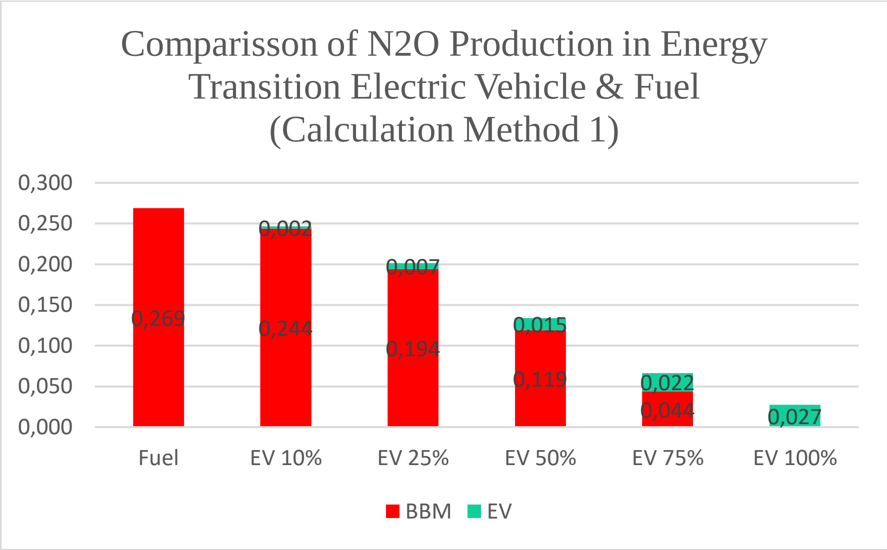



Figure 4.3 Comparission of N2O Production in energy Transition

If electrification is carried out on a 100% basis (equivalent to 55 units), the decrease up to 90%, as can be seen in figure 4.3.

### 4.4.2 GHG Analysis based on Calculation method 2 of Head Truck with Electrification

The decrease in CO2 can be seen in figure 4.4 since the 10% electrification was carried out, the decrease that occurred was 14%. Then in electrification of 25% of the emissions that were reduced were 1484.23 TobCO2/Year or equivalent to 32% of the previous total. A reduction in emissions of 45% or the equivalent of 2111,693 Ton CO2/Year occurred when electrification was carried out by 50% or equivalent to 30 units. When electrification is carried out by 75%, the decrease is around 2310,706 or equivalent to 51%. Then, if full electrification or 100% is carried out, the decrease that occurs is also 47% or equivalent to 1718,244 Ton Co2/Year.

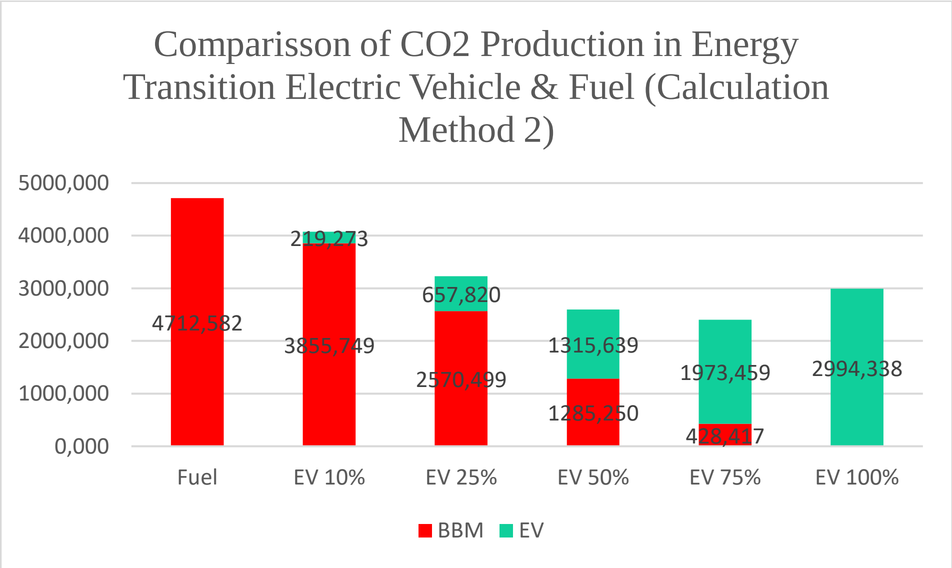



Figure 4.4 Comparission of CO2 Production in energy Transition

Based on the calculation with method 2, it can be seen that the decrease can be seen if electrification is carried out by 50% or the equivalent of 30 units. The decrease from a value of 4712,582 TonCo2/year to a value of 2600,889 TonCo2/year by carrying out a hybridization system with a scale of 50% electric and 50% conventional trucks can reduce CO2 production by 50%.

The CH4 reduction ratio also decreased with each electrification rate carried out. The significant decline began at 25% electrification, the decline is already 50% or equivalent to 0.099 TonCH4/Year. Then a drastic decrease in electrification of 75% decreased to 75% or equivalent to 0.184 TonCH4/Year. 100% electrification shows a very drastic decrease, which is around 80%.

The same decrease also occurred in NO2 due to the use of the same emission factor. Therefore, the decline that occurred in CH4 and N2O had the same value and the same decrease. This N2O calculation is very important considering that the production of fossil fuels itself is also carried out in the process of making the fuel. NO2 itself is one of the items that is indeed counted in greenhouse gas emissions.

