FINAL PROJECT PROPOSAL – TI234835

ANALYSIS OF THE SUPPORTING FACILITIES POLICY IMPACT FOR THE ELECTRIC MOTORCYCLE ADOPTION IN INDONESIA

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Department of Industrial and Systems Engineering

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TUGAS AKHIR – TI234835

ANALISIS DAMPAK KEBIJAKAN FASILITAS PENUNJANG UNTUK ADOPSI MOTOR LISTRIK DI INDONESIA

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hereby declare that the Final Assignment with the title "Analysis of The Supporting Facilities Policy Impact for The Electric Motorcycle Adoption in Indonesia" is 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 Sepuluh Nopember Institute of Technology.

Surabaya, 10 July 2024

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VALIDITY SHEET

ANALYSIS OF THE SUPPORTING FACILITIES POLICY IMPACT FOR THE ELECTRIC MOTORCYCLE ADOPTION IN INDONESIA

FINAL ASSIGNMENT PROPOSAL

Submitted to fulfill one of the requirements to

earn a bachelor's degree in

Study Program S-1 Industrial Engineering

Department of Industrial and Systems Engineering

Faculty of Industrial Technology and Systems Engineering

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KEMENTERIAN PENDIDIKAN, KEBUDAYAAN, RISET, DAN TEKNOLOGI
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
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DEPARTEMEN TEKNIK SISTEM DAN INDUSTRI

Surabaya, 10 July 2024

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ABSTRAK

ANALISIS DAMPAK KEBIJAKAN FASILITAS PENUNJANG UNTUK ADOPSI MOTOR LISTRIK DI INDONESIA

Nama Mahasiswa / NRP	**:**	**Rayhan Makarim / 5010201120**
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Abstrak

Pada pertengahan tahun 2023, 125 juta sepeda motor menghasilkan 300 juta kilogram emisi per hari yang menyumbang emisi terbesar kedua di Indonesia. Isu ini mendorong pemerintah Indonesia untuk mencapai target penurunan emisi sebesar 32%, salah satunya dengan mendorong transportasi energi bersih melalui adopsi 13.469.000-unit sepeda motor listrik hingga tahun 2030 dengan fokus pada faktor-faktor adopsi yang paling mempengaruhi, termasuk kebijakan mengenai infrastruktur fasilitas pendukung. Namun, adopsi yang didukung oleh kebijakan insentif masih mengalami penundaan yang signifikan karena besarnya populasi negara ini dengan karakteristik pengadopsi dan budaya yang beragam, sehingga hanya ada 62.409 populasi motor listrik yang digunakan pada akhir tahun 2023. Analisis kebijakan pemerintah pemerintah dalam menurunkan emisi gas buang dengan mengembangkan fasilitas penunjang sepeda motor listrik memerlukan pendekatan masalah sistemik-kompleks karena melibatkan berbagai entitas yang saling mempengaruhi sebagai keterkaitan sistemik. Metodologi Sistem Dinamik memungkinkan prediksi, analisis, dan evaluasi yang tepat terhadap dampak kebijakan fasilitas penunjang sepeda motor listrik, membuka ruang eksplorasi terhadap berbagai skenario kebijakan untuk mencapai hasil yang diharapkan. Perbaikan yang diusulkan mencakup insentif pembelian yang ditingkatkan menjadi 14,437% GDP per kapita, pergeseran industri sepeda motor dengan tingkat pergeseran 5% sesuai perkembangan GDP manufaktur, pengembangan fasilitas penunjang sebesar 90% tingkat pemenuhan terhadap permintaan, pengembangan baterai sepeda motor listrik sebesar 14,4% berdasarkan tingkat perkembangan baterai, skenario dengan kombinasi keempat faktor tersebut, serta skenario dengan kombinasi dan nilai input yang ditingkatkan. Penelitian ini menemukan bahwa skenario paling efektif adalah kombinasi dari keempat faktor dengan nilai input yang ditingkatkan untuk mencapai target yang diharapkan. Hasilnya menunjukkan bahwa pendekatan terintegrasi dengan meningkatkan input variabel pergeseran industri cara adalah terbaik untuk mempercepat adopsi motor listrik dan secara signifikan mengurangi emisi di Indonesia pada tahun 2030 dengan pencapaian 143,30% dan 123,22% secara berurutan. Namun, pencapaian ini tidak secara langsung saling bepengaruh sehingga kebijakan baru dibutuhkan untuk menurunkan penggunaan motor konvensional.

Kata kunci: ***Motor Listrik, Fasilitas Penunjang, Kebijakan, Sistem Dinamik, Emisi***.

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ABSTRACT

ANALYSIS OF THE SUPPORTING FACILITIES POLICY IMPACT FOR THE ELECTRIC MOTORCYCLE ADOPTION IN INDONESIA

Student Name / NRP	**:**	**Rayhan Makarim / 5010201120**
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Abstract

By mid-2023, 125 million conventional motorcycles produce 300 million kilograms of emissions per day that contributes the second largest of Indonesian emission. This issue strives the government of Indonesia to achieve a 32% emission reduction target, one of which is by promoting clean energy transportation through 13.469.000 units of electric motorcycle adoption until 2030 focusing on its most affecting adoption factors, including policy regarding supporting facility infrastructure. However, the adoption supported by incentive policy still suffers from significant delays due to the country's massive population with diverse characteristics of adopters and cultures, resulting in only 62.409 electric motorcycle population by the end of 2023. Analysis of government policy to exhaust gas emissions by developing a clean energy based supporting facilities infrastructure for electric motorcycle, requires a systemic-complex problem approach due to involvement of various entities that influence each other as systemic linkages. System Dynamics allows precise prediction, analysis, and evaluation of electric motorcycle supporting facility policy impact, enabling exploration of various policy scenarios to obtain the expected outcome. The proposed improvement consists of enhanced incentive of purchase to 14,437% of GDP per capita, motorcycle industry shift with a 5% rate based on manufacturing GDP growth, development of supporting facility infrastructure with 90% of fulfillment, electric motorcycle battery development with 14,4% rate, scenarios with combinations of these four factors, and scenario of with combination and enhanced input values. The result points out that integrated approach with enhanced variable input of industry shifting is the best way to accelerate the adoption of electric motorcycle and significantly reduce emission in Indonesia by 2030 with achievements of 143,30% and 123,22% respectively. However, these achievements do not directly influence each other, so new policies are needed to reduce the conventional motorcycles.

Keywords: ***Electric Motorcycle, Supporting Facility, Policy, System Dynamics, Emission.***

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PREFACE

Praise and gratitude for the author pray to Allah SWT for all the blessings, mercy, and guidance that have been given, so that the author can finish activity series of Final Assignment and its report with a title of “Analysis of The Supporting Facilities Policy Impact for The Electric Motorcycle Adoption in Indonesia”. The final assignment is arranged to fulfill the academic requirements to pursue a bachelor’s degree in Department of Industrial and System Engineering, Faculty of Industrial Technology and Systems Engineering, Sepuluh Nopember Institute of Technology. During the progress, the Authors received support and help from several parties and want to thank the parties as follow:

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6. The author’s significant other and all the friends that helped and supported the processing of the author’s final assignment.
7. All parties that had helped us with finishing the Final Assignment and the making of the Final Assignment report that can’t be written one by one.

Thanks for all the help and support that has been given to the author. Knowing that the result of the Final Assignment and its report is far from excellent, the author accepts all criticism and suggestions for better further results.

Surabaya, 10 July 2024

Author

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CHAPTER 1
INTRODUCTION

The Introduction chapter consists of background, problem formulation, limitation, assumption, objective, and benefit of the electric motorcycle policy impact research that is motivated by the 2030 emission reduction target of Indonesia and cascaded into electric motorcycle targets and adoption.

1.1 Background

Emission is a pollution that blends with air, originating from human activities (Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup, 2021). Indonesia is contained in top 10 countries with most carbon emission production ranked number 6 in the world with contribution of 1.80% globally (Zulfikar, 2024). The Government of Indonesia has tried to overcome emission by developing sustainable efforts, which is previously highly motivated by the Paris Agreement as part of UN Framework Convention on Climate Change. The aim is to reduce hold the increase in the global average temperature under 2 °C until limiting at 1,5 °C. This treaty is later cascaded to countries target per period in Indonesia or National Long-Term Development Plan of Indonesia (RPJPN) in Indonesia. Cascading the direction of 2005-2025 National Long-Term Development Plan of Indonesia (RPJPN) to shorter term, it is stated in the Republic of Indonesia National Medium-Term Development Plan For 2020-2024 (RPJMN), that by 2024, Indonesia must achieve 29% emission reduction. The effort is indicated by GHG emissions maintained below 1,56 GtCO2e per year with intensity below 333,7 tons CO2e/Rp billion (Presidential Regulation, 2020). It is also stated in Enhanced Nationally Determined Contribution (ENDC) document that Indonesia targets reduction of GH emission by 31,89% (own effort) by 2030, additional 2,9% from the 2024 target in RPJMN (BRIN, 2023). To classify the emission that has been produced, **Figure 1.1** shows the emission contribution percentage that were recapitulated in 2021.

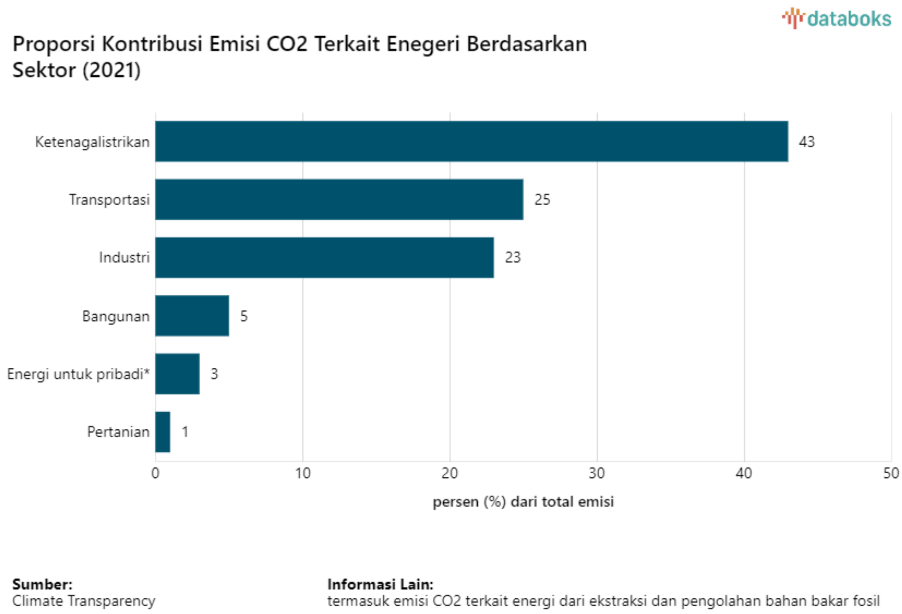


Figure 1.1 Emission Contribution Percentage per Sector in Indonesia in 2021
Source: Databoks.id by (Santika, 2023)

Energy has become the main contributor of emission with 43% contribution, followed with transportation activity that contributes 25%, and industrial activities with 23% of emission in Indonesia. The government has attempted to intervene with the top contributing sector to reduce emissions. Intervention of sectors must be handled carefully which it might affect the country's economic aspect. On that occasion, **Figure 1.2** shows the GDP contribution of sectors in Indonesia in 2023.

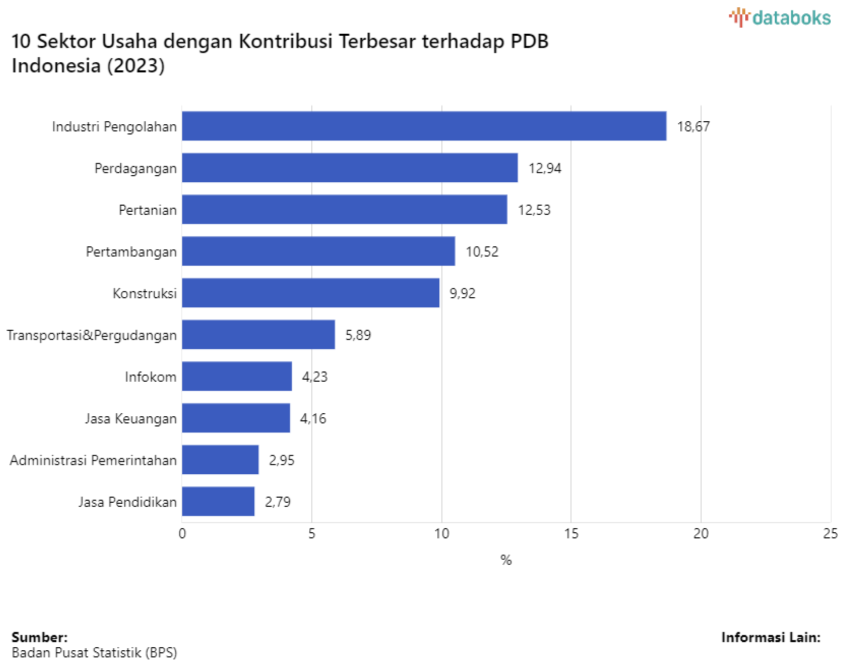


Figure 1.2 Top 10 Highest Business Sectors Contribution to Indonesian GDP in 2023
Source: Databoks.id by (Annur, 2024)

The energy sector is one of the main sources of Indonesian economy activities which has 10,52% of pure mining and drilling GDP contribution, combined with part of 18,67% processing Industry GDP contribution, to convert and process into useable energy. Therefore, it is hard to intervene in a short term of time especially with massive changes only in years from present time until 2030. The transportation sector is the feasible sector to intervene with since it has only half of pure mining GDP contribution and it has many alternatives with flexibility in utilization.

Motorized vehicles are a daily necessity for human transportation to fulfill their daily needs. However, the daily use of motorized vehicles will of course also have negative impacts, the most known and negatively impactful is emission of air pollution due to the fuel burning of the vehicle's fuel. Air pollution can lead to serious consequences if overloads a region, especially for health, safety, and environmental aspects. Awareness and considerations throughout Internal Combustion Engine vehicles, vehicle that runs by conventional mechanism of engine and releases emission due to residues in the combustions, must be very focused present day by both government and society (Wuling, 2024).

The contribution of transportation to emission is represented by the large amount of personal vehicles utilization. Based on statistical data, up to 2022, there are 17,168,862 listed passenger cars and 125,305,332 listed motorcycles throughout Indonesia and this number is increasing every day. The visualization of amount of vehicle and its distribution per provinces in Indonesia are served in **Figure 1.3** and **1.4** below. (Badan Pusat Statistik Indonesia, 2024).

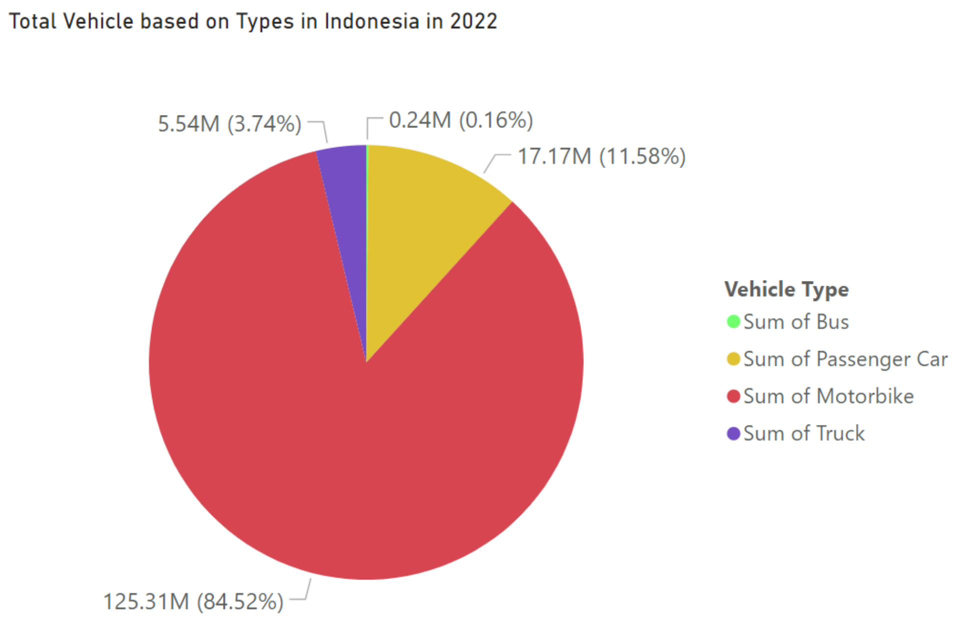


Figure 1.3 Total of Motorized Vehicle in Indonesia
Source: (Badan Pusat Statistik Indonesia, 2024)

From **Figure 1.3**, it known that motorcycles have the greatest number of totals in Indonesia with proportion of 84,52% of whole vehicle population in Indonesia. Passenger car lies on the second list with a proportion of 11,58% from the whole vehicle population in Indonesia. Next list is followed by trucks and busses with proportion of 3,74% and 0,16% consecutively. This indicates that the prioritized vehicle type to consider is the Motorcycles which gives the most population throughout all vehicle types.

Figure 1.4 Vehicle Population Density by Province in Indonesia
Source: (Badan Pusat Statistik Indonesia, 2024)

From **Figure 1.4**, Java Island is the island with the most populated area filled with vehicles of any kind which can linearly indicate the emission level in Java Island has the most amount. **Figure 1.4** below showing distribution of Motorcycle and Cars by Provinces in Indonesia.

Figure 1.5 Distribution of Cars by Province in Indonesia
Source: (Badan Pusat Statistik Indonesia, 2024)

According to **Figure 1.5**, the distribution of cars is widely concentrated across provinces in Indonesia but bulks mainly in Java Island especially near the capital city of Indonesia, Jakarta.

Figure 1.6 Distribution of Motorcycles by Province in Indonesia
Source: (Badan Pusat Statistik Indonesia, 2024)

According to **Figure 1.6**, the distribution of motorcycles is mainly on Java Island equally concentrated. However, the population in other provinces outside of Java Island still have higher population coverage than cars as can be seen by comparing the size of the bubbles in Sumatra, Kalimantan, Sulawesi, Nusa Tenggara, Maluku, and Papua. It summarizes that the crucial contributor of emission is motorcycles especially in Java Island which may be the largest emission contributor in transportation sector indicated by the population and the distribution.

To prove that statement, an experiment to identify the average emission that is produced. Defining the emission caused by vehicle can be inferred from parameters released from the vehicle which are amount of Carbon Monoxide, Carbon Dioxide, Hydrocarbon, Oxygen, and Lambda value. Dwi Wahyu R. on Gridoto.com has run a test on comparing chemical gas released by Toyota Calya (one of the most common Low-Cost Green Car/LCGC in Indonesia) and Honda PCX (one of the common Automatic Transmission Motorcycle in Indonesia) (Wahyu R., 2019). The result of emission test ran by Dwi Wahyu is given in **Table 1.1** below.

Table 1.1 Emission Comparison Between Toyota Calya and Honda PCX

Parameter	Toyota Calya (Gasoline Car)	Honda PCX (Gasoline Motorcycle)
CO*	0,01%	0,01%
CO2	14,1%	14,7%
HC*	4 ppm	202 ppm
O2	0,04%	0,32%
Lamda	1,002	1,007

Source: Gridoto.com by (Wahyu R., 2019)

To summarize, in this report, emission is defined from the hydrocarbon level which indicates the fuel waste that is thrown from vehicle exhausts that mainly cause complications for health and environment. It is concluded that motorcycles contribute more air pollution compared to LCGCs indicated by HC level which motorcycles contribute 50 times more air pollution than common cars (LCGC). This fact is also supported by statement in the article by Executive Director of KPBB that 44,53% of air pollution in Jakarta is caused by motorcycles relative to all operating vehicles in Jakarta (Wahyu R., 2019).

To overcome the emission target that has been set, entering of electric vehicle especially electric motorcycle is one of the potential strategies to optimize the air pollution reduction in Indonesia by shifting to alternative energy utilization as daily transportation fuel. In action, the government of Indonesia cascaded the emission target into another key indicators of performance that leads to the electric vehicle adoptions and population. Responding to the alternative vehicle growth, the Coordinating Ministry for Maritime & Investment Affairs and other ministers have stated an approximate target of 10% electric vehicle of whole operating vehicle by 2030 which are around 2.000.000 units of electric cars, and 13.469.000 units of electric motorcycles (Antara Bali, 2024).

However, the challenges faced by the Government to push the society in adapting electric motorcycle are not that simple since the behavior of Indonesians are already settled with their daily mobilization habit. The target that has been set by the government cannot be achieved independently by societies actions on their own. Government must develop and apply policies that influence and shift motorcycle user society into utilizing electric motorcycles. The policy must achieve electric motorcycle supply and demand equilibrium with careful consideration of the dynamics. All the needs for using electric motorcycles must be served and supported by the government containing the electric motorcycle availability itself and the supporting facility of electric motorcycle in making it worth to adapt to electric motorcycle. Chandra Balijepalli has done research that calculates prioritization of societies' electric motorcycle adoption preferences in Bandung, Indonesia. The conclusion of the research was that the prioritized needs for society are electric vehicle battery facilities to charge or swap the battery for at least the development stage of the adoption (Balijepalli et al., 2023). Therefore, policies must be developed to support societies' preferences in their shifting. The policy regarding Electric Vehicle is arranged in Presidential Regulation Number 55 Year 2019 regarding the Battery Electric Vehicle Acceleration. The possible policies for electric vehicle are in a form of acceleration of domestic electric vehicle industry, providing incentives, infrastructure providing for battery charging and electric energy fee for electric vehicles, technical requirement of electric vehicle fulfillment, and living environment protection.

The condition of domestic electric motorcycle industry has developed throughout the years. Both local and foreign contributions have developed Indonesian electric vehicle industry especially in a form of manufacturing. However, the capacity to produce electric vehicle battery (EV main power supply component) domestically is predicted to only reach 0,4% of the global production (Rahayu, 2024). Incentive giving is a potential act by the government to at least initiate the mass shifting to electric motorcycle. The most known incentive in society is the purchase discounts for electric vehicles. Each electric motorcycle purchase is given a discount incentive with an amount of Rp7.000.000,00. However, incentives that have been provided by the government still have not fully influenced the shifting to electric motorcycle. Infrastructure that supports fuel-based vehicle must slowly shift to support the operational of electric vehicle such as electric vehicle charging station (SPKLU) and battery swapping station (SPBKLU) and must be developed throughout Indonesia, at least covers the early market entrée potential in near future. In 2022, Ministry of Energy and Mineral resources stated that the target of electric vehicle infrastructure such as charging station is 196.179 facilities by 2030 (CNN Indonesia, 2022). However, by the end of 2023, charging stations are still far below target with existing of 1.299 units which the existing built facility is only 0,6% from the target (PLN, 2024). The conditions that have been revealed are related quantitatively to the amount of adoption rate. The main issue is to make the adoption optimized by policy development. Throughout all of the acts and efforts to support the adoption, the electric motorcycle population in Indonesia at the end of 2023 only reaches 62.409 units which is still far from the 13.469.000-unit target of adoption 7 years ahead.

With the ongoing situation throughout the country, a sustainable policy must be developed to support electric motorcycle adoptions, future supply, and supporting facilities. The research focuses on policies due to the high power of Indonesian government to change, shift, and control the existing condition of Indonesia into an expected future output of electric motorcycle adoption and emission reduction. Policies must be made with the considerations not only for present existing condition, but also for the future dynamics through time. The fact that the electric motorcycle adoption issue has a very systematically structured cause-and-effect relation throughout activities but also linked directly with time bounds of the problem, development of policies needs a systematic, comprehensive, and segmented approach. Electric motorcycle adoption issue that that has nonlinearity relationship is the connection between adoption preference that affects the electric motorcycle population, which then demand a supporting facility that will result in an increase of adoption preference even higher for the electric motorcycle.

In this research, System Dynamics Simulation is selected as the method because it fulfills criteria of problems statement. Methodologies other than System Dynamics are considered less precise if utilized due to lack of systematical approach and comprehensive output. Systemic and comprehensive approach is highlighted so that the impact of the policy to the adoption can be completely identified. Simulation is a dynamic imitation of a process or system through time (Leonelli, 2021). It redescribes object or system abstraction and complexity to predict a result in future timeline. The purpose of system dynamics is to identify the behavior of the object or system by knowing the relationship between the components, stocks, flows, delays, and effects inside the system (Allam et al., 2022). It can capture information and material flow in terms of cause and effect and can be simulated not only for a present time point or a specific future point but also on an interval time as the desired amount of time. To simplify the problem due to complexity of transportation mode, motorcycles will be focused on this research as what the condition of majority emission in Indonesia are mainly caused by it. This research will indicate the success or failure of policy which determined by the future achievement from the simulation result compared with targets that has been set by the government towards emission reduction and number of electric motorcycle users. From the problem statement, the problem formulation is summarized as points below.

1.2 Problem Formulation

According to Background Chapter, Indonesia emission conditions are on critical stage since it already arise health and environmental complications. Officials and Government of Indonesia must take a continuous act towards vehicle utilization but also adapting with the citizen's habit which the majority uses motorcycles as their main transportation mode. Electric vehicles may be the solution to the problem if the government can quickly take advantage of it to boost the growth of electric motorcycle utilization and its shifting condition by developing policies and supporting facilities for the citizen. By using system dynamics, it can model the problem systematically and simulate future conditions of emission based existing data. The system dynamics methodology models the problem system into a causal loop and stock flow concept for simulations. The indicator of success and failure of problem can be determined by the future achievement from the simulation result compared with targets that has been set by the government towards emission reduction and number of electric motorcycle users. From the problem statement, the problem formulation is summarized as points below.

1. What factors and variables are included in the electric motorcycle adoption system?
2. How is the relationship flow of the factors and variables in the electric motorcycle adoption system?
3. What is the evaluation of the existing policy to achieve the 2030 goal by using system dynamics instruments?
4. Which is the best alternative policy model that increases the adoption of electric motorcycle and promotes the emission reduction program by using system dynamics instruments?

1.3 Scope of Research

The scope of research is defined by limitations and assumptions of the research as shown below.

1.3.1 Limitation

Limitations of the research are shown below:

1. The research is focused on capturing future adoption and end user emission reduction.
2. The model is focused only on capturing electric motorcycle policies development.
3. The policy modeling is limited only to the supporting facility of electric motorcycle operational.

4. The model is developed by using data that existed during the research.
5. The improvement is limited to the allowance according to acceleration effort stated in the Presidential Regulation Number 55 in the Year 2019.
6. The battery supporting facilities only include battery charging and swapping stations.
7. The model only captures emission at the end user of the motorcycle system.
8. The research is limited to the use of System Dynamics Methodology.

1.3.2 Assumption

Assumptions of the research are shown below:

1. Data gained from secondary sources are correct.
2. Government of Indonesia are assumed to have resources to support the policy development and its operational.
3. Both Government Sector and Private Sector can contribute to the Mid-term and Long-term effort of emission reduction through provision of Electric Vehicle supporting facility.
4. Population Change of Indonesia remains constant within the year scope of the research.
5. Electric motorcycle users only use public facilities.
6. Motorcycle adopter characteristics are defined by the willingness to adopt variables that have been modeled in this electric motorcycle adoption system.

1.4 Objective

The objectives of this research are as listed below:

1. Develop the model of existing electric motorcycle adoption condition by using system dynamics method.
2. Analyze the impact and evaluate the existing policy to reach the electric motorcycle and emission reduction target of Indonesia.
3. Develop an alternative policy model to increase the adoption of electric motorcycle and promote the emission reduction program in Indonesia.

1.5 Benefit

The benefits of this research are as listed below:

1. Knowing the growth of electric vehicle and reduction of emission in Indonesia throughout years.
2. Knowing the alternative scenario of electric vehicle policies as a result of existing evaluation that is potential to be implemented in Indonesia.

CHAPTER 2
LITERATURE REVIEW

The literature review chapter consists of reviews of Simulation, System Dynamics Methodology, Electric Motorcycle, Internal Combustion Engine Motorcycle, Government Policy Towards Electric Vehicle, Government Targets Related to Electric Vehicle, and previous research results as a source to run the research. The purpose of literature review is to enhance the understanding of theories and facts that need to be comprehended to run this research.

2.1 Previous Research Results

In this subchapter, the literature review of previous research is included. This subchapter includes research that are related to electric vehicles policy development that has conducted both in Indonesia and in foreign countries that are used as fundamentals to run this research.

(Liu & Xiao, 2018) have done research regarding policy incentives of EV. The method used by the authors is System Dynamics. The scenarios that are focused on the simulation are applying direct and indirect policies by government. It was concluded that the main affecting scenarios is by providing incentives for potential users and suppliers of EV in the governmental region. Research done by the author motivates this research to use System Dynamics as the methodology, followed with the incentive-based policy simulation that is implemented in the reviewed research.

(Setiawan I. C., 2019) has done research about EV policy simulations in Indonesia. The methods used by Indra is reviewing literature that are supporting the policy development. It was concluded by the author that the most effective and accurate method to develop policy for EV are System Dynamics and Agent-Based Models (ABM) adapting with situations in Indonesia by including stakeholders that are actively correlated in EV. Impacts must also be considered by the developer to ensure sustainability. Research done by the author motivates this research to implement System Dynamics as methodology which is highly recommended by the author's review. However, the author also recommends considering impact and sustainability of the policy which in this research will simulate the policy over the target deadline which is 2030.

(Yuniza et al., 2021) have done research regarding Indonesian incentive policy on EV. The research uses normative legal research which examines library materials and discussed using legal theories. The research summarized that EV development is delayed due to lack incentives for consumers, lack of policies regarding existing conventional vehicles, and lack of technical regulations regarding EV support. Research must be focused to forecast policy impacts especially on incentive and infrastructure provision. The reviewed research highlights that the policy development must lead to incentives and conventional vehicle control which will become the changing variables and scenario in this research.

(Peng & Li, 2022) have done a research of policy evolution and intensity evaluation of EV in a point of view of dual-credit policy. This research conducts dual-credit policy by using 2T model for constructions and PI index for calculations. The research concludes that the main factors EV development is policy, promotion, which includes financial and infrastructure. Dual-credit policy aligns financial and policies. Promotion policies are necessary for early stage of shifting. Financial roles give advantage for industries at a specific time. Charging infrastructure policy should be the latest development. Research done by the authors highlights the categorization and stages of policies. In the policy development, stage of policy implementation must be considered carefully.

(Balijepalli et al., 2023) have done research about preferences for electric motorcycle adoption. The method used by the authors is Standard Multinomial Logit and Mixed Logit Model. The most prioritized preference that the respondents chose are 10-minutes recharging stations and battery swapping stations availability. The second most prioritized is the battery capacity and performance. The reviewed research highlighted that in terms of policy development, the preferences of the society must be considered. Those consists of battery charging station and battery swapping stations availability that will become the scenarios on this research.

(Koestoer & Shahboz, 2023) have done a research of EV transition in Russia and in Indonesia. The research regional scope is determined by the similarities of condition and issue from the two countries which is emission. The methodology used by the author is study case method or qualitative descriptive technique. This research concluded that research and development battery of EV are the key variables of the transition. The author said that both countries can cooperate to achieve the same goal in EV transition. They highlighted that electric vehicle adoption is the key indicators to reduce emission, which in this research, the emission reduction will be measured. EV Battery is highlighted as the key to adoption, which in this research, battery facilities will be included as changing policies. Incentives are recommended to be measured in its sensitivity.

(Syabani, 2023) has done a research of policy development supporting adoption rate of electric vehicle in Indonesia specified for electric cars. The research uses System Dynamics simulation as its main methodology. The scenarios that are put into the simulations are EV selling price, EV variants, EV battery range, socialization effectiveness rate, and amount and distribution of EV charging stations. It was concluded that the most affecting variable is EV charging stations with an estimation of more than 10 years until adoption rate reaches maximum point. This research will raise again the adoption rate changing variables that has been measured by using System Dynamics by the author such as EV selling price, EV variants, EV battery range, socialization effectiveness rate, and amount and distribution of EV charging stations but specified for electric motorcycle.

2.1.1 Research Position

Research position subchapter serves the comparison scope of region, method, changing variable, and response variable of previous research paired between each other. **Table 2.1** below shows the relationship between previous research and this research.

Table 2.1 Research Position of The Current Research

No.	Author	Methods Used	Indonesia	System Dynamics	EV Charging Station	EV Battery Swapping Station	EV Incentives	EV Battery Range Capacity	E2W Population	Emission	Description
1	This Research	System Dynamics	✓	✓	✓	✓	✓	✓	✓	✓	**The research used system dynamics on effects of facilities, incentives, and battery ranges to predict E2W adoption along with emission.**
2	(Liu & Xiao, 2018)	System Dynamics	✓				✓		✓		The research used system dynamics and analyses effects of incentives to EV in general.

No.	Author	Methods Used	Indonesia	System Dynamics	EV Charging Station	EV Battery Swapping Station	EV Incentives	EV Battery Range Capacity	E2W Population	Emission	Description
3	(Setiawan I. C., 2019)	Literature Review	✓	✓					✓		The research summarized that most effective method to analyze EV policy impact is by system dynamics.
4	(Yuniza et al., 2021)	Normative Legal Research	✓		✓	✓	✓		✓		The research summarized that EV policies are impactful if given in a form of incentive, infrastructure, and control towards ICE motorcycle.
5	(Peng & Li, 2022)	2T Model & PI Index			✓	✓	✓		✓		The research summarized that the policies containing EV facility and incentives must be arranged in stages.
6	(Balijepalli et al., 2023)	Standard Multinomial Logit & Mixed Logit Model			✓	✓		✓	✓		The research summarized that most preferred development in E2W by society are battery facilities.
7	(Koestoer & Shahboz, 2023)	Case Study Method and Qualitative Descriptive Technique	✓				✓	✓		✓	The research summarized that emission reduction is the main goal in increasing EV adoption by policies in a form of incentives, facilities, and EV battery support.
8	(Syabani, 2023)	System Dynamics	✓	✓	✓	✓	✓	✓			The research used system dynamics and analyses the effects of facilities, incentives, and battery ranges to predict electric cars population and adoption.

2.2 Electric Motorcycle

As stated inside the Indonesian Presidential Regulation regarding EV, Electric Vehicle (EV) is a vehicle that is driven by electric motor and gained electric power from battery both from internal vehicle component and external components. Electric vehicles are divided into two groups which are two or three-wheeled and four-wheeled or more. In the revision, there were additional groupings regarding the electric vehicle which are electric vehicle in new state, and electric vehicle as a result of conversion done by Conversion Workshop (Presiden Republik Indonesia, 2023). Electric Two-wheeler (E2W), a two-wheeled electric vehicle (EV), is a two-wheeled vehicle that is motorized with electrical energy resource for its internal operational supported with electrical battery as their main source of power supply (Aia, 2013). E2W are divided into two categories which are electric bicycles and electric scooters or motorcycle. The main difference between the two vehicles is the capabilities to run indicated from top speed. The differences are described in **Table 2.2** shown below.

Table 2.2 E2W Categorization Comparison in Term of Speed Capability

E2W Category	Minimum Capabilities	Maximum Capabilities
Electric Bicycle	top speed ≤ 20 kph	top speed < 32 kph
Electric Scooters	top speed 45 kph	top speed 50 kph
Electric Motorcycles	top speed > 45 kph	top speed > 50 kph

Source: (Aia, 2013)

Electric motorcycles were first introduced by Thomas Davenport, an expert in Electrical and Magnetism Sciences, in 1834. At that year, Davenport successfully invented the very first electric motorcycle by using electromagnetic with rotor and stator. The first intention for the invention is to create an efficient vehicle in terms of time and power (Alvin, 2024).

Electric motorcycles are predicted to be the main alternative to minimize negative impact of land transportation especially for emission problems in developing countries. Electric motorcycles and other E2Ws also have an advantage in terms of noise of engine mechanism. E2W does not have any mechanism that produces loud noises on ignition and gas (acceleration). This indicates E2W lower noise compared to the conventional ones. However, the challenge of the adoption is affected by factors of acquisition and maintenance cost, limited range of travel, battery issue, safety of the motorcycle due to water issue, and reselling value. It was stated by (Suwignjo et al., 2022), the acquisition is higher than the conventional due to battery accountability is valued 40% more. For battery consumption, electric motorcycles have a lower consumption rate than conventional motorcycles with a value eight times lower. Due to this problem, the adoption of the electric motorcycle is still detained.

In this research, the author focused on highlighting motorcycles as the simulated transportation mode. This is based on the massive population of motorcycle covering 84,52% with a population of 125,305,332 and the population is widely concentrated across the provinces in Indonesia as shown in **Figure 1.5**. The research will utilize the population of E2W in general but focused on the growth of electric motorcycles as the apple-to-apple substitute for ICE motorcycle. The data comparison between population of transportation modes in 2022 is as shown in **Table 2.3** below.

Table 2.3 Population of Vehicles in Indonesia by Province

Province	Cars	Buses	Trucks	Motorcycle	Total Vehicle
Aceh	174.453	1.197	70.347	2.180.812	2.426.809
North Sumatra	730.264	6.102	284.260	6.318.408	7.339.034
West Sumatra	285.254	4.229	138.873	2.228.335	2.656.691
Riau	380.764	5.423	217.343	3.627.077	4.230.607
Jambi	182.176	35.108	142.349	2.213.171	2.572.804
South Sumatra	409.464	6.557	331.641	3.271.433	4.019.095
Bengkulu	110.743	854	51.297	964.276	1.127.170
Lampung	299.817	3.056	185.076	3.433.426	3.921.375
Bangka Belitung Isl.	85.621	1.195	47.399	1.025.876	1.160.091
Riau islands	159.694	2.157	28.450	947.219	1.137.520
DKI Jakarta	3.772.850	37.854	753.241	17.347.866	21.911.811
West Java	3.803.808	21.997	433.001	13.341.328	17.600.134
Central Java	1.450.700	34.779	605.671	17.443.730	19.534.880
Yogyakarta	377.930	3.883	64.732	2.665.625	3.112.170
East Java	2.039.556	36.861	778.503	20.750.505	23.605.425
Banten	263.103	3.666	87.271	2.508.475	2.862.515
Bali	479.690	9.521	158.331	3.978.552	4.626.094
West Nusa Tenggara	103.331	2.666	77.531	1.823.857	2.007.385
East Nusa Tenggara	61.325	3.745	51.532	877.060	993.662

Province	Cars	Buses	Trucks	Motorcycle	Total Vehicle
West Kalimantan	165.951	1.623	109.347	2.627.031	2.903.952
Central Kalimantan	104.914	1.580	76.792	1.369.862	1.553.148
South Kalimantan	242.522	3.312	146.367	2.489.139	2.881.340
East Kalimantan	300.897	6.822	203.929	2.841.342	3.352.990
North Kalimantan	14.846	124	9.572	164.549	189.091
North Sulawesi	136.876	1.383	72.057	843.874	1.054.190
Central Sulawesi	96.717	956	53.678	1.163.869	1.315.220
South Sulawesi	559.426	3.987	208.427	3.908.744	4.680.584
Southeast Sulawesi	195.136	552	42.832	818.856	1.057.376
Gorontalo	37.948	347	28.341	424.292	490.928
West Sulawesi	22.980	51	14.604	355.523	393.158
Maluku	25.558	472	14.307	307.277	347.614
North Maluku	21.383	143	13.366	291.875	326.767
West Papua	36.730	382	18.151	321.687	376.950
Papua	36.435	866	25.555	430.381	493.237
Indonesia	**17.168.862**	**243.450**	**5.544.173**	**125.305.332**	**148.261.817**

Source: (Badan Pusat Statistik Indonesia, 2024)

2.2.1 Types of Electric Motorcycle

Electric motorcycle types are differentiated by the mechanism of the electrical system. There are DC type, Induction type, and Synchronous type. (Adira Finance, 2023)

1. **The DC Electric Motorcycle** relies on a stator and rotor that flows electric through magnetic fields. Magnet moves from the north surface to gain electric current and will return the magnet to the south surface.
2. **The Induction Electric Motorcycle** relies on Lorentz force to create electric current on the stator and rotor by using electromagnetic concept. The velocity of this type is not consistent.
3. **The Synchronous Electric Motorcycle** works by relying on consistent velocity with specific frequency. The consistency is caused due to fixed magnet on rotor which creates a stable rotation according to current frequency that has been set.

2.2.2 Electric Motorcycle in Indonesia

The availability of the electric motorcycle has been provided by companies, both local and foreign brands. Until the writing time of this research, the listed electric motorcycle that are available in Indonesia is 61 variants in total (Oto, n.d.). It is shown in **Table 2.4** below several brands consisting of 20 recapitulated brands and 32 types of electric motorcycles. It includes the brand, variant from the brand, maximum speed of the bike, and its price range of selling.

Table 2.4 List of Electric Motorcycle Available in Indonesia

No	Brand	Variant	Max. Speed (km/hour)	Approximate Price (Rp)
1	Gesits	ECO	45	Rp 28.000.000

No	Brand	Variant	Max. Speed (km/hour)	Approximate Price (Rp)	
2	Gesits	Urban	60	Rp	28.000.000
3	Gesits	Sport	70	Rp	28.000.000
4	Honda	V-Go	55	Rp	16.000.000
5	Honda	U-Be	55	Rp	7.500.000
6	Uwinfly	N9 Pro	65	Rp	13.600.000
7	Uwinfly	GT2	55	Rp	10.250.000
8	Uwinfly	T3	60	Rp	10.000.000
9	Yamaha	Neos	30	Rp	32.800.000
10	Yamaha	e-Vino	45	Rp	23.000.000
11	ECGO 2	ECGO 2	60	Rp	11.000.000
12	Selis	Eagle Prix	40	Rp	14.000.000
13	Volta	401	45	Rp	15.700.000
14	Gogoro	S1 Performance	45	Rp	68.000.000
15	Gogoro	1 Series	45	Rp	53.600.000
16	Gogoro	VIVA	45	Rp	25.000.000
17	Gogoro	VIVA Mix	45	Rp	30.000.000
18	Gogoro	VIVA Xl	90	Rp	35.000.000
19	Gogoro	Delight	88	Rp	31.400.000
20	NIU	Uqim	32	Rp	18.000.000
21	Yadea	G5	55	Rp	45.000.000
22	Enine	V5	50	Rp	15.300.000
23	Alessa	eX300	70	Rp	17.700.000
24	Oyika	Rakata S9	45	Rp	9.900.000
25	Oyika	Niu Gova 3	60	Rp	11.900.000
26	Alva One	Alva One	90	Rp	36.490.000
27	Viar	Q1	60	Rp	18.000.000
28	United Motor	T1800	65	Rp	27.000.000
29	Smoot	Tempur	60	Rp	13.900.000
30	Zero	DSR	163	Rp	270.000.000
31	BMW	CE 02	95	Rp	115.000.000
32	Charged	Anoa	90	Rp	32.000.000

Source: (Setiawan, 2024)

Based on (Kompas, 2023), according to Minister of Industry at IMOS 2023, there are a total of 48 electric motorcycle companies that are available in Indonesia. In summary, the total production capacity per year of electric motorcycle is 1.427.000 units per year. As of 2022, according to (Jemadu, 2024) and (M R, 2024), the population of electric motorcycle is approximately 17.198 units. In the end 2023, it is reported that electric motorcycle population has reached approximately 62.409 units. Based on (Yuwono, 2024) and (Kumparan.com, 2024) electric motorcycle covers maximum of 150 and to 200 kilometers (for motorcycles) of a trip for a single full battery capacity. The battery of electric motorcycle is durable for 3 to 5 years of utilization (Dok Grid, 2023). However, this number may increase due to electric vehicle battery growth from research and development that at the Compound Annual Growth Rate (CAGR) of 14,4% (Markets and Markets Research, 2024).

2.3 Electric Vehicle Supporting Facility

The main concept of electric motorcycle power system depends on the battery of the vehicle. The battery store electric energy for the operation of the vehicle. Battery will wear out at some point which the energy renewal method contains two main methods, battery direct charging or swapping the battery with filled one. It is stated by (McDonald, 2019), the "minimum acceptable ratio of electric motorcycle to Charging Station (or included with Battery Swapping Station) is 10 to 1. The facilities to provide the operation of electric motorcycles are Electric Vehicle Charging Stations (SPKLU) and Battery Swapping Stations (SPBKLU).

2.3.1 Battery Charging Station

Electric Vehicle Charging Stations (SPKLU) are facilities that provide electric battery refilling or charging service (Direktorat Jendral Ketenagalistrikan Kementrian ESDM RI, 2020). The concept of Electric Vehicle battery charging is similar to gas refilling with hose or cable but takes more time than refilling fuel into cars. The concept is shown as in **Figure 2.1**.

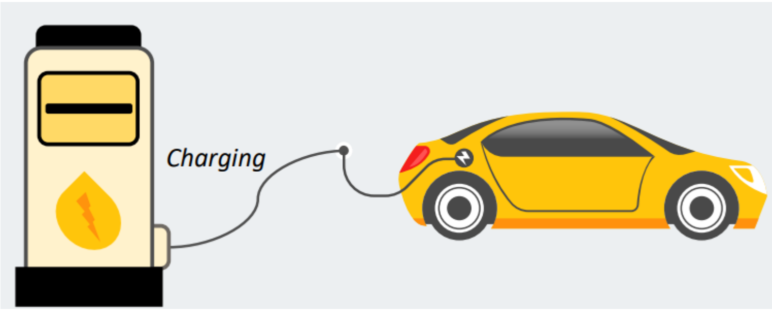


Figure 2.1 EV Battery Charging

Source: (Direktorat Jendral Ketenagalistrikan Kementrian ESDM RI, 2020)

While with the same purpose but different mechanism, the duration of the charging may differ between conditions which can be calculated according to this charging time formula on the **Formula 1** shown below (Daihatsu, 2023).

$$Charging\ Time\ (hour) = \frac{Battery\ Capacity\ (kWh)}{Charging\ Capacity\ (kW)} \quad (1)$$

The fee of charging is classified into two which are charging amount fee and service fee. The charging amount fee depends on the variability of the amount with a rate of Rp1.650 to Rp2.466 per kWh (Wuling, 2023). The fee of charging service is arranged in Ministry of Energy and Mineral Resources Decision No.182.K/TL.04/MEM.S/2023 about Fee of Electric Charging Service on Electric Vehicle Charging Station (Menteri Energi dan Sumber Daya Mineral, 2023). The electric vehicle charging station types are described in **Table 2.5** below.

Table 2.5 Battery Charging Type

Battery Charging Type	Charging Capacity	Maximum Exit Current	Plug-in Connector Type	Estimated Charging Time	Location
Ultrafast Charging	$\leq$ 150 kW	300 AC/ 500 DC	Combined Charging Type CSS2 and	15 minutes	Charging Stations

Battery Charging Type	Charging Capacity	Maximum Exit Current	Plug-in Connector Type	Estimated Charging Time	Location
			Chademo (IEC 62196-4)		
Fast Charging	≤ 50 kW	100 AC/ 250 DC	Combined Charging Type CSS and Chademo (IEC 62196-3)	30 minutes	Charging Stations
Medium Charging	≤ 22 kW	63 AC	Type 2 (IEC 62196-2)	4 hours	Special Installation (houses)
Slow Charging	≤ 3,7 kW	16 AC	Type 1 (IEC 62196-1)	8 hours	Special Installation (offices)

Source: (Direktorat Jendral Ketenagalistrikan Kementrian ESDM RI, 2020)

The plug-in connector between charging type differs which is visualized as in **Figure 2.2** below.

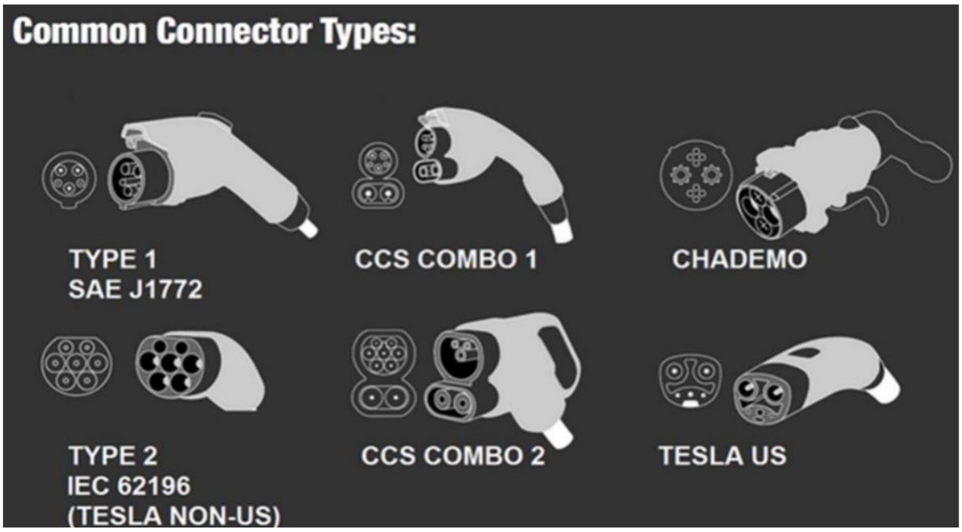


Figure 2.2 Battery Charging Connector Types
Source: (Direktorat Jendral Ketenagalistrikan Kementrian ESDM RI, 2020)

According to **Figure 2.2**, there are several types of plug-in connector depending on the charging station type and the vehicle type. It consists of Type 1, Type 2, CCS Combo 1, CCS Combo 2, Chademo, and Tesla US. However, if adjustments are needed, there are options to use converter for plug-ins to match different charging types with the electric vehicle or motorcycles. In building charging stations, (Dwi A., 2023) stated that it charges around Rp342.000.000 per unit of charging station requiring minimum space of 42 meters square.

As of December 2022, there are 439 units of charging stations according to (Kompas, 2023). Data of each type has been recapitulated as of 18 April 2023 which are shown in **Table 2.6** below (Finaka, 2023).

Table 2.6 Electric Vehicle Charging Station by Type

Electric Vehicle Charging Station Type	Unit
Ultrafast Charging	32
Fast Charging	91
Medium Charging	267
Medium-Slow Charging	162
Slow Charging	290

Source: (Finaka, 2023)

Until the end of 2023, there are a total of 1081 unit of electric vehicle charging stations and this number is going up (PLN, 2024).

2.3.2 Battery Swapping Station

Battery Swapping Stations (SPBKLU) is a facility to swap batteries mainly used for low battery or empty battery with charged battery thus giving less service time or without charging (Direktorat Jendral Ketenagalistrikan Kementrian ESDM RI, 2020). The concept of battery swapping station is as shown in **Figure 2.3** below.

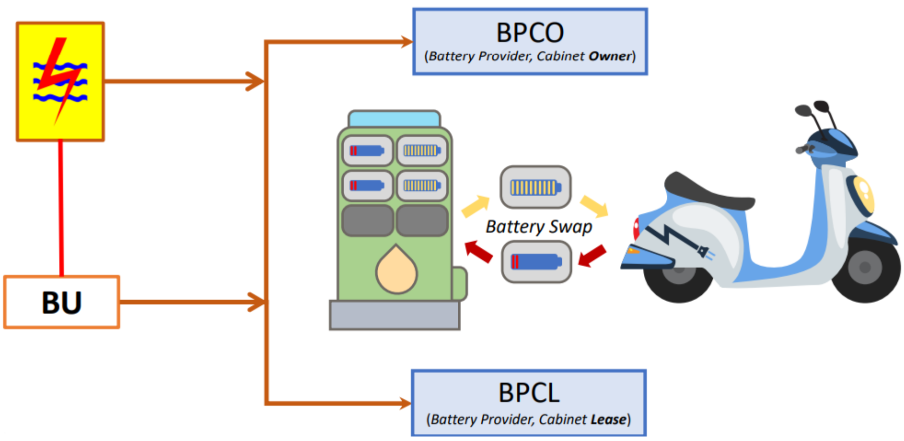


Figure 2.3 Battery Swapping Concept
Source: (Direktorat Jendral Ketenagalistrikan Kementrian ESDM RI, 2020)

The concept of battery swapping switches a worn off battery from a vehicle and trades it with the battery served in the Battery Swapping Station (SPBKLU). The Battery Swapping Station will provide batteries that are charged inside the station slot. Then, the slot is filled with worn batteries and the vehicle is installed with the charged battery. As of December 2022, there are 961 unit of Battery Swapping Stations all over Indonesia (Kompas, 2023). Until 2023, the Battery Swapping Station is available at 1.401 units (Kumparan Bisnis, 2024).

2.4 Internal Combustion Engine Motorcycle

Internal Combustion Engine (ICE) Motorcycle is a motorcycle or a two wheeled vehicle that is run with conventional mechanism of engine by using petrol-based power. According to (Wuling, 2024), the power system that is brought by conventional motorcycles are by ignition of petrol. The ignition process will transform fuel into energy that powers the movement of motorcycle. However, not all fuel can be perfectly transformed into kinetics. It will also turn into residues and waste in the form of heat and exhaust gas, or so-called emission released from exhaust system of the vehicle (Firmansyah et al., 2023). Emission can be in the form of negative impact and non-negative impact. Negative impact emission is contained in chemical units such as:

1. Carbon Monoxide (CO)
   Carbon Monoxide does not have any smell or colors but is very dangerous to humans if inhaled.
2. Carbon Dioxide (CO2)
   Carbon Dioxide is a very dangerous gas that highly affects global warming.
3. Nitrogen Oxide (NOx)
4. Nitrogen Oxide has similar effects to CO which is dangerous if inhaled and can cause vision illness.
5. Hydrocarbon (HC)
   Hydrocarbon is the gas that is released due to imperfect combustion of vehicles.
6. Other components
   Other components such as PM10 and SO2 are included as emission in some cases of vehicle.

According to (Asri et al., 2022), emission caused by vehicles have their own conversion rate towards all negative gas waste based on their types of vehicles. It depends on pollutant mass and its travel distance. It can be differed between conventional motorcycles, gasoline cars, solar cars, buses, and trucks. The number of gases released by types of vehicles are shown in **Table 2.7** below.

Table 2.7 Emission Released per Vehicle Type

Type of Vehicle	CO (g/km)	NOx (g/km)	PM10 (g/km)	CO2 (g/kg BBM)	SO2 (g/km)
Motorcycle	14	0,29	0,24	3180	0,008
Gasoline Cars	40	2	0,01	3180	0,026
Solar Cars	2,8	3,5	0,53	3172	0,44
Bus	11	11,9	1,4	3172	0,93
Truck	8,4	17,7	1,4	3172	0,82

Source: (Asri et al., 2022)

The current population of motorcycle in Indonesia is 125.305.332 as of 2022 recorded by (Badan Pusat Statistik Indonesia, 2024). However, it is still summarized as both conventional and electric motorcycle. According to a report by Kompas, in 2022, ICE Motorcycle has produced 54,1-million-ton Carbon Dioxide Equivalent or about 36,1% of the total emission (Pristiandaru, 2023). It then summarized that each ICE motorcycle produces approximately 0,432 tons of Carbon Dioxide Equivalent per year. One of the most notable incidents is the air pollution of Jakarta in 2022 to 2023 which caused more than 100.000 health cases of Acute Respiratory Infection (ISPA) (Komariah, 2023).

According to (Oto, n.d.), ICE motorcycles in Indonesia has approximately 300 variants of motorcycle available for purchase in Indonesia. The range of average motorcycles covers around 285 kilometers of trip (Planet Ban, 2023). The durability of ICE motorcycle products averages at 15 years of lifespan (Uje, 2021). ICE motorcycles operational requires gas stations for refueling, which in Indonesia, there are a total of 6.729 units of gas stations (SPBU) in whole Indonesia (Gaikindo, 2023). The ICE Motorcycle production capacity consists of 6.867.217 unit per year in 2023 (Dananjaya & Ferdian, 2023).

2.5 Policy Towards Electric Vehicle

According to Basic Methods of Policy Analysis and Planning Third Edition Book by (Patton et al., 1986), policy is a procedure that is set systematically of a specific object for both tangible and intangible form. Government of Indonesia, in this case, act as a policy maker towards how the electric vehicle works in Indonesia. It can be in any form as it is written and released on the national rule. The purpose of the policy making is based on the main objective of the country towards the object that is being ruled, in this case, electric vehicle and its adoption rate. Government has released policies and rules on how the electric vehicle can run in Indonesia.

The Indonesian Government has released a Presidential Regulation Number 55 Year 2019 regarding the Battery Electric Vehicle Acceleration (Presiden Republik Indonesia, 2019). In December 2023, the regulation towards Battery Electric Vehicle Regulation has been revised and re-released to the society (Presiden Republik Indonesia, 2023). Several items of the regulation are still the same as the 2019 release. According to Chapter 2 Article 3, in summary, the effort for accelerating electric vehicle contains:

a. acceleration of domestic Electric Vehicle industry
b. providing incentives
c. infrastructure providing for battery charging and electric energy fee for Electric Vehicles
d. technical requirement of Electric Vehicle fulfillment
e. living environment protection.

In Chapter 2 Article 7 Paragraph 3, government tends to support the research, development, growth, and innovation of Electric Vehicle by:

a. development of Electric Vehicle main components
b. development of efficient Electric Vehicle charging stations and battery swapping stations (paragraph renewed in 2023)
c. development of Electric Vehicle industry by adapting to latest technology
d. achieving highest Domestic Component Level (TKDN) of Electric Vehicle industry
e. development of Electric Vehicle that fulfills technical standards and environmentally friendly.

In Chapter 3 Article 17 about Providing Incentives, Paragraph 2 stated that the incentives provided are fiscal and non-fiscal. Incentives are given to:

a. industrial companies, colleges, and/or research institutions as stated in Article 7 Paragraph 1
b. industrial companies that prioritize utilizes prototypes and/or components that are sourced from research institutions that have done research, development, and innovation towards Electric Vehicle
c. industrial companies that have fulfilled Domestic Component Level as stated in Article 8 and that produced Electric Vehicle domestically as stated in Article 9
d. industrial companies related to components of Electric Vehicle as stated in Article 10
e. industrial companies of Electric Vehicle that are national brand as stated in Article 14
f. companies that provide battery swapping for electric motorcycles
g. industrial companies that accelerate production and facility preparation of Electric Vehicles

h. companies that manage battery waste (paragraph renewed in 2023)
i. companies that provide Electric Vehicle charging station and battery swapping station (paragraph renewed in 2023)
j. companies of public transportation that uses Electric Vehicle
k. individuals that use Electric Vehicle.

In Article 19, in summary, fiscal incentives are explained and can be in a form of:

a. import duty incentives for the import of Electric Vehicle in a Completely Knock Down state, in an Incompletely Knock Down state, or main components for a certain quantity and period of time.
b. sales tax incentives on luxury goods
c. incentives for exemption or reduction of central taxes
d. incentives for exemption or reduction of regional taxes
e. incentives for import duties on the import of machinery, goods, and materials for the purpose of capital investment
f. incentives for import duties borne by the government on the import of raw materials and/or auxiliary materials used in the production process.
g. incentives for making Electric Vehicle charging stations and battery swapping stations equipment (paragraph renewed in 2023)
h. export financing incentives.
i. fiscal incentives for research, development, and technological innovation activities as well as industrial vocational activities for Electric Vehicle components
j. parking rates at locations determined by the Regional Government
k. reduced electricity charging fees at Electric Vehicle charging stations.
l. financial support for Electric Vehicle charging stations infrastructure development.
m. professional competency certification for Electric Vehicle industry human resources
n. product certification and/or technical standard for Electric Vehicle companies and Electric Vehicle component companies.

In the revision and renewal of the Presidential Regulation 2019, in 2023 it was announced that there is an additional Article 19A which contains descriptions towards Article 18 Paragraph 1 and 2 and Electric Vehicle company requirements to receive incentives.

In the Article 20, non-fiscal incentives are:

a. exemption from certain road use restrictions
b. delegation of production rights for technology related to Battery-Based KBL whose patent license has been held by the Central Government and/or Regional Government
c. fostering security and/or securing operational activities in the industrial sector for the continuity or smoothness of logistics and/or production activities for certain industrial companies which are vital national objects.

In 2022, the President of Indonesia released a Presidential Instruction Number 7 Year 2022 about Utilization of Electric Vehicle as an Operational Service Vehicle and/or Individual Vehicle for The Service of Central Government and Regional Government. In the instruction, it contains a requirement to use electric vehicle as operational service vehicles and/or individual service vehicles for central government and regional government agencies replacing current operational service vehicles and/or individual service vehicles for central government and regional government agencies (Presiden Republik Indonesia, 2022).

To increase the number of the running electric motorcycle, according to Minister of Industry Regulation Number 6 of 2023 Conjunction with Number 21 of 2023, government provides an incentive discount of Rp7.000.000 for every purchase of a unit of two-wheeled electric vehicle (KBLBB) that has minimum domestic component level of 40 percent. Until now, there are 16 companies that are listed in the incentive program with over 38 motorcycle types. There are over 7.500 receiver of the incentive as of 20th September 2023. According to (Kementrian Energi dan Sumber Daya Mineral Republik Indonesia, 2023) on 29th December 2023, the incentive was raised to Rp10.000.000 for every purchase to increase the interest to utilize the electric motorcycle shifting from the conventional motorcycle. The change was arranged inside the Regulation of the Minister of Energy and Mineral Resources (ESDM) Number 13 of 2023 concerning Amendments to Regulation of the Minister of Energy and Mineral Resources Number 3 of 2023 concerning General Guidelines for Government Assistance in the Conversion Program for Motorcycles with Combustion Motor Drives into Battery-Based electric motorcycle.

2.6 Government Targets Related to Electric Vehicle

The Indonesian Government has set targets related to electric vehicle. It contains several indicators such as electric vehicle users in general, electric cars user, electric motorcycle users, electric vehicle charging station, electric vehicle battery swapping stations, Domestic Component Level of electric vehicle and many more. All those indicators will lead to the key indicator which is emission reduction. Emission reduction became the main trigger of the electric vehicle shifting.

According to (PR of Cabinet Secretariat of The Republic of Indonesia, 2015), President of Indonesia has set a target of emission reduction by 29% as of 2030. It reflected the Paris Agreement that needs to be achieved. However, it was restated by (BRIN, 2023) that the target was increased to 31.89% on its own efforts by 2030. The emission target represent all activities that releases emission with only domestic efforts. With the data of emission contribution, transportation contributes 25% of the whole emission as can be seen on the **Figure 2.4** below (Santika, 2023).

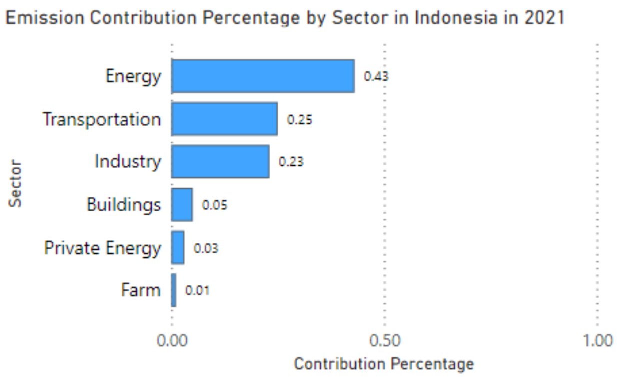


Figure 2.4 Emission Contribution Percentage per Sector in Indonesia in 2021
Source: Databoks.id by (Santika, 2023)

Thereby, Indonesian Government cascades the target to a smaller scale which are Electric Vehicle populations which has their own target and indicators.

In the Presidential Regulation Number 55 Year 2019 regarding the Battery Electric Vehicle Acceleration, Domestic Component Level meaning that the component of electric vehicle and the electric vehicle itself is produced by companies that are built based on Indonesian Law and having a business permit to create or produce components of Electric

Vehicle based on legislation as it was explained in Chapter 2 Article 9 and 10 (Presiden Republik Indonesia, 2019). The government has set the target of Domestic Component Level (TKDN) for a group of electric vehicles which is arranged in Chapter 2 Article 8 Paragraph 1. However, it was revised in 2023. The paragraph revision contains:

a. for two and/or three-wheeled Electric Vehicle
    1) minimum Domestic Component Level between 2019 to 2026 is 40%
    2) minimum Domestic Component Level between 2027 to 2029 is 60%
    3) minimum Domestic Component Level in 2030 and so forth is 80%,
b. for four wheeled or more Electric Vehicle
    1) minimum Domestic Component Level between 2019 to 2021 is 35%
    2) minimum Domestic Component Level between 2022 to 2026 is 40%
    3) minimum Domestic Component Level between 2027 to 2029 is 60%
    4) minimum Domestic Component Level in 2030 and so forth is 80%.

However, this target does not apply to Converted Electric Vehicle as it was stated in the 2023 revised Article 8.

According to (CNN Indonesia, 2022), quoting from Ministry of Energy and Mineral Resources of the Republic of Indonesia, Indonesia has a target of 13.469.000 unit of electric motorcycle population by 2030 as the roadmap effort reaching emission decrease. For electric cars, it stated that the target is 2.000.000 unit of electric cars population. The target of charging stations is 48.118 units while the battery swapping station is 196.179 units. However, the target was restated in 2023. Electric vehicle battery swapping station is targeted to be operating at 67.000 units while charging station target is 32.000 units all over Indonesia (CNN Indonesia, 2023).

2.7 Simulation

There are several definitions of simulations. According to (Leonelli, 2021), simulation is a dynamic imitation of a process or system through time. While according to (Vallverdú, 2014), simulation is a model that is rebuilt and redescribed computationally. According to (Stewart, 2004), simulation is an imitation, copy, or mimic of something that could be an object or a system. There are four main aspect that pillars simulation. Those pillars are system, purpose, simplification, and experimentation. Simulation must include a system to be run or can be said as the object. The purpose of the system must be defined clearly to identify the desired output of the simulation. Simplification of the system in a simulation is necessary due to impossibilities of perfect mimicking. Experimentation is the trial and error running of the simulation according to the defined purpose or objective (Stewart, 2004).

In simulation, modeling is a necessary step to conduct with. Models are classified in many ways. Data-driven classification model for prediction is one of the related classifications that are divided into predictive, descriptive, and prescriptive models. Predictive model is a model that is focused to predict, estimate, forecast future conditions by using historical data analysis to identify patterns and trends. Descriptive model is a model that is focused to give comprehensive understanding of present conditions by using statistical analysis techniques. Descriptive model mainly described by mean, standard deviation, and other statistical values for gain deep understanding of the existing data. Prescriptive model is a model that is focused to generate a next action towards existing conditions and data with future consequences. Prescriptive models are mainly used to estimate pricing and cost factors (Bazzarelli, 2023). System dynamic is considered as predictive model since it predicts and estimates future conditions and consequences by using historical data.

Simulation is an alternative to do direct experiments in a cheaper, faster, replicable, safer, ethical, and legal way. Simulation model needs assumptions to fixate how the system works. Simulation can do "what-if" analysis, change how the real system works to predict impact, and even guide real world development of the system (Leonelli, 2021). Simulation has a key component that is mandatory to bind with, which is time occurrence. Time may exist or not, depending on the simulation type that desired to be run. Thereby, there are several classifications in simulation. Simulation is divided into several classifications which are by the output, containing stochastic and deterministic, by time passage occurrence containing static and dynamic, and by event containing discrete and continuous event.

2.7.1 Stochastic and Deterministic Simulation

Stochastic simulation is a simulation that involves random variable inputs which also cause involvement of uncertainty on the output (Leonelli, 2021). Stochastic simulation can be exampled on a production system if the system uses random input as lead times. In the stochastic model, the output remains unknown but can be predicted in ranges of number depending on the distribution frequence. An example of stochastic simulation is fallen leaves that has a maximum number of fallen leaves. The number of fallen leaves can be predicted from 0 to maximum number of leaves.

Deterministic simulation is a simulation that involves a predictable behavior and outputs that has fixed input variable (Leonelli, 2021). Deterministic simulation can be exampled on a production system if the system uses fixed input or assumption as lead times. An example of deterministic simulation is chemical reaction with a base of differential equation.

2.7.2 Static and Dynamic Simulation

Static simulation is a simulation that does not involve time passage factor meaning that it mimics a specific point of time with same variable (Stewart, 2004). This type of simulation may not have historical input and output of the system. Monte Carlo simulation is considered as static simulation (Leonelli, 2021).

On the other hand, dynamic simulation is a simulation that involves time passage which changes and evolves variable model over time (Stewart, 2004). Dynamic simulation can be exampled by simulation of a bank service during the working hours or an agricultural industry and system in a country that involves variable model evolution from time to time. However, dynamic simulation is divided into two other types of simulation which are discrete-event and continuous-event simulation.

2.7.3 Discrete Event and Continuous simulation

Discrete event simulation is a simulation that captures system changes at a specific point of time (Stewart, 2004). The modeling type of the discrete event simulation is series event based which can be exampled with queuing service, repairing service, waiting time, and other specific activities. An example of discrete-event simulation model is served as in **Figure 2.5** below.

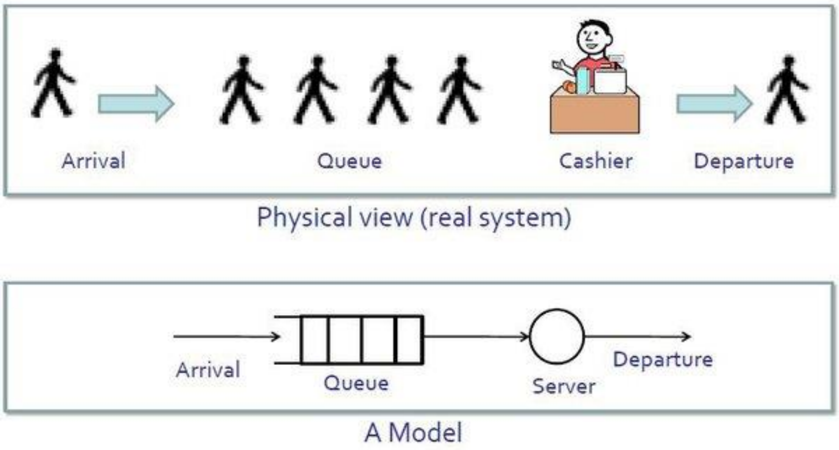


Figure 2.5 Discrete-event Simulation Model Example
Source: Quora

Figure 2.5 above shows a discrete-event model of a shop focused on the queuing system of the cashier. It is classified as a discrete event because the model captures specific activity at a specific time interval which is the operational hour of the shop.

Continuous-event simulation variable model continuously changing over time (Leonelli, 2021) Continuous event simulation is identical with ongoing, non-stop or non-time bounded, high volume, and fast-moving system flow (Stewart, 2004). It can be exampled with monetary flows, large scale of industry, such as agricultural system, transportation system, and environmental system. An example of continuous simulation model is served as in **Figure 2.6** below.

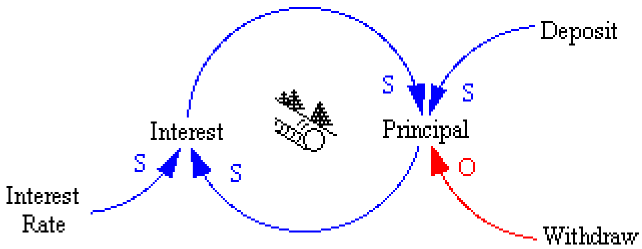


Figure 2.6 Continuous Simulation Model Example
Source: (Bellinger, 2004)

The example shows an interest system containing deposit and withdrawal activities. The model of the system contains a causal loop effect between one and another that has two types of cause-and-effect relation of reinforcing/same and balancing/opposite. The system does not work at a specific point of time which indicates a continuous classification of a simulation.

2.8 System Dynamics Methodology

According to Jay Wright Forrester, the founder of System Dynamics, System Dynamic is some knowledge about the representation of real-world complexity, nonlinearity, and cause-effect relationships structure (Forrester, System Dynamics, Systems Thinking, and Soft OR, 1994). In 1961, the term system dynamics was first introduced by Forrester in his book, Industrial Dynamics. Another term introduced also by Forrester, Industrial Dynamics is the computerized research knowledge and modeling towards a system characteristics and feedback loops to develop policies and organizational form (Forrester, Industrial Dynamics, 1961).

Based on (Allam et al., 2022), System Dynamics Approach is a simulation science that redescribe object or system abstraction and complexity to predict a result in future timeline. The purpose of system dynamics is to identify the behavior of the object or system by knowing the relationship between the components, stocks, flows, delays, and effects inside the system. According to (Siradjuddin, 2022), System Dynamics model development is a model development that understands system that has open and closed loop relationship between its components. Based on (Tasrif et al., 2015), System Dynamics is a methodology that focus and manages complex cause-effect system. According to (Lyu et al., 2018), System Dynamics Methodology is a science that deepens problem solving by the systematical feedback theory. System Dynamics necessarily develops models by comprehensive definition of the system, variables, and its relationships.

The methodology of System Dynamics involves multiple steps. As described by Forrester, it involves steps as visualized in **Figure 2.7** below.

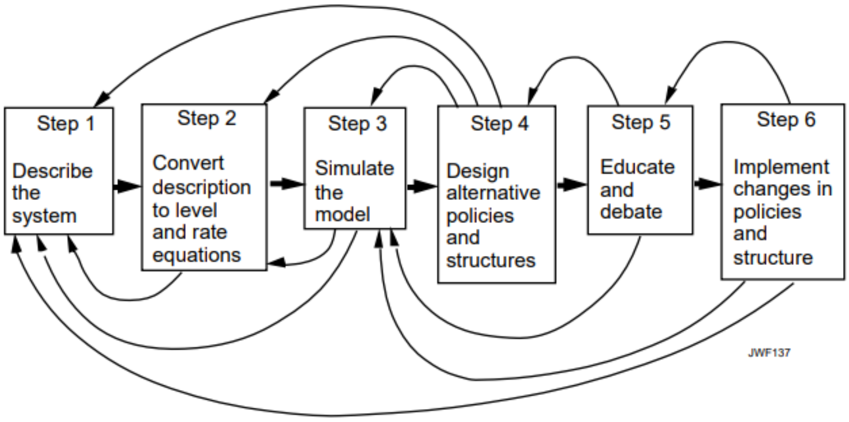


Figure 2.7 System Dynamics Steps According to Forrester
Source: (Forrester, System Dynamics, Systems Thinking, and Soft OR, 1994)

Based on the visual above, the steps are described in detail below.

1. **The first step is describing the system**. Describing the system involves the actual condition, hypothesis, and the main problem to be improved as the goal. Describing the system details the elements, variables, network, and relationships as in the equal measurement.
2. **The second step is to detail the system components into equation** of level and rate. Level and rate in system dynamics is necessary especially to model the stock flow diagram. In converting the description, the modeler can use their intuitive to make the equation work as how the real system works. This step may return to step 1 if there are system elements that are missing or have not been described.
3. **The third step focuses on simulation modeling** with a requirement of passing logical test of the second step. However, the simulation running may take several revisions due to matching both real and simulated system then reconsidering system description (step 1) and level and rate equations (step 2) after result of the simulation is shown. This step may require tests of verification, replication, and validation. This step finishes until the simulation is adequate but may not necessarily be fully valid due to impossibility to prove the representation of real world. In simulation, an adjustment may be conducted and redo the previous steps. In simulating, an adjustment may be conducted and redo the previous steps according to the result of the simulation whether it shows as hypothesized/calculated scope or not.

4. **The fourth step is to develop an alternative** for the system in the form of policy or structure. To develop the alternative, the modeler can use their intuition based on their knowledge on the development from step one to three. In developing alternative, rules and policies that are currently in effect are the main cue to prevent legality issues.
5. **The fifth step is to educate and debate**. This step involves discussion with people throughout the simulation and alternatives that have been developed to improve the later implementation. In discussion, new points and insights are gathered in many points of views to improve the system holistically.
6. **The sixth step is to implement the system change** using the alternative that has been developed. This step requires a monitoring system of the ongoing system running with the current policy. It has a purpose for improvements of the policy to reach the objective better in terms of effectiveness and efficiency.

In system dynamics, the use of visualization and conceptual modeling is necessary by developing causal loop diagram and stock flow diagram. It is necessary to assist in developing the simulation model.

2.8.1 Causal Loop Diagram

Causal Loop Diagram is a diagram in that models cause and effect relationships between components of a system (Rifaldi et al., 2021). Causal Loop Diagram is helpful to discover key for inputs and impact of components (Jahan et al., 2022). Each component is at least tagged by one arrow influenced or influencing another component. The influence status or polarity is marked with a sign of "+" for reinforcing or increasing influence and sign of "-" for negative or balancing influence. Causal Loop Diagram defines closed loop type by giving an arrowed unclosed circle in the middle of the loop. For positive closed loop, the arrow is heading clockwise while negative closed loop is marked by the arrow heading counterclockwise Causal Loop Diagram example is visualized as **Figure 2.8** below.

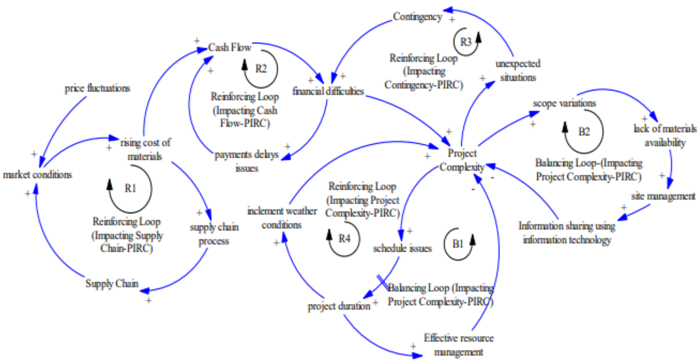


Figure 2.8 Causal Loop Diagram Example
Source: (Jahan et al., 2022)

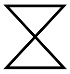
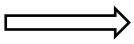
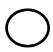
Based on the causal loop diagram example, the interconnections between components with polarity are marked with "+" and "-" at the end of the arrowed line. Loops in the system marked by cycle arrow with "R" for reinforcing or positive loop and "B" for balancing or negative loop and a number code.

2.8.2 Stock Flow Diagram

Stock Flow Diagrams is a diagram that describes accumulations of cause-and-effect structure that includes time functions and can be simulated by computers (Noor H., 2018). Stock Flow Diagram also describes the feedback structure that is described in causal loop diagram. The difference between Stock Flow Diagram and Causal Loop

Diagram is that Causal Loop Diagram focuses on structuring cause and effect of a system while Stock Flow Diagram focuses on capturing stocks and flows of the system. Stock Flow Diagram can be simulated by using STELLA. The components of Stock Flow Diagram are described in **Table 2.8** below.

Table 2.8 Components of Stock Flow Diagram

No	Symbol	Component	Description
1		Stock/Level	Stock or Level describes an accumulated quantity result as a state variable that are mainly affected by flows. Stocks creates delay caused by accumulations from inflows and outflows
2		Rate/Auxiliary	Rate or valve or auxiliary is included with a function to give value changes of the flow from the stock. Rate comes together with flow and source/sink as a set.
3		Flow	Flow describes the rate, movement, and velocity of an activity in a period that gives effects to stocks. Flow is classified as inflow and outflow. Inflow is a flow that is heading to a stock which adds value to the stock. Outflow is a flow that goes out from stock which subtracts value from the stock. Flow comes together with rate and source/sink as a set.
4		Source or Sink	Source or sink describes the stocks originating or leaving the flow that is outside the model. Source or sink only occurs when the origin of inflow or ending of outflow is not included in the model. Source/sink comes together with flow and rate as a set.
5		Converter	Converter is a constant related to the system in any type of form.

2.9 Verification, Replication, and Validation

After modeling the system by using causal loop and stock flow diagram, a verification and validation step must be conducted to reduce errors and ensure correctness of the simulation model.

2.9.1 Verification

Verification is a process of proving correctness of a state (Hasad, 2011). The verification is classified into two types of error testing which are syntax and semantic error. Syntax error testing is the ability of the simulation to be run. Semantic error is testing of the components mechanism correctness. Semantic error is done by checking the variables, equations, and units of the simulation model with the real model (Mbula, n.d.).

2.9.2 Validation

Validation is a process of acceptance and agreement after the checking. (Hasad, 2011) Validation of simulation model can be done by using several methods such as Black Box Method, 2. ANOVA F-test and Student's t-test, Delphi Method, Turing Test, and Extreme Behavior. In this research, the author uses the validation method of Black Box Method.

2.9.2.1 Black Box Validation

Black Box validation method is a data-driven validation method that compares the result of simulation model with real model by using mean of the data (Barlas, 1994). This method requires unknown system mechanisms for both modeled and real. The comparison on Black Box method can be calculated by using **Formula 2** below.

$$E = \left|\frac{(S-A)}{A}\right| \quad (2)$$

The notations of the formula are:
E = Variance of Error, valid if *E* < 0,1
S = Simulated Result
A = Actual Data

2.9.2.2 Extreme Value Validation

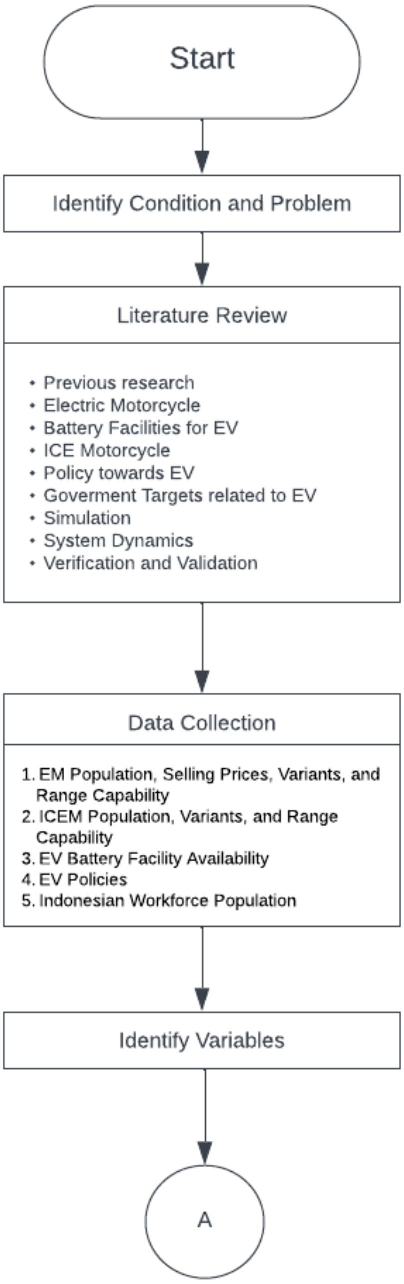
Extreme Value Validation or Sensitivity Analysis is an iterative validation method that tests variables in a data system with changing data input with extreme value relative to the simulated value. The test is purposed to test the significance of influence of the variable in the system. Non-influential variables are considered not necessarily to be put inside the system. (Mugiono, 2017)

CHAPTER 3
METHODOLOGY

The Methodology Chapter will discuss the sequence of research methodology and the descriptions of research methodology.

3.1 Sequence of Research Methodology

In this chapter, the sequence of research methodology is visualized in the graph that is given in **Figure 3.1** below.



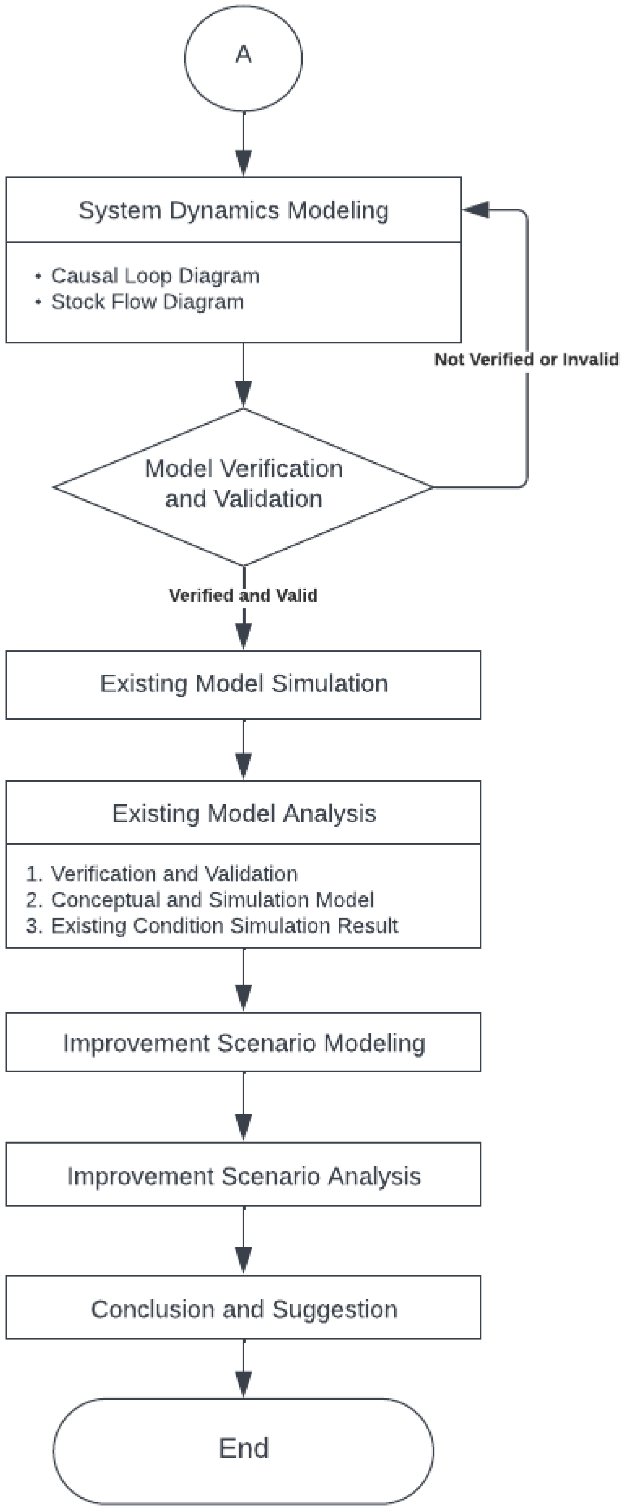


Figure 3.1 Research Methodology Flowchart

The research flow is visualized by using flow chart. The steps are Identify Condition and Problems, Literature Review, Data Collection, Identify Variable, Causal Loop Diagram Modeling, Stock Flow Diagram Modeling, Model Verification and Validation, Existing Model Simulation, Existing Model Analysis, Improvement Scenario Modeling, Improvement Scenario Analysis, Conclusion, and Suggestion.

3.2 Descriptions of Research Methodology

In this chapter, the research methodology is described based on its sequence that has been visualized in **Chapter 3.1**.

3.2.1 Identify Condition and Problem

In this step of research, identifying condition and problem of electric motorcycle in Indonesia is conducted. It is categorized as the very first step of this research. The identification process gathers facts regarding the object problem, existing condition, and the root cause of the system that will be researched. This contains the existing condition of electric motorcycle adoption in Indonesia and Indonesian Government actions towards emission reduction. Then, the main problem is formulated to hold the baseline of this research, namely efforts to bind the adoption of electric motorcycle. The writing of this identification contains contents of background, problem formulation, objective, limitation, and assumptions of the research.

The problem identification will lead to the decision of methodology that will be utilized. In this research, System Dynamics Simulation is selected because it fulfills criteria of problems statement of systematical and comprehensive-quantitative output approach. Other methodologies are considered less precise if utilized due to lack of systematical approach and comprehensive output.

The condition and problem identification will also lead to literature reviews to support the fundamental of the research. This will lead and support data collections fundamentals and variable identification for the research. System Dynamics model development will also be based on existing condition of the electric motorcycle adoption condition and issue that has been identified.

3.2.2 Literature Review

Literature review is the step to enlighten author's knowledge towards lifted issue of electric motorcycle adoption rate. This step is purposed to strengthen the fundamentals of the research by reviewing literature and theories related to the topic and reviewing previous research and journals. This contains material towards:

a. Previous research summary that is related to electric motorcycle adoption.
b. General descriptions regarding Electric Motorcycle.
c. General descriptions regarding Battery Facilities for EV.
d. ICE Motorcycle descriptions and emission factor.
e. Policy details towards EV.
f. Government Targets related to EV.
g. Descriptions and definitions of Simulation.
h. Methodology descriptions of System Dynamics and its modeling.
i. Steps in verification and validation of a model.

3.2.3 Data Collection

Data collection step consists of the gathering of supporting information for the model development. The data collection step is gathered by gaining secondary data that is credible and available online. The time horizon of the simulation research is cued from data from the year 2022 to early 2024. In this research, the data that is necessary to be gathered are:

1. EM Population, Selling Prices, Variants, and Range Capability.

2. ICEM Population, Variants, and Range Capability
3. EV Battery Facility Availability
4. EV Policies
5. Indonesian Population, Change Rates, and Workforce Rate.
6. Domestic Motorcycles Production Capacity

3.2.4 Identify Variables

Variable identification is a sequential step related to previous steps. Data collected is the cue of the identification of variable. This step identifies the components of the system and their correlation between one and another. Parameters are set to each variable that is included in the system. Later, the variables are the input for the modeling in the next step. In identifying variables, a table containing variables of the system, unit, and descriptions of each variable. The variable will be divided into each subsystem classification. The table is described as **Table 3.1** shown below.

Table 3.1 Variable Identification

No	Variable	Unit	Description

Variable columns will be filled with each variable that is identified in each subsystem. Unit is the measurement type of the variable. Description column contains the general description of the variable to equalize understanding of the author and readers of the variable. The subsystem will be divided into several terms such as Willingness to Adopt Subsystem, Population Subsystem, Motorcycle Subsystem, and Supporting Facility Subsystem. The subsystem diversification is based on the character of the variables in the subsystem such as working as an independent input variable, as a response variable or both. The subsystem classification will also be based on the material and information flow in tangible or intangible forms.