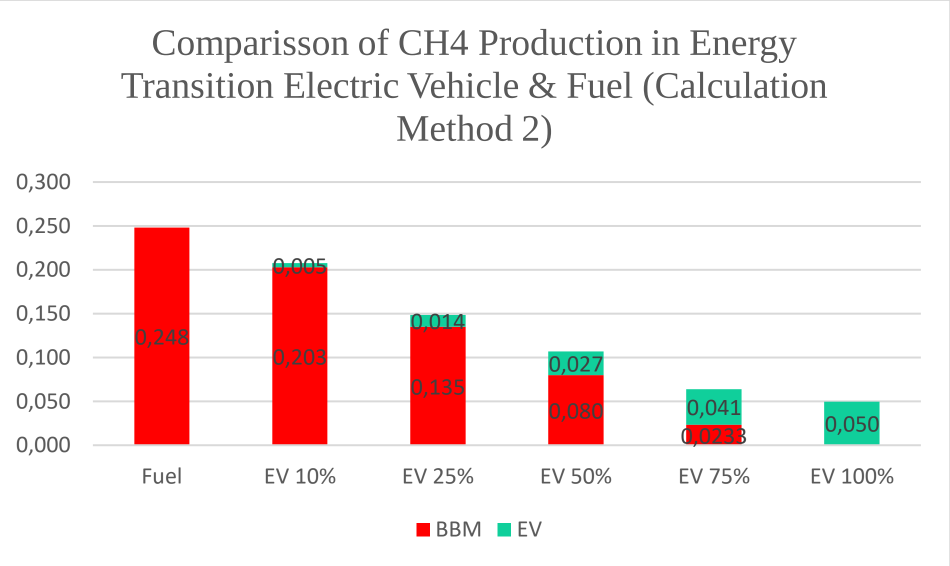



Figure 4.5 Comparisson of CH4 Production in energy Transition

The same decrease also occurred in NO2 due to the use of the same emission factor. Therefore, the decline that occurred in CH4 and N2O had the same value and the same decrease. This N2O calculation is very important considering that the production of fossil fuels itself is also carried out in the process of making the fuel. NO2 itself is one of the items that is indeed counted in greenhouse gas emissions. The same result can be seen in figure 4.6.

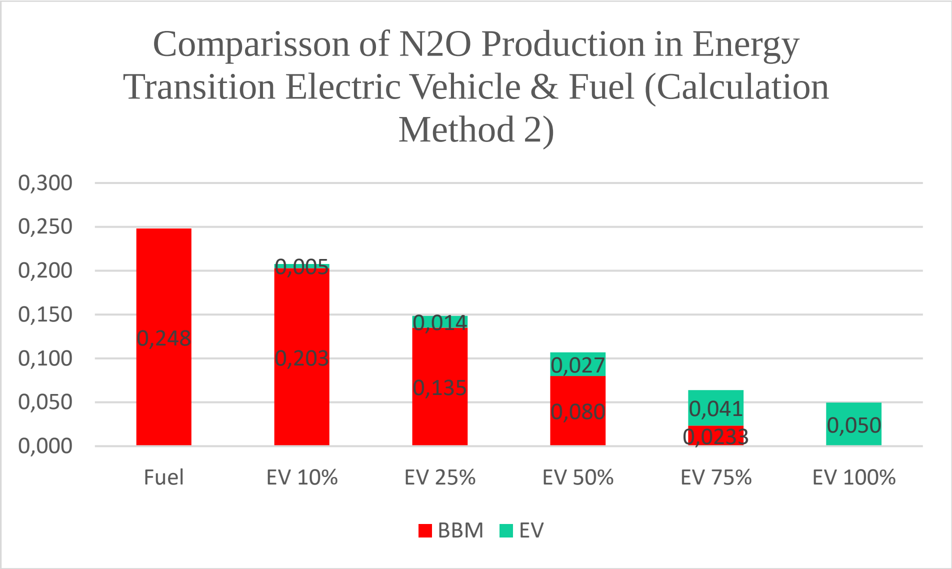



Figure 4.6 Comparission of N2O Production in energy Transition

### 4.4.3 Overview Emission Production

Based on the overview in figure 4.7, this calculation is a total calculation. Comparison of CO2 calculations with method 1 and method 2 has no difference, only around 389.105 TonCO2/Year. The CO2 calculation in method 1 and method 2 is a calculation of CO2 emissions from burning fossil fuel. The difference between the 2 methods is in the variables calculated. The decreases compared to Method 1 and method 2 with electrical vehicle is around 45%-50%.

Then the production of CO2 from electricity is worth 2294,338 TonCO2/Year, this is indirect emissions resulting from the use of electric vehicles. Indirect emissions can arise due to electricity production in Indonesia, where 66% of electricity in Indonesia is produced from coal power plants (BPS-Statistic, 2020). However, this indirect emission results in not much emissions being produced because electricity consumption in electric vehicles is also not too large compared to fuel consumption.