3.2.5 System Dynamics Model Development

System Dynamics model development is the model development by using Causal Loop Diagram and Stock Flow Diagram.

3.2.5.1 Causal Loop Diagram

Causal Loop Diagram is modeled by putting the variables identified into a cause-and-effect interaction between one and another. This diagram has a function to identify the behavior and delays in the modeled system. This model helps the author to understand more regarding the correlation between variables that are contained in the existing condition of the system. Each component is at least tagged by one arrow influenced or influencing another component marked with a sign of "+" for reinforcing or increasing influence and sign of "-" for negative or balancing influence. Causal Loop Diagram defines closed loop type by giving an arrowed unclosed circle in the middle of the loop. For positive closed loop, the arrow is heading clockwise while negative closed loop is marked by the arrow heading counterclockwise.

Causal loop diagram components will also be described in a table containing the variables in each subsystem and influence factors of the variable. An example of the table is shown as in **Table 3.2** below.

Table 3.2 Causal Loop Diagram Components

Subsystem A			
No	**Variable**	**Influenced by**	**Influences**

The influential factors of the variable containing column “Influenced by” and “Influences” will be filled by another variable with the relation of “(+)” for reinforcing factor or “(-)” balancing factor of described variable on the row relative to other variable.

Loops that existed in the causal loop diagram will be defined one by one in a table. The table will list all the loops that existed, followed by the type of loop consisting of positive loop or negative loop, and the variable flow of the discussed loop.

Previous research that includes system dynamics as methodology will also be the supporting factors to develop the electric motorcycle adoption system causal loop. Each of the loops that has been developed in previous research will be detailed in a table that consists of adapted loop followed with descriptions regarding relation to the previous research.

3.2.5.2 Stock Flow Diagram Modeling

Stock Flow Diagram is modeled by interpreting the causal loop relations of the identified variables into an accumulative movement, or so-called stock-flow relationship. Stock flow diagram is classified as both conceptual and simulation model. In this modeling, the variables are classified according to stock-flow components category. It contains stock/level, flow/rate, and auxiliary/converter. Equation is also necessary to be input in each variable to model the accumulation flow of the system. Stock Flow Diagram will be the only model that can be simulated using STELLA software. In stock flow diagram modeling, components must be input according to the identification and its component type. After that, the process of correlating the components must be done accurately by cueing to the causal loop diagram.

Stock or Level describes an accumulated quantity result as a state variable that is mainly affected by flows. Stocks create delay caused by accumulations from inflows and outflows. Rate or valve or auxiliary is included with a function to give value changes of the flow from the stock. Flow describes the rate, movement, and velocity of an activity in a period that gives effects to stocks. Flow is classified as inflow and outflow. Inflow is a flow that is heading to a stock which adds value to the stock. Outflow is a flow that goes out from stock which subtracts value from the stock. Source or sink describes the stocks originating or leaving the flow that is outside the model. Converter is a constant affecting the system in any form. Source or sink only occurs when the origin of inflow or ending of outflow is not included in the model. In STELLA’s stock flow diagram modeling, the source and sink will automatically exist if the modeler inputs a flow/rate component to the system.

Data inputs as in raw data that has been collected in the data collection steps will be included in a table that is included in list below.

- EM Population

- Domestic EM Production Capacity
- ICEM Population
- Domestic ICEM Industry Capacity
- Population of Indonesia
- Average EM Battery Range
- Average ICEM Range
- Buying Power
- ICEM Variants
- EM Variants
- EM Purchase Incentive
- Average EM Market Price
- Battery CS Population
- Battery SS Population

Each of the stock flow diagram components will be described in a table containing the variable of each subsystem and simulation input value. The table example is shown as in **Table 3.3** below.

Table 3.3 Stock Flow Diagram Components

Subsystem A			
No	**Variable**	**Type**	**Simulation Input Value**

This table will mainly describe the simulation input value of each variable. The simulation input value column may be filled with an independent number or a formula containing other variable as input of the variable.

3.2.6 Model Verification and Validation

Model Verification and Validation is a necessary step before running, interpreting, and analyzing the model to reduce errors and ensure correctness of the simulation model. If simulated and conceptual models don't pass verification and validation, the System Dynamics model development must be reconducted.

3.2.6.1 Model Verification

Model verification step is a process of proving correctness of a state. The verification is classified into two types of error testing which are syntax and semantic error. Syntax error testing is the ability of the simulation to be run which can be seen from the STELLA application when an error occurs during the running of the simulation. Semantic error is testing of the components mechanism correctness. Semantic error is done by checking the variables, equations, and units of the simulation model with the real model. Semantic errors may not be identified as easily as syntax error since it does not have any symptoms showing but can be identified from the result of the simulation according to the expectations that has been set. In STELLA, verification can be run by using STELLA feature called "Check Units" in Run. The feature will verify the model that has been designed on the software.

3.2.6.2 Model Validation

Model validation step is a process of acceptance and agreement after the checking. Validation is completely necessary to ensure the model correctness in terms of how the system works and how it resulted, comparing it to the real model.

In other research using primary data, validation of whole research step must be conducted due to reduction of subjective judgement. On other hand, this research used secondary data that are gathered online. Thus, it does not need an every-step-validation because it is publicly recognized and approved. The necessary validation is on the simulation modeling step to ensure the imitation of the real system. In validation, the test must result in no differences or insignificant differences of simulated model with real world model. In this research, the validation step will use Black Box Method. The reason behind the utilization of Black Box Method is the widely accepted simple utilization and flexibility to be utilized in different data types that are suitable for continuous event simulation. The author also utilizes Extreme Value Validation as a sensitivity testing for variable influences.

Black Box method requires method requires manual calculation for both modeled result and real model. The comparison on Black Box method can be calculated by using the formula below.

$$E = \left| \frac{(S-A)}{A} \right| \quad (2)$$

The notations of the formula are:
E = Variance of Error, valid if E < 0,1
S = Simulated Result
A = Actual Data

In this research, the variable that is going to be validated is the variable in a form of response, that has the most influence on the system. The list of variables that is going to be validated are:

1. Electric Motorcycle Population 2023
2. Charging Station Population 2023
3. Swapping Station Population 2023

The chosen variable is determined due to the existence of the 2023 data to correct the simulation model.

Extreme Value Validation or Sensitivity Analysis is an iterative validation method that tests variables in a data system with changing data input with extreme value relative to the simulated value. The variables will be tested in extreme values and the analysis will be based on graphs that are provided by STELLA software. The indication of the variable necessity is based on the influence of the tested independent variable to the response variable. There will be 3 classifications which are Not Necessary, Moderately Necessary, and Necessary. The classification of Not Necessary is indicated by the non-influential variable that is not necessarily included in the system. Moderately Necessary classification is indicated by the semi-influential variable which may be partly influential or non-influential but with potential as model improvements. Necessary variables are variables that are needed in the system and give a significant influence as indicated by the graph given in STELLA. By using the extreme value validation, the variable tested can become the potential scenario to develop improvements of the system.

3.2.7 Existing System Model Simulation

Model simulation contains the running of simulation using the modeled existing condition of stock flow diagram. Model simulation is supported by STELLA software to run the simulation by inputting the stock flow diagram modeling and its equations. The simulation in STELLA will result in graphs and tables containing output value of the variables. Model simulation in STELLA requires the stock flow diagram and its equation, followed with the specification and settings of the simulation such as time horizon of the simulation, time interval capturing, and other settings.

3.2.8 Existing System Model Analysis

The interpretation and analysis step describes and details the whole process of the conducted process of the research. Describing and analyzing the details will be specified by System Dynamics Model containing Causal Loop Diagram and Stock Flow Diagram, existing model simulation result. The analysis also contains verification and validation tests analysis. The validation result analysis will determine whether the model can be used as prediction tool or not. Existing condition analysis will later gain a main root cause and the sensitive variable related to it.

The existing system model analysis evaluates the existing system by predicting the output based on the simulation result. The main evaluation is indicated by achievement rate of variables based on the target that has been set by the government as of 2030. From the evaluation, the author will focus on improving variables that do not yet fulfill the target expected. The analysis is also the cue of improvement with support of extreme value test that has been conducted previously.

The achievement percentage of the target is calculated as in **Formula 3** and is shown below.

$$Achievement = \frac{Simulation\ Result}{Target} \tag{3}$$

For Emission Reduction, the achievement will be adjusted from the result value of the simulation. The adjustment of the emission reduction realization is calculated as in **Formula 4** that is shown below.

$$Emission\ Reduction\ Realization = 1 - \frac{2030\ Emission\ Simulation\ Result}{2022\ Emission} \tag{4}$$

After the calculation **Formula 4**, the achievement is calculated as of the 32% reduction target.

3.2.9 Improvement Scenario Model Development and Simulation

Improvement scenario modeling is the step to remodel the existing condition with a basis of the literature and research that has been reviewed in Chapter 2. The evaluation of existing system model is also the cue to make improvements to the model. Improvement will be in the form of policies and changes of variable or variable input of the modeling. The sensitive variable will could be the main consideration in model the improvement scenario. This also includes improvement models simulation and will result in new improved values. The remodeled system is later simulated using the same software, STELLA, to run the system dynamics improvement scenario.

In modeling the improvement scenario, the author plans to create two types of improvement scenarios consisting of a single/individual improvement, and multiple/mixed improvements in one improvement scenario. The fundamental of this development is due to the electric motorcycle adoption system character which are systemic and cause-and-effect type of problem that has been discussed in literature review. This step will result in a table that consists direct comparison of existing input values and improved input values followed with output value of the simulation for analysis support in the next chapter.

3.2.10 Improvement Scenario Analysis

The interpretation and analysis step describes and details the improved system conducted in the research. The improvement analysis consists of highlights of differences between input values and output values of existing scenarios and alternatives that are conducted on the simulation with the support of table that has been served in the modeling and simulation step. The best scenario will be defined in this section in detail with the correlating elements or system flow that has high influence factors to accelerate the adoption of electric motorcycle. The expectation of the best scenario fulfills all or most of the government targets that have been set to be achieved in 2030 consisting of electric motorcycle population, emission reduction, and supporting facilities population. The realization and achievement percentage of the target is calculated as in **Formula 3** and **Formula 4** that has been shown in **Subchapter 3.2.8**.

3.2.11 Conclusion and Suggestion

The conclusion summarizes the research holistically by answering the result of the research problem and objective. The conclusion will answer the following objective.

1. Develop the model of existing electric motorcycle adoption condition by using system dynamics method.
2. Analyze the impact and evaluate the existing policy to reach the electric motorcycle and emission reduction target of Indonesia.
3. Develop an alternative policy model to increase the adoption rate of electric motorcycle and promote the emission reduction program in Indonesia.

The formulation of suggestions is based on the conclusion of the research by giving advice. The advice consists of things to be improved and added for future research that is related to electric motorcycle adoption rate.

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CHAPTER 4
SYSTEM DYNAMICS MODEL DEVELOPMENT

The System Dynamics Model Development Chapter, the research development of Analysis of The Supporting Facilities Policy Impact for The Electric Motorcycle Adoption in Indonesia is described and served. Firstly, the chapter describes the existing system condition through condition identification, variable identifications, and causal loop diagram of existing system. The chapter then describes the System Dynamics model development through stock flow diagram and later will be validated. The existing system model is simulated, and the results are described. Later, it is continued with the improvement model of the system.

4.1 Existing System Description

The existing system is described through existing system identification, variable identification, and causal loop development of the existing condition. This subchapter describes the existing system and one of which by modeling causal loop diagram.

4.1.1 Existing System Condition Identification

Indonesia is currently listed the top 10 emission producer in the world with 1.80% of global contribution. Indonesia itself contributes emission mainly by energy production, transportation, and industry activities. With all the listed domestic emission, transportation is the most flexible scope to intervene. This issue triggers government of Indonesia to reduce the emission contribution in transportation by adopting with current trends. The current entering electric vehicle has been a great prospect of potential to reduce emission. With majority of transportation and emission contribution being motorcycles, the government of Indonesia plans to shift approximately 13.469.000 units of conventional motorcycles users to use electric motorcycles by 2030.

The policy regarding electric vehicles has been arranged by the government in Presidential Regulation Number 25 Year 2019, thereby, actions to support the adoption of electric motorcycle must align according to the regulation. The policy stated that efforts for adoptions are acceleration of domestic Electric Vehicle industry, providing incentives, infrastructure providing for battery charging and electric energy fee for Electric Vehicles, technical requirement of Electric Vehicle fulfillment, and living environment protection. The decision of effort focus must be considered carefully as it may cause an effect with delay of time in future time.

The condition statement starts with the most publicly recognized policy for electric motorcycles is the incentive of purchase. The incentive contains a Rp7.000.000,00 discount for a purchase per person for 250.000 people with purchase tax including 10% of the total purchase price. The incentives have supported the population of electric motorcycles that almost reaches 17.198 units in 2022 and raised to 62.409 in the end of 2023. Infrastructure to support the operation of electric motorcycles consisting of battery charging and swapping stations. The realization stated by Kompas has reached 439 units of charging stations and 961 units of swapping stations at the end of 2022. In the end of 2023, the population has reached 1.081 units of charging station and 1.401 per end of 2023. However, the ideal ratio of electric motorcycle and supporting facility infrastructure is 1 facility per 10 units of vehicle while the achievement is only 1 facility per 24,4 units of motorcycle. In a causal effect, the closer the ratio will also support the adoption of electric motorcycles to reach the 2030 target of 13.469.000 units, since the main preference for adoption is the availability of supporting facilities. Other preferences include the price of purchase and battery range capabilities in kilometers. The current government target of electric motorcycle system adoptions is served in **Table 4.1** below.

Table 4.1 Government Targets Regarding EM System

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Target	13.469.000,00	32.000,00	67.000,00	32,00%
Properties	Higher Better	Higher Better	Higher Better	Higher Better

Table 4.1 shows the target that is set by the government to be achieved in 2030 regarding electric motorcycle system containing electric motorcycle population, charging station population, swapping station population, and emission reduction. The four targets are targets that are set to be achieved in higher better considerations.

4.1.2 Variable Identification

From the existing system identification, the variables that are included in the electric motorcycle adoption cause and effect system can be identified. The variable identification is distinguished by subsystems that are divided into motorcycle subsystem, workforce population subsystem, willingness to adopt subsystem, and supporting facility subsystem. Each definition of the variable is described in **Table 4.2, 4.3, 4.4** and **4.5** that are served below. **Table 4.2** shows the Motorcycle Subsystem Variable Identification.

Table 4.2 Motorcycle Subsystem Variable Identification

Motorcycle Subsystem			
No	**Variable**	**Unit**	**Description**
1	EM Demand	unit	Total demand of electric motorcycle
2	EM Demand Fulfillment	unit/year	Total fulfillment of electric motorcycle demand per year
3	EM Population	unit	Total population of electric motorcycle
4	Domestic EM Production Capacity	unit	Maximum amount of domestic electric motorcycle production per year
5	EM Decrease	unit	Total population decrease of electric motorcycle per year
6	EM Decrease Rate	unit/year	Decrease rate constant of electric motorcycle per year
7	Motorcycle Demand	unit	Total motorcycle demand in Indonesia
8	ICEM Demand	unit/year	Total demand ICE motorcycle per year
9	ICEM Demand Fulfillment	unit/year	Total fulfillment of ICE motorcycle demand per year
10	ICEM Population	unit	Total population of ICE motorcycle
11	Domestic ICEM Industry Capacity	unit	Maximum amount of domestic ICE motorcycle production per year
12	ICEM Decrease	unit	Total population decrease of ICE motorcycle per year
13	ICEM Decrease Rate	unit/year	Decrease rate constant of ICEM motorcycle per year
14	ICEM eCO2 Rate	eCO2/ (year*unit of population)	Average rate of eCO2 released by ICE motorcycle per year
15	CO2 Emission from ICEM	eCO2	Total amount of eCO2 released from ICE motorcycle per year

The motorcycle subsystem in the electric motorcycle subsystem has 15 variables. It consists of tangible and intangible components directly related to physical conventional and electric motorcycles. **Table 4.3** shows the Workforce Subsystem Variable Identification.

Table 4.3 Workforce Subsystem Variable Identification

Workforce Subsystem			
No	**Variable**	**Unit**	**Description**
1	Workforce Population	person	Total population of workforce in Indonesia
2	Workforce Population Ratio	ratio	Ratio of workforce population
3	Population of Indonesia	person	Total population of Indonesia
4	Population Change	person	Total change (increase) of Indonesia population
5	Population Change Rate	person/ (year*population)	Rate of change of Indonesia population
6	Capable Workforce to Buy Motorcycle Ratio	ratio	Ratio of capable workforce to buy motorcycle
7	Capable Workforce to Buy Motorcycle	person	Total capable workforce to buy motorcycle

The workforce subsystem in the electric motorcycle subsystem has 7 variables. It consists of components regarding the population of Indonesia until it is cascaded into capable workforce to buy motorcycle that will become the motorcycle demand. **Table 4.4** shows the Willingness to Adopt Subsystem Variable Identification.

Table 4.4 Willingness to Adopt Subsystem Variable Identification

Willingness to Adopt Subsystem			
No	**Variable**	**Unit**	**Description**
1	EM Willingness to Adopt	ratio	Ratio of willingness to adopt to electric motorcycle
2	Average EM Battery Range	kilometer	Average electric motorcycle battery travel range for one trip without refilling
3	Average ICEM Range	kilometer	Average ICE motorcycle travel range for one trip without refilling
4	Range Ratio	ratio	Ratio between electric motorcycle battery range and ICE motorcycle range for one trip without refilling
5	EM Selling Price Ratio	ratio	Ratio of electric motorcycle selling price from variants and selling price average
6	Buying Power	rupiah	Average society buying power of electric motorcycle
7	ICEM Variants	variant	Total variants of ICE motorcycle available in Indonesia
8	EM Variants	variant	Total variants of electric motorcycle available in Indonesia
9	EM Variant Ratio	ratio	Ratio of electric motorcycle and ICE motorcycle variants
10	EM Purchase Incentive	rupiah	Total incentive received of electric motorcycle per purchase
11	Average EM Selling Price	rupiah	Average selling price of electric motorcycle after subtraction between market price and incentive
12	Average EM Market Price	rupiah	Average market price of electric motorcycle
13	Battery Facility to EM Ratio	ratio	Ratio between total battery supporting facility to fulfill the population of electric motorcycle
14	EM Purchase Tax	percentage	Amount of tax (value in percentage) that is paid for every EM purchase

The willingness to adopt subsystem in the electric motorcycle subsystem has 14 variables. It consists of components regarding the preference modeling to produce a ratio to whether adopt to electric or conventional motorcycle. **Table 4.5** shows the Supporting Facility Subsystem Variable Identification.

Table 4.5 Supporting Facility Subsystem Variable Identification

Supporting Facility Subsystem			
No	**Variable**	**Unit**	**Description**
1	Battery Facility Demand	unit/year	Total demand of battery supporting facility per year
2	Ideal Facility to EM Ratio	ratio	Ideal ratio between total battery supporting facility to fulfill the population of electric motorcycle
3	Battery CS Establishment	unit/year	Total establishment of battery charging station per year
4	Battery CS Population	unit	Total population of battery charging station
5	Battery Station Preference	ratio	Ratio of preference between battery charging station and battery swapping station
6	Battery SS Establishment	unit/year	Total establishment of battery swapping station per year
7	Battery SS Population	unit	Total population of battery swapping station
8	Capability to Fulfill	unit/(year*demand)	Rate of capability to fulfill electric motorcycle demand establishment

The supporting subsystem in the electric motorcycle subsystem has 8 variables. It consists of components regarding the supporting facilities including charging and swapping station in terms of demand and fulfillment.

4.1.3 Causal Loop Diagram Development

Causal Loop Diagram development cues from the variable that has been identified. The development consists of connecting the variables to a cause and effect to identify the interaction between them. The causal loop development is described in table consisting of variables and its “influencing” and “influenced by” relation. It also consists of diagram development.

The table of variable identification is served in **Table 4.6, 4.7, 4.8** and **4.9** served below which are divided between subsystems. **Table 4.6** shows the Motorcycle Subsystem Causal Loop Identification.

Table 4.6 Motorcycle Subsystem Causal Loop Identification

Motorcycle Subsystem			
No	**Variable**	**Influenced by**	**Influences**
1	EM Demand	Motorcycle Demand (+) EM Willingness to Adopt (+) EM Mouth to mouth Adoption Rate (+) EM Population (+)	EM Demand Fulfillment (+)
2	EM Demand Fulfillment	EM Demand (+) Domestic EM Production Capacity (+)	EM Population (+)
3	EM Population	EM Demand Fulfillment (+) EM Decrease (-)	Battery Facility to EM Ratio (+) EM Demand (+) Motorcycle Demand (-) EM Decrease (+)
4	Domestic EM Production Capacity	-	EM Demand Fulfillment (+)

Motorcycle Subsystem			
No	**Variable**	**Influenced by**	**Influences**
5	EM Decrease	EM Population (+) EM Decrease Rate (+)	EM Population (-)
6	Motorcycle Demand	EM Population (-) ICEM Population (-) Capable Workforce to Buy Motorcycle (+)	EM Demand (+) ICEM Demand (+)
7	ICEM Demand	EM Willingness to Adopt (-) Motorcycle Demand (+)	ICEM Demand Fulfillment (+)
8	ICEM Demand Fulfillment	ICEM Demand (+) Domestic ICEM Industry Capacity (+)	ICEM Population (+)
9	ICEM Population	ICEM Demand Fulfillment (+) ICEM Decrease (-)	Motorcycle Demand (-) eCO2 Emission from ICEM (+) ICEM Decrease (+)
10	Domestic ICEM Industry Capacity	-	ICEM Demand Fulfillment (+)
11	ICEM Decrease	ICEM Population (+) ICEM Decrease Rate (+)	ICEM Population (-)
12	ICEM eCO2 Rate	-	eCO2 Emission from ICEM (+)
13	eCO2 Emission from ICEM	ICEM Population (+) ICEM eCO2 Rate (+)	-
14	EM Decrease Rate	-	EM Decrease (+)
15	ICEM Decrease Rate	-	ICEM Decrease (+)

The motorcycle subsystem causal loop relationship is detailed in **Table 4.6**. The causal loop relationship example is on EM Decrease where it is influenced positively by EM Population and EM Decrease rate, where it also influences negatively to EM Population. **Table 4.7** shows the Workforce Subsystem Causal Loop Identification.

Table 4.7 Workforce Subsystem Causal Loop Identification

Workforce Subsystem			
No	**Variable**	**Influenced by**	**Influences**
1	Workforce Population	Population of Indonesia (+) Workforce Population Ratio (+)	Capable Workforce to Buy Motorcycle (+)
2	Workforce Population Ratio	-	Workforce Population (+)
3	Population of Indonesia	Population Change (+) Population Change Rate (+)	Population Change (+) Workforce Population (+)
4	Population Change	Population of Indonesia (+) Population Change Rate (+)	Population of Indonesia (+)
5	Population Change Rate	-	Population Change (+)
6	Capable Workforce to Buy Motorcycle Ratio	-	Capable Workforce to Buy Motorcycle (+)
7	Capable Workforce to Buy Motorcycle	Capable Workforce to Buy Motorcycle Ratio (+) Workforce Population (+)	Motorcycle Demand (+)

The workforce subsystem causal loop relationship is detailed in **Table 4.7**. The causal loop relationship example is on Population Change where it is influenced positively by Population of Indonesia and Population Change Rate, where it also influences positively to Population of Indonesia. **Table 4.8** shows the Willingness to Adopt Subsystem Causal Loop Identification.

Table 4.8 Willingness to Adopt Subsystem Causal Loop Identification

Willingness to Adopt Subsystem			
No	**Variable**	**Influenced by**	**Influences**
1	EM Willingness to Adopt	Range Ratio (+) EM Selling Price Ratio (+) Battery Facility to EM Ratio (+)	EM Demand (+) ICEM Demand (-)
2	Average EM Battery Range	-	Range Ratio (+)
3	Average ICEM Range	-	Range Ratio (-)
4	Range Ratio	Average EM Battery Range (+) Average ICEM Range (-)	EM Willingness to Adopt (+)
5	EM Selling Price Ratio	Buying Power (+) Variant Ratio (+) Average EM Selling Price (-)	EM Willingness to Adopt (+)
6	Buying Power	-	EM Selling Price Ratio (+)
7	ICEM Variants	-	Variant Ratio (-)
8	EM Variants	-	Variant Ratio (+)
9	Variant Ratio	ICEM Variants (-) EM Variants (+)	EM Selling Price Ratio (+)
10	EM Purchase Incentive	-	Average EM Selling Price (-)
11	Average EM Selling Price	EM Purchase Incentive (-) Average EM Market Price (+) EM Purchase Tax (+)	EM Selling Price Ratio (-)
12	Average EM Market Price	-	Average EM Selling Price (+)
13	Battery Facility to EM Ratio	Battery SS Population (+) Battery CS Population (+) EM Population (-)	EM Willingness to Adopt (+)
14	EM Purchase Tax	-	Average EM Selling Price (+)

The willingness to adopt subsystem causal loop relationship is detailed in **Table 4.8**. The causal loop relationship example is on Variant Ratio where it is influenced positively by ICEM Variants and EM Variants, where it also influences positively to EM Selling Price Ratio. **Table 4.9** shows the Supporting Facility Subsystem Causal Loop Identification.

Table 4.9 Supporting Facility Subsystem Causal Loop Identification

Supporting Facility Subsystem			
No	**Variable**	**Influenced by**	**Influences**
1	Battery Facility Demand	Ideal Facility to EM Ratio (+) EM Population (+)	Battery SS Establishment (+) Battery CS Establishment (+)
2	Ideal Facility to EM Ratio	-	Battery Facility Demand (+)
3	Battery CS Establishment	Battery Station Preference (+) Battery Facility Demand (+) Capability to Fulfill (+)	Battery CS Population (+)

Supporting Facility Subsystem			
No	**Variable**	**Influenced by**	**Influences**
4	Battery CS Population	Battery CS Establishment (+)	Battery Facility to EM Ratio (+)
5	Battery Station Preference	-	Battery SS Establishment (+) Battery CS Establishment (+)
6	Battery SS Establishment	Battery Station Preference (+) Battery Facility Demand (+) Capability to Fulfill (+)	Battery SS Population (+)
7	Battery SS Population	Battery SS Establishment (+)	Battery Facility to EM Ratio (+)
8	Capability to Fulfill	-	Battery CS Establishment (+) Battery SS Establishment (+)

The supporting facility subsystem causal loop relationship is detailed in **Table 4.9**. The causal loop relationship example is on Battery Facility Demand where it is influenced positively by Ideal Facility to EM Ratio and EM Population, where it also influences positively to Battery SS Establishment and Battery CS Establishment

From the causal loop relation identification table above, the causal loop diagram can be graphed according to the relationship that has been described above. The causal loop diagram is served in **Figure 4.1** below.

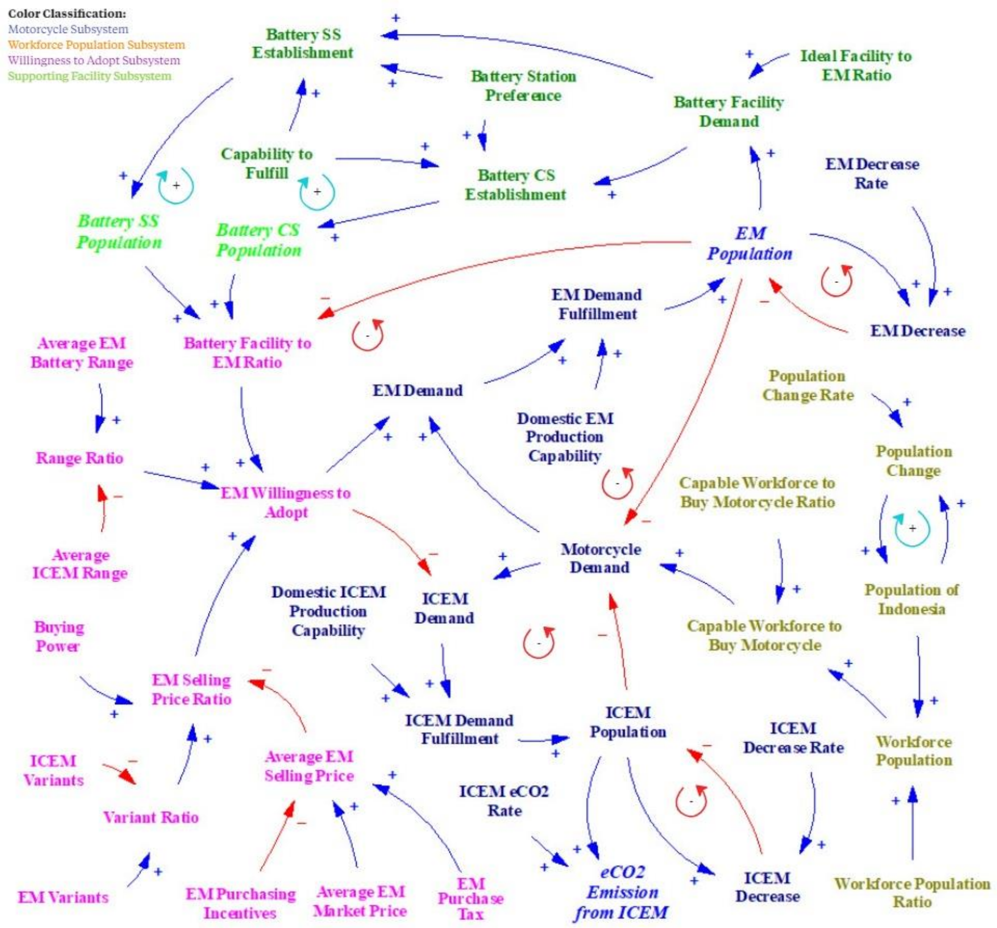


Figure 4.1 Causal Loop Diagram of Electric Motorcycle Adoption System

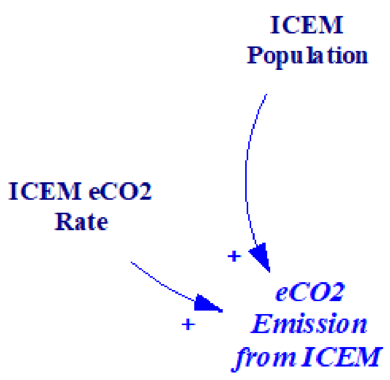
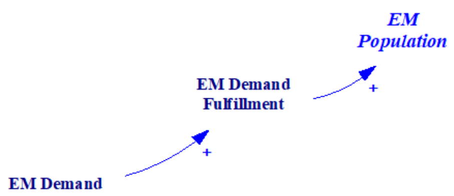
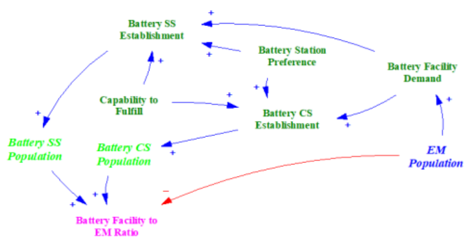
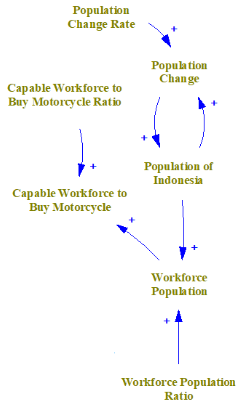
All the causal loop relationships that existed in the Causal Loop Diagram shown in **Figure 4.1** with a total of 11 loops are detailed in **Table 4.10** served below.

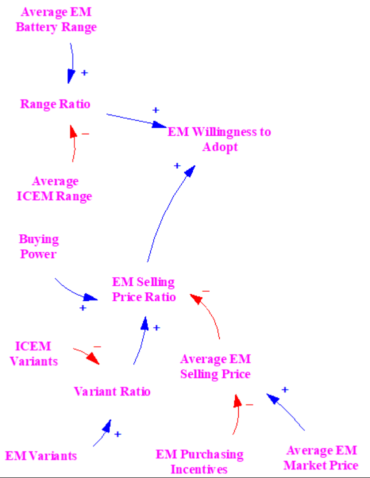
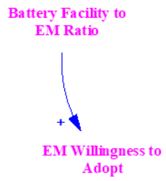
Table 4.10 Causal Loops Relationships of Electric Motorcycle Adoption System

Loop	Variable Loop Relationship
Loop 1 - Negative Loop	EM Willingness to Adopt
	EM Demand
	EM Demand Fulfillment
	EM Population
	Battery Facility to EM Ratio
Loop 2 - Positive Loop	EM Willingness to Adopt
	EM Demand
	EM Demand Fulfillment
	EM Population
	Battery Facility Demand
	Battery SS Establishment
	Battery SS Population
	Battery Facility to EM Ratio
Loop 3 - Positive Loop	EM Willingness to Adopt
	EM Demand
	EM Demand Fulfillment
	EM Population
	Battery Facility Demand
	Battery CS Establishment
	Battery CS Population
	Battery Facility to EM Ratio
Loop 4 - Positive Loop	EM Willingness to Adopt
	ICEM Demand
	ICEM Demand Fulfillment
	ICEM Population
	Motorcycle Demand
	EM Demand
	EM Demand Fulfillment
	EM Population
	Battery Facility to EM Ratio
Loop 5 - Negative Loop	EM Willingness to Adopt
	ICEM Demand
	ICEM Demand Fulfillment
	ICEM Population
Loop 5 (continued) - Negative Loop	Motorcycle Demand
	EM Demand
	EM Demand Fulfillment
	EM Population
	Battery Facility Demand
	Battery SS Establishment
	Battery SS Population
	Battery Facility to EM Ratio
Loop 6 - Negative Loop	EM Willingness to Adopt
	ICEM Demand
	ICEM Demand Fulfillment
	ICEM Population
	Motorcycle Demand
	EM Demand
	EM Demand Fulfillment
	EM Population
	Battery Facility Demand
	Battery CS Establishment
	Battery CS Population
	Battery Facility to EM Ratio
Loop 7 - Negative Loop	EM Population
	EM Decrease
Loop 8 - Negative Loop	EM Population
	Motorcycle Demand
	EM Demand
	EM Demand Fulfillment
Loop 9 - Negative Loop	ICEM Population
	ICEM Decrease
Loop 10 - Negative Loop	ICEM Population
	Motorcycle Demand
	ICEM Demand
	ICEM Demand Fulfillment
Loop 11 - Positive Loop	Population of Indonesia
	Population Change

The loops that occurred on the system are shown in **Table 4.10**. It consists of total 4 Positive Loops and 7 Negative Loops. The causal loop relationships that have been developed by the author are inspired and referred from previous research. The list of previously made causal loop relationship is served in **Table 4.11** below.

Table 4.11 Causal Loop Relationship Reference

No	Causal Loop Relationship	Relationship Reference	Notes
1		(Liu & Xiao, 2018)	The author modified the causal loop relationship between that has been made by Liu & Xiao with a direct relationship between ICEM Population to eCO2 Emission from ICEM. In previous research, it contains the mileage. While in current research, the author tends to simply the relationship with adding ICEM eCO2 rate to standardize the rate of mileage.
2		(Syabani, 2023) (Sulistyono, 2021)	Two previous research has developed a relationship of Demand-Fulfillment-Population of EV which in current research it is also applies for both EM and ICEM.
3		(Syabani, 2023)	Previous research developed a relationship between EV Population, Charging Station, and Ratios between the two. This research adapted the previous research by applying it for both CS and SS.
4		(Syabani, 2023)	Previous research developed a relationship Population loop which focused only on the workforce increase and decrease. This research adapted the previous research by developing main country population and categorizing it to workforce and capable workforce.

No	Causal Loop Relationship	Relationship Reference	Notes
5		(Syabani, 2023)	Previous research developed a relationship of Willingness to Adopt relationship. This current research tends to specify of each ratio that affects Willingness to Adopt.
6		(Sulistyono, 2021)	Previous research developed a relationship of Battery Station Availability with Willingness to Adopt relationship.

There are in total 6 sets of causal loop relationship that has been modeled previously by the research that has been reviewed by the author. It is adapted to be included in the current research system development.

4.2 System Dynamics Model Development

The system dynamics model development consists of system dynamics variable data gathering and formula processing and stock flow diagram development.

4.2.1 System Dynamics Variable Data Gathering and Processing

System Dynamics variables are identified followed with variable identification and causal loop diagram that has been developed on previous subchapter. The data gathered is served in **Table 4.12** below.

Table 4.12 System Dynamics Variable Data Gathering

No	Data	Value
1	EM Population	17198
2	Domestic EM Production Capacity	1427000
3	ICEM Population	125305332
4	Domestic ICEM Industry Capacity	6867217
5	Population of Indonesia	275773800
6	Average EM Battery Range	175
7	Average ICEM Range	285
8	Buying Power	15053568
9	ICEM Variants	300
10	EM Variants	61
11	EM Purchase Incentive	7000000
12	Average EM Market Price	34720000
13	Battery CS Population	439

No	Data	Value
14	Battery SS Population	961

The data served on **Table 4.12** above consist of both data that are ready to simulate and data that needs to be processed. The data is gathered online from official website of reports, automotives, and government regulations. Data that are ready for simulation are EM Population, Domestic EM Production Capacity, ICEM Population, Population of Indonesia, Average EM Battery Range, Average ICEM Range, Buying Power, ICEM Variants, EM Variants, EM Purchase Incentive, Average EM Market Price, Battery CS Population, and Battery SS Population. The data that are served are data that applies on the year 2022, the starting year of the simulation scheme.

4.2.2 Stock Flow Diagram Development

Stock flow diagram development models the System Dynamics simulation by converting the identified variables into stock flow components and putting into relationships of cause and effect and material flow. The identified variables are classified into stock-flow components consisting of stock, flow/rate, and converter. The Stock Flow Diagram models the flow of material and information relationship between the variables. The Stock Flow Diagram for the whole Electric Motorcycle Adoption System is modeled in **Figure 4.2** below.

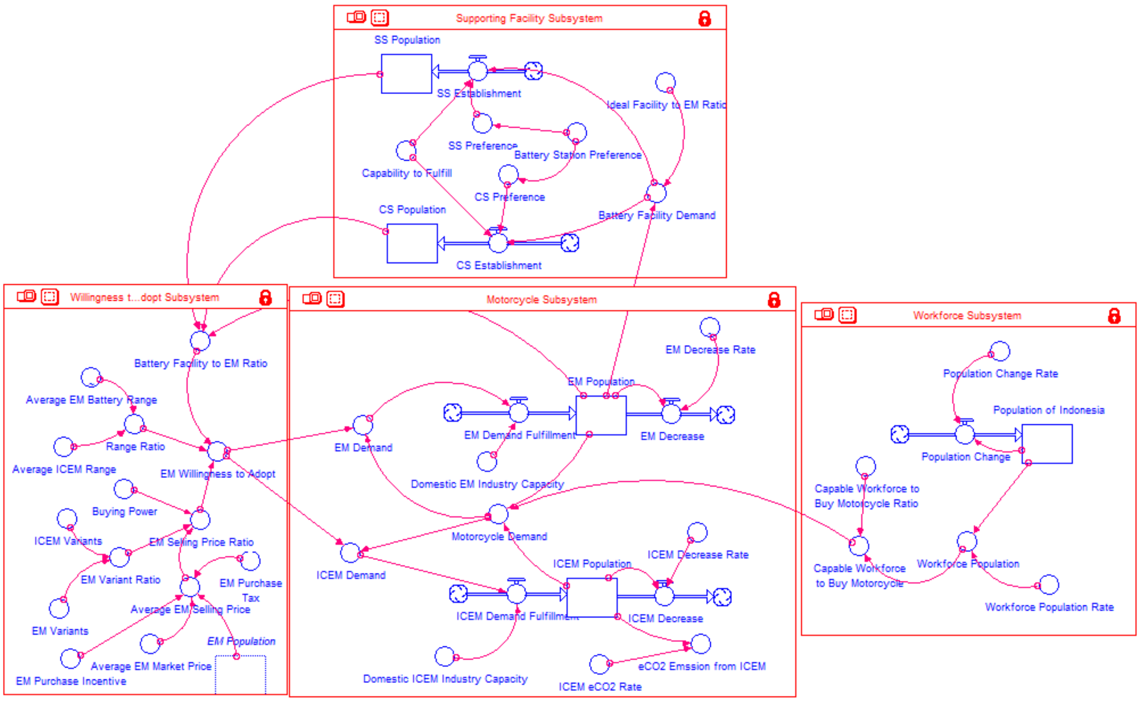


Figure 4.2 Electric Motorcycle Adoption System Stock Flow Diagram

The Stock Flow Diagram Development is divided into each subsystem containing Motorcycle Subsystem, Workforce Subsystem, Willingness to Adopt Subsystem, and Supporting Facility Subsystem.

4.2.2.1 Motorcycle Subsystem

The Motorcycle Subsystem describes the material flow of motorcycle units starting from demand, fulfillment, population, reductions, industry capability, and emissions. **Table 4.13** below serves the conversion of the identified into stock flow components type and its simulation input value of Motorcycle Subsystem.

Table 4.13 Motorcycle Subsystem Stock Flow Diagram Variable Identification

Motorcycle Subsystem			
No	**Variable**	**Type**	**Simulation Input Value**
1	EM Demand	Converter	EM_Willingness_to_Adopt*Motorcycle_Demand
2	EM Demand Fulfillment	Rate	IF(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)
3	EM Population	Stock	17198
4	Domestic EM Production Capacity	Converter	1427000
5	EM Decrease	Rate	EM_Decrease_Rate*EM_Population
6	Motorcycle Demand	Converter	Capable_Workforce_to_Buy_Motorcycle-(EM_Population+ICEM_Population)
7	ICEM Demand	Converter	EM_Willingness_to_Adopt*Motorcycle_Demand
8	ICEM Demand Fulfillment	Rate	IF(ICEM_Demand>Domestic_ICEM_Industry_Capacity) THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)
9	ICEM Population	Stock	125305332
10	Domestic ICEM Industry Capacity	Converter	6867217
11	ICEM Decrease	Rate	ICEM_Decrease_Rate*ICEM_Population
12	ICEM eCO2 Rate	Converter	0.432
13	eCO2 Emission from ICEM	Converter	ICEM_Population*ICEM_eCO2_Rate
14	EM Decrease Rate	Converter	0.2212
15	ICEM Decrease Rate	Converter	0.0645

The motorcycle subsystem stock flow simulation input value is shown in **Table 4.13**. It is modeled into stock flow diagram that is shown in **Figure 4.3** below.

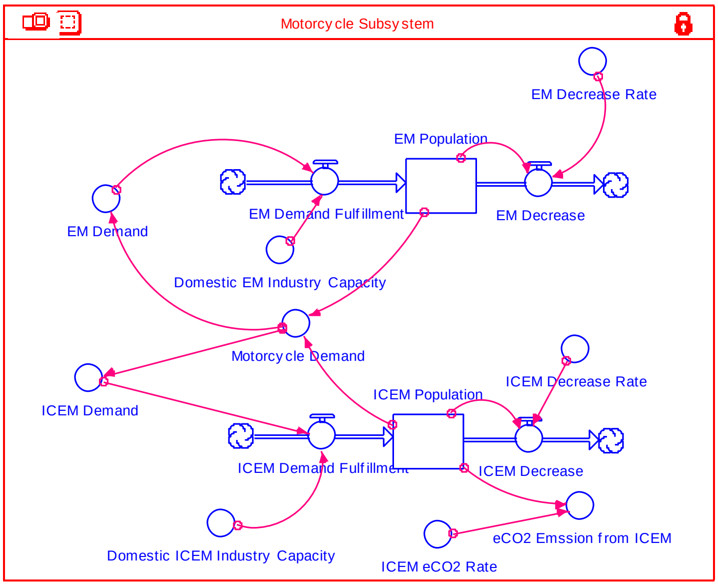


Figure 4.3 Motorcycle Subsystem Stock Flow Diagram

The motorcycle subsystem stock flow diagram is modeled based on the causal loop diagram relationship that has been modeled in the causal loop diagram development subchapter.

4.2.2.2 Workforce Subsystem

The Workforce Subsystem describes the material flow of workforce population increase and decrease following with the capability rate of workforce to buy motorcycles. **Table 4.14** below serves the conversion of the identified into stock flow components type and its simulation input value of Workforce Subsystem

Table 4.14 Workforce Subsystem Stock Flow Diagram Variable Identification

Workforce Subsystem			
No	**Variable**	**Type**	**Simulation Input Value**
1	Workforce Population	Converter	Workforce_Population_Rate*Population_of_Indonesia
2	Workforce Population Ratio	Converter	0.7594*0.6863
3	Population of Indonesia	Stock	275773800
4	Population Change	Rate	Population_of_Indonesia*Population_Change_Rate
5	Population Change Rate	Converter	0.0117
6	Capable Workforce to Buy Motorcycle Ratio	Converter	0.9414
7	Capable Workforce to Buy Motorcycle	Converter	Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

The workforce subsystem stock flow simulation input value is shown in **Table 4.14**. It is modeled into stock flow diagram that is shown in **Figure 4.4** below.