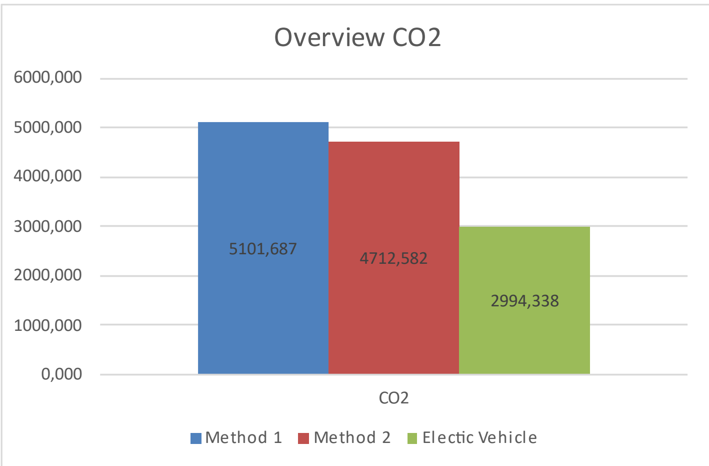



Figure 4.7 Overview Result of CO2 Total Production

Then, $CH_4$ also experiences a drastic decrease when using electric vehicles. This is due to the absence of fuel combustion in electric vehicles. The appearance of $CH_4$ is due to the possibility of incomplete combustion of the engine caused by the age of the vehicle and the type of fuel that is not compatible with the engine. In the graph it can be seen that the reduction ratio in $CH_4$ production from electric vehicles using method 1 and 2 calculations is around 80%. A drastic reduction compared to using vehicles that run on fossil fuels.

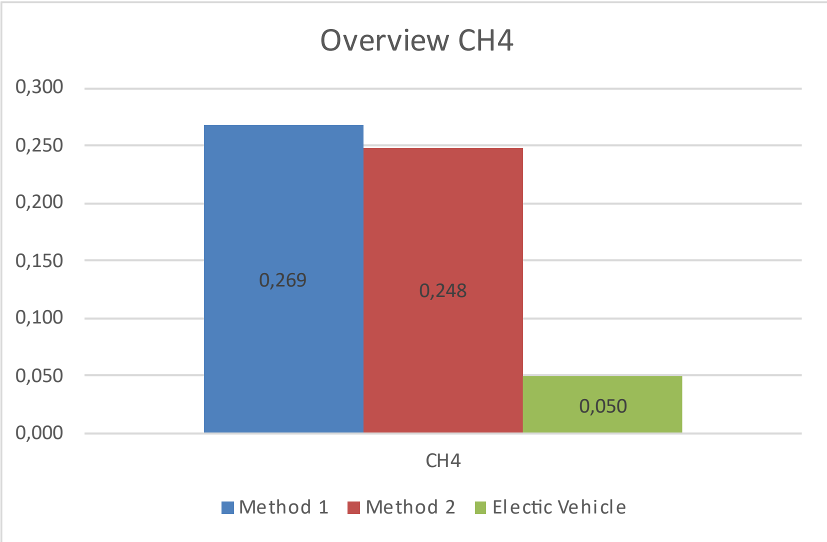



Figure 4.8 Overview Result of CH4 Total Production

Then $N_2O$ also decreased by around 88% -90%. This is because there is no burning of fossil fuels in electric vehicles. Burning fossil fuels, such as coal, natural gas, and oil, can produce $N_2O$ emissions. This process involves incomplete combustion, which can result in $N_2O$ as a byproduct.

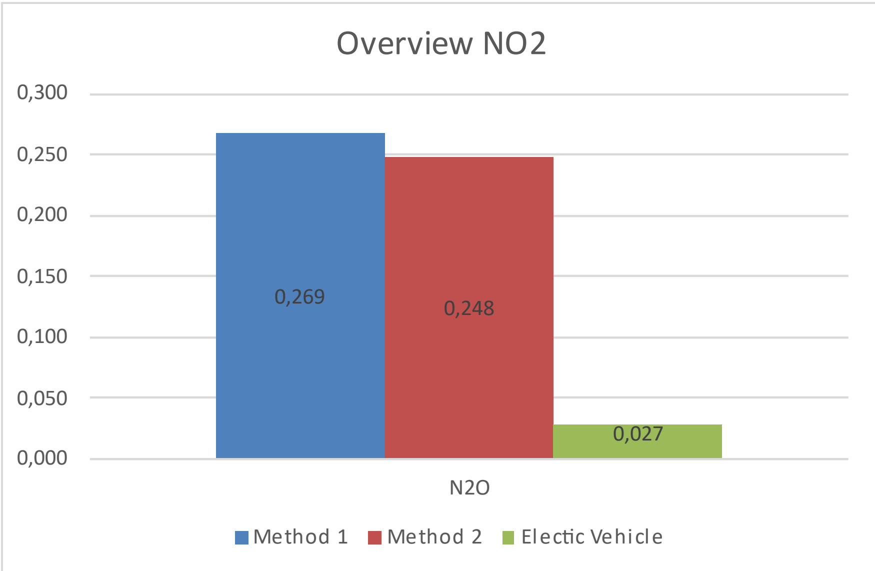



Figure 4.9 Overview Result of N2O Total Production

### 4.4.4 Operational Cost Comparison

The decrease was found in the aspect of operational costs. Reduced operating costs by up to 65%. This is due to the cost of electricity tariffs from PT. Pelindo which is only around Rp 1,500.00. / kWh Compared to the cost of B30 type diesel which is around Rp. 15,500.00. / liter When viewed from the aspect of operational costs, it is certainly more efficient.