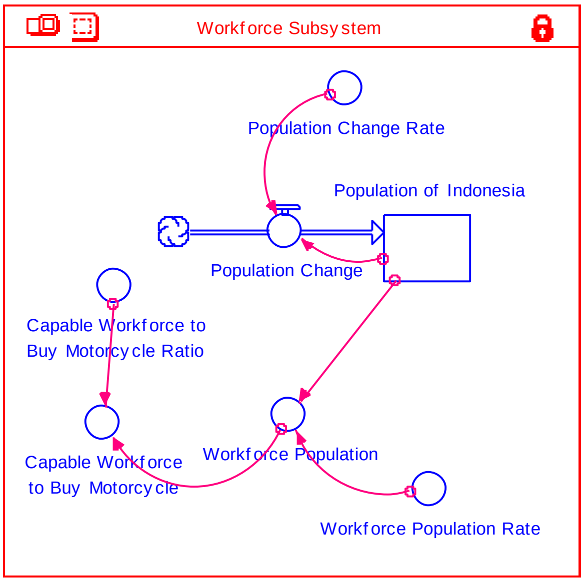


Figure 4.4 Workforce Subsystem Stock Flow Diagram

The workforce subsystem stock flow diagram is modeled based on the causal loop diagram relationship that has been modeled in the causal loop diagram development subchapter.

4.2.2.3 Willingness to Adopt Subsystem

The Willingness to Adopt Subsystem describes the flow of cause and effect to describe the willingness to adopt comparison between electric motorcycle and conventional motorcycle. **Table 4.15** below serves the conversion of the identified into stock flow components type and its simulation input value of Willingness to Adopt Subsystem

Table 4.15 Willingness to Adopt Subsystem Stock Flow Diagram Variable Identification

Willingness to Adopt Subsystem			
No	**Variable**	**Type**	**Simulation Input Value**
1	EM Willingness to Adopt	Converter	(Battery_Facility_to_EM_Ratio) *EM_Selling_Price_Ratio*Range_Ratio
2	Average EM Battery Range	Converter	175
3	Average ICEM Range	Converter	285
4	Range Ratio	Converter	Average_EM_Battery_Range/Average_ICEM_Range
5	EM Selling Price Ratio	Converter	EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)
6	Buying Power	Converter	15053568
7	ICEM Variants	Converter	300
8	EM Variants	Converter	61
9	Variant Ratio	Converter	EM_Variants/ICEM_Variants

Willingness to Adopt Subsystem			
No	**Variable**	**Type**	**Simulation Input Value**
10	EM Purchase Incentive	Converter	7000000
11	Average EM Selling Price	Converter	MAX ((IF(EM_Population<250000) THEN((Average_EM_Market_Price-EM_Purchase_Incentive) *(1+EM_Purchase__Tax)) ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)
12	Average EM Market Price	Converter	34720000
13	Battery Facility to EM Ratio	Converter	(CS_Population+SS_Population)/EM_Population
14	EM Purchase Tax	Converter	0.1

The willingness to adopt subsystem stock flow simulation input value that is shown in **Table 4.15**. It is modeled into stock flow diagram that is shown in **Figure 4.5** below.

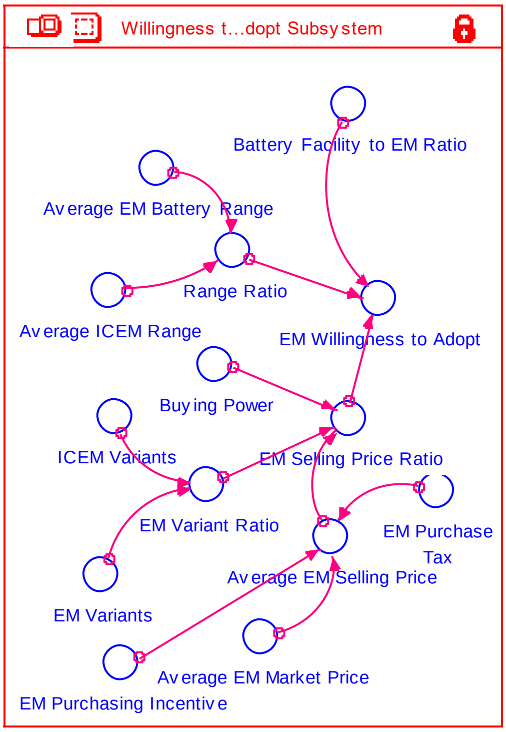


Figure 4.5 Willingness to Adopt Subsystem Stock Flow Diagram

The willingness to adopt subsystem stock flow diagram is modeled based on the causal loop diagram relationship that has been modeled in the causal loop diagram development subchapter.

4.2.2.4 Supporting Facility Subsystem

The Supporting Facility describes the flow of cause and effect to describe the electric motorcycle supporting facility availability. **Table 4.16** below serves the conversion of the identified into stock flow components type and its simulation input value of Supporting Facility Subsystem

Table 4.16 Supporting Facility Subsystem Stock Flow Diagram Variable Identification

Supporting Facility Subsystem			
No	**Variable**	**Type**	**Simulation Input Value**
1	Battery Facility Demand	Converter	EM_Population*(Ideal_Facility_to_EM_Ratio)
2	Ideal Facility to EM Ratio	Converter	0.1
3	Battery CS Establishment	Rate	Battery_Facility_Demand*CS_Preference
4	Battery CS Population	Stock	439
5	CS Preference	Converter	4.11/Battery_Station_Preference
6	Battery Station Preference	Converter	4.11+6.6
7	SS Preference	Converter	6.6/Battery_Station_Preference
8	Battery SS Establishment	Rate	SS_Preference*Battery_Facility_Demand
9	Battery SS Population	Stock	961
10	Capability to Fulfill	Converter	0.605763

The motorcycle subsystem stock flow simulation input value is shown in **Table 4.16**. It is modeled into stock flow diagram that is shown in **Figure 4.6** below.

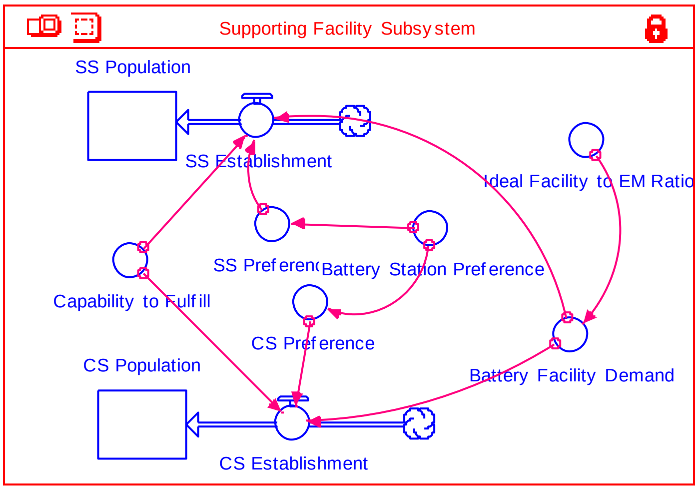


Figure 4.6 Supporting Facility Subsystem Stock Flow Diagram

The supporting facility subsystem stock flow diagram is modeled based on the causal loop diagram relationship that has been modeled in the causal loop diagram development subchapter.

4.3 Model Verification and Validation

After the system dynamics model is developed, verification and validation are necessary to check the accuracy of the model.

4.3.1 Model Verification

Model verification for System Dynamics Model Development is provided by STELLA software by using check units in the Run options in the taskbar. The result of the model verification is shown in **Figure 4.7** below.

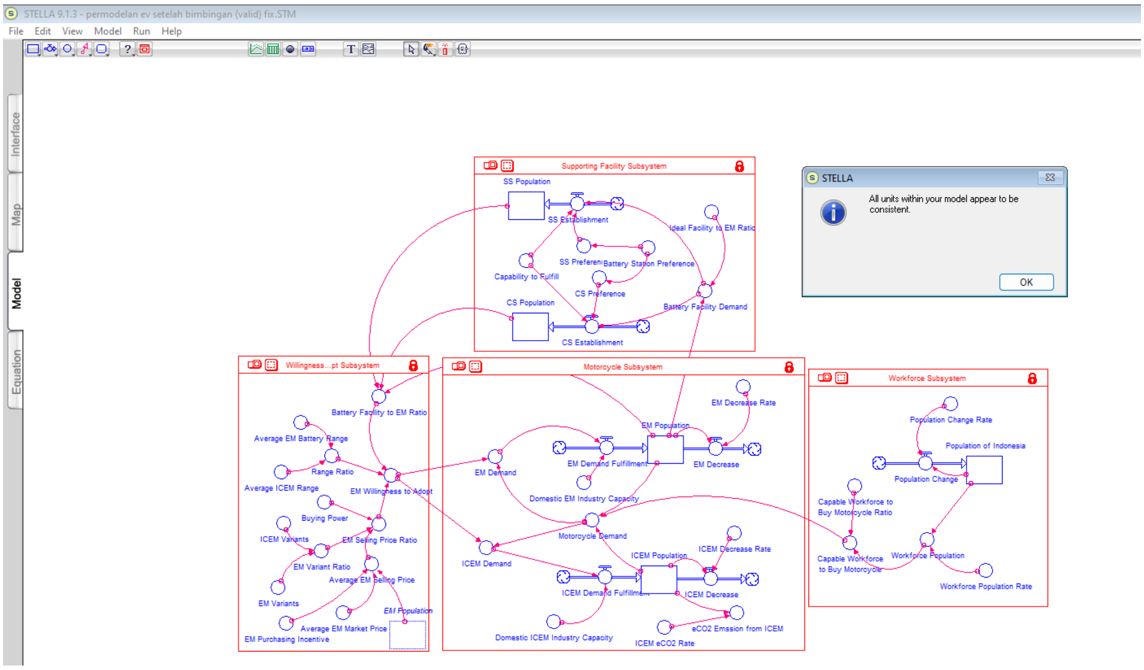


Figure 4.7 Model Verification

Figure 4.7 shows that there is no error on the model and can indicate that the developed electric motorcycle adoption model is verified. Other than software checking on verification step, the author also checked the measurement units of the simulation input manually. The units are standardized for time to be adjusted yearly/annually, and for individual units such as people and populations of motorcycles are standardized in unit.

4.3.2 Model Validation

Model validation of the electric motorcycle adoption model in this research is conducted to test the acceptance and agreement of the model. The validation step in this research utilizes two methods, which are Black Box Validation Method and Extreme Value Validation Method.

4.3.2.1 Black Box Validation

The validation process tests the variables that have been determined as response variables of the simulation. The formula for the model validation is **Formula 2** below.

$$E = \left| \frac{(S - A)}{A} \right| \quad (2)$$

The notations of the formula are:
E = Variance of Error, valid if *E* < 0,1
S = Simulated Result
A = Actual Data

The variables of the validation are Electric Motorcycle Population in 2023, Charging Station Population in 2023, and Swapping Station Population in 2023.

The validation for the Electric Motorcycle Population in 2023 is tested below. According to (M R, 2024), The real system data of Electric Motorcycle Population in 2023 is 62.409 units. The simulation showed the Electric Motorcycle Population in 2023 result is 63.479,71. The calculation of the error testing is as below.

$$E = \left|\frac{(63.479{,}71 - 62.409)}{62.409}\right|$$
$$E = 0{,}017156$$

The variance of error testing showed 0,017156 as the result, having a lower than 0,1 indicating that the variable of the model is valid.

The validation for the Charging Station Population in 2023 is tested below. According to (PLN, 2024), the real system data of Charging Station Population at the end of 2023 is 1.081 units. The simulation showed the Charging Station Population in 2023 result is 1.081,00 . The calculation of the error testing is as below.

$$E = \left|\frac{(1.081{,}00 - 1.081)}{1.081}\right|$$
$$E = 0{,}000$$

The variance of error testing showed 0,000 as the result, having a lower than 0,1 indicating that the variable of the model is valid.

The validation for the Swapping Station Population in 2023 is tested below. According to (Kumparan Bisnis, 2024), the real system data of Swapping Station Population in 2023 is 1.401 units. The simulation showed the Swapping Station Population in 2023 result is 1.360,79. The calculation of the error testing is as below.

$$E = \left|\frac{(1.360{,}79 - 1.401)}{1.401}\right|$$
$$E = 0{,}028701$$

The variance of error testing showed 0,028701 as the result, having a lower than 0,1 indicating that the variable of the model is valid. Therefore, the validation test result is recapitulated in **Table 4.17** below.

Table 4.17 Validation Test Result Recapitulation

Variable	Actual Data	Simulation Result	Variance of Error	Validity Result
EM Population 2023	62.409,00	63.479,71	0,01715634	Valid
CS Population 2023	1.081,00	1.081,00	0,00	Valid
SS Population 2023	1.401,00	1.360,79	0,028700928	Valid

All of the variables that are tested using the Black Box Method are having variance of error value below 0,1 indicating that all of the variables and the model is valid.

4.3.2.2 Extreme Value Validation

Extreme Value validation method tests the variable in each subsystem with a changed value to extremely different value. The test is supported with a graph of line chart in Stella Software to check the pattern significance differences of the response variable. The response variables that are observed are EM Population, eCO2 Emission from ICEM, CS Population, and SS Population. The variables that are tested for Extreme Value changing are Domestic EM Industry Capacity and Domestic ICEM Industry Capacity from Motorcycle Subsystem, Capable Workforce to Buy Motorcycle Ratio and Workforce Population Rate from Workforce Subsystem, EM Purchase Incentives and Buying Power from Willingness to Adopt Subsystem, and Ideal Facility to EM Ratio and Capability to Fulfill from Supporting Facility Subsystem. The variable is considered eliminated if all the response graphs have the same behavior as normal system state. The classification of necessities for the variables that are Extreme Value Validated are Maximum and Minimum Value Influence, Maximum Value Influence, Minimum Value Influence, and No Influence. The classification of No Influence is indicated by the non-influential variable to the graphics of response variable which is not necessarily included in the system. Maximum or Minimum Value Influence classification is a variable that is needed in the system and gives a significant influence as indicated by the graph given in STELLA.

The Extreme Value Validation is conducted for variables in each subsystem that is served in subchapters below. For further details on figures regarding data pattern of extreme value validation, it can be seen in **Appendix 8** until **Appendix 23**.

4.3.2.2.1 Motorcycle Subsystem

The extreme value validation for Motorcycle Subsystem utilizes variable Domestic EM Industry Capacity and Domestic ICEM Industry Capacity. The recapitulation of the validation test is served in **Table 4.18** below.

Table 4.18 Motorcycle Subsystem Variable Extreme Value Validation Recapitulation

Variable	Initial Input Value	Max Extreme Value Test	Min Extreme Value Test	Extreme Influence	Approximate Extreme Value
Domestic EM Industry	1427000	9999999999	0	Minimum Value	<500000
Domestic ICEM Industry	6867217	9999999999	0	No Influence	-

The domestic EM industry has the minimum value influence which the extreme value relies approximately at 500.000. The domestic ICEM industry does not have influence on the system but is considered to be the potential improvement. Thereby, the domestic ICEM industry variable is not eliminated from the system.

4.3.2.2.2 Workforce Subsystem

The extreme value validation for Workforce Subsystem utilizes variable Domestic EM Industry Capacity and Domestic ICEM Industry Capacity. The recapitulation of the validation test is served in **Table 4.19** below.

Table 4.19 Workforce Subsystem Variable Extreme Value Validation Recapitulation

Variable	Initial Input Value	Max Extreme Value Test	Min Extreme Value Test	Extreme Influence	Approximate Extreme Value
Capable Workforce to Buy Motorcycle Ratio	0.9414	1	0	Minimum Value	<=0
Workforce Population Rate	0.7594* 0.6863	1	0	Maximum and Minimum Value	>0.9 or <=0

The capable workforce to buy motorcycle ratio has a minimum value influence. The workforce population rate has maximum and minimum value influence.

4.3.2.2.3 Willingness to Adopt Subsystem

The extreme value validation for Willingness to Adopt Subsystem utilizes variable EM Purchas Incentives and Buying Power. The recapitulation of the validation test is served in **Table 4.20** below.

Table 4.20 Willingness to Adopt Subsystem Variable Extreme Value Validation Recapitulation

Variable	Initial Input Value	Max Extreme Value Test	Min Extreme Value Test	Extreme Influence	Approximate Extreme Value
EM Purchase Incentives	7000000	9999999999	0	Maximum Value	>34720000
Buying Power	15053568	9999999999	0	Maximum and Minimum Value	<50000 or > 34720000

The EM purchase incentive has a maximum value influence. The buying power has maximum and minimum value influence.

4.3.2.2.4 Supporting Facility Subsystem

The extreme value validation for Supporting Facility Subsystem utilizes variable Domestic EM Industry Capacity and Domestic ICEM Industry Capacity. The recapitulation of the validation test is served in **Table 4.21** below.

Table 4.21 Supporting Facility Subsystem Variable Extreme Value Validation Recapitulation

Variable	Initial Input Value	Max Extreme Value Test	Min Extreme Value Test	Extreme Influence	Approximate Extreme Value
Ideal Facility to EM Ratio	0.1	1	0	Maximum and Minimum Value	>0.3 or <=0
Capability to Fulfill	0.605763	1	0	Minimum Value	>0.9

The ideal facility to EM ratio has a maximum value influence. The capability to fulfill has a minimum value influence on the system.

4.4 Existing System Model Simulation

With the developed stock flow diagram on **Chapter 4.3**, the simulation result of the existing condition model of Electric Motorcycle Adoption system is served in **Table 4.22** below. It serves the EM Population, CS and SS Population, and eCO2 Emission from ICEM.

Table 4.22 Existing Condition Simulation Result

Year	CS Population	SS Population	EM Population	eCO2 Emission from ICEM
2022	439	961	17.198,00	54.131.903,42
2023	1.081,00	1.360,79	63.479,71	50.662.032,76
2024	3.450,69	2.836,46	95.792,46	47.414.356,78
2025	7.026,62	5.063,29	190.458,83	44.406.180,41
2026	14.136,43	9.490,77	293.595,53	41.604.736,77
2027	25.096,34	16.315,80	407.452,29	38.998.472,89
2028	40.306,50	25.787,58	581.041,53	36.596.997,43
2029	61.996,74	39.294,69	787.205,12	34.381.077,16
2030	**91.383,06**	**57.594,35**	**1.033.591,88**	**32.345.160,83**
2031	129.966,97	81.621,60	1.319.876,44	30.481.341,27
2032	179.237,87	112.303,93	1.646.099,68	28.782.348,48
2033	240.686,66	150.569,77	2.011.706,67	27.241.127,87
2034	315.783,54	197.334,64	2.415.714,31	25.850.841,90
2035	405.961,99	253.491,23	2.856.798,75	24.604.852,87

The simulation also resulted in graphics for analytics, especially for the response variable. The graph is served for response variables such as EM Population, CS Population, SS Population, and eCO2 Emission from ICEM. The graph is served in **Figure 4.8, Figure 4.9, Figure 4.10,** and **Figure 4.11** consecutively. **Figure 4.8** shows the graph of EM Population from 2022 to 2035.

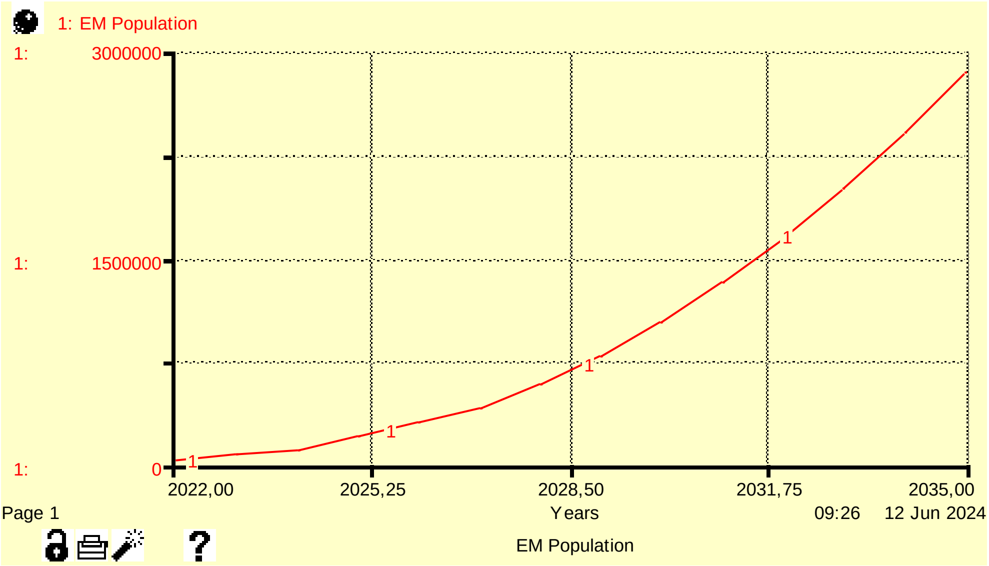


Figure 4.8 EM Population Existing Condition Simulation Result Graph

The EM Population Existing Condition Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.9** shows the graph of Facility Population from 2022 to 2035.

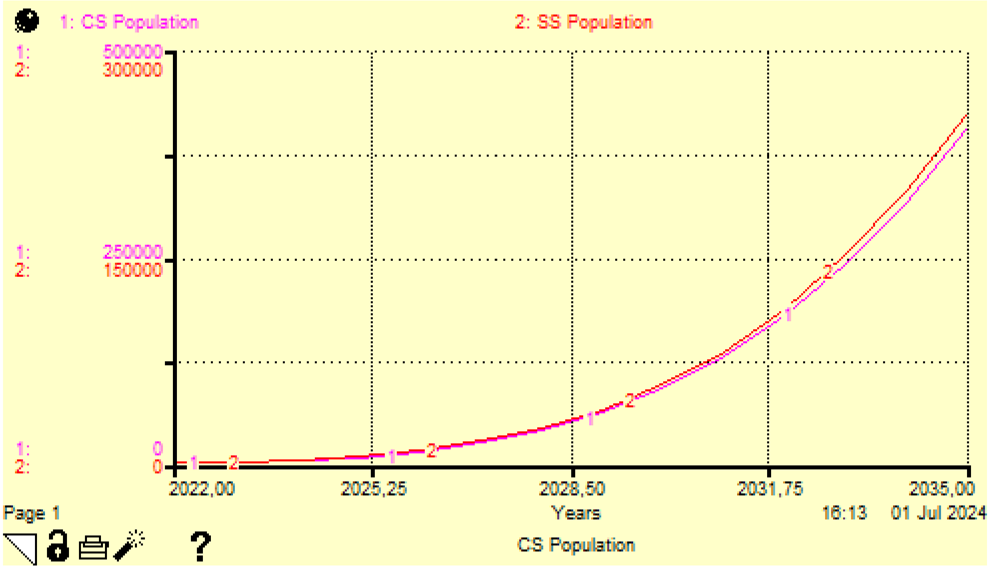


Figure 4.9 Facility Population Existing Condition Simulation Result Graph

The Facility Population Existing Condition Simulation Result Graph consisting of charging station and swapping station resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.10** shows the graph of WTA from 2022 to 2035.

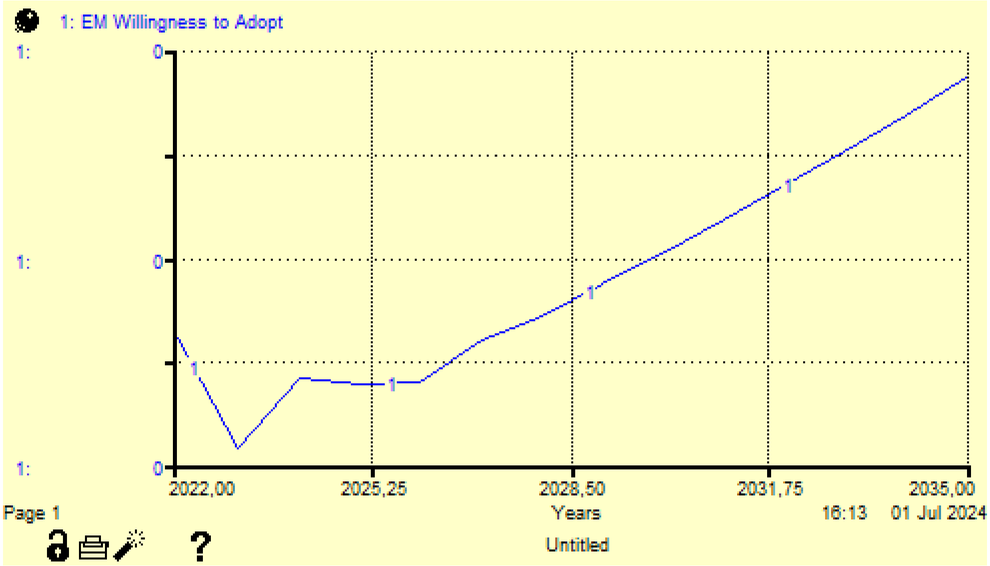


Figure 4.10 WTA Existing Condition Simulation Result Graph

The Willingness to Adopt Existing Condition Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the ratio in 2022 until 2035. However, it indicates a volatile condition starting from 2022 until approximately 2027 which occurs inconsistent increase and decrease during that period. **Figure 4.11** shows the eCO2 Emission from ICEM from 2022 to 2035.

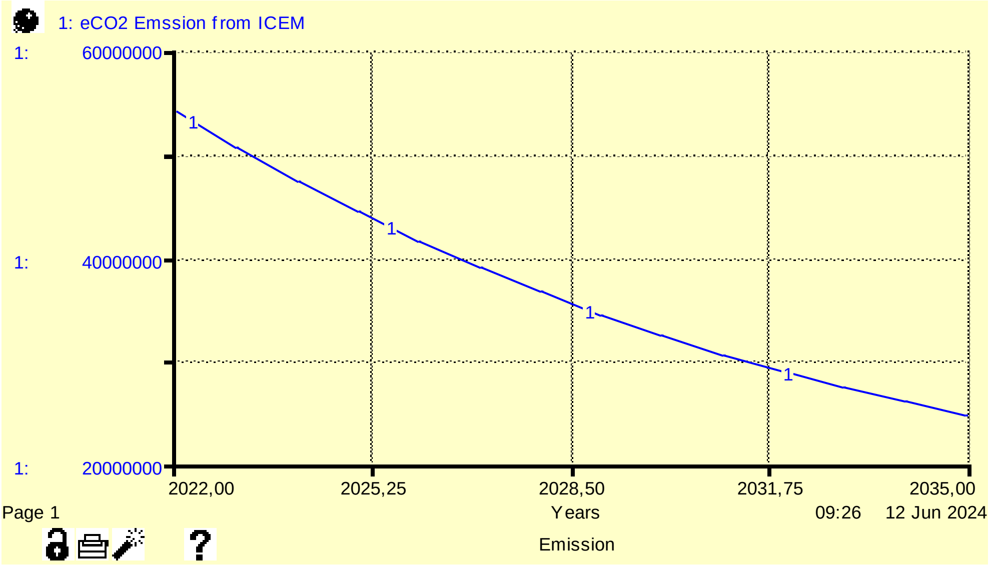


Figure 4.11 eCO2 Emission from ICEM Existing Condition Simulation Result Graph

The eCO2 Emission from ICEM Existing Condition Simulation Result Graph resulted in de-acceleration character of graph starting from the initial value of the emission in 2022 until 2035. From the 4 graph above, the majority of the response variable resulted in increase for EM Population, CS Population, and SS Population and decrease for eCO2 Emission from ICEM in an exponential behavior.

The performance prediction for the electric motorcycle adoption system with the indicator as per stated in **Chapter 4.1** is served in **Table 4.23** below.

Table 4.23 Existing System Performance Measurement

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Realization (2030)	1.033.591,88	91.383,06	57.594,35	40,25%
Target	13.469.000,00	32.000,00	67.000,00	32% reduction of 2022 data
Properties	Higher Better	Higher Better	Higher Better	Higher Better
Achievement (2030)	7,67%	285,57%	85,96%	125,77%

The targets that have been predicted to be achieved are Charging Station Population and Emission reduction. The unachieved targets are Electric Motorcycle Population and Swapping Station Population. Thereby, the improvement model development will focus to mainly increase the achievement of Electric Motorcycle Population and Swapping Station Population.

4.5 Improvement Model Development

Improvement Model Development chapter serves the improvements conducted by the author with a purpose to accelerate the electric motorcycle adoption system followed with the emission reduction by 2030. While the majority of the target is predicted to be achieved by 2030, except EM Population and SS Population target, the improvement is focused on the electric motorcycle population with the correlation that will reduce emission even further. The scenarios consisting of 4 individual scenarios consisting of purchase incentive increase, motorcycle industry shifting, facility development, and battery development, and followed with 2 mixed scenarios, one with proposed input value, the other with enhanced input value from evaluation.

4.5.1 Scenario 1: Purchase Incentive Increase

Incentive improvement is one of the recommendations of 5 previous research and one of the effort statements in the Presidential Regulation Number 55 Year 2019. One of the research states that incentives should the promotion media to initiate conversion of society utilization from conventional to electrified motorcycle. With further adaptation, this research implements the suggestion from previous research by focusing on developing an effective incentive as promotion for adoption. The simulation data input for Scenario 1 is given in **Table 4.24** below.

Table 4.24 Scenario 1: Purchase Incentive Increase - Data Input

Scenario 1: Purchase Incentive Increase		
Variable	**Existing System Input Value**	**Improvement Input Value**
EM Purchase Incentive	7000000	10254601,1
Average EM Selling Price	MAX ((IF(EM_Population<250000) THEN((Average_EM_Market_Price-EM_Purchase_Incentive) *(1+EM_Purchase__Tax)) ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)	MAX ((IF(EM_Population<500000) THEN((Average_EM_Market_Price-hase_Incentive) *(1+EM_Purchase__Tax)) ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)
EM Purchase Tax	0.1	0

The Purchase Incentive Increase improvement scenario focuses on the response variable of willingness to adopt that is specifically affected by Average EM Selling Price Ratio. The variables affecting the Average EM Selling Price Ratio are EM Purchase Incentive, EM Purchase Tax, Average EM Market Price, and EM Population. (Syabani, 2023) stated that Chinese Government, a shifted electric vehicle country, has developed EM Purchase Incentive with a basis of 14,437% of the country's GDP per capita. The author used China as a reference for incentive benchmark due to the similarities in terms of economic growth which both countries have GDP Growth Rate above 5%. With calculations for implementation in Indonesia, the incentive will be valued in Rp10.254.601,00 as of calculation from Indonesian original GDP per capita, which is Rp71.030.000,00. For further support, EM Purchase Tax can be reduced to 0% of the market price. In the existing system, incentives were given only for 250.000 first purchases. The number of incentives quota can be increased to 500.000, two times the existing amount.

The simulation result value is served in **Table 4.25** below. It serves the EM Population, CS and SS Population, and eCO2 Emission from ICEM.

Table 4.25 Scenario 1: Purchase Incentive Increase - Simulation Result

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2022	17.198,00	439	961,00	54.131.903,42
2023	75.817,45	1.081,00	1.360,79	50.667.362,67
2024	107.357,23	3.911,26	3.123,27	47.420.187,96
2025	227.639,34	7.918,90	5.618,94	44.423.806,59
2026	346.549,67	16.416,66	10.910,72	41.631.593,18
2027	542.695,64	29.353,34	18.966,75	39.064.206,21
2028	675.394,08	49.612,13	31.582,45	36.653.749,76
2029	913.617,65	74.824,54	47.282,91	34.457.035,06
2030	**1.189.811,33**	**108.929,83**	**68.521,20**	**32.441.175,81**
2031	1.509.650,11	153.345,41	96.179,99	30.600.586,79
2032	1.872.659,21	209.700,54	131.273,87	28.927.928,63
2033	2.278.092,41	279.606,79	174.806,39	27.416.172,69

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2034	2.724.741,73	364.647,82	227.763,77	26.058.472,92
2035	3.211.032,03	466.362,25	291.104,11	24.848.150,79

Table 4.25 shows the result of the Scenario 1 Purchase Incentive Increase Simulation Result that consists of the 1.189.811,33 EM Population result, 108.929,83 CS Population result, 68.521,20 SS Population, and 32.441.175,81 eCO2 Emission from ICEM result. The simulation graph pattern is served in **Figure 4.12**, **4.13**, **4.14**, and **4.15** below. **Figure 4.12** shows the graph of EM Population from 2022 to 2035.

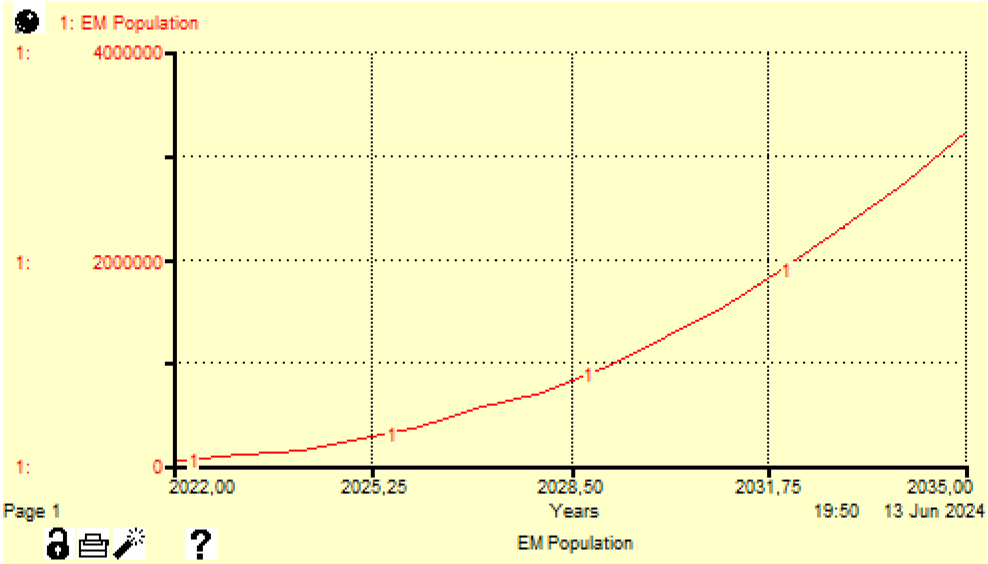


Figure 4.12 Scenario 1: Purchase Incentive Increase - EM Population Graph

The EM Population Scenario 1 Purchase Incentive Increase Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.13** shows the graph of Facility Population from 2022 to 2035.

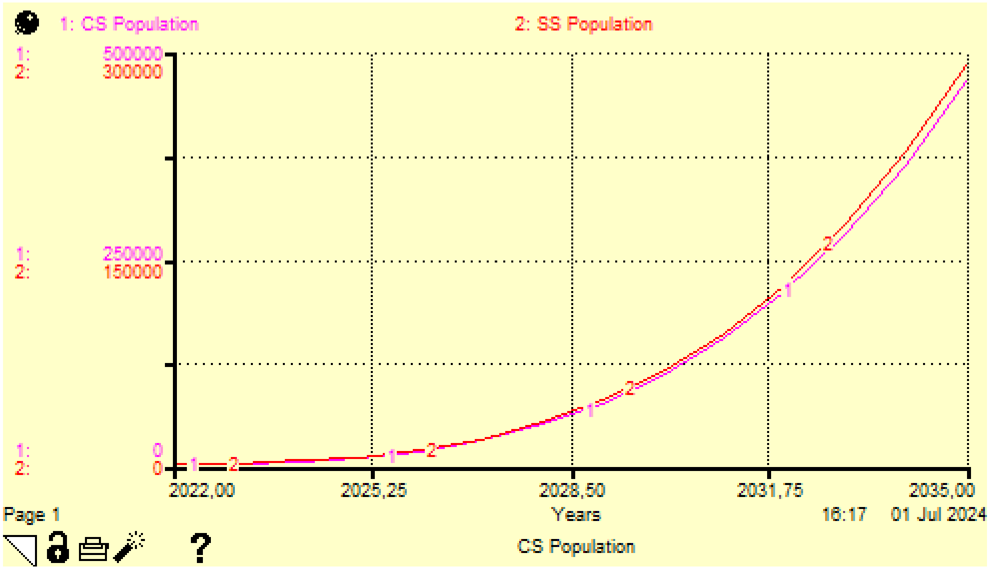


Figure 4.13 Scenario 1: Purchase Incentive Increase - Facility Population Graph

The Facility Population Scenario 1 Purchase Incentive Increase Simulation Result Graph consisting of charging station and swapping station resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.14** shows the graph of WTA from 2022 to 2035.

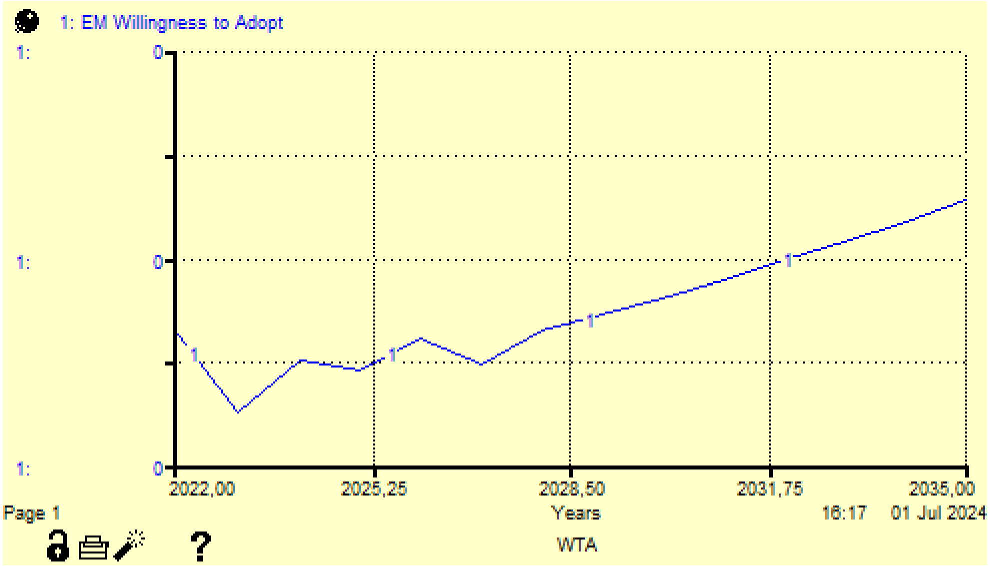


Figure 4.14 Scenario 1: Purchase Incentive Increase - WTA Graph

The Willingness to Adopt Scenario 1 Purchase Incentive Increase Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the ratio in 2022 until 2035. However, it indicates a volatile condition starting from 2022 until approximately 2028 which occurs inconsistent increase and decrease during that period. **Figure 4.15** shows the graph of eCO2 Emission from ICEM from 2022 to 2035.

Figure 4.15 Scenario 1: Purchase Incentive Increase - Emission Graph

The eCO2 Emission from ICEM Scenario 1 Purchase Incentive Increase Simulation Result Graph resulted in de-acceleration character of graph starting from the initial value of the emission in 2022 until 2035.

From the data result above, the existing simulation pattern and improvement scenario pattern are similar but having different values due to moderate level of incentive variable. The improvement scenario resulted in performance measurement that is recapitulated in **Table 4.26** below.

Table 4.26 Scenario 1: Purchase Incentive Increase - Performance Measurement

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Improvement Prediction (2030)	1.189.811,33	108.929,83	68.521,20	40,07%
Target	13.469.000,00	32.000,00	67.000,00	32% reduction of 2022 data
Properties	Higher Better	Higher Better	Higher Better	Higher Better
Improvement Achievement (2030)	8,83%	340,41%	102,27%	125,22%

Scenario 1 Purchase Incentive Increase resulted in an unachieved target of EM Population with only 8,83% of the 2030 target. The CS Population, SS Population, Emission Reduction have reached the expected target by 2030.

4.5.2 Scenario 2: Motorcycle Industry Shift

Motorcycle Industry Shifting scenario is the scenario that pushes industry shifting from ICEM motorcycle to electric motorcycle. This scenario is performed due to the fulfillment of the motorcycle is determined by the industry that provides the supply. Willingness to adopt section is also affected by the product variant in the marketplace. This scenario is also one of the policies in the Presidential Regulation Number 55 Year 2019 stating that acceleration of domestic Electric Vehicle industry is one of the electric vehicle adoption acceleration efforts. The simulation data input for Scenario 2 is served in **Table 4.27** and **4.28** below.

Table 4.27 Scenario 2: Motorcycle Industry Shift - Data Input

Scenario 2: Motorcycle Industry Shift Focus		
Variable	**Existing System Input Value**	**Improvement Input Value**
Domestic EM Production Capacity	1427000	Served in Table 4.28
Domestic ICEM Production Capacity	6867217	
EM Variants	61	
ICEM Variants	300	

The data input is put in graphical value where it grows and differs between years with a cue of GDP growth of manufacturing industry that are served in **Table 4.28**.

Table 4.28 Scenario 2: Motorcycle Industry Shift - Data Input Growth

	Development Rate of Additive Manufacturing Industry (GDP)			
	5% per year			
Year	**Domestic ICEM Production Capacity**	**Domestic EM Production Capacity**	**ICEM Variants**	**EM Variants**
2022	6.867.217	1.427.000	300	61
2023	6.452.506	1.841.711	285	64
2024	6.037.795	2.256.422	270	67
2025	5.623.084	2.671.133	255	71
2026	5.208.374	3.085.843	240	74
2027	4.793.663	3.500.554	225	78
2028	4.378.952	3.915.265	210	82
2029	3.964.241	4.329.976	195	86
2030	3.549.530	4.744.687	180	90
2031	3.134.819	5.159.398	165	95
2032	2.720.109	5.574.109	150	99
2033	2.305.398	5.988.819	135	104
2034	1.890.687	6.403.530	120	110
2035	1.475.976	6.818.241	105	115

In this scenario, the form of shifting is performed in change of the domestic production capacity and variants that is available in the marketplace. The shifting affects inversely proportional between the ICEM and EM industries. The cue for the shifting is indicated by the Gross Domestic Product growth in manufacturing which is 5% in 2022. The GDP Growth works as a gap of improvement to the industry that is regulated to shift the industry from conventional to electric motorcycle productions.

The simulation result value is served in **Table 4.29** below. It serves the EM Population, CS and SS Population, and eCO2 Emission from ICEM.

Table 4.29 Scenario 2: Motorcycle Industry Shift - Simulation Result

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2022	17.198,00	439	961,00	54.131.903,42
2023	63.479,71	1.081,00	1.360,79	50.662.032,76
2024	101.176,50	3.450,69	2.836,46	47.416.682,69
2025	215.653,54	7.227,61	5.188,45	44.417.429,00
2026	352.080,86	15.277,94	10.201,61	41.632.048,94
2027	530.159,43	28.421,09	18.386,21	39.057.356,01
2028	823.961,88	48.211,91	30.710,49	36.715.740,39
2029	1.228.524,33	78.970,35	49.864,61	34.601.082,59
2030	**1.777.934,07**	**124.831,08**	**78.423,34**	**32.724.053,59**
2031	2.517.545,19	191.201,24	119.753,85	31.102.760,67
2032	3.518.961,58	285.181,03	178.277,63	29.769.817,08
2033	4.832.894,31	416.543,63	260.080,70	28.753.549,16
2034	6.638.218,11	596.955,25	372.427,94	27.938.232,69
2035	9.116.713,93	844.759,49	526.742,39	27.000.290,12

Table 4.29 shows the result of the Scenario 2 Motorcycle Industry Shift Simulation Result that consists of the 1.777.934,07 EM Population result, 124.831,08 CS Population result, 78.423,34 SS Population, and 32.724.053,59 eCO2 Emission from ICEM result. The simulation graph pattern is served in **Figure 4.16**, **4.17**, **4.18**, and **4.19** below. **Figure 4.16** shows the graph of EM Population from 2022 to 2035.

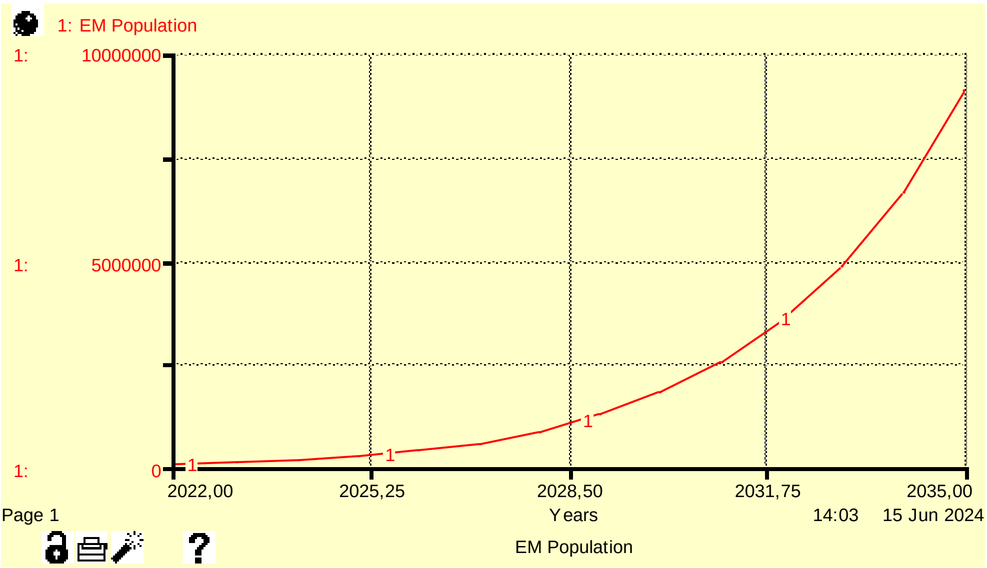


Figure 4.16 Scenario 2: Motorcycle Industry Shift - EM Population Graph

The EM Population Scenario 2 Motorcycle Industry Shift Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.17** shows the graph of Facility Population from 2022 to 2035.

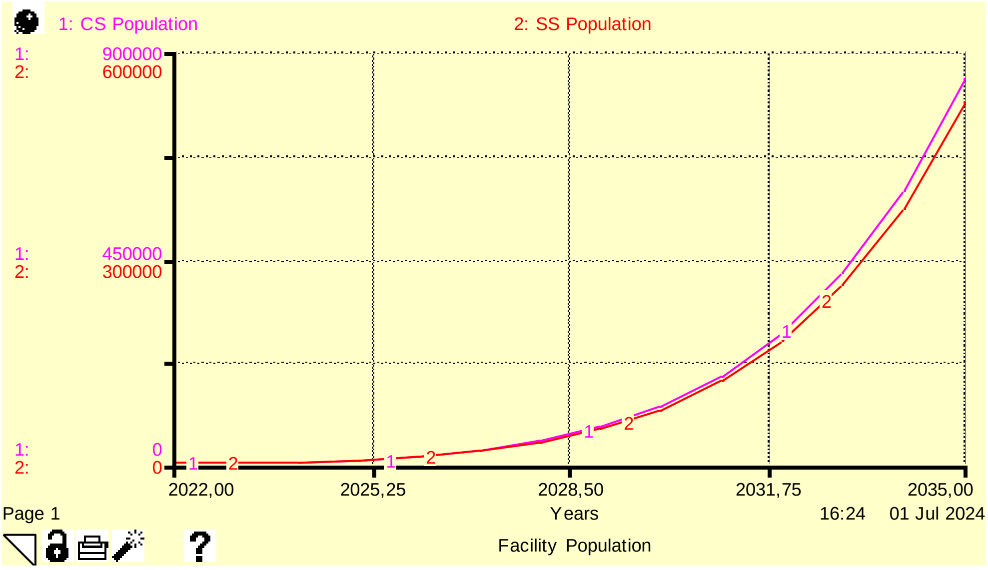


Figure 4.17 Scenario 2: Motorcycle Industry Shift - Facility Population Graph

The Facility Population Scenario 2 Motorcycle Industry Shift Simulation Result Graph consisting of charging station and swapping station resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.18** shows the graph of WTA from 2022 to 2035.

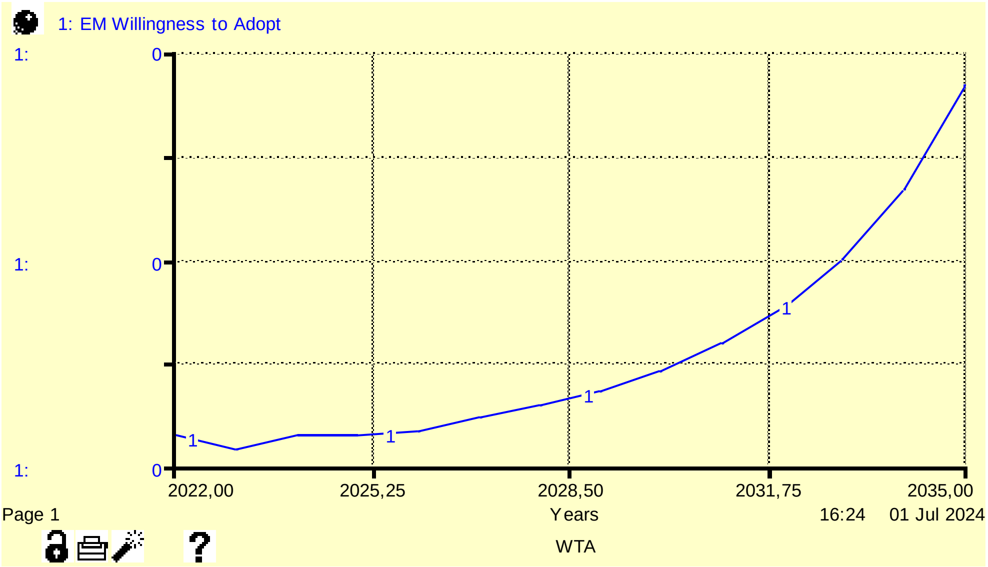


Figure 4.18 Scenario 2: Motorcycle Industry Shift - WTA Graph

The Willingness to Adopt Scenario 1: Purchase Incentive Increase Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the ratio in 2022 until 2035. However, it indicates a stable change condition starting from 2022 until approximately 2026 which occurs inconsistent increase and decrease during that period. **Figure 4.19** shows the graph of eCO2 Emission from ICEM from 2022 to 2035.

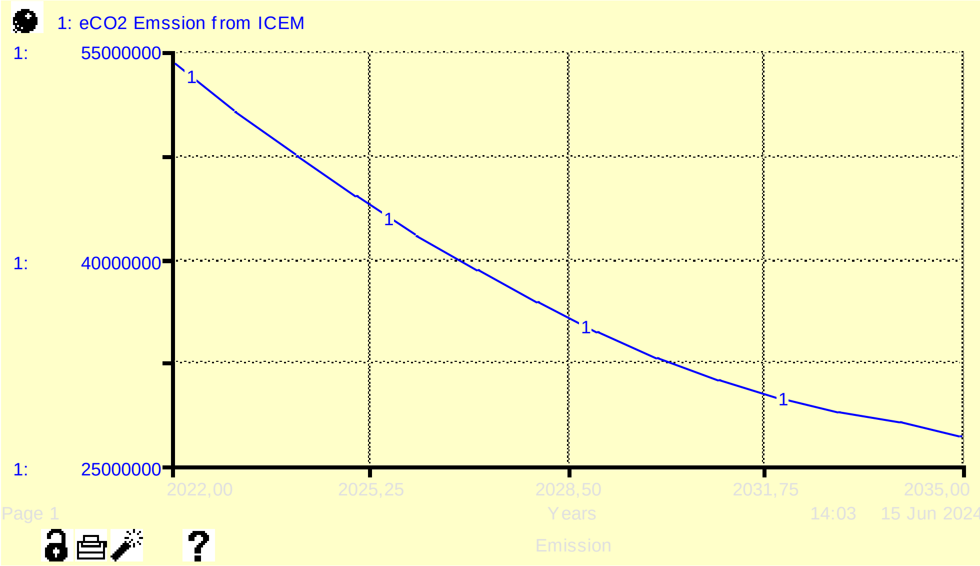


Figure 4.19 Scenario 2: Motorcycle Industry Shift - Emission Graph

The eCO2 Emission from ICEM Scenario 2 Motorcycle Industry Shift Simulation Result Graph resulted in de-acceleration character of graph starting from the initial value of the emission in 2022 until 2035.

From the data result above, the existing simulation pattern and improvement scenario 2 pattern are also similar but having different values due to the improved is focused on the variable that has placement in the middle of the system flow. The improvement scenario resulted in performance measurement that is recapitulated in **Table 4.30** below.

Table 4.30 Scenario 2: Motorcycle Industry Shift - Performance Measurement

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Improvement Prediction (2030)	1.777.934,07	124.831,08	78.423,34	39,55%
Target	13.469.000,00	32.000,00	67.000,00	32% reduction of 2022 data
Properties	Higher Better	Higher Better	Higher Better	Higher Better
Improvement Achievement (2030)	13,20%	390,10%	117,05%	123,59%

Scenario 2 Motorcycle Industry Shift resulted in an unachieved target of EM Population with only 13,20% of the 2030 target. The CS Population, SS Population, Emission Reduction have reached the expected target by 2030.

4.5.3 Scenario 3: Facility Development

Facility Development is one of the recommendations of previous research as one of the effort statements in Presidential Regulation Number 55 Year 2019. The regulation stated that (a) infrastructure providing for battery charging and electric energy fee for Electric Vehicles and (b) technical requirement of Electric Vehicle fulfillment are efforts to accelerate the adoption of electric motorcycles. In this case, the government pushes the fulfillment of the electric motorcycle supporting facilities that includes battery charging and swapping stations all over the country. The simulation data input for Scenario 3 is served in **Table 4.31** below.

Table 4.31 Scenario 3: Facility Development - Data Input

Scenario 3: Facility Development		
Variable	**Existing System Input Value**	**Improvement Input Value**
Capability to Fulfill	0.605763	0.9

The facility development scenario focuses only on one variable in the simulation system which is the capability to fulfill the facility. The variable will affect the establishment of charging and swapping station as in the simulation flow. The target of the capability to fulfill is increased to 90% of the whole demand which the demand is determined by the ideal ratio of facility and electric motorcycle population.

The simulation result value is served in **Table 4.32** below. It serves the EM Population, CS and SS Population, and eCO2 Emission from ICEM.

Table 4.32 Scenario 3: Facility Development - Simulation Result

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2022	17.198,00	439	961,00	54.131.903,42
2023	63.479,71	1.392,84	1.554,98	50.662.032,76
2024	105.398,81	4.913,56	3.747,43	47.418.506,72
2025	227.040,14	10.759,21	7.387,68	44.422.633,83
2026	359.362,95	23.351,35	15.229,15	41.636.233,00
2027	517.667,25	43.282,41	27.640,76	39.053.423,58
2028	757.047,27	71.993,36	45.519,85	36.687.357,38
2029	1.043.367,13	113.980,86	71.666,61	34.517.055,23
2030	**1.389.075,73**	**171.848,28**	**107.702,23**	**32.539.753,78**
2031	1.792.780,35	248.889,45	155.677,87	30.748.077,91
2032	2.254.309,80	348.320,97	217.596,59	29.135.522,83
2033	2.772.359,73	473.349,92	295.455,53	27.695.497,41
2034	3.344.911,52	627.111,04	391.206,77	26.421.402,46
2035	3.969.374,56	812.627,15	506.732,71	25.306.624,43

Table 4.32 shows the result of the Scenario 3 Facility Development Simulation Result that consists of the 1.389.075,73 EM Population result, 171.848,28 CS Population result, 107.702,23 SS Population, and 32.539.753,78 eCO2 Emission from ICEM result. The simulation graph pattern is served in **Figure 4.20**, **4.21**, **4.22**, and **4.23** below. **Figure 4.20** shows the graph of EM Population from 2022 to 2035.

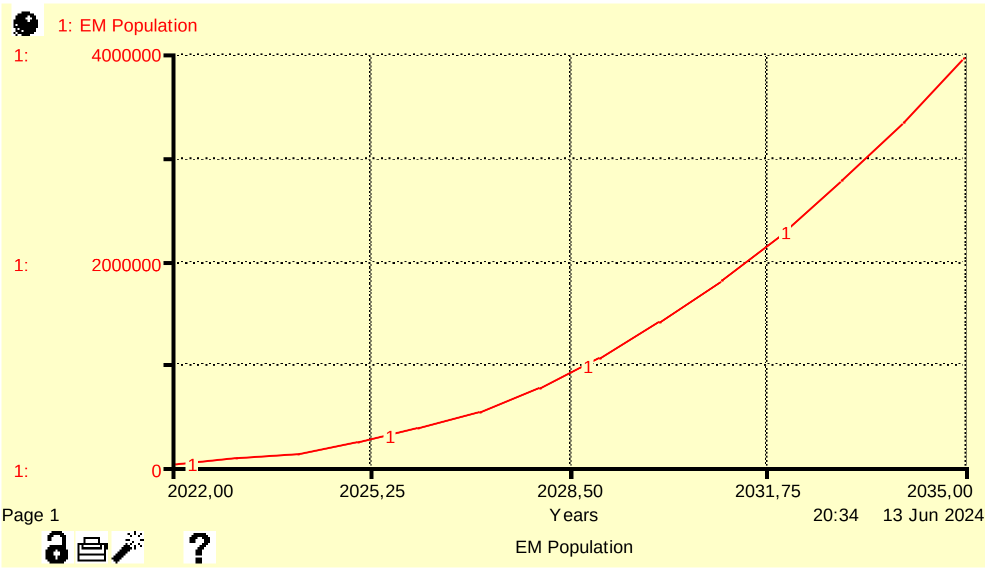


Figure 4.20 Scenario 3: Facility Development - EM Population Graph

The EM Population Scenario 3 Facility Development Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.21** shows the graph of Facility Population from 2022 to 2035.

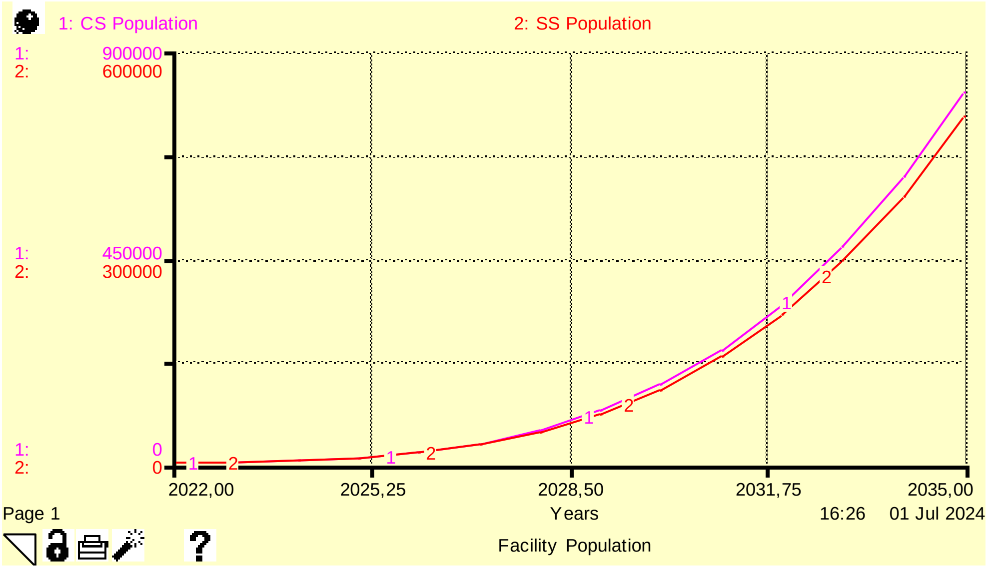


Figure 4.21 Scenario 3: Facility Development - Facility Population Graph

The Facility Population Scenario 3 Facility Development Simulation Result Graph consisting of charging station and swapping station resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.22** shows the graph of WTA from 2022 to 2035.

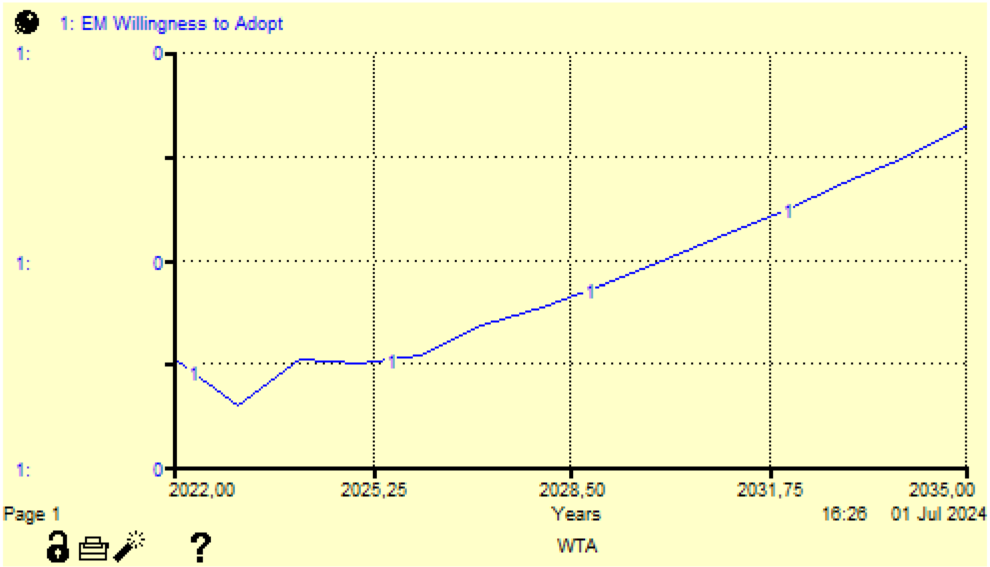


Figure 4.22 Scenario 3: Facility Development - WTA Graph

The Willingness to Adopt Scenario 3 Facility Development Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the ratio in 2022 until 2035. However, it indicates a volatile condition starting from 2022 until approximately 2024 which occurs inconsistent increase and decrease during that period. **Figure 4.23** shows the graph of eCO2 Emission from ICEM from 2022 to 2035.

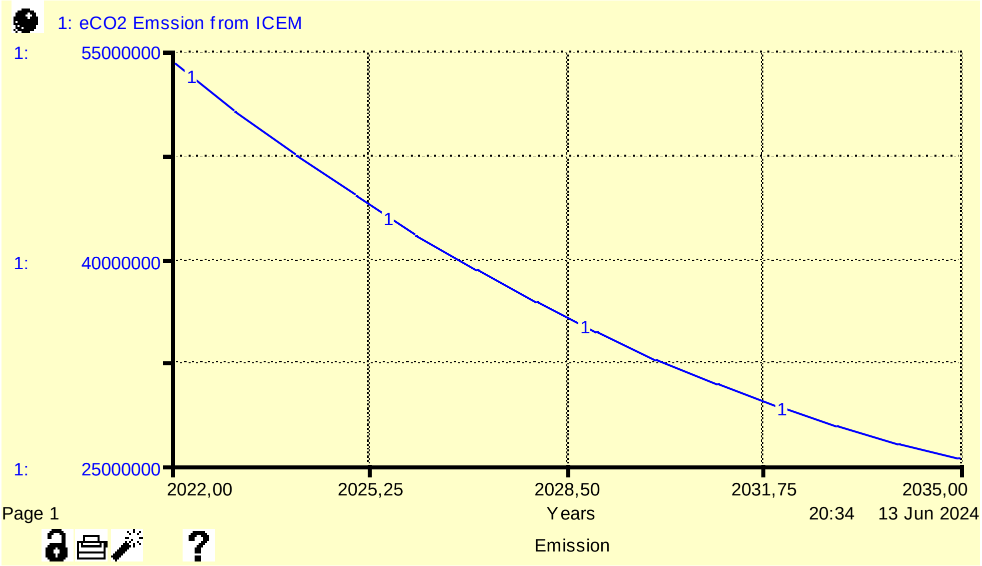


Figure 4.23 Scenario 3: Facility Development - Emission Graph

The eCO2 Emission from ICEM Scenario 3 Facility Development Simulation Result Graph resulted in de-acceleration character of graph starting from the initial value of the emission in 2022 until 2035.

From the data result above, the existing simulation pattern and improvement scenario 3 pattern are similar but having different values for population and emission due to the focus of improvement is on the supporting facility subsystem flow. The improvement scenario resulted in performance measurement that is recapitulated in **Table 4.33** below. However, the improvement still has not achieved the EM Population target.

Table 4.33 Scenario 3: Facility Development - Performance Measurement

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Improvement Prediction (2030)	1.389.075,73	171.848,28	107.702,23	39,89%
Target	13.469.000,00	32.000,00	67.000,00	32% reduction of 2022 data
Properties	Higher Better	Higher Better	Higher Better	Higher Better
Improvement Achievement (2030)	10,31%	537,03%	160,75%	124,65%

Scenario 3 Facility Development resulted in an unachieved target of EM Population with only 10,31% of the 2030 target. The CS Population, SS Population, Emission Reduction have reached the expected target by 2030.

4.5.4 Scenario 4: EM Battery Development

Electric motorcycle battery development is one of the most lately research's topic due to Indonesian conservation of nickel, especially for battery development. This scenario focuses on research and development of electric vehicle batteries. The development meant in this scenario is the capacity for travel range and for durability of utilization. The simulation data input for Scenario 4 is served in **Table 4.34** and **4.35** below.

Table 4.34 Scenario 4: EM Battery Development - Data Input

Scenario 4: EM Battery Development		
Variable	**Existing System Input Value**	**Improvement Input Value**
Average EM Battery Range	175	Served in Table 4.35
EM Decrease Rate	0.2212	

The data input is put in graphical value where it grows and differs between years with a reference of battery technology growth of 14,4% rate. The average battery range is also assumed that the maximum is 285, which is the average travel range of ICEM. The data input is served in **Table 4.35**.

Table 4.35 Scenario 4: EM Battery Development - Data Input Growth

	Compound Annual EV Battery Growth 14,4% 2023-2033	
Year	**Average EM Battery Range**	**EM Decrease Rate**
2022	175	0,2212
2023	200	0,1963
2024	225	0,1764
2025	251	0,1602
2026	276	0,1467
2027	285	0,1353
2028	285	0,1255
2029	285	0,1171
2030	285	0,1097
2031	285	0,1032
2032	285	0,0974
2033	285	0,0922
2034	285	0,0876
2035	285	0,0834

In the simulation system improvement, this scenario will be focused on the EM battery range and EM decrease rate variable in the electric motorcycle adoption system. The battery range will increase per year at a rate of 14,4%. The battery growth rate is based on the resources that has been gathered from research regarding electric vehicle battery growth. This scenario also puts assumption where durability improves 14,4% longer than previous year by adapting with the failure rate per period per population formula.

The simulation result value is served in **Table 4.36** below. It serves the EM Population, CS and SS Population, and eCO2 Emission from ICEM.

Table 4.36 Scenario 4: EM Battery Development - Simulation Result

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2022	17.198,00	439	961,00	54.131.903,42
2023	63.483,15	1.081,00	1.360,79	50.662.032,76
2024	103.994,94	3.450,82	2.836,54	47.417.216,27
2025	222.789,72	7.332,95	5.254,05	44.418.051,15
2026	372.285,38	15.649,67	10.433,10	41.633.068,20
2027	562.392,49	29.547,06	19.087,38	39.053.452,93
2028	849.782,64	50.541,13	32.160,96	36.691.524,37
2029	1.205.659,43	82.263,46	51.915,32	34.524.737,15
2030	**1.650.153,05**	**127.270,65**	**79.942,53**	**32.550.884,77**
2031	2.188.745,57	188.870,75	118.302,59	30.762.209,72
2032	2.827.210,10	270.576,47	169.182,97	29.151.411,70
2033	3.570.214,22	376.116,04	234.905,34	27.711.064,88
2034	4.422.142,17	509.391,89	317.899,85	26.433.628,67
2035	5.381.825,35	674.470,16	420.698,59	25.311.354,91

Table 4.36 shows the result of the Scenario 1 Purchase Incentive Increase Simulation Result that consists of the 1.650.153,05 EM Population result, 127.270,65 CS Population result, 79.942,53 SS Population, and 32.550.884,77 eCO2 Emission from ICEM result. The simulation graph pattern is served in **Figure 4.24**, **4.25**, **4.26**, and **4.27** below. **Figure 4.24** shows the graph of EM Population from 2022 to 2035.

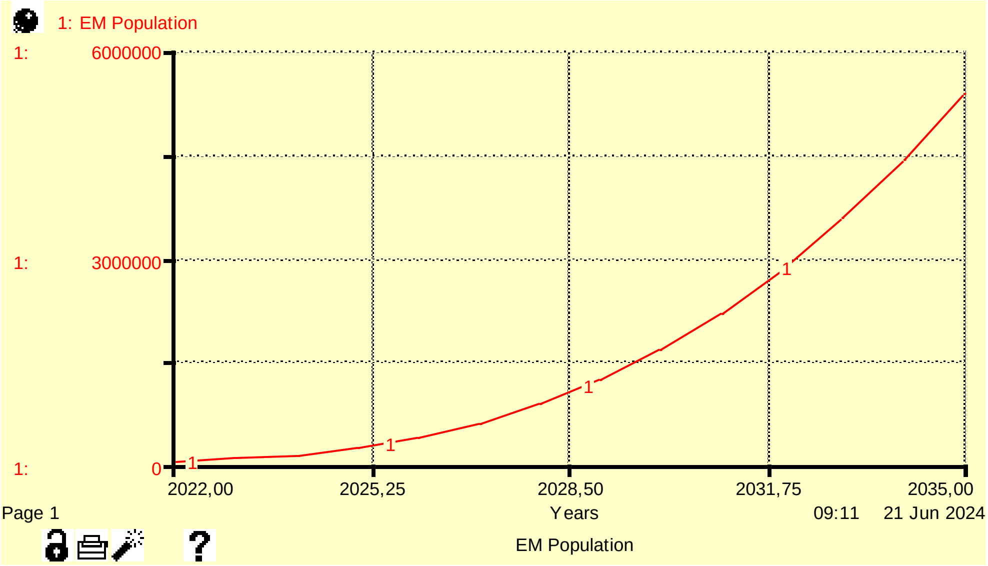


Figure 4.24 Scenario 4: EM Battery Development - EM Population Graph

The EM Population Scenario 4 EM Battery Development Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.25** shows the graph of Facility Population from 2022 to 2035.

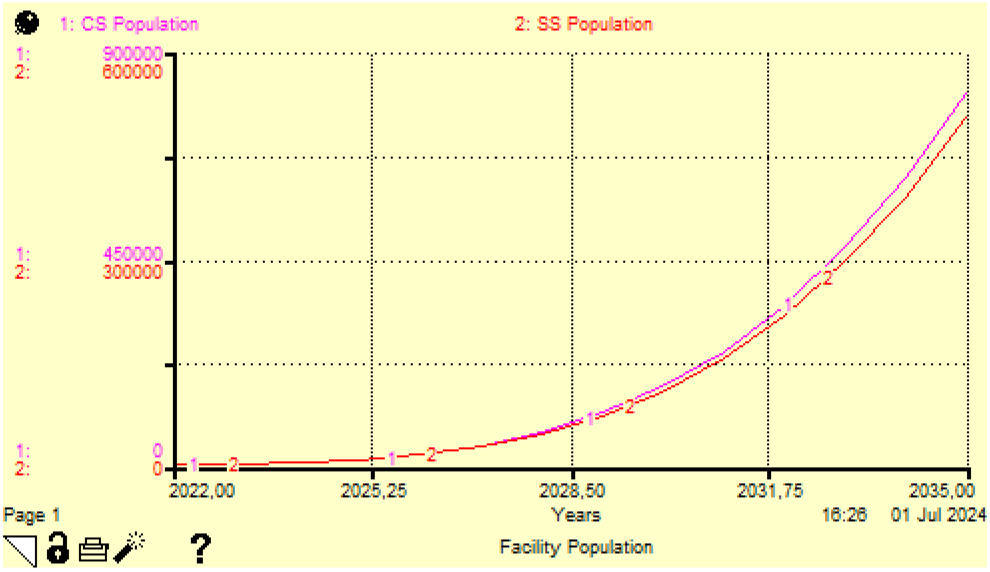


Figure 4.25 Scenario 4: EM Battery Development - Facility Population Graph

The Facility Population Scenario 4 EM Battery Development Simulation Result Graph consisting of charging station and swapping station resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.26** shows the graph of WTA from 2022 to 2035.

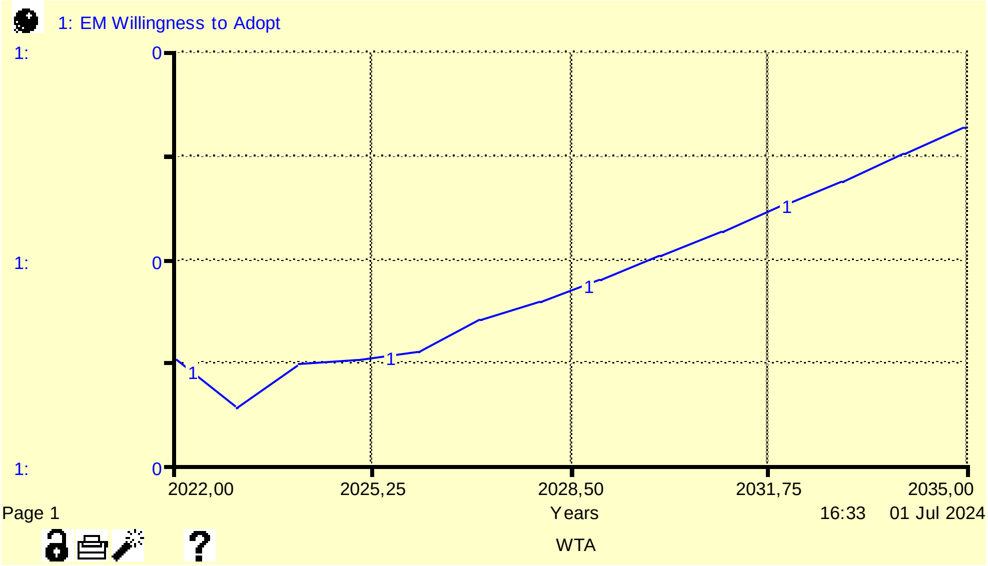


Figure 4.26 Scenario 4: EM Battery Development - WTA Graph

The Willingness to Adopt Scenario 4 EM Battery Development Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the ratio in 2022 until 2035. However, it indicates a volatile condition starting from 2022 until approximately 2027 which occurs inconsistent increase and decrease during that period. **Figure 4.27** shows the graph of eCO2 Emission from ICEM from 2022 to 2035.

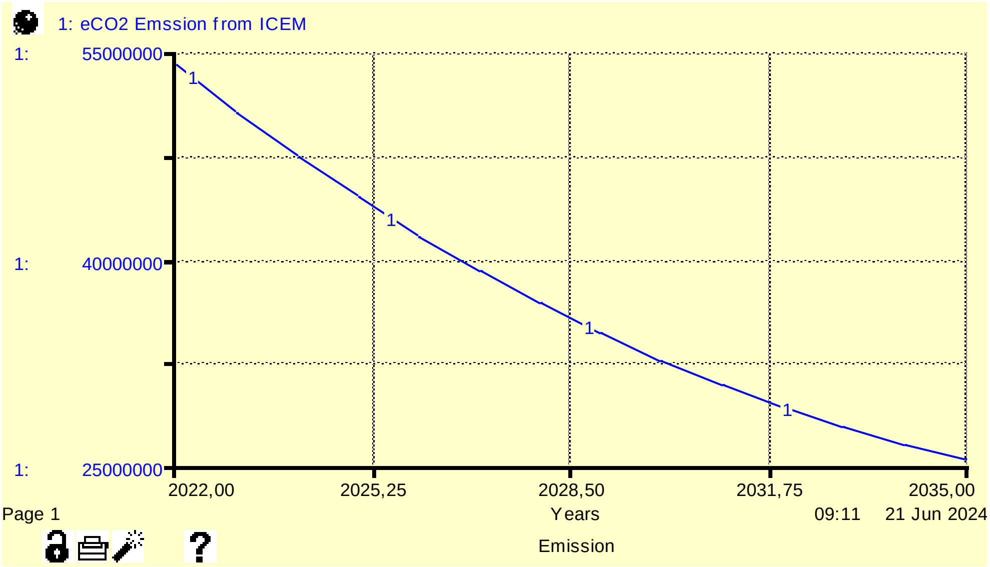


Figure 4.27 Scenario 4: EM Battery Development - Emission Graph

The eCO2 Emission from ICEM Scenario 4 EM Battery Development Simulation Result Graph resulted in de-acceleration character of graph starting from the initial value of the emission in 2022 until 2035.

From the data result above, the existing simulation pattern and improvement scenario 4 pattern are similar but have different values. The improvement scenario resulted in performance measurement that is recapitulated in **Table 4.37** below. However, the improvement still has not achieved the EM Population target.

Table 4.37 Scenario 4: EM Battery Development - Performance Measurement

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Improvement Prediction (2030)	1.650.153,05	127.270,65	79.942,53	39,87%
Target	13.469.000,00	32.000,00	67.000,00	32% reduction of 2022 data
Properties	Higher Better	Higher Better	Higher Better	Higher Better
Improvement Achievement (2030)	12,25%	397,72%	119,32%	124,59%

Scenario 4 EM Battery Development resulted in an unachieved target of EM Population with only 12,25% of the 2030 target. The CS Population, SS Population, Emission Reduction have reached the expected target by 2030.

4.5.5 Scenario 5: Mixed Scenario

Mixed scenario is one of the scenario formulations that integrates the 4 conducted improvements. The mixed scenario is performed due to an insufficient target achievement that has been run in each simulation scenario for the response variable of EM population. The data input for the simulation is served in **Table 4.38**.

Table 4.38 Scenario 5: Mixed Scenario - Data Input

Scenario 5: Mixed Scenario		
Variable	**Existing System Input Value**	**Improvement Input Value**
EM Purchase Incentive	7000000	10254601,1
Average EM Selling Price	MAX ((IF(EM_Population<250000) THEN((Average_EM_Market_Price-EM_Purchase_Incentive) *(1+EM_Purchase__Tax)) ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)	MAX ((IF(EM_Population<500000) THEN((Average_EM_Market_Price-EM_Purchase_Incentive) *(1+EM_Purchase__Tax)) ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)
EM Purchase Tax	0.1	0
Domestic EM Production Capacity	1427000	Served in Table 4.28
Domestic ICEM Production Capacity	6867217	
EM Variants	61	
ICEM Variants	300	
Capability to Fulfill	0.605763	0.9
Average EM Battery Range	175	Served in Table 4.35
EM Decrease Rate	0.2212	

The data inputs are the same as the previously conducted improvement model simulation in which it only differs in the integration. Other data are served in **Table 4.28** and **3.35**

The simulation result value is served in **Table 4.39** below. It serves the EM Population, CS and SS Population, and eCO2 Emission from ICEM.

Table 4.39 Scenario 5: Mixed Scenario - Simulation Result

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2022	17.198,00	439	961,00	54.131.903,42
2023	75.820,89	1.498,82	1.620,98	50.667.362,67
2024	139.669,81	6.171,26	4.530,63	47.433.330,30
2025	384.715,11	14.778,36	9.890,51	44.490.385,02
2026	686.332,29	38.486,29	24.654,09	41.777.677,09
2027	1.141.730,57	80.781,28	50.992,33	39.323.241,17

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2028	1.927.432,49	151.140,03	94.806,64	37.193.038,88
2029	3.017.362,98	269.917,38	168.772,54	35.369.448,04
2030	**4.569.992,66**	**455.861,32**	**284.564,90**	**33.911.447,02**
2031	6.691.027,17	737.485,52	459.939,97	32.856.974,05
2032	9.567.656,32	1.149.817,72	716.710,48	32.127.413,85
2033	13.337.177,32	1.739.421,19	1.083.872,64	31.269.547,65
2034	17.998.157,01	2.561.320,08	1.595.691,49	30.292.053,83
2035	22.708.319,19	3.670.450,20	2.286.377,07	29.202.216,36

Table 4.39 shows the result of the Scenario 1 Purchase Incentive Increase Simulation Result that consists of the 4.569.992,66 EM Population result, 455.861,32 CS Population result, 284.564,90 SS Population, and 33.911.447,02 eCO2 Emission from ICEM result. The simulation graph pattern is served in **Figure 4.28**, **4.29**, **4.30**, and **4.31** below. **Figure 4.28** shows the graph of EM Population from 2022 to 2035.

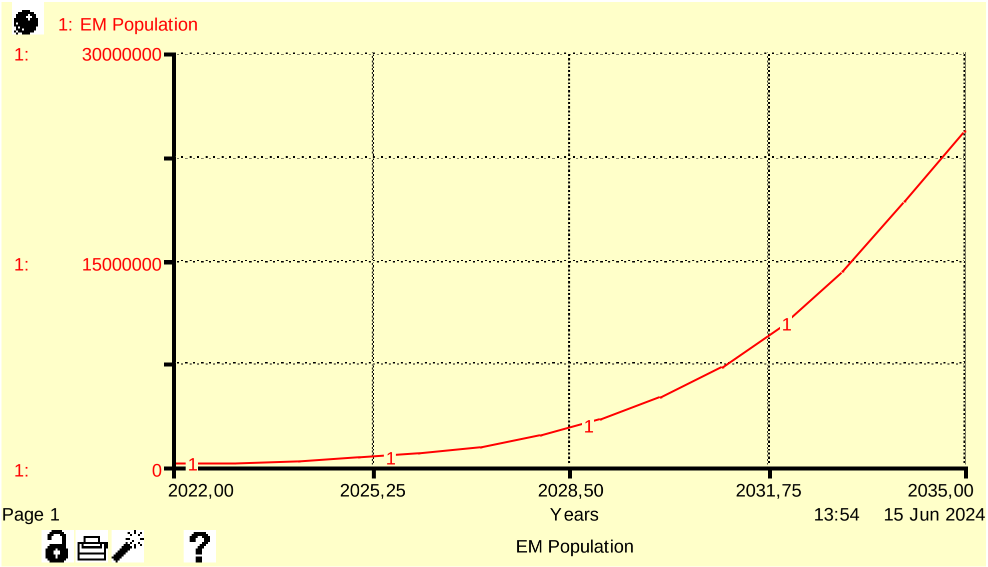


Figure 4.28 Scenario 5: Mixed Scenario - EM Population Graph

The EM Population Scenario 5 Mixed Scenario Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.29** shows the graph of Facility Population from 2022 to 2035.

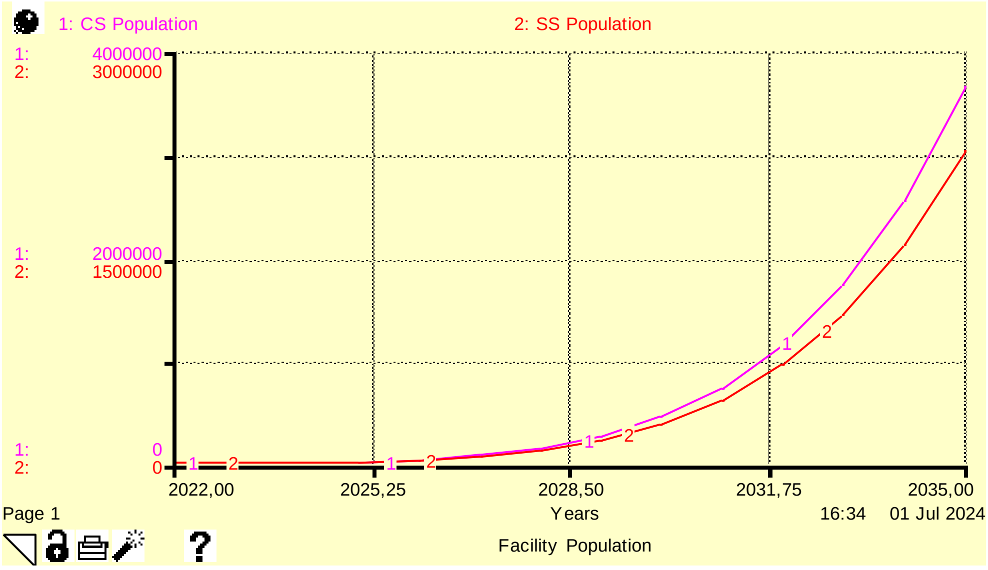


Figure 4.29 Scenario 5: Mixed Scenario - Facility Population Graph

The Facility Population Scenario 5 Mixed Scenario Simulation Result Graph consisting of charging station and swapping station resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. **Figure 4.30** shows the graph of WTA from 2022 to 2035.

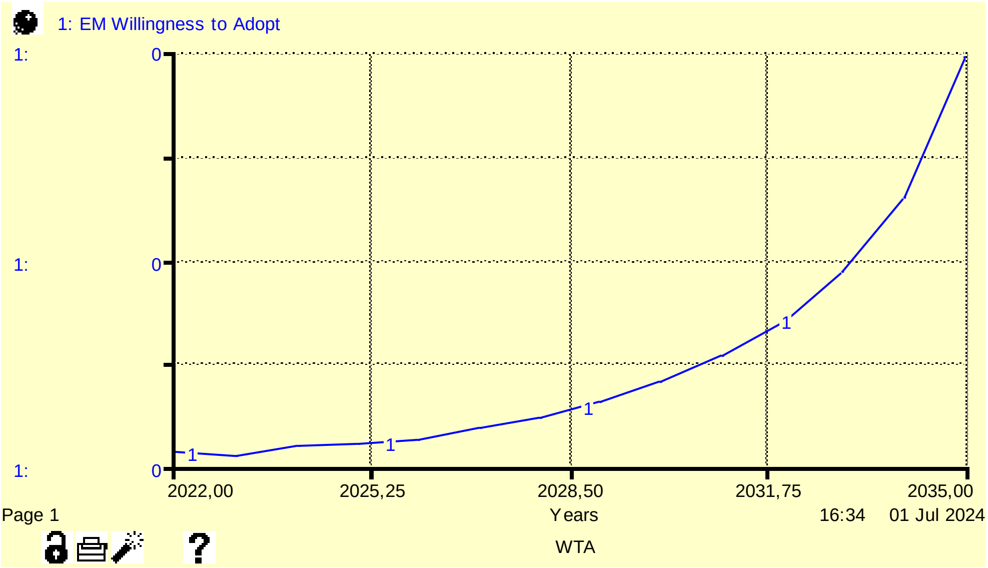


Figure 4.30 Scenario 5: Mixed Scenario - WTA Graph

The Willingness to Adopt Scenario 5 Mixed Scenario Simulation Result Graph resulted in stable acceleration character of graph starting from the initial value of the ratio in 2022 until 2035. It differs from the 4 previous Willingness to Adopt graph since they have volatilities. **Figure 4.31** shows the graph of eCO2 Emission from ICEM from 2022 to 2035.

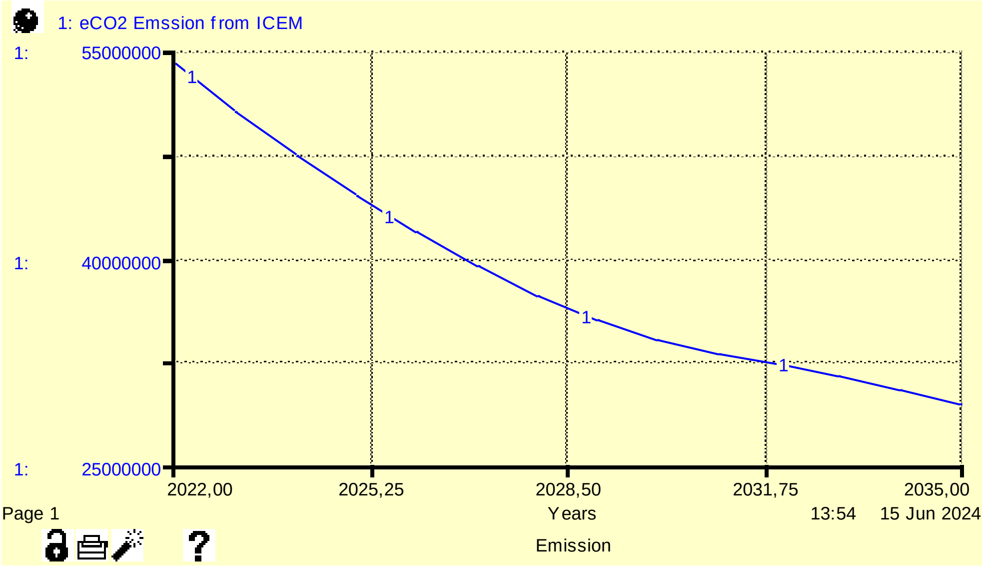


Figure 4.31 Scenario 5: Mixed Scenario - Emission Graph

The eCO2 Emission from ICEM Scenario 5 Mixed Scenario Simulation Result Graph resulted in reduction character of graph starting from the initial value of the emission in 2022 until 2035.

From the data result above, the existing simulation pattern and improvement scenario 5 pattern are similar with improved values for electric motorcycle adoption due to improvement in various subsystems. The improvement scenario resulted in performance measurement that is recapitulated in **Table 4.40** below. The improvement has reached an increasement in the EM population result but not achieved the EM Population target as of 2030.