Table 4.9 Operational Cost Comparison

| Total Electrical Truck | Operational Cost per Year | Total Conventional Head Truck | Operational Cost per Year | Total Cost |
|---|---|---|---|---|
| 0 | 0 | 55 | IDR 29.643.180.065 | IDR 29.643.180.065 |
| 5 | IDR 945.000.000 | 50 | IDR 26.948.345.514 | IDR 27.893.345.514 |
| 15 | IDR 2.835.000.000 | 40 | IDR 21.558.676.411 | IDR 24.393.676.411 |
| 30 | IDR 5.670.000.000 | 25 | IDR 13.474.172.757 | IDR 19.144.172.757 |
| 45 | IDR 8.505.000.000 | 10 | IDR 5.389.669.103 | IDR 13.894.669.103 |
| 55 | IDR 10.395.000.000 | 0 | 0 | IDR 10.395.000.000 |

This decrease is due to the difference in fuel prices and electricity consumption prices is very high in Indonesia. This price difference can be said to be beneficial for electric vehicle users in Indonesia. Especially tax exemption for electric vehicle users in Indonesia. However, the cost of maintenance and the availability of spare parts in Indonesia is quite difficult to find and has to wait for a long time, not only difficult but also expensive.

### 4.4.5 Marginal Abatement Cost

The calculation of the marginal abatemeen cost of headtruck electrification is carried out by the calculation in the following table 4.10,

| MACC Head Truck Electric | | | |
|---|---|---|---|
| **Item** | **Amount** | **Unit** | **Detail** |
| Total Cost | 220.000.000.000 | Billion | TERBERG YT 200 |
| Investment Cost Spread | 15 | Year(s) | Optional |
| Productivity | 76.170 | Box | 1385 Box/month (Port) |
| Fuel Consumption/Box | 2,00 | Litre/Box | |
| Total Fuel Consumption | 152.340 | Litre | |
| Fuel Price/Litre/Year | 15.500 | IDR/Litre | |
| Total Fuel Cost | 2.361.270.000 | IDR | |
| Electric Consumption/Box | 20,00 | kWh/Box | |
| Electric Cost/kwh | 1.500 | IDR/kwh | |
| Total Electric Cost/Year | 2.285.100.000 | IDR | |
| Margin Cost | 76.170.000 | IDR | |
| CO2 Emission | 406 | Ton/Year | |
| Cost of Changes + Operational Margin Cost | 14.590.496.667 | IDR/Year | |
| MACC | 35.903.387 | IDR/Ton | |

Figure 4.10 Marginal Abatement Cost Detail Calculation

In figure 4.10 and table 4.10, it can be seen that the cost of reducing $CO_2$ emissions can be reduced by a cost of IDR 35,903,387 / $TonCO_2$ if electrification is carried out on the head truck. Calculations for $CH_4$ and $N_2O$ emissions are ignored because the resulting emission values are very small. With the investment value spent at this value, there needs to be a comparison with other emission reduction methods from different tools. The prices above can change according to the operating pattern, type of tool, vehicle brand, and price of the electric vehicle. The comparison needs to be done to find out the cheapest and most efficient cost in seeing the emission reduction.

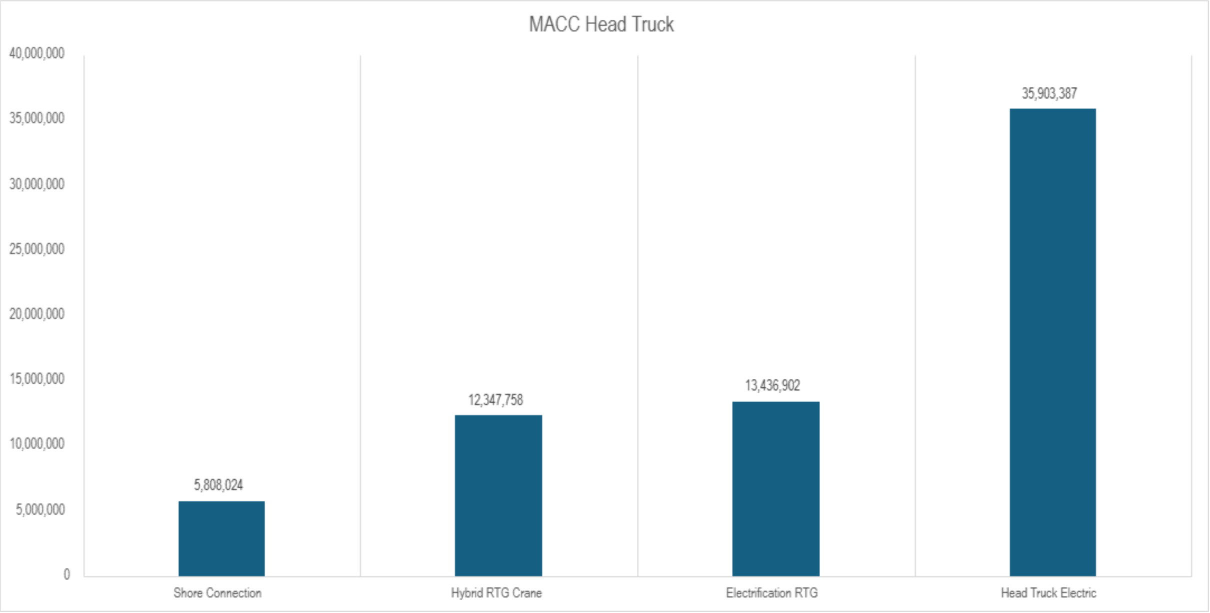



Figure 4.11 Marginal Abatement Cost Graph of Electrification Head Truck

In figure 4.11, when compared with other methods for reducing emissions, it can be seen that the truck head electrification method itself requires quite expensive costs to reduce emissions per ton. This is because the method used is to completely replace all conventional truck head units and make them fully electric. It is also supported by a large number of headtruck units, namely 55 units. However, this price can change if there are different unit prices, specifications and operational technicalities of the truck. This wide price comparison is due to the method used for each emission reduction. Because other methods only modify some parts and add components, not replace them completely.