Table 4.40 Scenario 5: Mixed Scenario - Performance Measurement

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Improvement Prediction (2030)	4.569.992,66	455.861,32	284.564,90	37,35%
Target	13.469.000,00	32.000,00	67.000,00	32% reduction of 2022 data
Properties	Higher Better	Higher Better	Higher Better	Higher Better
Improvement Achievement (2030)	33,93%	1424,57%	424,72%	116,73%

Scenario 5 Mixed Scenario resulted in an unachieved target of EM Population with only 33,93% of the 2030 target. The CS Population, SS Population, Emission Reduction have reached the expected target by 2030.

4.5.6 Scenario 6: Improved Mixed Scenario

Improved mixed scenario is scenario formulation that integrates the 4 conducted improvements with improved values. The mixed scenario is performed due to an insufficient target achievement that has been run in mixed scenario of improvement for the response variable of EM population. Thereby, a new data input has been made to improve the result. The data input for the simulation is served in **Table 4.41** below.

Table 4.41 Scenario 6: Improved Mixed Scenario - Data Input

Scenario 6: Improved Mixed Scenario		
Variable	**Existing System Input Value**	**Improvement Input Value**
EM Purchase Incentive	7000000	10254601,1

Scenario 6: Improved Mixed Scenario		
Variable	**Existing System Input Value**	**Improvement Input Value**
Average EM Selling Price	MAX ((IF(EM_Population<250000) THEN((Average_EM_Market_Price-EM_Purchase_Incentive) *(1+EM_Purchase__Tax)) ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)	MAX ((IF(EM_Population<500000) THEN((Average_EM_Market_Price-EM_Purchase_Incentive) *(1+EM_Purchase__Tax)) ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)
EM Purchase Tax	0.1	0
Domestic EM Production Capacity	1427000	Served in Table 4.42
Domestic ICEM Production Capacity	6867217	
EM Variants	61	
ICEM Variants	300	
Capability to Fulfill	0.605763	1
Average EM Battery Range	175	Served in Table 4.35

The data inputs are the same as the previously conducted improvement model simulation in which it only differs in the integration. The data are served in **Table 4.42**.

Table 4.42 Scenario 6: Improved Mixed Scenario - Data Input Growth of Industry

	Shifting Percentage per Year		**Variant Growth Percentage per Year**	
	15% (three times the GDP growth of manufacturing industry)			
Year	**Domestic ICEM Production Capacity**	**Domestic EM Production Capacity**	**ICEM Variants**	**EM Variants**
2022	6.867.217	1.427.000	300	61
2023	5.623.084	2.671.133	255	70
2024	4.378.952	3.915.265	210	81
2025	3.134.819	5.159.398	165	93
2026	1.890.687	6.403.530	120	107
2027	646.554	7.647.663	75	123
2028	0	8.294.217	30	141
2029	0	8.294.217	1	162
2030	0	8.294.217	1	187
2031	0	8.294.217	1	215
2032	0	8.294.217	1	247
2033	0	8.294.217	1	284
2034	0	8.294.217	1	326
2035	0	8.294.217	1	375

The data input is put in graphical value where it grows and increases between years with a shift capability of three times GDP growth of manufacturing industry which is 15%. This applies for the rate of domestic production capacity shift and variant growths.

The simulation result value is served in **Table 4.43** below. It serves the EM Population, CS and SS Population, and eCO2 Emission from ICEM.

Table 4.43 Scenario 6: Improved Mixed Scenario - Simulation Result

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2022	17.198,00	439	961,00	54.131.903,42
2023	75.817,46	1.498,82	1.620,98	50.667.362,67
2024	156.193,39	6.171,05	4.530,50	47.440.459,79
2025	494.784,35	15.796,41	10.524,48	44.538.697,13
2026	1.008.925,53	46.287,32	29.512,00	41.922.259,65

Year	EM Population	CS Population	SS Population	eCO2 Emission from ICEM
2027	2.089.716,79	108.462,00	68.229,87	39.749.246,53
2028	4.771.927,56	237.240,07	148.423,48	37.464.731,46
2029	12.464.881,69	531.308,43	331.547,87	35.048.256,28
2030	**19.300.707,53**	**1.299.452,40**	**809.892,07**	**32.787.643,75**
2031	25.471.846,70	2.488.851,75	1.550.563,48	30.672.840,73
2032	31.142.463,49	4.058.545,38	2.528.054,52	28.694.442,50
2033	36.415.861,53	5.977.688,79	3.723.157,46	26.843.650,96
2034	41.359.819,27	8.221.803,51	5.120.628,90	25.112.235,47
2035	46.014.155,18	10.770.587,89	6.707.826,44	23.492.496,28

Table 4.43 shows the result of the Scenario 6 Improved Mixed Scenario Increase Simulation Result that consists of the 19.300.707,53 EM Population result, 1.299.452,40 CS Population result, 809.892,07 SS Population, and 32.787.643,75 eCO2 Emission from ICEM result. The simulation graph pattern is served in **Figure 4.32**, **4.33**, **4.34**, and **4.35** below. **Figure 4.32** shows the graph of EM Population from 2022 to 2035.

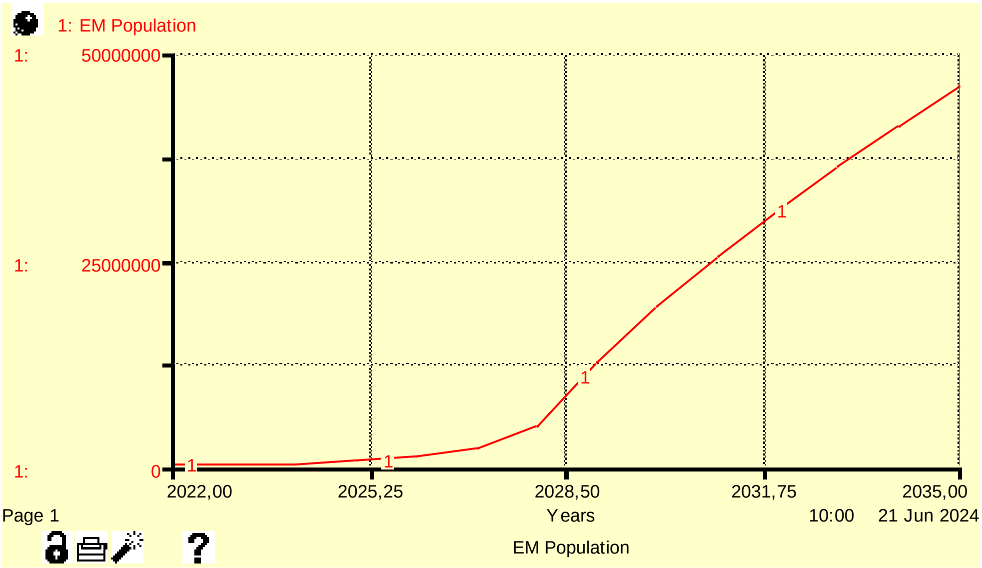


Figure 4.32 Scenario 6: Improved Mixed Scenario - EM Population Graph

The EM Population Scenario 6 Improved Mixed Scenario Simulation Result Graph resulted in significant constant increase character of graph starting from the from 2028 until 2035. However, from 2022 to 2028, an increase also occurred but the constant is lower than 2028-2035. **Figure 4.33** shows the graph of Facility Population from 2022 to 2035.

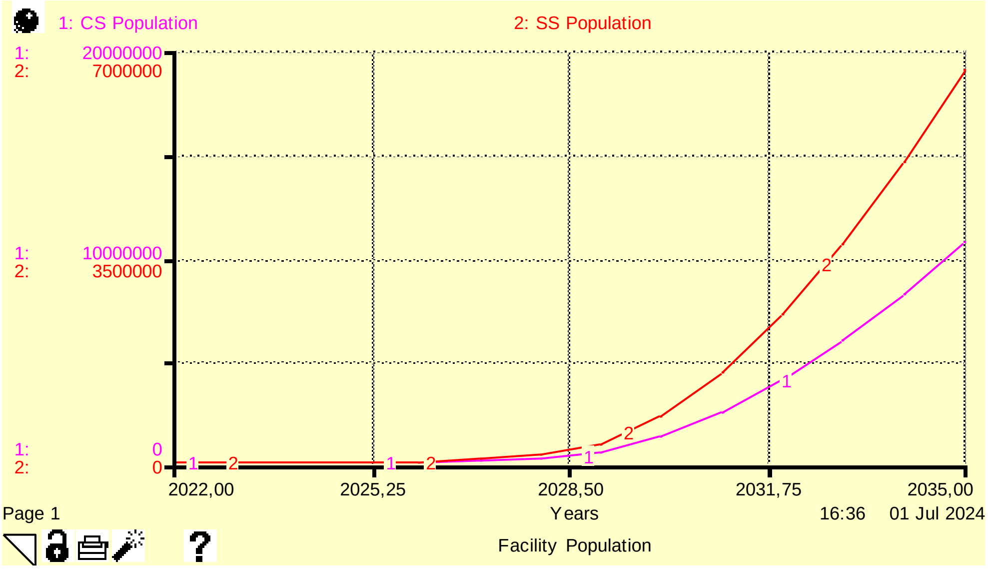


Figure 4.33 Scenario 6: Improved Mixed Scenario - Facility Population Graph

The Facility Population Scenario 6 Improved Mixed Scenario Simulation Result Graph consisting of charging station and swapping station resulted in acceleration character of graph starting from the initial value of the population in 2022 until 2035. However, the charging and swapping station have different constants in their accelerations. **Figure 4.34** shows the graph of WTA from 2022 to 2035.

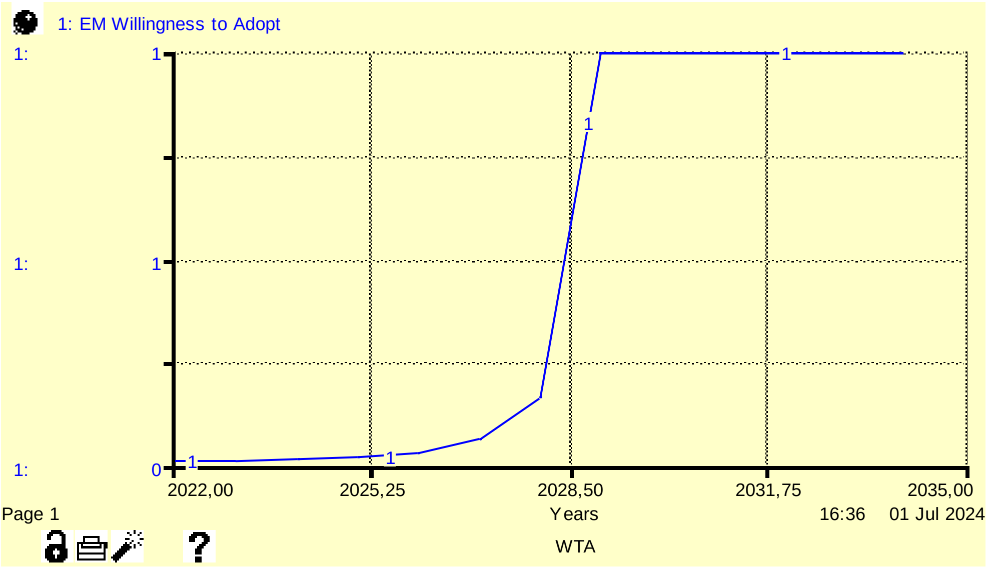


Figure 4.34 Scenario 6: Improved Mixed Scenario - WTA Graph

The Willingness to Adopt Scenario 6 Improved Mixed Scenario Simulation Result Graph resulted in acceleration character of graph starting from the initial value of the ratio in 2022 until 2035. However, it indicates a volatile condition starting from 2022 until approximately 2027 which occurs inconsistent increase and decrease during that period. **Figure 4.35** shows the graph of eCO2 Emission from ICEM from 2022 to 2035.

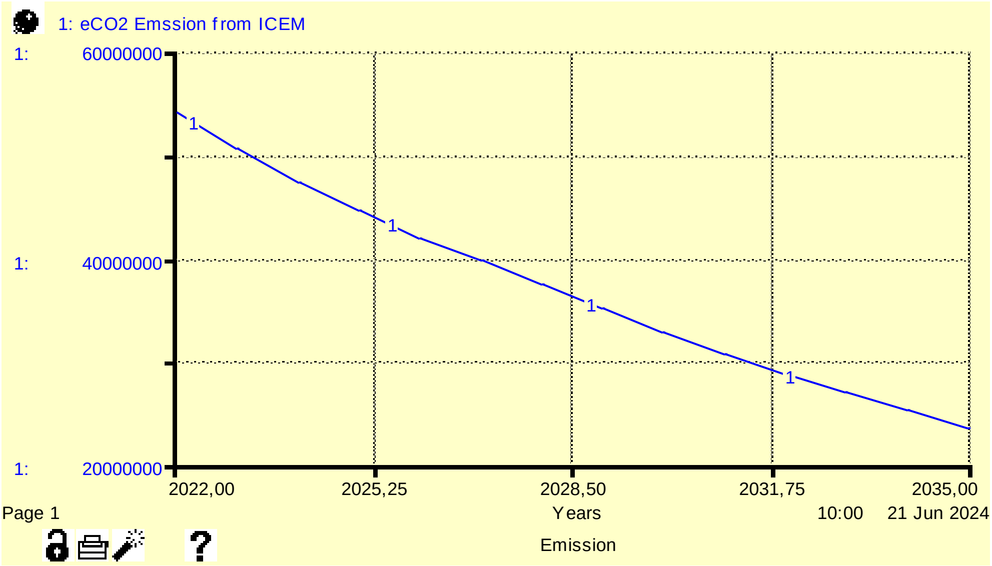


Figure 4.35 Scenario 6: Improved Mixed Scenario - Emission Graph

The eCO2 Emission from ICEM Scenario 6 Improved Mixed Scenario Simulation Result Graph resulted in decrease character of graph starting from the initial value of the emission in 2022 until 2035.

From the data result above, the existing simulation pattern and improvement scenario 3 pattern are for population and emission due to the focus of improvement is on the supporting facility subsystem flow. The improvement scenario resulted in performance measurement that is recapitulated in **Table 4.44** below.

Table 4.44 Scenario 6: Improved Mixed Scenario - Performance Measurement

Indicators	EM Population	CS Population	SS Population	Emission Reduction
Improvement Prediction (2030)	19.300.707,53	1.299.452,40	809.892,07	39,43%
Target	13.469.000,00	32.000,00	67.000,00	32% reduction of 2022 data
Properties	Higher Better	Higher Better	Higher Better	Higher Better
Improvement Achievement (2030)	143,30%	4060,79%	1208,79%	123,22%

The improvement has reached an increasement in the EM population result with achieving the EM Population target as of 2030. All of the targets have achieved its target,

4.6 Simulation Result Recapitulation

The recapitulation results for the main variable result for each year from 2022 to 2035 are served on **Table 4.45** below. The variable consists of EM Population, CS Population, SS Population, Emission Caused by ICEM, and Willingness to Adopt.

Table 4.45 Simulation Result Recapitulation

Scenario	Year	EM Population	CS Population	SS Population	Emission Caused by ICEM	Willingness to Adopt
Existing System	2022	17.198,00	439	961,00	54.131.903,42	0,01
	2023	63.479,71	1.081,00	1.360,79	50.662.032,76	0,00
	2024	95.792,46	3.450,69	2.836,46	47.414.356,78	0,00
	2025	190.458,83	7.026,62	5.063,29	44.406.180,41	0,00
	2026	293.595,53	14.136,43	9.490,77	41.604.736,77	0,00
	2027	407.452,29	25.096,34	16.315,80	38.998.472,89	0,01
	2028	581.041,53	40.306,50	25.787,58	36.596.997,43	0,01

Scenario	Year	EM Population	CS Population	SS Population	Emission Caused by ICEM	Willingness to Adopt
	2029	787.205,12	61.996,74	39.294,69	34.381.077,16	0,01
	2030	**1.033.591,88**	**91.383,06**	**57.594,35**	**32.345.160,83**	**0,01**
	2031	1.319.876,44	129.966,97	81.621,60	30.481.341,27	0,01
	2032	1.646.099,68	179.237,87	112.303,93	28.782.348,48	0,01
	2033	2.011.706,67	240.686,66	150.569,77	27.241.127,87	0,01
	2034	2.415.714,31	315.783,54	197.334,64	25.850.841,90	0,01
	2035	2.856.798,75	405.961,99	253.491,23	24.604.852,87	0,01
Scenario 1: Purchase Incentive Increase	2022	17.198,00	439	961,00	54.131.903,42	0,01
	2023	75.817,45	1.081,00	1.360,79	50.667.362,67	0,00
	2024	107.357,23	3.911,26	3.123,27	47.420.187,96	0,01
	2025	227.639,34	7.918,90	5.618,94	44.423.806,59	0,00
	2026	346.549,67	16.416,66	10.910,72	41.631.593,18	0,01
	2027	542.695,64	29.353,34	18.966,75	39.064.206,21	0,00
	2028	675.394,08	49.612,13	31.582,45	36.653.749,76	0,01
	2029	913.617,65	74.824,54	47.282,91	34.457.035,06	0,01
	2030	**1.189.811,33**	**108.929,83**	**68.521,20**	**32.441.175,81**	**0,01**
	2031	1.509.650,11	153.345,41	96.179,99	30.600.586,79	0,01
	2032	1.872.659,21	209.700,54	131.273,87	28.927.928,63	0,01
	2033	2.278.092,41	279.606,79	174.806,39	27.416.172,69	0,01
	2034	2.724.741,73	364.647,82	227.763,77	26.058.472,92	0,01
	2035	3.211.032,03	466.362,25	291.104,11	24.848.150,79	0,01
Scenario 2: Industry Capacity Shifting	2022	17.198,00	439	961,00	54.131.903,42	0,01
	2023	63.479,71	1.081,00	1.360,79	50.662.032,76	0,00
	2024	101.176,50	3.450,69	2.836,46	47.416.682,69	0,00
	2025	215.653,54	7.227,61	5.188,45	44.417.429,00	0,00
	2026	352.080,86	15.277,94	10.201,61	41.632.048,94	0,01
	2027	530.159,43	28.421,09	18.386,21	39.057.356,01	0,01
	2028	823.961,88	48.211,91	30.710,49	36.715.740,39	0,01
	2029	1.228.524,33	78.970,35	49.864,61	34.601.082,59	0,01
	2030	**1.777.934,07**	**124.831,08**	**78.423,34**	**32.724.053,59**	**0,02**
	2031	2.517.545,19	191.201,24	119.753,85	31.102.760,67	0,02
	2032	3.518.961,58	285.181,03	178.277,63	29.769.817,08	0,03
	2033	4.832.894,31	416.543,63	260.080,70	28.753.549,16	0,03
	2034	6.638.218,11	596.955,25	372.427,94	27.938.232,69	0,05
	2035	9.116.713,93	844.759,49	526.742,39	27.000.290,12	0,06
Scenario 3: Facility Development	2022	17.198,00	439	961,00	54.131.903,42	0,01
	2023	63.479,71	1.392,84	1.554,98	50.662.032,76	0,00
	2024	105.398,81	4.913,56	3.747,43	47.418.506,72	0,01
	2025	227.040,14	10.759,21	7.387,68	44.422.633,83	0,00
	2026	359.362,95	23.351,35	15.229,15	41.636.233,00	0,01
	2027	517.667,25	43.282,41	27.640,76	39.053.423,58	0,01
	2028	757.047,27	71.993,36	45.519,85	36.687.357,38	0,01
	2029	1.043.367,13	113.980,86	71.666,61	34.517.055,23	0,01
	2030	**1.389.075,73**	**171.848,28**	**107.702,23**	**32.539.753,78**	**0,01**
	2031	1.792.780,35	248.889,45	155.677,87	30.748.077,91	0,01
	2032	2.254.309,80	348.320,97	217.596,59	29.135.522,83	0,01
	2033	2.772.359,73	473.349,92	295.455,53	27.695.497,41	0,01
	2034	3.344.911,52	627.111,04	391.206,77	26.421.402,46	0,01
	2035	3.969.374,56	812.627,15	506.732,71	25.306.624,43	0,02
Scenario 4: EM Battery Development	2022	17.198,00	439	961,00	54.131.903,42	0,01
	2023	63.483,15	1.081,00	1.360,79	50.662.032,76	0,00
	2024	103.994,94	3.450,82	2.836,54	47.417.216,27	0,00

Scenario	Year	EM Population	CS Population	SS Population	Emission Caused by ICEM	Willingness to Adopt
	2025	222.789,72	7.332,95	5.254,05	44.418.051,15	0,00
	2026	372.285,38	15.649,67	10.433,10	41.633.068,20	0,01
	2027	562.392,49	29.547,06	19.087,38	39.053.452,93	0,01
	2028	849.782,64	50.541,13	32.160,96	36.691.524,37	0,01
	2029	1.205.659,43	82.263,46	51.915,32	34.524.737,15	0,01
	2030	**1.650.153,05**	**127.270,65**	**79.942,53**	**32.550.884,77**	**0,01**
	2031	2.188.745,57	188.870,75	118.302,59	30.762.209,72	0,01
	2032	2.827.210,10	270.576,47	169.182,97	29.151.411,70	0,01
	2033	3.570.214,22	376.116,04	234.905,34	27.711.064,88	0,01
	2034	4.422.142,17	509.391,89	317.899,85	26.433.628,67	0,01
	2035	5.381.825,35	674.470,16	420.698,59	25.311.354,91	0,00
Scenario 5: Mixed Scenario	2022	17.198,00	439	961,00	54.131.903,42	0,01
	2023	75.820,89	1.498,82	1.620,98	50.667.362,67	0,00
	2024	139.669,81	6.171,26	4.530,63	47.433.330,30	0,01
	2025	384.715,11	14.778,36	9.890,51	44.490.385,02	0,01
	2026	686.332,29	38.486,29	24.654,09	41.777.677,09	0,01
	2027	1.141.730,57	80.781,28	50.992,33	39.323.241,17	0,02
	2028	1.927.432,49	151.140,03	94.806,64	37.193.038,88	0,02
	2029	3.017.362,98	269.917,38	168.772,54	35.369.448,04	0,03
	2030	**4.569.992,66**	**455.861,32**	**284.564,90**	**33.911.447,02**	**0,04**
	2031	6.691.027,17	737.485,52	459.939,97	32.856.974,05	0,05
	2032	9.567.656,32	1.149.817,72	716.710,48	32.127.413,85	0,07
	2033	13.337.177,32	1.739.421,19	1.083.872,64	31.269.547,65	0,09
	2034	17.998.157,01	2.561.320,08	1.595.691,49	30.292.053,83	0,13
	2035	22.708.319,19	3.670.450,20	2.286.377,07	29.202.216,36	0,20
Scenario 6: Improved Mixed Scenario	2022	17.198,00	439	961,00	54.131.903,42	0,01
	2023	75.817,46	1.498,82	1.620,98	50.667.362,67	0,01
	2024	156.193,39	6.171,05	4.530,50	47.440.459,79	0,01
	2025	494.784,35	15.796,41	10.524,48	44.538.697,13	0,01
	2026	1.008.925,53	46.287,32	29.512,00	41.922.259,65	0,03
	2027	2.089.716,79	108.462,00	68.229,87	39.749.246,53	0,04
	2028	4.771.927,56	237.240,07	148.423,48	37.464.731,46	0,09
	2029	12.464.881,69	531.308,43	331.547,87	35.048.256,28	0,19
	2030	**19.300.707,53**	**1.299.452,40**	**809.892,07**	**32.787.643,75**	**1,00**
	2031	25.471.846,70	2.488.851,75	1.550.563,48	30.672.840,73	1,00
	2032	31.142.463,49	4.058.545,38	2.528.054,52	28.694.442,50	1,00
	2033	36.415.861,53	5.977.688,79	3.723.157,46	26.843.650,96	1,00
	2034	41.359.819,27	8.221.803,51	5.120.628,90	25.112.235,47	1,00
	2035	46.014.155,18	10.770.587,89	6.707.826,44	23.492.496,28	1,00

The data recapitulation is served to support the analysis at Chapter V by visualizing the comparison between each scenario simulation result. The realization and achievement for the whole scenario including existing system and improvements are recapitulated in **Table 4.46**.

Table 4.46 Existing System and Improvement Prediction and Achievement by 2030

Indicators		EM Population	CS Population	SS Population	Emission Reduction
Predicted Existing Achievement (2030)		7,67%	285,57%	85,96%	**125,77%**
Target		13.469.000,00	32.000,00	67.000,00	32%
Properties		Higher Better	Higher Better	Higher Better	Higher Better
Scenario 1: Purchase	**Improvement Prediction (2030)**	1.189.811,33	108.929,83	68.521,20	40,07%

Indicators		EM Population	CS Population	SS Population	Emission Reduction
Incentive Increase	**Improvement Achievement (2030)**	8,83%	340,41%	102,27%	125,22%
Scenario 2: Industry Shift	**Improvement Prediction (2030)**	1.777.934,07	124.831,08	78.423,34	39,55%
	Improvement Achievement (2030)	13,20%	390,10%	117,05%	123,59%
Scenario 3: Facility Development	**Improvement Prediction (2030)**	1.389.075,73	171.848,28	107.702,23	39,89%
	Improvement Achievement (2030)	10,31%	537,03%	160,75%	124,65%
Scenario 4: EM Battery Development	**Improvement Prediction (2030)**	1.650.153,05	127.270,65	79.942,53	39,87%
	Improvement Achievement (2030)	12,25%	397,72%	119,32%	124,59%
Scenario 5: Mixed Scenario	**Improvement Prediction (2030)**	4.569.992,66	455.861,32	284.564,90	37,35%
	Improvement Achievement (2030)	33,93%	1424,57%	424,72%	116,73%
Scenario 6: Improved Mixed Scenario	**Improvement Prediction (2030)**	19.300.707,53	1.299.452,40	809.892,07	39,43%
	Improvement Achievement (2030)	**143,30%**	**4060,79%**	**1208,79%**	123,22%

The bolded achievement is tagged as the best achievement by 2030 throughout the whole scenario that has been simulated. The recapitalization consists of prediction achievement of existing condition, scenarios of purchase incentive increase, industry shift, facility development, EM battery development, mixed scenario, and improved mixed scenario.

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CHAPTER 5
ANALYSIS

This fifth chapter will serve the analysis for each of the segmentations of the research consisting of Existing System Analysis, Existing System Simulation Analysis, Improvement Model Analysis, and Simulation Result Comparison Analysis.

5.1 Existing System Model Analysis

The existing system identification in **Chapter 4.1** describes the existing system condition and variable identification followed with the causal loop diagram development. It is stated that government of Indonesia are trying to reduce the global emission contribution with one of the efforts being focused to push an adoption program of electric vehicle. With the majority of the vehicle in Indonesia is motorcycle, a focus to convert conventional motorcycle into electric based is needed. The limitation and recommendation of the adoption program is arranged in the Presidential Regulation Number 55 in the Year 2019. Thus, efforts are guided and limited only by the limitation stated in the regulation which contains acceleration of domestic Electric Vehicle industry, providing incentives, infrastructure providing for battery charging and electric energy fee for Electric Vehicles, technical requirement of Electric Vehicle fulfillment, and living environment protection. The government has set targets for emission reduction of 32% and 13.469.000 units of electric motorcycle by 2030. To push the adoption, the government must deal with the complexity of Indonesia population and society habit and culture regarding transportation mode utilization and preferences. Operational support must be provided by the government to achieve sustainability of the adoption with target set for electric motorcycle charging stations and battery swapping station. With the identification of the existing condition, an electric motorcycle adoption system can be depicted into a cause-and-effect chain between one variable and another with the main response variable being electric motorcycle population, charging station population, swapping station population, and eCO2 emission from conventional motorcycle (ICEM).

The electric motorcycle adoption system is identified into several subsystems. The system is divided into motorcycle subsystem, workforce population subsystem, willingness to adopt subsystem, and supporting facility subsystem. The subsystem is divided into segmented variables that are focused as independent and response.

The system flow starts from the workforce of Indonesia in workforce population subsystem, that demands motorcycle as their transportation mode option. The population is segmented into people that are at the productive age that can afford motorcycles. With the segmentation identified, it flows as information of whole motorcycle demand that triggers adoption.

The decision phase of the motorcycle adoption or buying is defined in the willingness to adopt subsystem where it defines their willingness and preferences to adopt. The subsystem will determine whether it fulfills their need to adapt to electric motorcycles or conventional motorcycles. The willingness to adopt is defined by the ratios of preferences between conventional and electric motorcycles. The ratio that contains selling price ratio, travel range ratio, and supporting facility availability to maintain operational which are charging and swapping stations. Incentives are also contained in this subsystem which will affect selling price ratios. Battery technology also gives affection to the travel range ratio that supports electric motorcycle preference.

The motorcycle subsystem is the main core of the electric motorcycle adoption system where it flows and connects on material and information sourced from other subsystems such as workforce population subsystem that influences the motorcycle demand and willingness to adopt subsystem that influences determination of adoption (to electric or convention). The main response is located in this subsystem where it identifies how big the motorcycle population for both electric and conventional followed with the amount of emission that are produced from conventional motorcycle. However, the motorcycle subsystem also acts as an influence subsystem directed to supporting facilities subsystem. This is identified by the influence of electric motorcycle population that pushes supporting facilities demand and establishment which it will affect back to the population in a loop.

The main loop of the system is identified with the supporting facilities subsystem. It is influenced by the increasing of the electric motorcycle population that pushes the development of supporting facility infrastructure in the form of battery charging and swapping stations. The more the facility increases, the willingness to adopt electric motorcycles by providing the operational infrastructure. However, it also must be supported with the other preferences that are defined in the willingness to adopt subsystem.

The causal loop diagram is formed to describe the cause-and-effect relationship between the variable with the cue of the identified systems and subsystem. In total, the diagram formed 11 causal loops with 7 loops being negative and 4 loops being positive. The causal loop has 6 formations that referred to previous research. This gave an indication where the causal loop is considered verified and valid as of previous research release. The stock flow diagram is formed to describe the material and information flow of the whole system. The diversification of the system is the same as the causal loop diagram where divides into 4 subsystems.

The verification is conducted in two methods consisting of manual checking of units and with using STELLA software features called "Check Units". Manual checking step is conducted by making sure the units of the simulation input value are standardized in yearly period followed with each measurement unit type of the variables. STELLA "Check Unit" feature also pops a notification that the input units of measurement are consistent.

The validation is conducted by using two methods, Black Box Method and Extreme Value Validation Method. The variables of the validation for Black Box Method are Electric Motorcycle Population in 2023, Charging Station Population in 2023, and Swapping Station Population in 2023.The real system data of Electric Motorcycle Population in 2023 is 62.409 units. The simulation showed the Electric Motorcycle Population in 2023 result is 63.479,71. The variance of error testing showed 0,017156 as the result, having a lower than 0,1 indicating that the variable of the model is valid. The real system data of Charging Station Population at the end of 2023 is 1.081 units. The simulation showed the Charging Station Population in 2023 result is 1.081,00. The variance of error testing showed 0,000 as the result, having a lower than 0,1 indicating that the variable of the model is valid. The real system data of Swapping Station Population in 2023 is 1.401 units. The simulation showed the Swapping Station Population in 2023 result is 1.360,79The variance of error testing showed 0,028701 as the result, having a lower than 0,1 indicating that the variable of the model is valid. The variables of the validation for Extreme Value Validation Method are Domestic EM Industry Capacity, Domestic ICEM Industry Capacity, Capable Workforce to Buy Motorcycle Ratio, Workforce Population Rate, EM Purchase Incentives, Buying Power, Ideal Facility to EM Ratio, and Capability to Fulfill. Each of the tested variables will result in necessity classification consisting of Necessary, Moderately Necessary, and Not Necessary indicating that the variable has a relatively high influence towards the system or potential improvement scenario. Necessary variables consisting of Domestic EM Industry Capacity, Capable Workforce to Buy Motorcycle Ratio, Workforce Population Rate, and EM Purchase Incentives. Moderately Necessary variables are Domestic ICEM Industry Capacity, Buying Power, Ideal Facility to EM Ratio, and Capability to Fulfill.

5.2 Existing System Model Simulation Analysis

The existing system model simulation of the modeled stock flow diagram resulted in values of achievement that are still under the target. The target statement for the response variable is 13.469.000,00 units of Electric Motorcycle Population, 32.000,00 units of Charging Station Population, 67.000,00 units of Swapping Station Population, and 32,00% Emission Reduction from 2022 data. However, the prediction of the existing system resulted in 1.033.591,88 units of Electric Motorcycle Population, 91.383,06 units of Charging Station Population, 57.594,35 units of Swapping Station Population, and 40,25% Emission Reduction. The EM Population and Facility Population have an accelerating graph characteristic which is as expected. The Willingness to Adopt graph is decreasing at the first year due to sinking incentive quota and the number increasing with unstable pattern until 2027. The eCO2 Emission from ICEM produces a deacceleration graph line which is as expected. The achieved target is the Charging Station Population and Emission Reduction. The EM Population achievement is far from target with an achievement of 7,67%. The Swapping Station Population also does not achieve its target, but the achievement is far higher than Electric Motorcycle Population and closer to the target with 85,96% achievement. Thereby, improvements were made to focus on uplifting the unachieved target.

The unachieved target is mainly caused by the undeveloped and unstructured government effort to make the promotion of electric motorcycle adoption program persuasive. Until the present day, the most highlighted and marketed promotion is the incentive giving of Rp7.000.000,00 per electric motorcycle purchase. Even though incentive is given in large amount of discount value, it still needs sustainability to promote more than first 250.000 users. However, there are still many more persuasive acts and efforts that need to be done such as battery range improvement, tax reductions, motorcycle product variant increasement, and many more that affect the willingness to adopt to make the electric motorcycle features and product highly competitive compared with existing conventional motorcycle in any terms and aspect. When the willingness has increased, the supply of products and operational support must be provided by the government which is determined by Domestic EM Production Capacity, Charging and Swapping Station variable in the model. In summary, to achieve the target, the willingness to adopt and operational support must be boosted. Systematic improvements are also needed since the issue is categorized as complex cause-and-effect with closed loop relationship that may give future feedback.

5.3 Improvement Model Analysis

The improvement model scenario is modeled based on the modeler's intuition based on trial and error of the simulation. The author developed 6 improvement models with various scenarios throughout the electric motorcycle adoption subsystems. The improvement model consists of individual models and combined models. Individual models consist of Purchase Incentive Increase, Motorcycle Industry Shift, Facility Development, EM Battery Development, while the combined model is Mixed Scenario and Improved Mixed Scenario. The analysis is focused and segmented to the result of EM Population, CS Population, SS Population, and Emission Reduction at the year of target deadline which is 2030.

5.3.1 Scenario 1: Purchase Incentive Increase

The purchase incentive increase scenario focuses on the response variable of willingness to adopt, in the willingness to adopt subsystem, that is specifically affected by Average EM Selling Price Ratio. The variables affecting the Average EM Selling Price Ratio are EM Purchase Incentive, EM Purchase Tax, Average EM Market Price, and EM Population.

The input for the improvement is the change EM Purchase Incentive with a basis of 14,437% of the country's GDP per capita. The author used China as a reference for incentive benchmark due to the similarities in terms of economic growth which both countries have GDP Growth Rate above 5%. With calculations for implementation in Indonesia, the incentive will be valued in Rp10.254.601,00. For further support, EM Purchase Tax can be reduced to 0% of the market price. In the existing system, incentives were given only for 250.000 first purchases. The number of incentives quota can be increased to 500.000, two times the existing amount.

Thereby, this resulted in increasing amount of EM Population (1.189.811,33), CS Population (108.929,83), and SS Population (68.521,20). The result achieved the 2030 target of CS Population (340,41%) and SS Population (102,27%) but still not having to achieve EM Population (8,83%) 2030 target. However, Emission Reduction (40,07%) resulted in a slightly lower value than the result of the existing system simulation but still has the target achieved, which is higher than target of 32% of reduction. The first scenario result is figured in a graph where it has the same pattern and characteristics of the simulation result value as the existing condition. The EM Population and Facility Population have an accelerating graph characteristic which is as expected. The Willingness to Adopt graph is decreasing in the first year due to sinking incentive quota and the number having volatility after the sunk in 2023 until 2028. Later, the Willingness to Adopt is followed with a linear increase until the end of the simulation year. The eCO2 Emission from ICEM produces a deacceleration graph line which is as expected.

The anomaly of this scenario occurred on the increase amount of EM Population but having higher Emission and lower Emission Reductions. This is due to the significant increase of price after the incentive quota is out which influences people to adopt back to conventional motorcycle (ICEM). This scenario result indicates that sustainability of the adoption needs to be improved to a massively higher incentive quota due to the massive population of Indonesia. The increase of EM Population, CS Population, and SS Population are caused by the increasing amount of Willingness to Adopt variable that are affected directly by the Selling Price of EM due to increase of Incentives. By the analysis, it can be concluded that incentive does not fulfill the electric motorcycle adoption target.

5.3.2 Scenario 2: Motorcycle Industry Shift

The motorcycle industry shift scenario is performed in change of the domestic production capacity and variants that is available in the marketplace. The shifting affects inversely proportional between the ICEM and EM industries. The cue for the shifting is indicated by the Gross Domestic Product growth in manufacturing which is 5% in 2022.

The data input for the domestic EM and ICEM production capacity was initially at 1.427.000 and 6.867.217 consecutively. This scenario takes the assumption where the domestic production capacity of motorcycle in total holds the same sum value of 8.294.217 (total between EM and ICEM production capacity). The scenario focused on changing each of the production capacity with a rate of 5% shifting capability per year which also holds the same value as initial sum value of the conventional and electric motorcycle domestic production. This applies until the end of the simulation period. The GDP Growth works as a gap of improvement to the industry that is regulated to shift the industry from conventional to electric motorcycle productions. Then, the data input is put into graphical values in STELLA software.

Thereby, this resulted in increasing amount of EM Population (1.777.934,07), CS Population (124.831,08), and SS Population (78.423,34). This result achieved the 2030 target of CS Population (390,10%) and SS Population (117,05%) but still not having to achieve EM Population (13,20%) 2030 target. The Emission Reduction (39,55%) resulted in an even lower value than the result of the existing system simulation and incentive improvement scenario but still having the target achieved, which is higher than target of 32% of reduction. This is due to the incentive issue that has been discussed in previous analysis but also pops a new indication. The second scenario result is figured in graph with the similar pattern with steeper increase of EM population and decrease of emission at near the end of the simulation capture time. However, characteristics of the simulation result value are still the same as the existing condition and previous improvement with difference is on the scale of the graph and the higher value result of each variable. The EM Population and Facility Population have an accelerating graph characteristic which is as expected. The Willingness to Adopt graph is having stable change, the most stable early willingness to adopt change from the whole individual improvement scenario, during the early years from 2022 to 2024 followed with an acceleration until 2035. The eCO2 Emission from ICEM produces a deacceleration graph line which is as expected.

The second scenario summarizes that industry shift delivers the highest amount of EM Population compared to all four individual improvements as it is mainly indicated by an acceleration character of the Willingness to Adopt. However, it also summarizes that the higher the electric motorcycle population may not directly and significantly affect the decrease of conventional motorcycles (ICEM). This is due to the lack of policy to decrease the active conventional motorcycle (ICEM) users. This scenario also indicates that the industry shift will affect the electric motorcycle adoption only if the demand value is high enough to equal the maximum capacity of production to supply. If the value of demand is not high enough, the improvement will not work as effectively as to fulfill the target. By the analysis, it can be concluded that incentive does not fulfill the electric motorcycle adoption target.

5.3.3 Scenario 3: Facility Development

The facility development scenario focuses only on one variable in the simulation system which is the capability to fulfill the facility. The variable will affect the establishment of charging and swapping station as in the simulation flow.

The target of the capability to fulfill is increased to 90% of the whole demand in which mainly to support the operational activities of electric motorcycle. The fulfillment rate was initially at approximately 60,58% based on historical data of PLN facility fulfillment.

Thereby, the third scenario resulted in increasing amount of EM Population (1.389.075,73), CS Population (171.848,28), and SS Population (107.702,23). This result achieved the 2030 target of CS Population (537,03%) and SS Population (160,75%) but also still does not achieve the EM Population (10,31%) 2030 target. The Emission Reduction (39,89%) resulted in a still lower value than the result of the existing system simulation and incentive improvement scenario but still having the target achieved. This is due to the same issue that has been discussed in previous analysis. The third scenario result is figured in graph where it also has the similar pattern with steeper increase of EM population than existing system, but still lower than the industry shift scenario, and decrease of emission at near the end of the simulation capture time. However, characteristics of the simulation result value are still the same as the existing condition and previous improvement with difference is on the scale of the graph and the higher value result of each variable where focuses more on the increase of the battery facility population. The EM Population and Facility Population have an accelerating graph characteristic which is as expected. The Willingness to Adopt graph is decreasing at the first year due to sinking incentive quota and having unstable increase pattern until 2027 and increases linearly until end of simulation year. The eCO2 Emission from ICEM produces a deacceleration graph line which is as expected. The significant increase of battery facility population is caused by the increase of demand capability of facility fulfillment.

This scenario was one of the research focuses since the recommendation from previous research stated that one of the main adoption preferences is by providing facilities to support the operational. However, a lone effort of increasing the facility fulfillment itself was not enough to increase the adoption. A new indication was found in this scenario and previous scenario where there should be another factor to improve the adoption of electric motorcycle. By the analysis, it can be concluded that incentive does not fulfill the electric motorcycle adoption target and still needs another improvement scenario.

5.3.4 Scenario 4: EM Battery Development

This fourth scenario focuses on developing batteries for electric motorcycles. The battery development scenario is conducted due to one of the recommendations from previous research. In this scenario, it is focused on the variable of travel range (Average EM Battery Range) and the battery durability (EM Decrease Rate). The reference of the battery development rate was found in one of the world forums (IEA) of electric vehicles where development rate per year is 14,4%.

The data input for this improvement changes the average EM battery range from 175 to a graphical value of 14,4% increase per year with a maximum value of 285 (the average travel range of ICEM). The EM Decrease Rate variable uses also 14,4% of development rate indicating that the product lifespan increases 14,4% and will decrease the failure rate of the electric motorcycle. The decrease rate was initially at 0,2212 by the calculation of periodically failure rate of product with exponential distribution. With the increase, the value will decrease to 19,63% in the second year, 17,64% in the third year, and so forth until the final simulation year.

Thereby, the fourth scenario resulted in increasing amount of EM Population (1.650.153,05), CS Population (127.270,65), and SS Population (79.942,53). This result achieved the 2030 target of CS Population (397,72%) and SS Population (119,32%) but also still does not achieve the EM Population (12,25%) 2030 target. The Emission Reduction (39,87%) resulted in a still lower value than the result of the existing system simulation and incentive improvement scenario but still having the target achieved. This is due to the same issue that has been discussed in previous analysis. The fourth scenario result is figured in graph where it also has the same pattern and characteristics as three previous improvements. The only difference is on the scale of the graph and the value result of each variable where focuses more on the increase of the electric motorcycle population increase which is higher than incentive and facility development scenario but having lower value than the industry shift scenario. The EM Population and Facility

Population have an accelerating graph characteristic which is as expected. The Willingness to Adopt graph is decreasing at the first year due to sinking incentive quota and the number increasing with unstable pattern until 2027 and followed with a linear increase until the end of the simulation year. The eCO2 Emission from ICEM produces a deacceleration graph line which is as expected. The significant increase of EM population is caused by the increase of willingness to adopt by the EM battery range ratio increase.

In summary, after the journey of improving by developing 4 segmented individual scenarios, EM Battery Development gives a high EM Population result in 2030 which is ranked two out of four individual scenarios giving that Battery Development is a considerable improvement. However, the four improvements scenario still cannot achieve the electric motorcycle target.

5.3.5 Scenario 5: Mixed Scenario

The fifth scenario focuses on integrating all four individual scenarios with the same data input for each improved variable. The mixed scenario is influenced by the unachieved target for each of the individual improvement scenarios that could not work effectively if were improved in only one improvement segmentation. The author summarized from previous improvement that the issue of electric motorcycle adoption is a systematic cause-and-effect that needs to be improved structurally from whole aspects. The aspect includes the willingness to adopt preferences, supporting facility for operational when populations are on the target, and supply from domestic industry capacity. All the processes are integrated as a systematic flow in the system with a causal loop between one and another.

The data input for the simulation uses the same input as previous improvements. The input value of previous improvement is put into one system so that the result will improve systematically.