## CHAPTER 5

## CONCLUSSION

1. In the calculation of method 1, the $CO_2$ production produced by the head truck is 5101.687 Tons$CO_2$/Year, while the production of $CH_4$ and $N_2O$ is 0.269 Tons/Year. When compared between the calculation of method 2, $CO_2$ production is 4712,582 Tons$CO_2$/Year, while for $CH_4$ and $N_2O$ it is 0.248 Tons/Year. Different results are obtained due to the use of different calculation formulas.
2. In the calculation of method 1, $CO_2$ production can be reduced by up to 42% if electrification is carried out on all head truck units. Then $CH_4$ and $N_2O$ production also experienced a drastic decrease of up to 75% if the energy transition from the use of fossil fuel vehicles to electric vehicles is carried out. When compared to the calculation of method 2, $CO_2$ production decreases by 45%-50% when compared to the calculation of emissions of methods 1 and 2. Then $CH_4$ gas drops by up to 80% if a complete energy transition is carried out with electric vehicles. The smallest production is $N_2O$ where the production drops to 88%-90%.
3. The use of electric energy vehicles can also reduce the operational costs of these vehicles. The use of electric vehicles can save costs of up to IDR19,248,180,065 or reduce up to 75% of operational costs if using conventional trucks. However, the investment costs that must be incurred are also not small. With an estimated price of 1 unit of truck is around IDR4,000,000,000/unit. If electrification is carried out as many as 55 units or 100%, the investment value that must be spent is IDR 220,000,000,000. If analyzed more deeply using the Marginal Abatement Cost (MAC) method, it is known that the reduction of emissions per ton in each year can be done by investing a value of IDR 35,903,387 to reduce $CO_2$ emissions. It is necessary to have a comparison of other brands, types of tools, and operating patterns in order to reduce emissions and streamline investment costs.

# BIBLIOGRAPHY

A. Dey, M. A. Amin, A. A. (2019). Air Emission Form In-Land Activities of Chittagong Port of Bangladesh. *Journal of Fundamental of Applied Science*. http://www.globalbuddhism.org/jgb/index.php/jgb/article/view/88/100

Azarkamand, S., Ferré, G., & Darbra, R. M. (2020). Calculating the Carbon Footprint in ports by using a standardized tool. *Science of the Total Environment*, *734*, 139407. https://doi.org/10.1016/j.scitotenv.2020.139407

Azmi, K., & Arif, C. (2018). Analisis sensitivitas emisi gas metana (CH4) pada sawah dengan metode korelasi rank spearman. *Jurnal Teknik Sipil Dan Lingkungan*, *3*(2), 97–110. https://doi.org/10.29244/jsil.3.2.97-110

Barberi, S., Sambito, M., Neduzha, L., & Severino, A. (2021). Pollutant emissions in ports: A comprehensive review. *Infrastructures*, *6*(8). https://doi.org/10.3390/infrastructures6080114

BPS-Statistic. (2020). *Indonesia Electricity Statistic 2015-2020*.

Brander, A. M., Sood, A., Wylie, C., Haughton, A., Lovell, J., Reviewers, I., & Davis, G. (2011). Electricity-specific emission factors for grid electricity. *Ecometrica*, *August*, 1–22.

Change, N. G. C. (2020). *The Greenhouse Effect. A Briefing from the Hadley Centre, Hadley Centre for Climate Prediction and Research, UK Meteorological Office, Exeter. May*, 1–11.

Gao, J., Guan, C. H., & Zhang, B. (2020). China's CH4 emissions from coal mining: A review of current bottom-up inventories. *Science of the Total Environment*, *725*, 138295. https://doi.org/10.1016/j.scitotenv.2020.138295

Global Maritime Forum; University College London. (2022). *Shipping's Energy Transition: Strategic Opportunities in Indonesia*. 113. https://oceanjusticeinitiative.org/wp-content/uploads/2022/08/Shippings-Energy-Transition_Strategic-Opportunities-in-Indonesia.pdf

Huzaifi, M. H., Budiyanto, M. A., & Sirait, S. J. (2020). Study on the carbon emission evaluation in a container port based on energy consumption data. *Evergreen*, *7*(1), 97–103. https://doi.org/10.5109/2740964

Iberdlola. (2024). *Greenhouse effect The consequences of the greenhouse effect: from desertification to floods*. https://www.iberdrola.com/sustainability/greenhouse-effects-consequences-and-impacts

IPCC. (2006). *CHAPTER 1 INTRODUCTION TO THE 2006 GUIDELINES*. 1–12.

IPCC. (2013). Intergovernmental Panel of Climate Change 2021—The Physical Science Basis. In *Chemistry International* (Vol. 43, Issue 4). https://doi.org/10.1515/ci-2021-0407

Jatmiko, A. R., Suryani, E., & Octabriyantiningtyas, D. (2019). The analysis of greenhouse gas emissions mitigation: A system thinking approach (case study: East Java). *Procedia Computer Science*, *161*, 951–958. https://doi.org/10.1016/j.procs.2019.11.204

Jun, P., Gillenwater, M., & Barbour, W. (2001). CO2 , CH4 , and N2O Emissions from Transportation-WaTer-Borne Navigation. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 71–92. http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/2_4_Water-borne_Navigation.pdf

KLHK. (2012). Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional Buku II - Volume 1 Metodologi Penghitungan Tingkat Emisi Gas Rumah Kaca. *Kegiatan Pengadaan Dan Penggunaan Energi*, *1*(3), 1–250.

PLTU, P. (2018). *PLTU Paiton di Probolinggo Berkapasitas Terbesar di Indonesia*. https://paiton.probolinggokab.go.id/pltu-paiton-di-probolinggo-berkapasitas-terbesar-di-indonesia/#:~:text=PLTU Paiton 3 menggunakan batu,7%2C4 triliun%2Ftahun.

Pratama, R., & Kunci, K.-K. (2019). Efek Rumah Kaca Terhadap Bumi. *Cetak) Buletin Utama Teknik*, *14*(2), 1410–4520.

Psaraftis, H. N., & Kontovas, C. A. (2021). Decarbonization of maritime transport: Is there light at the end of the tunnel? *Sustainability (Switzerland)*, *13*(1), 1–16. https://doi.org/10.3390/su13010237

Rekker, L., Kesina, M., & Mulder, M. (2023). Carbon abatement in the European chemical industry: assessing the feasibility of abatement technologies by estimating firm-level marginal abatement costs. *Energy Economics*, *126*(September 2022), 106889. https://doi.org/10.1016/j.eneco.2023.106889

Syarifuddin, M., Musadieq, M., & Yulianto, E. (2016). Pentingnya Pelabuhan Bagi Perekonomian Jawa Timur (Studi pada PT. PELINDO III Surabaya). *Jurnal Administrasi Bisnis S1 Universitas Brawijaya*, *35*(1), 172–178.

UNFCCC. (2010). *Report of the Conference of the Parties on Its Fifteenth Session, Held in Copenhagen from 7 to 19 December 2009, Addendum, Part Two: Action Taken by the Conference of the Parties at Its Fifteenth Session*. United Nations Framework Convention on Climate Change.

Wang, K., Xian, Y., Yang, K., Shi, X., Wei, Y. M., & Huang, Z. (2020). The marginal abatement cost curve and optimized abatement trajectory of CO2 emissions from China's petroleum industry. *Regional Environmental Change*, *20*(4). https://doi.org/10.1007/s10113-020-01709-3

# ATTACHMENT

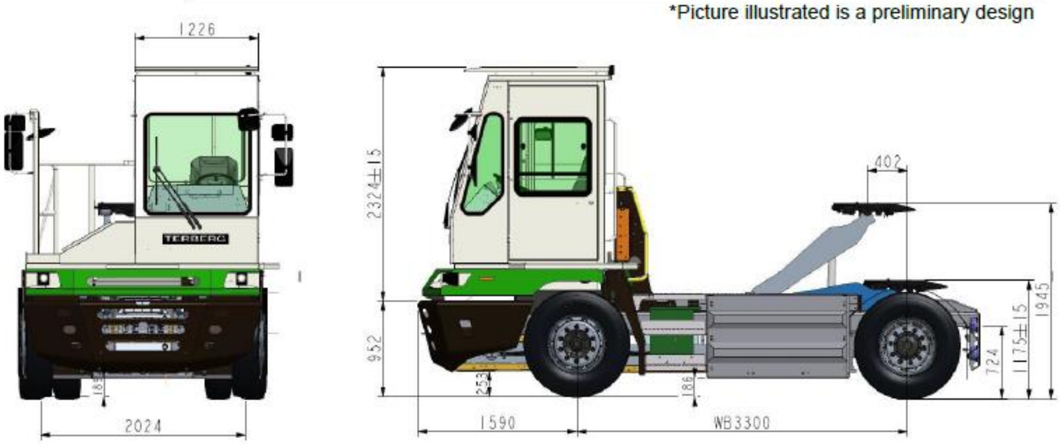
Attachment 1 Terberg YT200 EV Spesification

(Source: Terberg YT200 EV Brochure)

TERBERG TRACTORS MALAYSIA
*Manufacturer of special vehicles*

**TERBERG YT 200 EV, 4x2 Technical Specification**

*Picture illustrated is a preliminary design




**TRACTION MOTOR**

**Greatland 240/120kW (GLMP320L3)**
Asynchronus water cooled E-motor with well matched Inverter + dedicated control-ECU.

Rated Power: ............................120kW
Max Power: ..............................240kW
Rated Torque: ......................... 1160Nm
Max Torque: ...........................2500Nm

**BATTERY PACKS**

**CATL L302**
Terberg integrated CATL battery packs using LFP cells and equipped with fluid operated temperature conditioning system to allow operation in all climates.

**3300mm WB:**
Capacity:...............................350 kWh
Working Voltage:.......................579.6 V

**BATTERY CHARGER**

Charging the vehicle is possible with every charger that fullfills the *CCS2.0 charging standard. Detailed charger requirement information can be provided.

*Charger capacity:..min 150 kW/charging plug*
*Charger plug type:..................CCS2.0 (dual gun charging)
*Charger capacity depending on charger model

**FRONT AXLE**

**Terberg TTA 62-XX**
Non-driven steering axle
Capacity: 11.000 KGs (at 20 km/h)*
* depending on tyre rating

**REAR AXLE**

**Fixed axle: Terberg TTA 71-XX**
Capacity 38.000 kgs (20 km/h)*
Reduction ratio 16.22:1
* depending on tyre rating

**SUSPENSION**

**Front:** Parabolic leaf springs in rubber mountings with 2 telescopic shock absorbers. Maintenance free system.

**Rear:** Directly bolted to chassis frame.

**GROSS COMBINATION WEIGHT**

GCW capacity: up to 88* tons (TTA71-16.22:1)
*depending on axle + ratio

**RIMS AND TYRES**

**Tyres:** 11 R 22.5 (6 pieces)
**Rims:** 10 stud disc wheels B8.25x22.5

**STEERING SYSTEM**

Fully hydrostatic orbitrol steering-system and double acting steering cylinder.
Emergency steering property.
Steering wheel diameter 350 mm.