Thereby, the fifth scenario resulted in a massive increasing amount of EM Population (4.569.992,66), CS Population (455.861,32), and SS Population (284.564,90). This result massively achieved the 2030 target of CS Population (1424,57%) and SS Population (424,72%). However, the result still does not achieve the EM Population (33,93%) 2030 target, only increased three times from average result of previous scenario. The Emission Reduction (37,35%) resulted in a relatively lowest value than all the previous improvement results and the existing system simulation result still has the target achieved. The graph and patterns behave acceleratively the same as previous improvement with only higher result the EM and battery facilities population. The EM Population and Facility Population have an accelerating graph characteristic which is as expected. The Willingness to Adopt graph is accelerating from 2023 to the end of the simulation year. The eCO2 Emission from ICEM produces a deacceleration graph line which is as expected.

This result indicates that the integrated scenario needs an adjustment within its input value to fulfill the target. Most of the adjustment should be on the promotion and willingness to adopt subsystem to initiate utilization of electric motorcycle. The willingness to adopt subsystem should be modeled with an input that has worthiness value higher of electric motorcycle willingness to adopt than conventional motorcycle (ICEM).The second most adjustment should be on domestic capacity variable to supply the incoming massive response from the willingness to adopt variable increase. For supporting facility subsystem can accommodate the operational if the value is already on

90% of fulfillment with an indication of success level that has been achieved from this scenario. Therefore, a new scenario is needed with adjusted values in willingness to adopt and production capacity.

5.3.6 Scenario 6: Improved Mixed Scenario

The sixth scenario focuses on improving the integrated scenario that has been conducted previously. The improved mixed scenario is influenced by the insufficient achievement for each of the individual improvement scenarios that could not work effectively if were improved in only one improvement segmentation. The author summarized from previous mixed scenario that the acceleration is needed systematically from willingness to adopt to promote and domestic production capacity to fulfill demand.

The data input for the simulation uses different input as previous mixed scenario. This scenario increases the domestic production capacity shifting and variants increase rate to 15% per year (three times of the original improvement).

Thereby, the sixth scenario resulted in a massive increasing amount of EM Population (19.300.707,53), CS Population (1.299.452,40), and SS Population (809.892,07). This result massively achieved the 2030 target of CS Population (4060,79%) and SS Population (1208,79%). In this scenario, the EM Population finally fulfills its target with an achievement of 143,30% from the 13.469.000-unit target by 2030. The Emission Reduction (39,43%) resulted in a relatively lower value than all the previous improvement results except the unenhanced mixed scenario and the existing system simulation result still have the target achieved. However, if compared to the 2035 emission data, the emission is much lower, and the reduction is higher than the other four improvements. The EM Population and Facility Population have an accelerating graph characteristic which is as expected. The Willingness to Adopt graph is accelerating from 2023 to the end of the simulation year. The eCO2 Emission from ICEM produces a deacceleration graph line which is as expected. This scenario finally fulfills all the target of measurement that has been set by the government. The sixth scenario success indicates the minimum value of input to achieve the whole target by 2030.

The improved mixed scenario summarizes that the electric motorcycle adoption system is a complex, systematic, cause-and-effect system that needs whole aspect consideration. The main drive of electric motorcycle adoption is the willingness to adopt and preference. This aspect needs to have value far higher than the worth of the existing conventional motorcycle at any aspect such as travel ranges, variants, pricing, supporting facility, and even production capacity to supply. However, the attempt must be noted as only for electric motorcycle adoption, not to decrease the number of conventional motorcycles. In this system, the conventional motorcycle will always exist in a large amount until the demand cannot be fulfilled by the production capacity and all the active conventional motorcycles have reached the end of their product lifespan. Therefore, to decrease the conventional motorcycle and emission, a further policy must be regulated to control and decrease the active conventional motorcycle and force them shift to electric motorcycle.

5.4 Simulation Result Comparison Analysis

After conducting all the simulation, a comparison is necessary between the existing system and all the improvement scenarios. In summary of whole simulation result, the best result for EM Population (19.300.707,53), CS Population (1.299.452,40), and SS Population (809.892,07) is on the sixth scenario by using the improved mixed scenario. However, the best

Emission Reduction achievement is still held by the existing condition at the year 2030 (125,77%) and followed with the incentive scenario (125,22%) as second place. To look further into sustainability of emission reductions indicated by the Emission in 2035, the best result is on the improved mixed scenario (23.492.496,28), existing system (24.604.852,87), and followed by incentive scenario (24.848.150,79) with only slight differences between the existing condition and the best improvement. This indicates that the sustainability for the improved mixed scenario is considered better than other improvements.

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CHAPTER 6
CONCLUSION AND SUGGESTION

The conclusion and suggestion chapter are the final phase of the research which consists of the answering of the electric motorcycle adoption research objective and to give recommendations for stakeholders of electric motorcycle adoption.

6.1 Conclusion

From the conducted research, the conclusion to answer the electric motorcycle adoption research objectives are as stated in points below.

1. The Electric Motorcycle Adoption Research focuses on designing the electric motorcycle adoption system by using system dynamics with the main purpose to reduce the emission contribution by 32% by accelerating the electric motorcycle adoption until reaches 13.469.000 units in 2030. The designing of system dynamics model utilizes causal loop diagram to model the cause-and-effect relationship between variables of the system and stock flow diagram to model the material and information flow of the system with time functions. The author gathers information of the existing condition where the main system is divided into four subsystems based on their system workflow, variable segments, and characteristics. The subsystems are Motorcycle Subsystem, Workforce Population Subsystem, Willingness to Adopt Subsystem, and Supporting Facility Subsystem. The main initiator of the system is the Workforce Population Subsystem that triggers the demand. The Willingness to Adopt Subsystems focuses on determining adoption preferences. The Motorcycle Subsystem is the core of the system where it responds from the Workforce Population Subsystem and Willingness to Adopt Subsystem. It will flow the physical material of motorcycles both electric and conventional followed with the emission. The Supporting Facility Subsystem receives demand from Electric Motorcycle Population and flows it back to the Willingness to Adopt in terms of operational support where it flows as the big loop of the system.
2. The impact of the existing simulation predicts the future condition and measures the existing performance by comparing it to the target that has been set by the government. The existing condition resulted in success for Charging Station (CS) Population at 340,41% achievement and Emission Reduction at 125,77% achievement as of 2030. Swapping Station (SS) Target did not fulfill the expectation since it only reached 85,96%. However, the main variable, Electric Motorcycle Population did not reach its target with a value of achievement only at 7,67% of achievement. Thereby, a structured improvement is needed to boost the achievement of Electric Motorcycle Population by considering the whole entities in system since it is a very systematic, complex, and cause-and-effect based issue.
3. The alternative policy scenarios are developed by the author reaching 6 scenarios consisting of 4 being individual and segmented scenarios, and 2 scenarios being mixed scenarios of the individuals. The best scenario went to the improved mixed scenario where it focuses on improving 3 subsystems consisting of Willingness to Adopt Subsystem to initiate and trigger adoption at a larger scale, Domestic Productions of Conventional Motorcycle Industry shifting to Electric Motorcycle in the Motorcycle Subsystem to supply demand and Increase of the Facility Fulfillment to maintain operational of the active electric motorcycle. The improved mixed scenario resulted in 143,30% achievement of Electric Motorcycle Population,

4060,79% achievement of Charging Station Population, 1208,79% achievement of Swapping Station Population, and 123,22% achievement of Emission Reduction relative to the 32% target. The value that needs to be maximized to achieve the Electric Motorcycle adoption is the Willingness to Adopt ratio where it compares the preference whether adopts to Electric Motorcycle and Conventional Motorcycle (ICEM). The Electric Motorcycle features and functions must be competitive and worth much more than the conventional. After the preferences have settled to Electric Motorcycles, the supply and operational support of Electric Motorcycle must be developed such as supply availability and supporting facilities that consists of Battery Charging and Swapping Stations. The Conventional Motorcycle Population and its emission impacts the same as any improvement scenario since there are no direct policy to control Conventional Motorcycles and the behavior of the society prefers to shift only if their transportation mode, Conventional Motorcycles, has reached the end of their product lifespan. Otherwise, the Conventional Motorcycle population won't decrease drastically. Therefore, to reduce emission to a better state, a policy to control the reduction of Conventional Motorcycles must be developed with full consideration.

6.2 Suggestion

From the conducted research, there are suggestions that may be considered for all related stakeholders of the electric motorcycle adoption.

1. The next related research that has focus on emission reduction in Indonesia may consider a new research scope and limitation that focuses on policy development to minimize active conventional motorcycle and/or cars and their emissions.
2. The next related research that has focus on supporting facilities of operational may consider to detail aspects to fulfill electric vehicle facility demand by the Indonesian government and/or private sectors.
3. The next related research that has focused on achieving optimal motorcycle adoption may consider using optimization research method to produce an exact value of improvement.
4. The next related research that focuses on electric vehicle adoption may consider reaching credible stakeholders to fully validate the existing condition of the system.
5. The next related research that focuses on electric vehicle adoption may consider dividing motorcycle adopter characteristics based on technology adopter characteristics theories.
6. The next related research that focuses on electric vehicle adoption emission impact may consider in capturing emission on the energy production upstream.

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APPENDIX

Appendix 1. Existing Electric Motorcycle Adoption System Model Equation

CS_Population(t) = CS_Population(t - dt) + (CS_Establishment) * dt

INIT CS_Population = 439

INFLOWS:

CS_Establishment = Battery_Facility_Demand*CS_Preference*Capability_to_Fulfill

EM_Population(t) = EM_Population(t - dt) + (EM_Demand_Fulfillment - EM_Decrease) * dt

INIT EM_Population = 17198

INFLOWS:

EM_Demand_Fulfillment = if(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)

OUTFLOWS:

EM_Decrease = EM_Decrease_Rate*EM_Population

ICEM_Population(t) = ICEM_Population(t - dt) + (ICEM_Demand_Fulfillment - ICEM_Decrease) * dt

INIT ICEM_Population = 125305332

INFLOWS:

ICEM_Demand_Fulfillment = if(ICEM_Demand>Domestic_ICEM_Industry_Capacity) THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)

OUTFLOWS:

ICEM_Decrease = ICEM_Decrease_Rate*ICEM_Population

Population_of_Indonesia(t) = Population_of_Indonesia(t - dt) + (Population_Change) * dt

INIT Population_of_Indonesia = 275773800

INFLOWS:

Population_Change = Population_of_Indonesia*Population_Change_Rate

SS_Population(t) = SS_Population(t - dt) + (SS_Establishment) * dt

INIT SS_Population = 961

INFLOWS:

SS_Establishment = SS_Preference*Battery_Facility_Demand*Capability_to_Fulfill

Average_EM_Battery_Range = 175

Average_EM_Market_Price = 34720000

Average_EM_Selling_Price = MAX(

(IF(EM_Population<250000)

THEN((Average_EM_Market_Price-EM_Purchasing_Incentive)*(1+EM_Purchase__Tax))

ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)

Average_ICEM_Range = 285

Battery_Facility_Demand = EM_Population*(Ideal_Facility_to_EM_Ratio)

Battery_Facility_to_EM_Ratio = (CS_Population+SS_Population)/EM_Population

Battery_Station_Preference = 4.11+6.6

Buying_Power = 15053568

Capability_to_Fulfill = 0.605763

Capable_Workforce_to_Buy_Motorcycle = Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

Capable_Workforce_to_Buy_Motorcycle_Ratio = 0.9414

CS_Preference = 6.6/Battery_Station_Preference

Domestic_EM_Industry_Capacity = 1427000

Domestic_ICEM_Industry_Capacity = 6867217

eCO2_Emssion_from_ICEM = ICEM_Population*ICEM_eCO2_Rate

EM_Decrease_Rate = 0.2212

EM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

EM_Purchase__Tax = 0.1

EM_Purchasing_Incentive = 7000000

EM_Selling_Price_Ratio = EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)

EM_Variants = 61

EM_Variant_Ratio = EM_Variants/ICEM_Variants

EM_Willingness_to_Adopt = (Battery_Facility_to_EM_Ratio)*EM_Selling_Price_Ratio*Range_Ratio

ICEM_Decrease_Rate = 0.0645

ICEM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

ICEM_eCO2_Rate = 0.432

ICEM_Variants = 300

Ideal_Facility_to_EM_Ratio = 0.1

Motorcycle_Demand = Capable_Workforce_to_Buy_Motorcycle-(EM_Population+ICEM_Population)

Population_Change_Rate = 0.0117

Range_Ratio = Average_EM_Battery_Range/Average_ICEM_Range

SS_Preference = 4.11/Battery_Station_Preference

Workforce_Population = Workforce_Population_Rate*Population_of_Indonesia

Workforce_Population_Rate = 0.7594*0.6863

Appendix 2. Incentive Increase Improvement Scenario Equation

CS_Population(t) = CS_Population(t - dt) + (CS_Establishment) * dt

INIT CS_Population = 439

INFLOWS:

CS_Establishment = Battery_Facility_Demand*CS_Preference*Capability_to_Fulfill

EM_Population(t) = EM_Population(t - dt) + (EM_Demand_Fulfillment - EM_Decrease) * dt

INIT EM_Population = 17198

INFLOWS:

EM_Demand_Fulfillment = if(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)

OUTFLOWS:

EM_Decrease = EM_Decrease_Rate*EM_Population

ICEM_Population(t) = ICEM_Population(t - dt) + (ICEM_Demand_Fulfillment - ICEM_Decrease) * dt

INIT ICEM_Population = 125305332

INFLOWS:

ICEM_Demand_Fulfillment = if(ICEM_Demand>Domestic_ICEM_Industry_Capacity)THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)

OUTFLOWS:

ICEM_Decrease = ICEM_Decrease_Rate*ICEM_Population

Population_of_Indonesia(t) = Population_of_Indonesia(t - dt) + (Population_Change) * dt

INIT Population_of_Indonesia = 275773800

INFLOWS:

Population_Change = Population_of_Indonesia*Population_Change_Rate

SS_Population(t) = SS_Population(t - dt) + (SS_Establishment) * dt

INIT SS_Population = 961

INFLOWS:

SS_Establishment = SS_Preference*Battery_Facility_Demand*Capability_to_Fulfill

Average_EM_Battery_Range = 175

Average_EM_Market_Price = 34720000

Average_EM_Selling_Price = MAX(

(IF(EM_Population<500000)

THEN((Average_EM_Market_Price-EM_Purchase_Incentive)*(1+EM_Purchase__Tax))

ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)

Average_ICEM_Range = 285

Battery_Facility_Demand = EM_Population*(Ideal_Facility_to_EM_Ratio)

Battery_Facility_to_EM_Ratio = (CS_Population+SS_Population)/EM_Population

Battery_Station_Preference = 4.11+6.6

Buying_Power = 15053568

Capability_to_Fulfill = 0.605763

Capable_Workforce_to_Buy_Motorcycle = Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

Capable_Workforce_to_Buy_Motorcycle_Ratio = 0.9414

CS_Preference = 6.6/Battery_Station_Preference

Domestic_EM_Industry_Capacity = 1427000

Domestic_ICEM_Industry_Capacity = 6867217

eCO2_Emssion_from_ICEM = ICEM_Population*ICEM_eCO2_Rate

EM_Decrease_Rate = 0.2212

EM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

EM_Purchase_Incentive = 10254601

EM_Purchase__Tax = 0

EM_Selling_Price_Ratio = EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)

EM_Variants = 61

EM_Variant_Ratio = EM_Variants/ICEM_Variants

EM_Willingness_to_Adopt = (Battery_Facility_to_EM_Ratio)*EM_Selling_Price_Ratio*Range_Ratio

ICEM_Decrease_Rate = 0.0645

ICEM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

ICEM_eCO2_Rate = 0.432

ICEM_Variants = 300

Ideal_Facility_to_EM_Ratio = 0.1

Motorcycle_Demand = Capable_Workforce_to_Buy_Motorcycle-(EM_Population+ICEM_Population)

Population_Change_Rate = 0.0117

Range_Ratio = Average_EM_Battery_Range/Average_ICEM_Range

SS_Preference = 4.11/Battery_Station_Preference

Workforce_Population = Workforce_Population_Rate*Population_of_Indonesia

Workforce_Population_Rate = 0.7594*0.6863

Appendix 3. Motorcycle Industry Shift Improvement Scenario Equation

CS_Population(t) = CS_Population(t - dt) + (CS_Establishment) * dt

INIT CS_Population = 439

INFLOWS:

CS_Establishment = Battery_Facility_Demand*CS_Preference*Capability_to_Fulfill

EM_Population(t) = EM_Population(t - dt) + (EM_Demand_Fulfillment - EM_Decrease) * dt

INIT EM_Population = 17198

INFLOWS:

EM_Demand_Fulfillment = if(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)

OUTFLOWS:

EM_Decrease = EM_Decrease_Rate*EM_Population

ICEM_Population(t) = ICEM_Population(t - dt) + (ICEM_Demand_Fulfillment - ICEM_Decrease) * dt

INIT ICEM_Population = 125305332

INFLOWS:

ICEM_Demand_Fulfillment = if(ICEM_Demand>Domestic_ICEM_Industry_Capacity) THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)

OUTFLOWS:

ICEM_Decrease = ICEM_Decrease_Rate*ICEM_Population

Population_of_Indonesia(t) = Population_of_Indonesia(t - dt) + (Population_Change) * dt

INIT Population_of_Indonesia = 275773800

INFLOWS:

Population_Change = Population_of_Indonesia*Population_Change_Rate

SS_Population(t) = SS_Population(t - dt) + (SS_Establishment) * dt

INIT SS_Population = 961

INFLOWS:

SS_Establishment = SS_Preference*Battery_Facility_Demand*Capability_to_Fulfill

Average_EM_Battery_Range = 175

Average_EM_Market_Price = 34720000

Average_EM_Selling_Price = MAX(

(IF(EM_Population<250000)

THEN((Average_EM_Market_Price-EM_Purchase_Incentive)*(1+EM_Purchase__Tax))

ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)

Average_ICEM_Range = 285

Battery_Facility_Demand = EM_Population*(Ideal_Facility_to_EM_Ratio)

Battery_Facility_to_EM_Ratio = (CS_Population+SS_Population)/EM_Population

Battery_Station_Preference = 4.11+6.6

Buying_Power = 15053568

Capability_to_Fulfill = 0.605763

Capable_Workforce_to_Buy_Motorcycle = Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

Capable_Workforce_to_Buy_Motorcycle_Ratio = 0.9414

CS_Preference = 6.6/Battery_Station_Preference

eCO2_Emssion_from_ICEM = ICEM_Population*ICEM_eCO2_Rate

EM_Decrease_Rate = 0.2212

EM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

EM_Purchase_Incentive = 7000000

EM_Purchase__Tax = 0.1

EM_Selling_Price_Ratio = EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)

EM_Variant_Ratio = EM_Variants/ICEM_Variants

EM_Willingness_to_Adopt = (Battery_Facility_to_EM_Ratio)*EM_Selling_Price_Ratio*Range_Ratio

ICEM_Decrease_Rate = 0.0645

ICEM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

ICEM_eCO2_Rate = 0.432

Ideal_Facility_to_EM_Ratio = 0.1

Motorcycle_Demand = Capable_Workforce_to_Buy_Motorcycle-(EM_Population+ICEM_Population)

Population_Change_Rate = 0.0117

Range_Ratio = Average_EM_Battery_Range/Average_ICEM_Range

SS_Preference = 4.11/Battery_Station_Preference

Workforce_Population = Workforce_Population_Rate*Population_of_Indonesia

Workforce_Population_Rate = 0.7594*0.6863

Domestic_EM_Industry_Capacity = GRAPH(TIME)

(2022, 1.4e+006), (2023, 1.8e+006), (2024, 2.2e+006), (2025, 2.6e+006), (2026, 3e+006), (2027, 3.5e+006), (2028, 3.9e+006), (2029, 4.3e+006), (2030, 4.7e+006), (2031, 5.1e+006), (2032, 5.5e+006), (2033, 5.9e+006), (2034, 6.3e+006), (2035, 0.00)

Domestic_ICEM_Industry_Capacity = GRAPH(TIME)

(2022, 6.9e+006), (2023, 6.5e+006), (2024, 6.1e+006), (2025, 5.7e+006), (2026, 5.2e+006), (2027, 4.8e+006), (2028, 4.4e+006), (2029, 4e+006), (2030, 3.6e+006), (2031, 3.2e+006), (2032, 2.8e+006), (2033, 2.4e+006), (2034, 2e+006), (2035, 0.00)

EM_Variants = GRAPH(TIME)

(2022, 61.0), (2023, 64.0), (2024, 67.0), (2025, 70.0), (2026, 74.0), (2027, 77.0), (2028, 82.0), (2029, 86.0), (2030, 90.0), (2031, 95.0), (2032, 99.0), (2033, 104), (2034, 110), (2035, 115)

ICEM_Variants = GRAPH(TIME)

(2022, 300), (2023, 282), (2024, 264), (2025, 246), (2026, 228), (2027, 210), (2028, 192), (2029, 174), (2030, 156), (2031, 138), (2032, 120), (2033, 101), (2034, 83.0), (2035, 65.0)

Appendix 4. Facility Development Improvement Scenario Equation

CS_Population(t) = CS_Population(t - dt) + (CS_Establishment) * dt

INIT CS_Population = 439

INFLOWS:

CS_Establishment = Battery_Facility_Demand*CS_Preference*Capability_to_Fulfill

EM_Population(t) = EM_Population(t - dt) + (EM_Demand_Fulfillment - EM_Decrease) * dt

INIT EM_Population = 17198

INFLOWS:

EM_Demand_Fulfillment = if(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)

OUTFLOWS:

EM_Decrease = EM_Decrease_Rate*EM_Population

ICEM_Population(t) = ICEM_Population(t - dt) + (ICEM_Demand_Fulfillment - ICEM_Decrease) * dt

INIT ICEM_Population = 125305332

INFLOWS:

ICEM_Demand_Fulfillment = if(ICEM_Demand>Domestic_ICEM_Industry_Capacity) THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)

OUTFLOWS:

ICEM_Decrease = ICEM_Decrease_Rate*ICEM_Population

Population_of_Indonesia(t) = Population_of_Indonesia(t - dt) + (Population_Change) * dt

INIT Population_of_Indonesia = 275773800

INFLOWS:

Population_Change = Population_of_Indonesia*Population_Change_Rate

SS_Population(t) = SS_Population(t - dt) + (SS_Establishment) * dt

INIT SS_Population = 961

INFLOWS:

SS_Establishment = SS_Preference*Battery_Facility_Demand*Capability_to_Fulfill

Average_EM_Battery_Range = 175

Average_EM_Market_Price = 34720000

Average_EM_Selling_Price = MAX(

(IF(EM_Population<250000)

THEN((Average_EM_Market_Price-EM_Purchase_Incentive)*(1+EM_Purchase__Tax))

ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)

Average_ICEM_Range = 285

Battery_Facility_Demand = EM_Population*(Ideal_Facility_to_EM_Ratio)

Battery_Facility_to_EM_Ratio = (CS_Population+SS_Population)/EM_Population

Battery_Station_Preference = 4.11+6.6

Buying_Power = 15053568

Capability_to_Fulfill = 0.9

Capable_Workforce_to_Buy_Motorcycle = Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

Capable_Workforce_to_Buy_Motorcycle_Ratio = 0.9414

CS_Preference = 6.6/Battery_Station_Preference

Domestic_EM_Industry_Capacity = 1427000

Domestic_ICEM_Industry_Capacity = 6867217

eCO2_Emssion_from_ICEM = ICEM_Population*ICEM_eCO2_Rate

EM_Decrease_Rate = 0.2212

EM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

EM_Purchase_Incentive = 7000000

EM_Purchase__Tax = 0.1

EM_Selling_Price_Ratio = EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)

EM_Variants = 61

EM_Variant_Ratio = EM_Variants/ICEM_Variants

EM_Willingness_to_Adopt = (Battery_Facility_to_EM_Ratio)*EM_Selling_Price_Ratio*Range_Ratio

ICEM_Decrease_Rate = 0.0645

ICEM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

ICEM_eCO2_Rate = 0.432

ICEM_Variants = 300

Ideal_Facility_to_EM_Ratio = 0.1

Motorcycle_Demand = Capable_Workforce_to_Buy_Motorcycle-(EM_Population+ICEM_Population)

Population_Change_Rate = 0.0117

Range_Ratio = Average_EM_Battery_Range/Average_ICEM_Range

SS_Preference = 4.11/Battery_Station_Preference

Workforce_Population = Workforce_Population_Rate*Population_of_Indonesia

Workforce_Population_Rate = 0.7594*0.6863

Appendix 5. EM Battery Development Improvement Scenario Equation

CS_Population(t) = CS_Population(t - dt) + (CS_Establishment) * dt

INIT CS_Population = 439

INFLOWS:

CS_Establishment = Battery_Facility_Demand*CS_Preference*Capability_to_Fulfill

EM_Population(t) = EM_Population(t - dt) + (EM_Demand_Fulfillment - EM_Decrease) * dt

INIT EM_Population = 17198

INFLOWS:

EM_Demand_Fulfillment = if(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)

OUTFLOWS:

EM_Decrease = EM_Decrease_Rate*EM_Population

ICEM_Population(t) = ICEM_Population(t - dt) + (ICEM_Demand_Fulfillment - ICEM_Decrease) * dt

INIT ICEM_Population = 125305332

INFLOWS:

ICEM_Demand_Fulfillment = if(ICEM_Demand>Domestic_ICEM_Industry_Capacity) THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)

OUTFLOWS:

ICEM_Decrease = ICEM_Decrease_Rate*ICEM_Population

Population_of_Indonesia(t) = Population_of_Indonesia(t - dt) + (Population_Change) * dt

INIT Population_of_Indonesia = 275773800

INFLOWS:

Population_Change = Population_of_Indonesia*Population_Change_Rate

SS_Population(t) = SS_Population(t - dt) + (SS_Establishment) * dt

INIT SS_Population = 961

INFLOWS:

SS_Establishment = SS_Preference*Battery_Facility_Demand*Capability_to_Fulfill

Average_EM_Market_Price = 34720000

Average_EM_Selling_Price = MAX(

(IF(EM_Population<250000)

THEN((Average_EM_Market_Price-EM_Purchase_Incentive)*(1+EM_Purchase__Tax))

ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)

Average_ICEM_Range = 285

Battery_Facility_Demand = EM_Population*(Ideal_Facility_to_EM_Ratio)

Battery_Facility_to_EM_Ratio = (CS_Population+SS_Population)/EM_Population

Battery_Station_Preference = 4.11+6.6

Buying_Power = 15053568

Capability_to_Fulfill = 0.605763

Capable_Workforce_to_Buy_Motorcycle = Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

Capable_Workforce_to_Buy_Motorcycle_Ratio = 0.9414

CS_Preference = 6.6/Battery_Station_Preference

Domestic_EM_Industry_Capacity = 1427000

Domestic_ICEM_Industry_Capacity = 6867217

eCO2_Emssion_from_ICEM = ICEM_Population*ICEM_eCO2_Rate

EM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

EM_Purchase_Incentive = 7000000

EM_Purchase__Tax = 0.1

EM_Selling_Price_Ratio = EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)

EM_Variants = 61

EM_Variant_Ratio = EM_Variants/ICEM_Variants

EM_Willingness_to_Adopt = (Battery_Facility_to_EM_Ratio)*EM_Selling_Price_Ratio*Range_Ratio

ICEM_Decrease_Rate = 0.0645

ICEM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

ICEM_eCO2_Rate = 0.432

ICEM_Variants = 300

Ideal_Facility_to_EM_Ratio = 0.1

Motorcycle_Demand = Capable_Workforce_to_Buy_Motorcycle-(EM_Population+ICEM_Population)

Population_Change_Rate = 0.0117

Range_Ratio = Average_EM_Battery_Range/Average_ICEM_Range

SS_Preference = 4.11/Battery_Station_Preference

Workforce_Population = Workforce_Population_Rate*Population_of_Indonesia

Workforce_Population_Rate = 0.7594*0.6863

Average_EM_Battery_Range = GRAPH(TIME)

(2022, 175), (2023, 200), (2024, 225), (2025, 251), (2026, 276), (2027, 285), (2028, 285), (2029, 285), (2030, 285), (2031, 285), (2032, 285), (2033, 285), (2034, 285), (2035, 0.00)

EM_Decrease_Rate = GRAPH(TIME)

(2022, 0.221), (2023, 0.196), (2024, 0.176), (2025, 0.16), (2026, 0.147), (2027, 0.135), (2028, 0.126), (2029, 0.117), (2030, 0.11), (2031, 0.103), (2032, 0.0974), (2033, 0.092), (2034, 0.088), (2035, 0.0834)

Appendix 6. Mixed Improvement Scenario Equation

CS_Population(t) = CS_Population(t - dt) + (CS_Establishment) * dt

INIT CS_Population = 439

INFLOWS:

CS_Establishment = Battery_Facility_Demand*CS_Preference*Capability_to_Fulfill

EM_Population(t) = EM_Population(t - dt) + (EM_Demand_Fulfillment - EM_Decrease) * dt

INIT EM_Population = 17198

INFLOWS:

EM_Demand_Fulfillment = if(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)

OUTFLOWS:

EM_Decrease = EM_Decrease_Rate*EM_Population

ICEM_Population(t) = ICEM_Population(t - dt) + (ICEM_Demand_Fulfillment - ICEM_Decrease) * dt

INIT ICEM_Population = 125305332

INFLOWS:

ICEM_Demand_Fulfillment = if(ICEM_Demand>Domestic_ICEM_Industry_Capacity) THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)

OUTFLOWS:

ICEM_Decrease = ICEM_Decrease_Rate*ICEM_Population

Population_of_Indonesia(t) = Population_of_Indonesia(t - dt) + (Population_Change) * dt

INIT Population_of_Indonesia = 275773800

INFLOWS:

Population_Change = Population_of_Indonesia*Population_Change_Rate

SS_Population(t) = SS_Population(t - dt) + (SS_Establishment) * dt

INIT SS_Population = 961

INFLOWS:

SS_Establishment = SS_Preference*Battery_Facility_Demand*Capability_to_Fulfill

Average_EM_Market_Price = 34720000

Average_EM_Selling_Price = MAX(

(IF(EM_Population<500000)

THEN((Average_EM_Market_Price-EM_Purchase_Incentive)*(1+EM_Purchase__Tax))

ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)

Average_ICEM_Range = 285

Battery_Facility_Demand = EM_Population*(Ideal_Facility_to_EM_Ratio)

Battery_Facility_to_EM_Ratio = (CS_Population+SS_Population)/EM_Population

Battery_Station_Preference = 4.11+6.6

Buying_Power = 15053568

Capability_to_Fulfill = 1

Capable_Workforce_to_Buy_Motorcycle =
Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

Capable_Workforce_to_Buy_Motorcycle_Ratio = 0.9414

CS_Preference = 6.6/Battery_Station_Preference

eCO2_Emssion_from_ICEM = ICEM_Population*ICEM_eCO2_Rate

EM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

EM_Purchase_Incentive = 10254601

EM_Purchase__Tax = 0

EM_Selling_Price_Ratio = EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)

EM_Variant_Ratio = EM_Variants/ICEM_Variants

EM_Willingness_to_Adopt =
(Battery_Facility_to_EM_Ratio)*EM_Selling_Price_Ratio*Range_Ratio

ICEM_Decrease_Rate = 0.0645

ICEM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

ICEM_eCO2_Rate = 0.432

Ideal_Facility_to_EM_Ratio = 0.1

Motorcycle_Demand = Capable_Workforce_to_Buy_Motorcycle-
(EM_Population+ICEM_Population)

Population_Change_Rate = 0.0117

Range_Ratio = Average_EM_Battery_Range/Average_ICEM_Range

SS_Preference = 4.11/Battery_Station_Preference

Workforce_Population = Workforce_Population_Rate*Population_of_Indonesia

Workforce_Population_Rate = 0.7594*0.6863

Average_EM_Battery_Range = GRAPH(TIME)

(2022, 175), (2023, 200), (2024, 225), (2025, 251), (2026, 276), (2027, 285), (2028, 285), (2029, 285), (2030, 285), (2031, 285), (2032, 285), (2033, 285), (2034, 285), (2035, 285)

Domestic_EM_Industry_Capacity = GRAPH(TIME)

(2022, 1.4e+006), (2023, 1.8e+006), (2024, 2.2e+006), (2025, 2.6e+006), (2026, 3e+006), (2027, 3.5e+006), (2028, 3.9e+006), (2029, 4.3e+006), (2030, 4.7e+006), (2031, 5.1e+006), (2032, 5.5e+006), (2033, 5.9e+006), (2034, 6.3e+006), (2035, 6.7e+006)

Domestic_ICEM_Industry_Capacity = GRAPH(TIME)

(2022, 6.9e+006), (2023, 6.5e+006), (2024, 6.1e+006), (2025, 5.7e+006), (2026, 5.2e+006), (2027, 4.8e+006), (2028, 4.4e+006), (2029, 4e+006), (2030, 3.6e+006), (2031, 3.2e+006), (2032, 2.8e+006), (2033, 2.4e+006), (2034, 2e+006), (2035, 1.6e+006)

EM_Decrease_Rate = GRAPH(TIME)

(2022, 0.221), (2023, 0.196), (2024, 0.176), (2025, 0.16), (2026, 0.147), (2027, 0.135), (2028, 0.126), (2029, 0.117), (2030, 0.11), (2031, 0.103), (2032, 0.0974), (2033, 0.092), (2034, 0.088), (2035, 0.0834)

EM_Variants = GRAPH(TIME)

(2022, 61.0), (2023, 64.0), (2024, 67.0), (2025, 70.0), (2026, 74.0), (2027, 77.0), (2028, 81.0), (2029, 85.0), (2030, 89.0), (2031, 94.0), (2032, 98.0), (2033, 103), (2034, 108), (2035, 113)

ICEM_Variants = GRAPH(TIME)

(2022, 300), (2023, 282), (2024, 264), (2025, 246), (2026, 228), (2027, 210), (2028, 192), (2029, 174), (2030, 156), (2031, 138), (2032, 120), (2033, 101), (2034, 83.0), (2035, 65.0)

Appendix 7. Improved Mixed Scenario Equation

CS_Population(t) = CS_Population(t - dt) + (CS_Establishment) * dt

INIT CS_Population = 439

INFLOWS:

CS_Establishment = Battery_Facility_Demand*CS_Preference*Capability_to_Fulfill

EM_Population(t) = EM_Population(t - dt) + (EM_Demand_Fulfillment - EM_Decrease) * dt

INIT EM_Population = 17198

INFLOWS:

EM_Demand_Fulfillment = if(EM_Demand>Domestic_EM_Industry_Capacity) THEN(Domestic_EM_Industry_Capacity) ELSE(EM_Demand)

OUTFLOWS:

EM_Decrease = EM_Decrease_Rate*EM_Population

ICEM_Population(t) = ICEM_Population(t - dt) + (ICEM_Demand_Fulfillment - ICEM_Decrease) * dt

INIT ICEM_Population = 125305332

INFLOWS:

ICEM_Demand_Fulfillment = if(ICEM_Demand>Domestic_ICEM_Industry_Capacity) THEN(Domestic_ICEM_Industry_Capacity) ELSE(ICEM_Demand)

OUTFLOWS:

ICEM_Decrease = ICEM_Decrease_Rate*ICEM_Population

Population_of_Indonesia(t) = Population_of_Indonesia(t - dt) + (Population_Change) * dt

INIT Population_of_Indonesia = 275773800

INFLOWS:

Population_Change = Population_of_Indonesia*Population_Change_Rate

SS_Population(t) = SS_Population(t - dt) + (SS_Establishment) * dt

INIT SS_Population = 961

INFLOWS:

SS_Establishment = SS_Preference*Battery_Facility_Demand*Capability_to_Fulfill

Average_EM_Market_Price = 34720000

Average_EM_Selling_Price = MAX(

(IF(EM_Population<500000)

THEN((Average_EM_Market_Price-EM_Purchase_Incentive)*(1+EM_Purchase__Tax))

ELSE(Average_EM_Market_Price*(1+EM_Purchase__Tax))),1)

Average_ICEM_Range = 285

Battery_Facility_Demand = EM_Population*(Ideal_Facility_to_EM_Ratio)

Battery_Facility_to_EM_Ratio = (CS_Population+SS_Population)/EM_Population

Battery_Station_Preference = 4.11+6.6

Buying_Power = 15053568

Capability_to_Fulfill = 1

Capable_Workforce_to_Buy_Motorcycle = Capable_Workforce_to_Buy_Motorcycle_Ratio*Workforce_Population

Capable_Workforce_to_Buy_Motorcycle_Ratio = 0.9414

CS_Preference = 6.6/Battery_Station_Preference

eCO2_Emssion_from_ICEM = ICEM_Population*ICEM_eCO2_Rate

EM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

EM_Purchase_Incentive = 10254601

EM_Purchase__Tax = 0

EM_Selling_Price_Ratio = EM_Variant_Ratio*(Buying_Power/Average_EM_Selling_Price)

EM_Variant_Ratio = EM_Variants/ICEM_Variants

EM_Willingness_to_Adopt = min((Battery_Facility_to_EM_Ratio)*EM_Selling_Price_Ratio*Range_Ratio,1)

ICEM_Decrease_Rate = 0.0645

ICEM_Demand = EM_Willingness_to_Adopt*Motorcycle_Demand

ICEM_eCO2_Rate = 0.432

Ideal_Facility_to_EM_Ratio = 0.1

Motorcycle_Demand = Capable_Workforce_to_Buy_Motorcycle-(EM_Population+ICEM_Population)

Population_Change_Rate = 0.0117

Range_Ratio = Average_EM_Battery_Range/Average_ICEM_Range

SS_Preference = 4.11/Battery_Station_Preference

Workforce_Population = Workforce_Population_Rate*Population_of_Indonesia

Workforce_Population_Rate = 0.7594*0.6863

Average_EM_Battery_Range = GRAPH(TIME)

(2022, 175), (2023, 200), (2024, 225), (2025, 251), (2026, 276), (2027, 285), (2028, 285), (2029, 285), (2030, 285), (2031, 285), (2032, 285), (2033, 285), (2034, 285), (2035, 285)

Domestic_EM_Industry_Capacity = GRAPH(TIME)

(2022, 1.4e+006), (2023, 2.7e+006), (2024, 3.9e+006), (2025, 5.2e+006), (2026, 6.4e+006), (2027, 7.6e+006), (2028, 8.3e+006), (2029, 8.3e+006), (2030, 8.3e+006), (2031, 8.3e+006), (2032, 8.3e+006), (2033, 8.3e+006), (2034, 8.3e+006), (2035, 8.3e+006)

Domestic_ICEM_Industry_Capacity = GRAPH(TIME)

(2022, 6.9e+006), (2023, 5.6e+006), (2024, 4.4e+006), (2025, 3.1e+006), (2026, 1.9e+006), (2027, 646554), (2028, 0.00), (2029, 0.00), (2030, 0.00), (2031, 0.00), (2032, 0.00), (2033, 0.00), (2034, 0.00), (2035, 0.00)

EM_Decrease_Rate = GRAPH(TIME)

(2022, 0.221), (2023, 0.196), (2024, 0.176), (2025, 0.16), (2026, 0.147), (2027, 0.135), (2028, 0.126), (2029, 0.117), (2030, 0.11), (2031, 0.103), (2032, 0.097), (2033, 0.092), (2034, 0.088), (2035, 0.083)

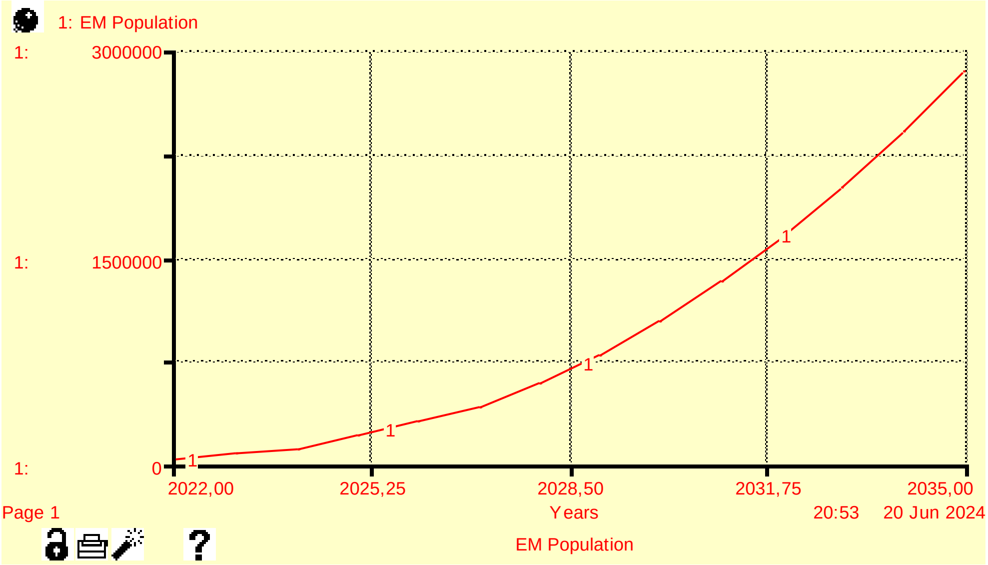
EM_Variants = GRAPH(TIME)

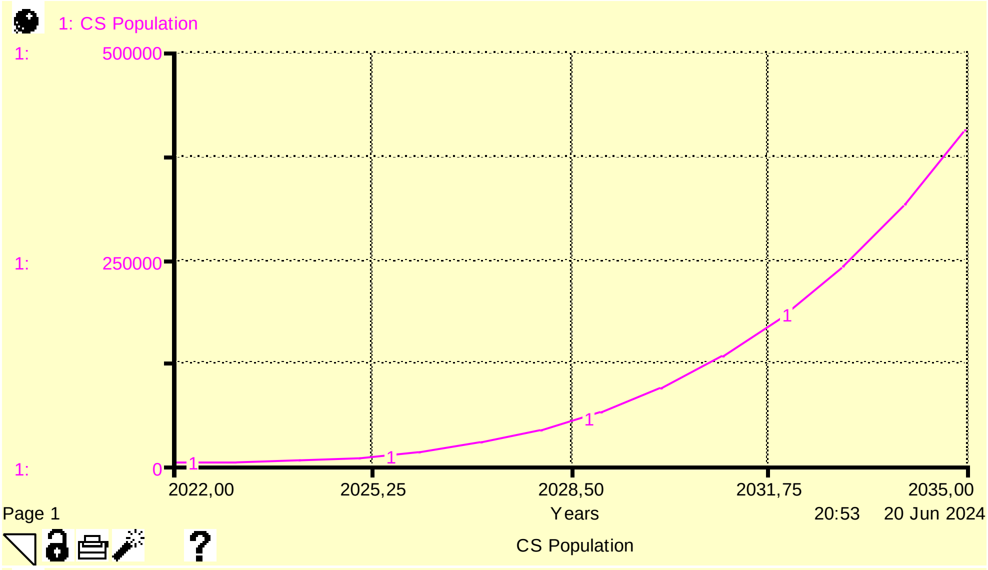
(2022, 61.0), (2023, 70.0), (2024, 81.0), (2025, 93.0), (2026, 107), (2027, 123), (2028, 141), (2029, 162), (2030, 187), (2031, 215), (2032, 247), (2033, 284), (2034, 326), (2035, 375)

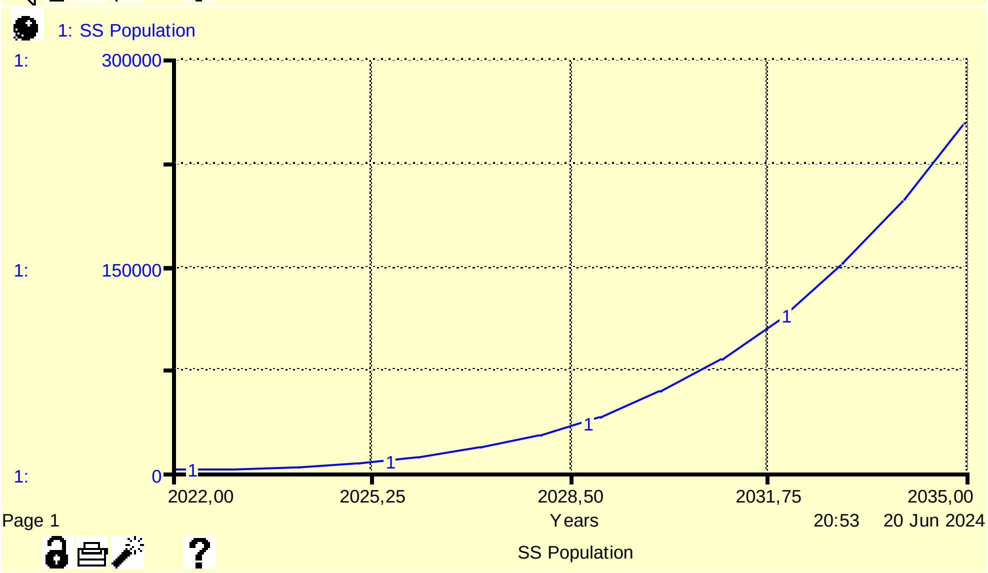
ICEM_Variants = GRAPH(TIME)