Turning circle over front bumper (m)
WB 3300 14.5m

**$5^{th}$ WHEEL**

**Terberg 2" Cast steel plate**

Technical capacity 36.000 kgs.
Automatic locking of jaw system.
Pneumatic unlocking of 5th wheel, operated from cabin.

**HYDRAULIC SYSTEM**

HV E-motor driven fixed displacement pump for steering icw orbitrol steering unit and 2.2ltr oiltank with low oil level alarm..

HV E-motor driven fixed displacement pump for lifting/lowering fifth wheel plate. Hydraulic valve electrically/pneumatically operated from inside the cab to lift/lower/hold the $5^{th}$ wheel. Working pressure 220 Bar.
Hydraulic oil tank capacity $40dm^3$
2 heavy-duty hydraulic double acting lift cylinders.

**CHASSIS**

Welded construction of rolled steel channels 200x100x10 mm
All components protected mounted to the chassis.
Ergonomically designed access steps on both sides with anti-slip surface.
40mm towing pin attachment at front and rear of chassis.

**BRAKE SYSTEM**

2-cyl HV air compressor.
Full air brake system with split front- and rear-axle and parking brake circuits.
Parking brake working on rear axle.
TTA front and rear axles equipped with S-Cam brake system with automatic slack adjusters. ABS Brake System.

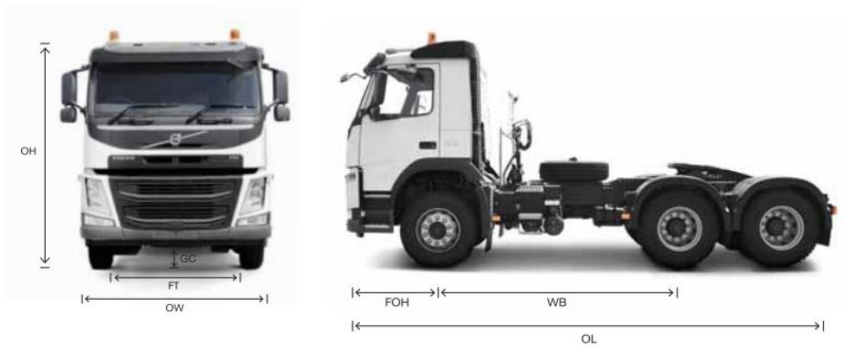
Brake pressure: 7.8-8.5 Bar
Air reservoirs: 3x40 dm3.
$dm^3$ with standard air dryer.

2 Line trailer brake system mounted on rear side of cabin, with yellow and red spiral hoses with glad-hands.

Attachment 2 Volvo FM400 Specification

(Source: Volvo FM400 Brochure)

# TECHNICAL SPECIFICATION




| Drive | |
|---|---|
| 6x4, Right hand drive | |

| Engine | D11A370 |
|---|---|
| Max output at 1600-1900 r/min | 370 hp(273 kW) |
| Max engine speed | 2100 r/min |
| Max torque at 1000-1400 r/min | 1770 Nm |
| No of Cylinders | 6 |
| Displacement | 10.8 $dm^3$ |
| Stroke | 152 mm |
| Bore | 123 mm |
| Compression ratio | 18.3 : 1 |
| Economy engine speed | 1050-1500 r/min |
| Exhaust brake effect at 2400 r/min | 160 kW |
| VEB - Volvo Engine Brake effect at 2400 r/min | 290 kW |
| Oil filters | 2 full-flow, 1 bypass |
| Oil change volume, incl filter | 36 l |
| Cooling system, total volume | 36 l |

| Clutch | CS43B-OR |
|---|---|
| Type | Drag type clutch with a single friction disc which provides good manoeuvrability |
| Disc diameter | 430 m |

| Transmission | VT2009B |
|---|---|
| Type | Synchronized range change splitter gearbox |
| No of speeds | 8 forward, 1 crawler and 2 reverse |

Gear ratios

| | | | | | |
|---|---|---|---|---|---|
| 1st | 16.85 | 6th | 2.72 | R1 | 15.08 |
| 2nd | 10.18 | 7th | 1.91 | R2 | 4.02 |
| 3rd | 7.16 | 8th | 1.34 | | |
| 4th | 5.04 | 9th | 1.00 | | |
| 5th | 3.75 | | | | |

| Steering | |
|---|---|
| Type | Power steering system |
| Ratio | 20.0:1 |

| Front Axle | FA-HIGH |
|---|---|
| Type | Front axle with high ground clearance |
| Max. axle pressure | 8000 kgs |

| Front Suspension | FST - PAR3 |
|---|---|
| Description | 3 leaf parabolic suspension |
| Number of springs | 3 with 2 shock absorbers and stabilizer |
| Capacity | 8000 kgs |

| Rear Axle | RTS2370A |
|---|---|
| Type | Tandem axle with single reduction, hypoid gears |
| Ratio | 3.40 |

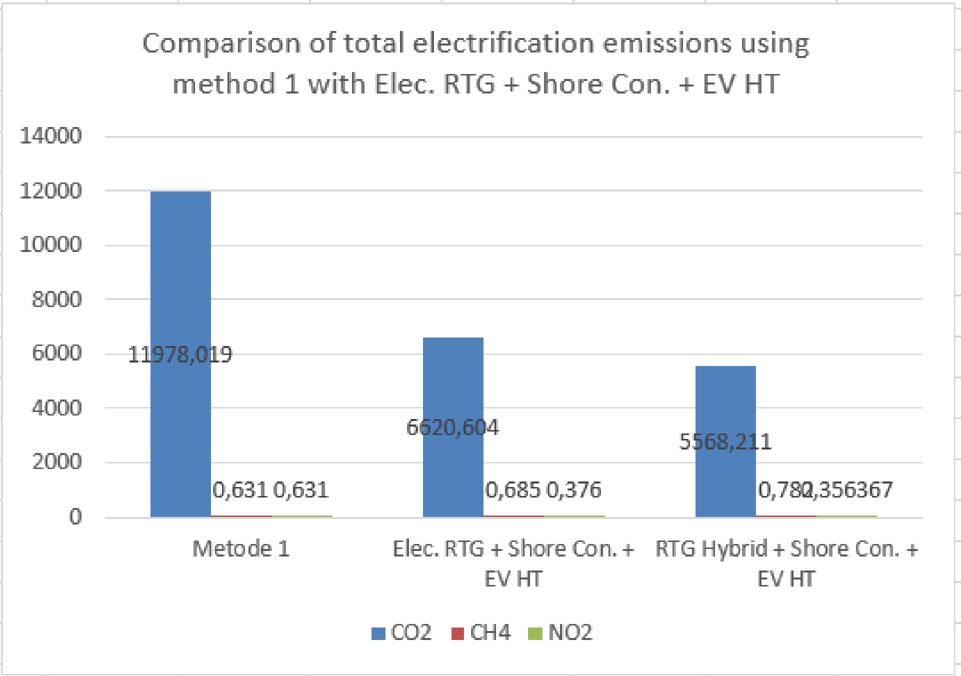
| Rear Suspension | |
|---|---|
| Type | Bogie type with multi-leaf springs with reaction rods and V-Stay Rods and shock absorbers |
| Capacity | 23000 Kgs |

| Brakes | |
|---|---|
| Brake system | Pneumatic brakes with ABS |
| Service brakes | Dual line full air brakes with automatic adjustment and asbestos-free liners |
| Parking brakes | Manually operated electric parking brake |
| Trailer brakes | Trailer brake connection with long coiled trailer brake |

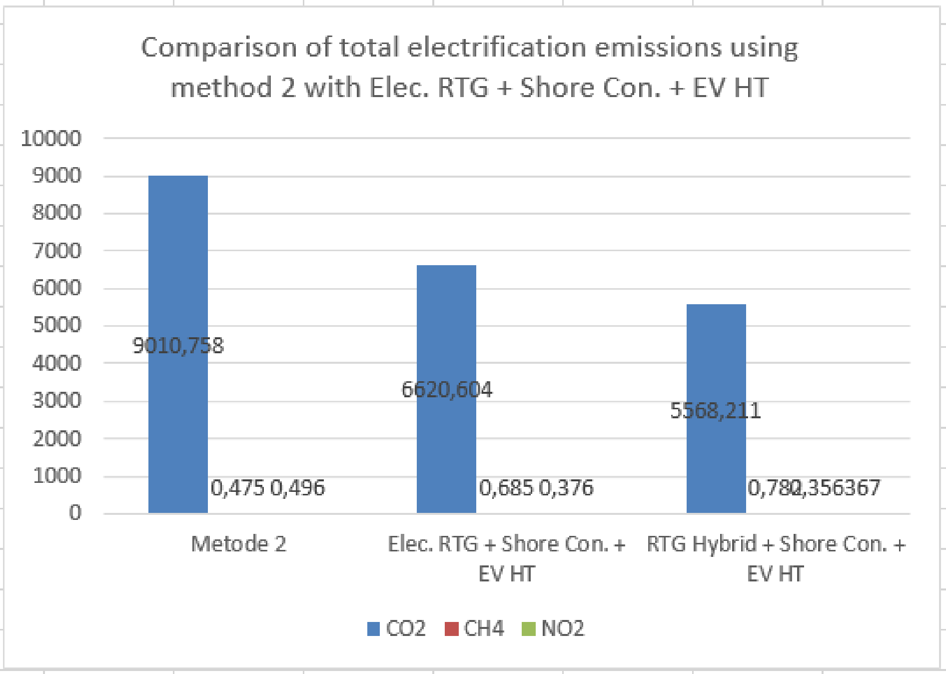
| Wheels and tires | |
|---|---|
| Wheels | 8.25" x 22.5" |
| Tyres | 295/80 R22.5 |
| Spare wheel | Same type as front wheel |

**Interior**

Attachment 3 Comparison of total electrification emissions using method 1 with Elec. RTG + Shore Con. + EV HT




Attachment 4 Comparison of total electrification emissions using method 2 with Elec. RTG + Shore Con. + EV HT



# AUTHOR BIODATA

The author was born in Jember, 02 May 2001, is the second child of 2 brothers. The author has received formal education, namely at Kindergarten Pertiwi Jember, SDN Kepatihan 6 Jember, SMPN 1 Jember and SMAN 1 Jember. After graduating from SMAN in 2020, the author took part in the SBMPTN and was accepted into the Department of Shipping Systems Engineering - ITS in 2020 and was registered with NRP 5019201066.

In the Department of Marine Systems Engineering, the author was active in several seminar activities organized by the Department and the Marine Solar Boat Team (MSBT) which is overseen by ITS.