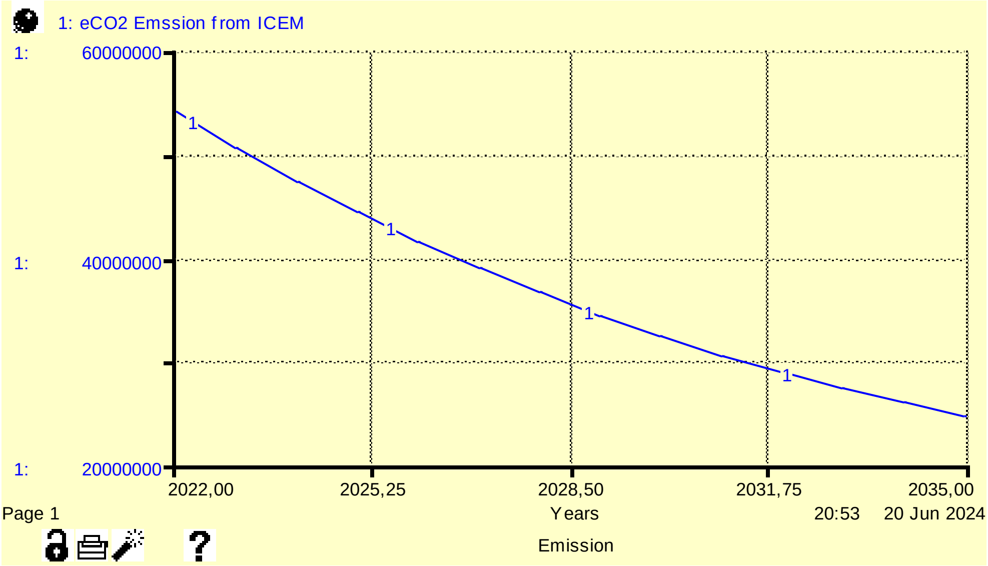
(2022, 300), (2023, 255), (2024, 210), (2025, 165), (2026, 120), (2027, 75.0), (2028, 30.0), (2029, 1.00), (2030, 1.00), (2031, 1.00), (2032, 1.00), (2033, 1.00), (2034, 1.00), (2035, 1.00)

Appendix 8. Domestic EM Industry Maximum Extreme Value Test

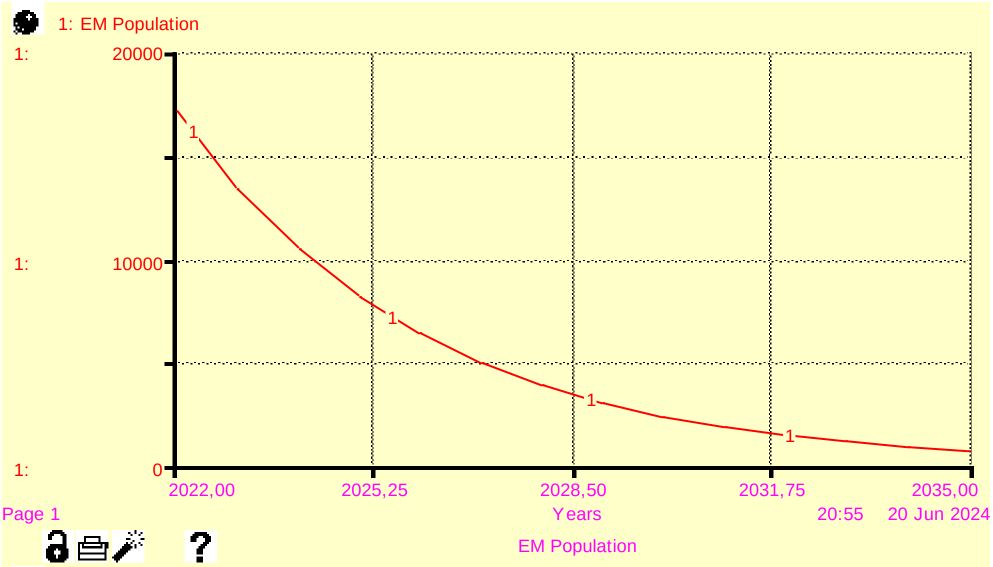


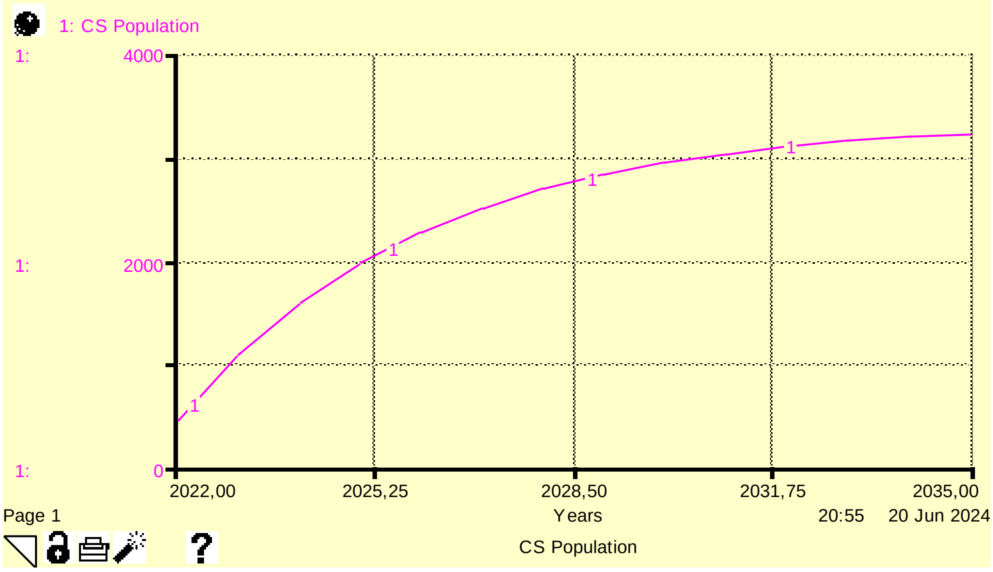


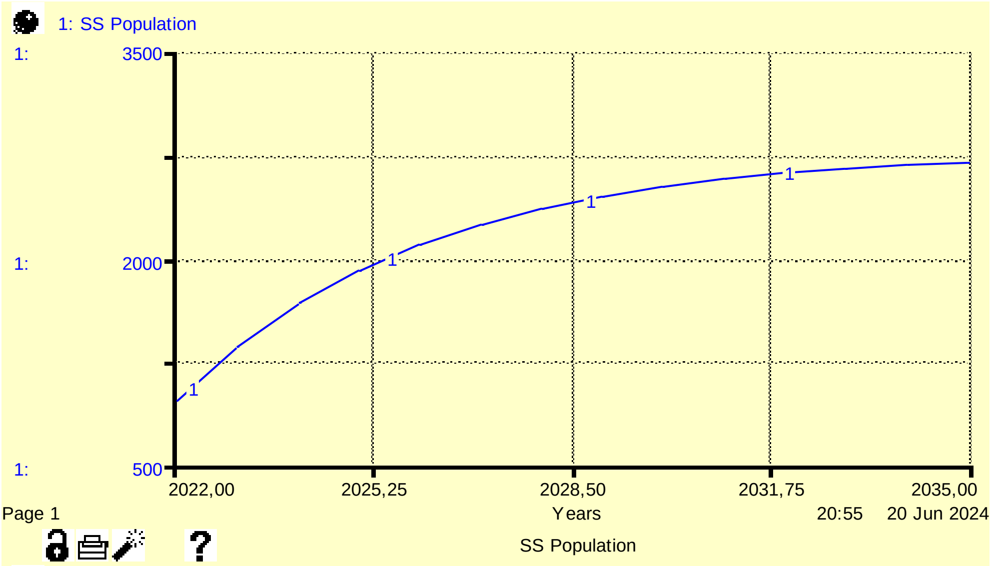


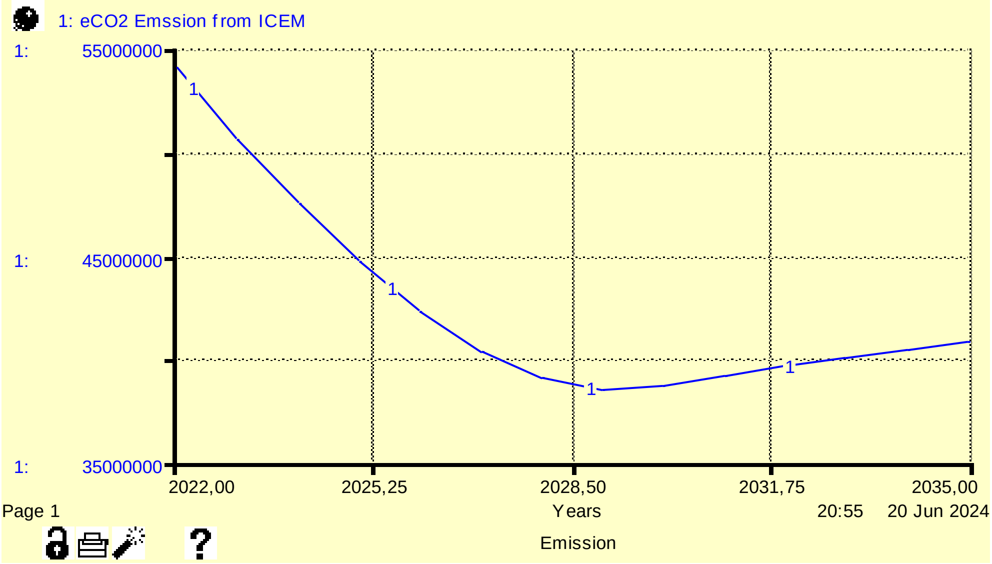


Appendix 9. Domestic EM Industry Minimum Extreme Value Test

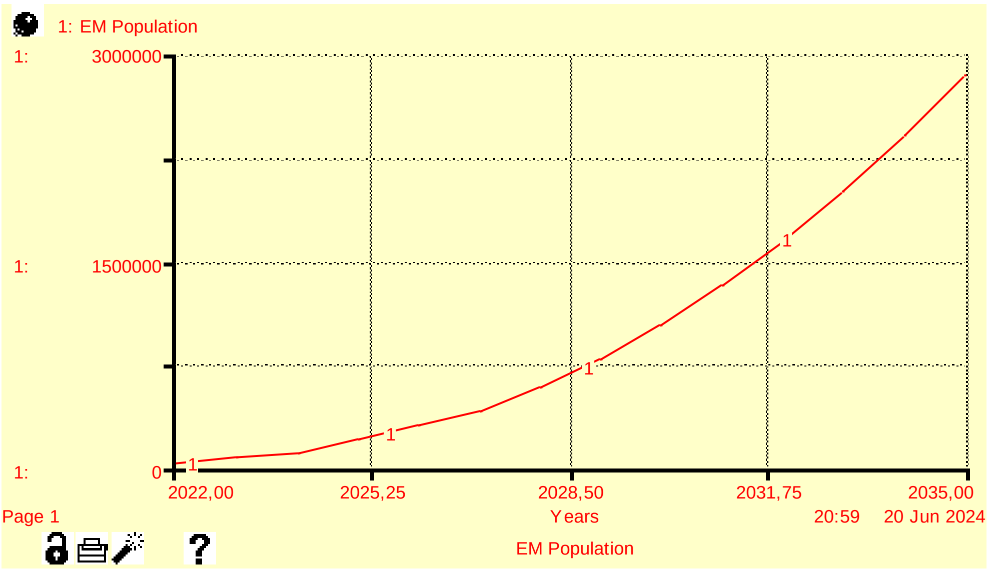


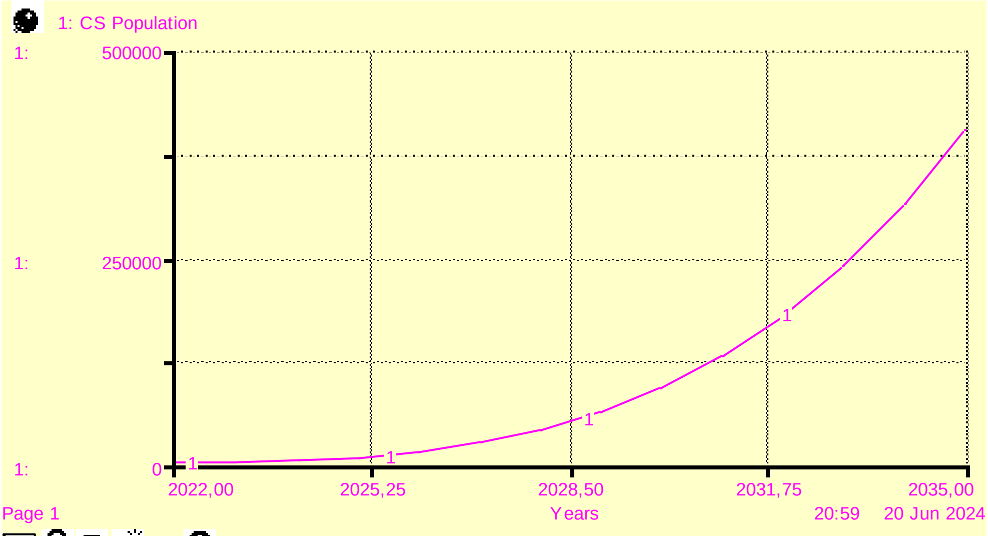




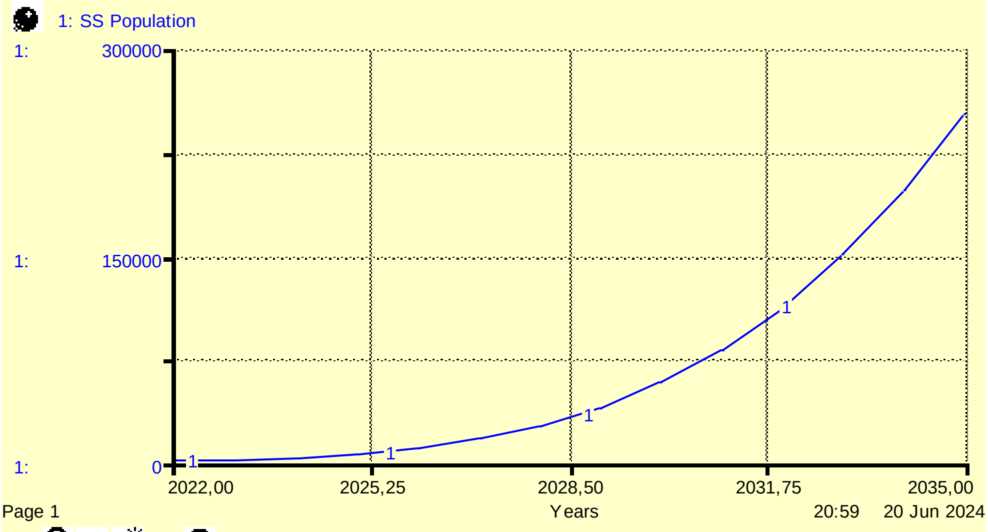


Appendix 10. Domestic ICEM Industry Maximum Extreme Value Test

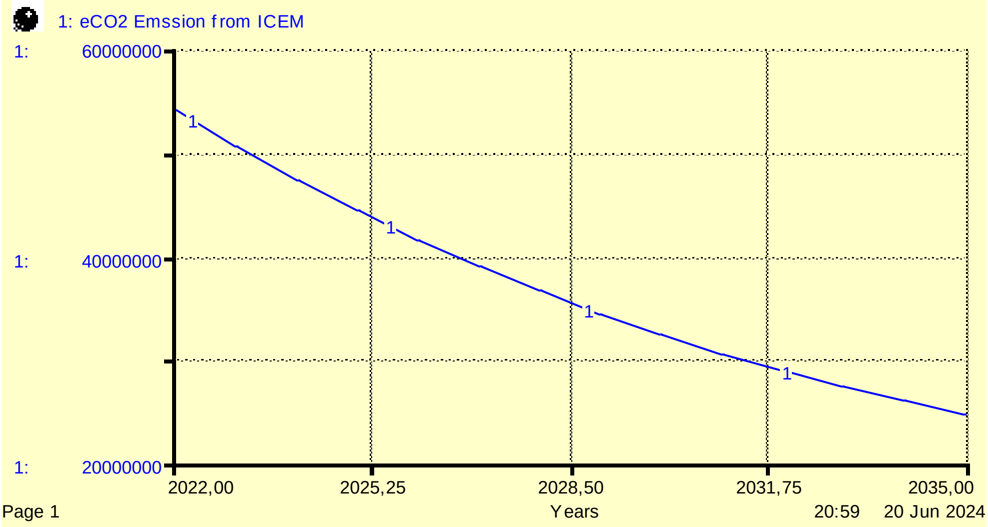




CS Population

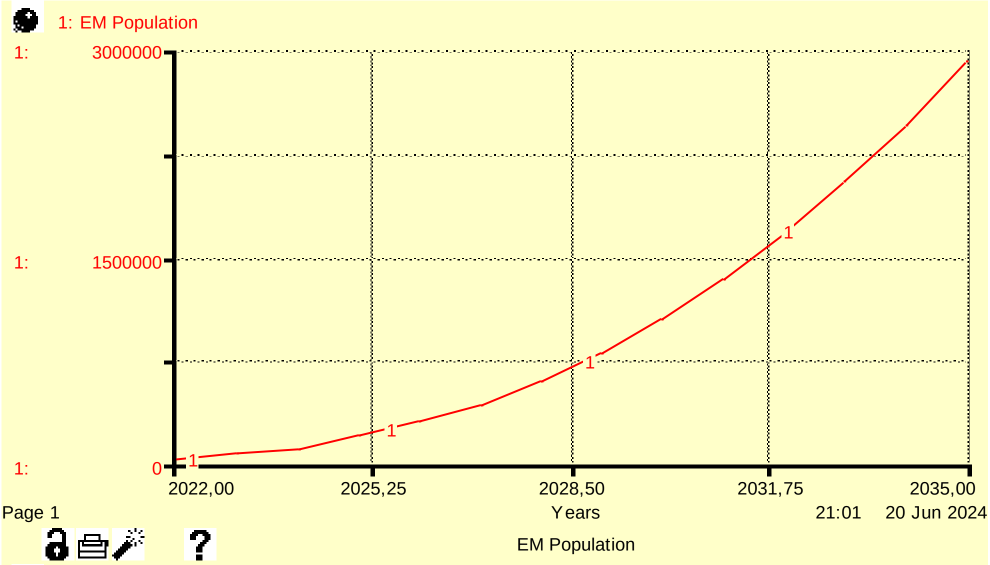


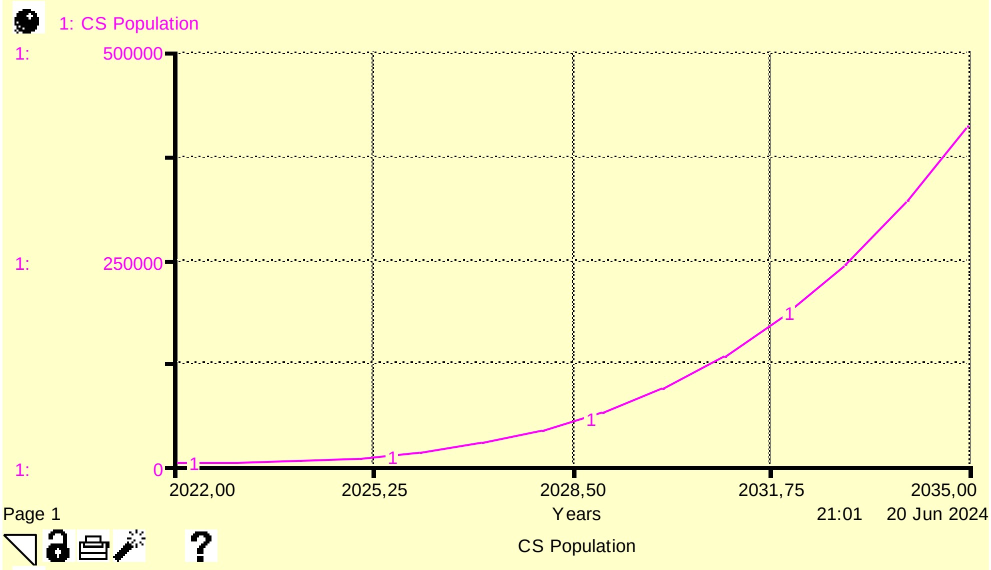
SS Population

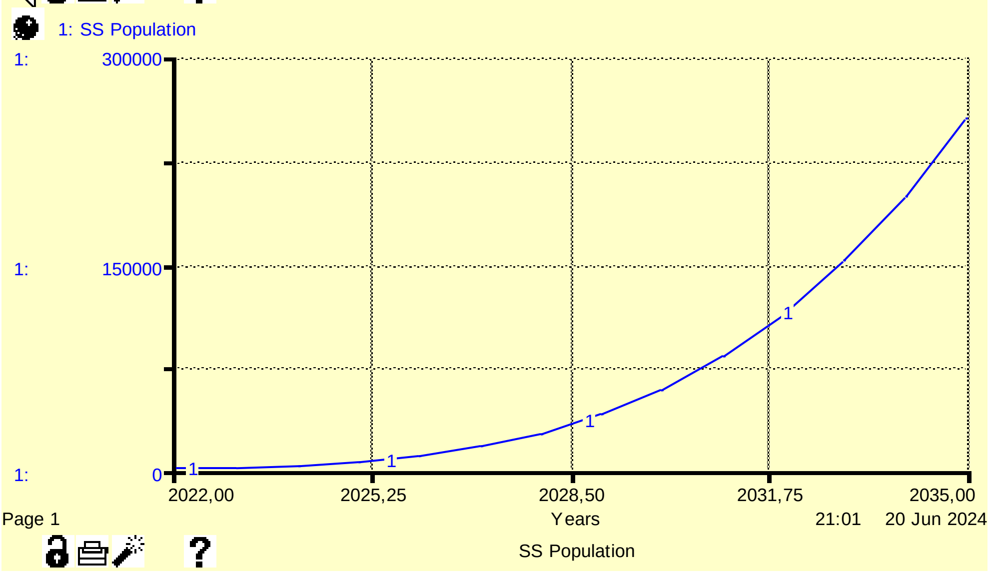


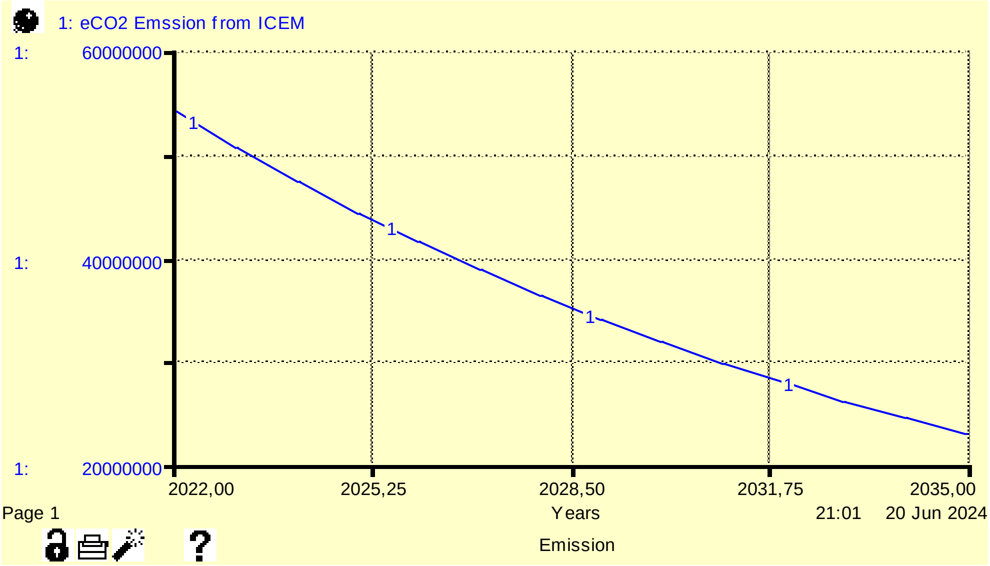
Emission

Appendix 11. Domestic ICEM Industry Minimum Extreme Value Test

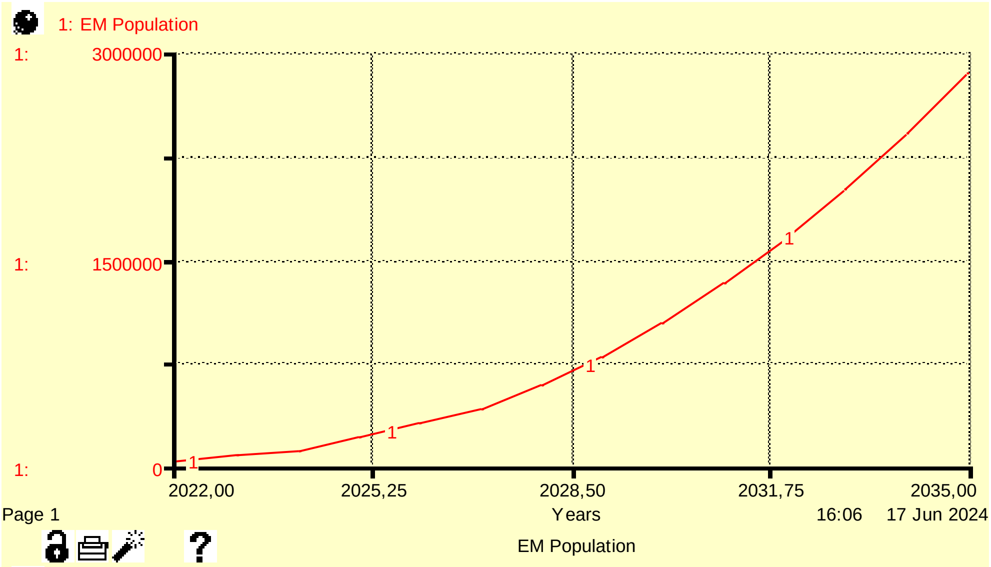


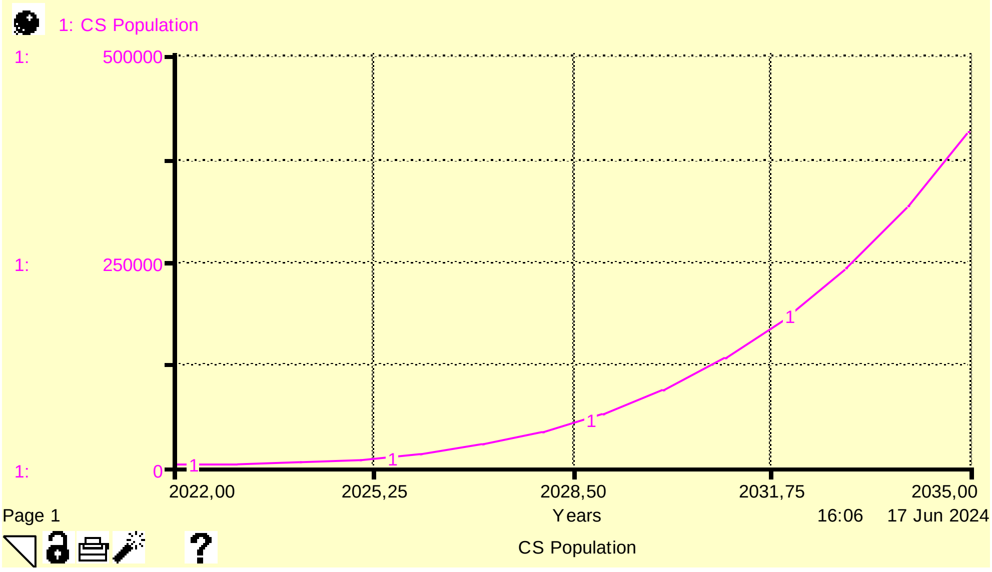


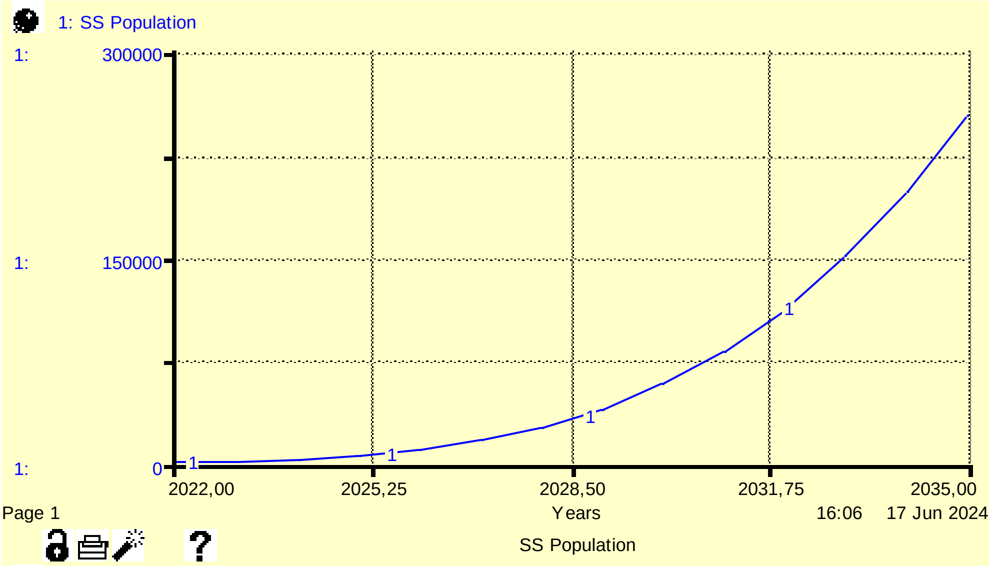


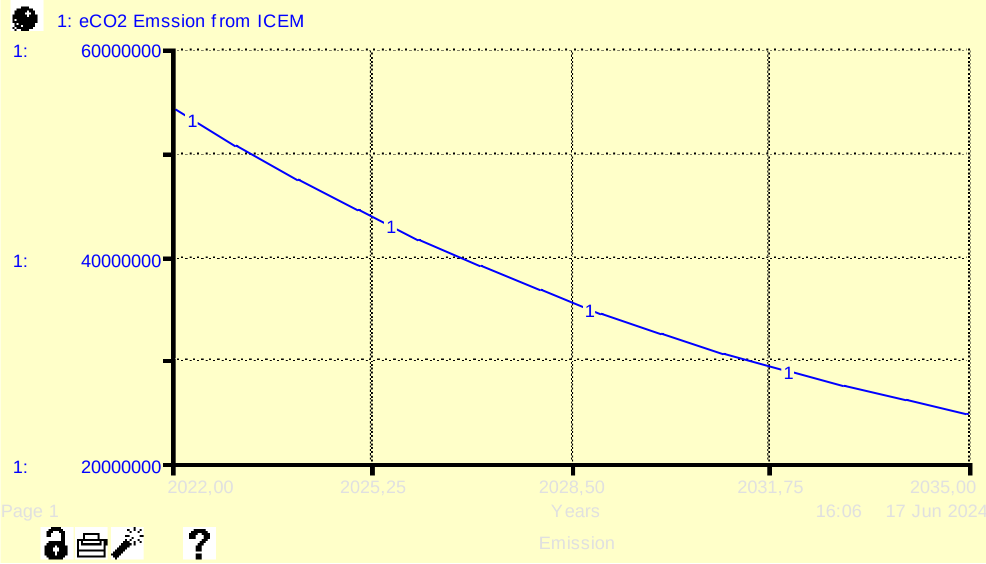


Appendix 12. Capable Workforce to Buy Motorcycle Ratio Maximum Extreme Value Test

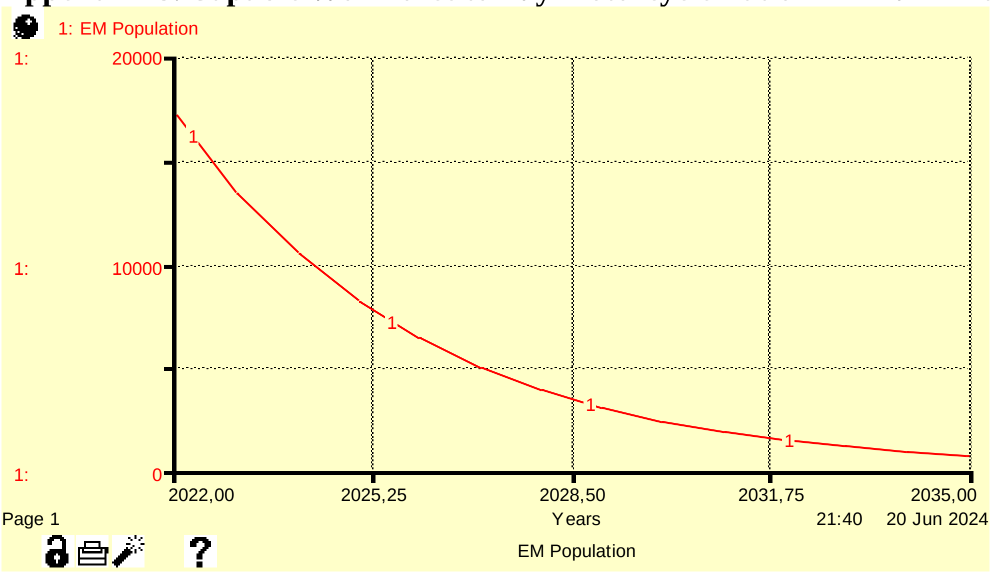


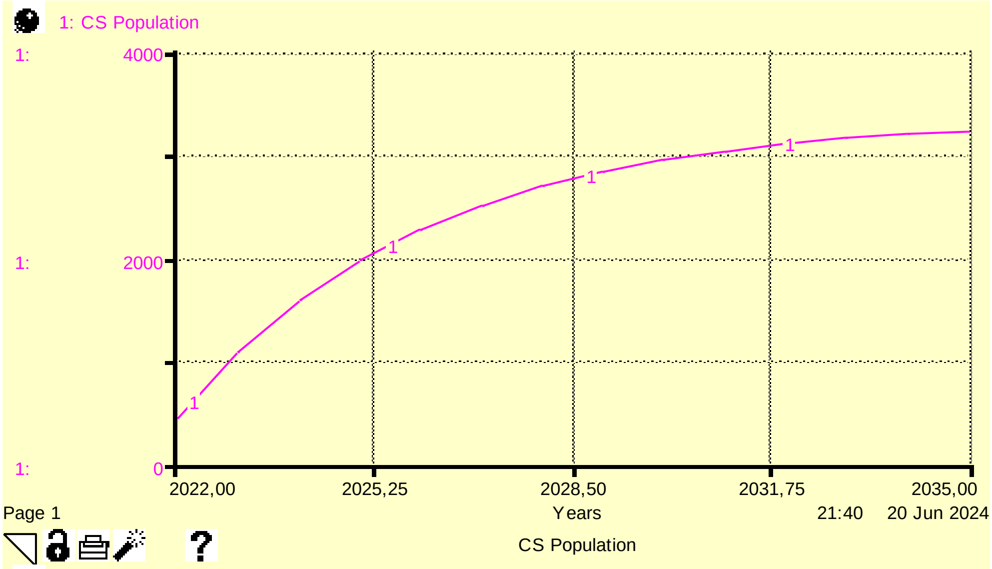


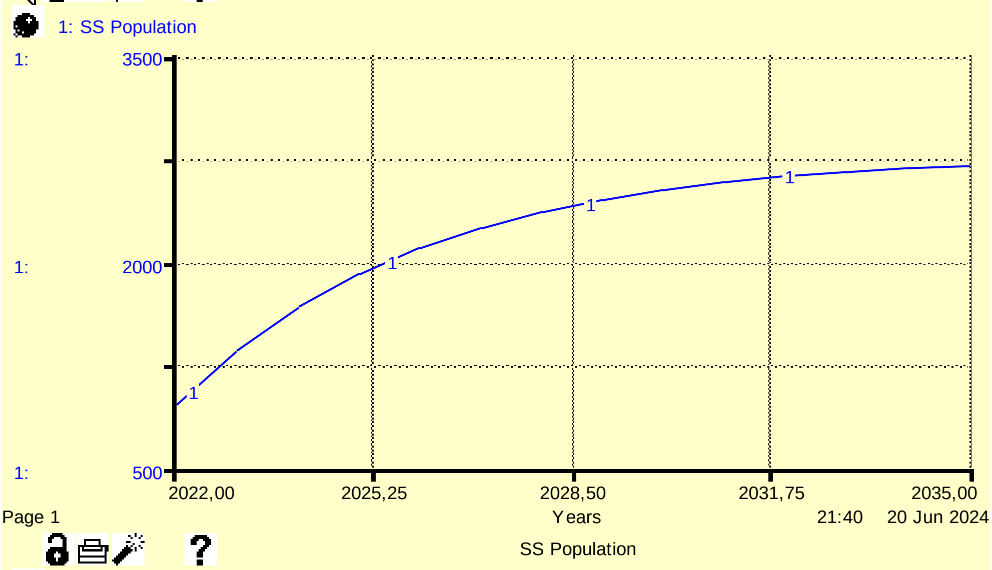


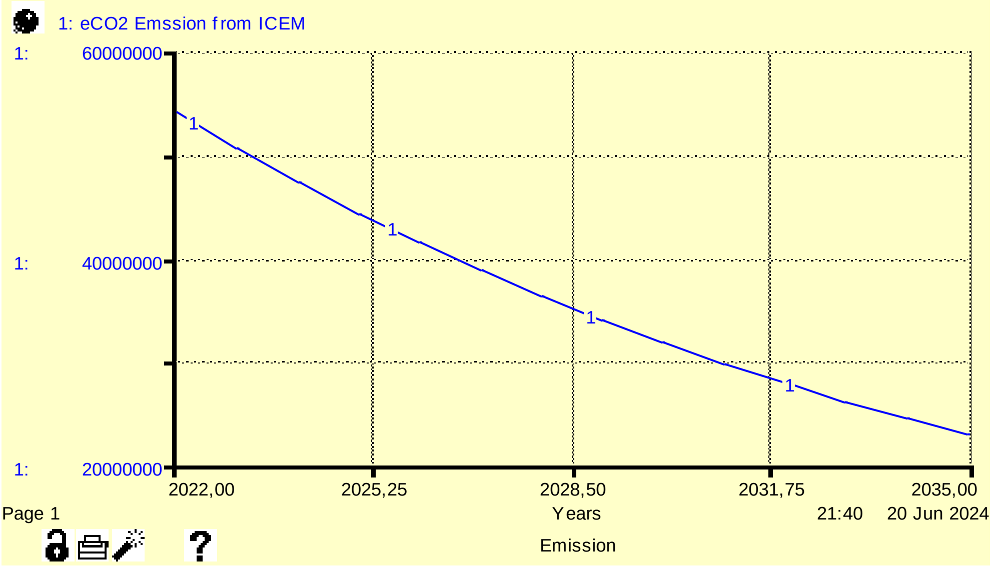


Appendix 13. Capable Workforce to Buy Motorcycle Ratio Minimum Extreme Value Test

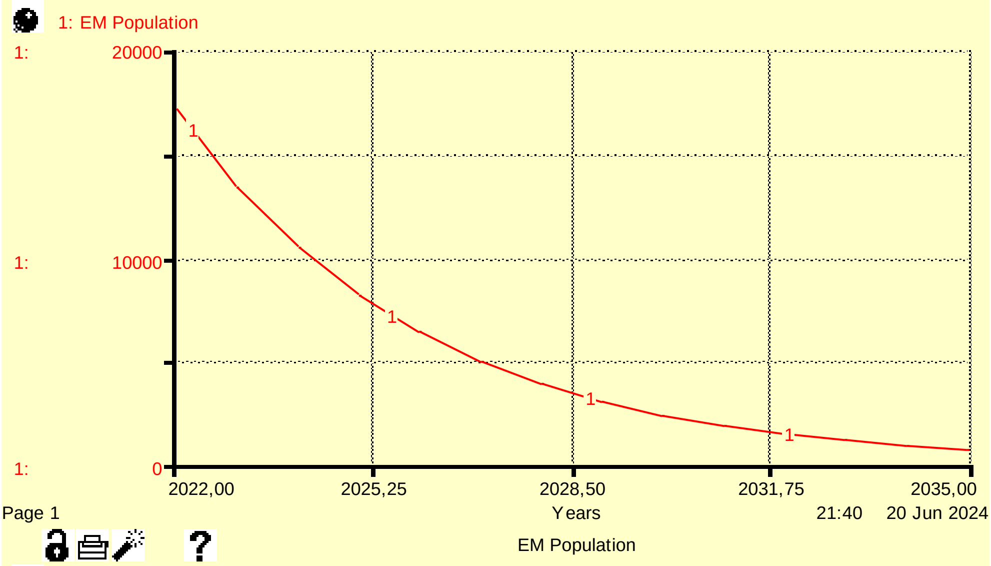


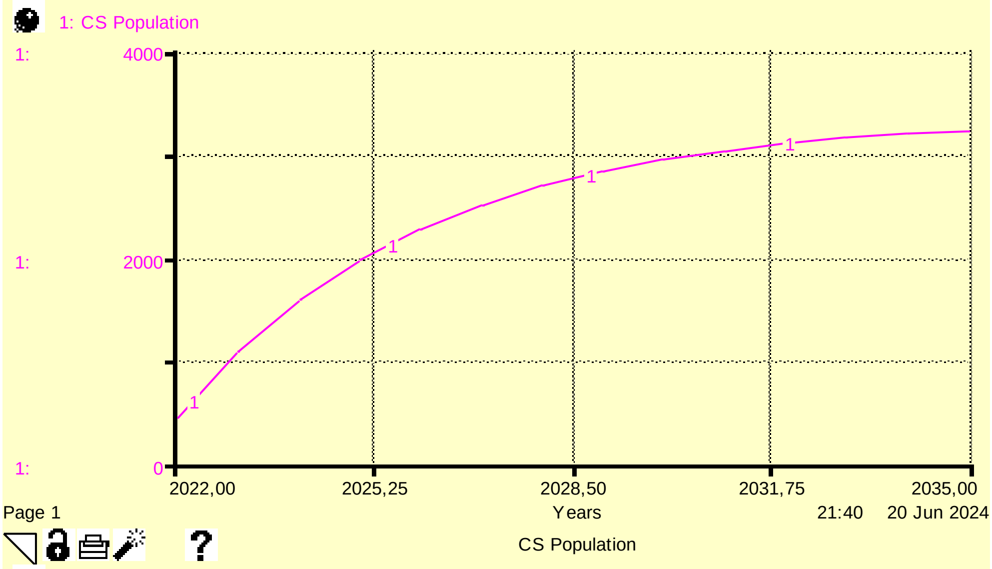

1: CS Population
1: 4000
1: 2000
1: 0
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:40 20 Jun 2024
CS Population

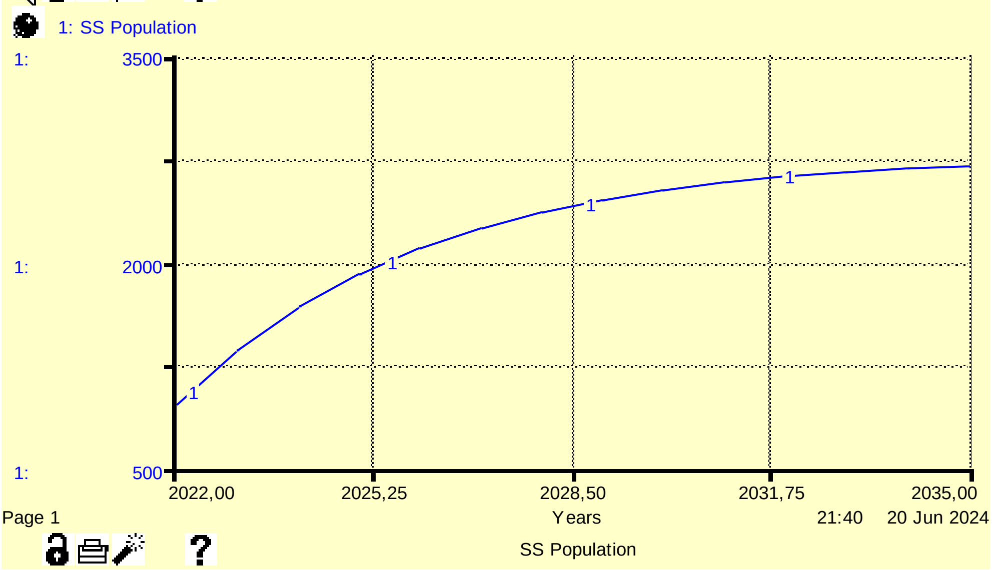

1: SS Population
1: 3500
1: 2000
1: 500
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:40 20 Jun 2024
SS Population

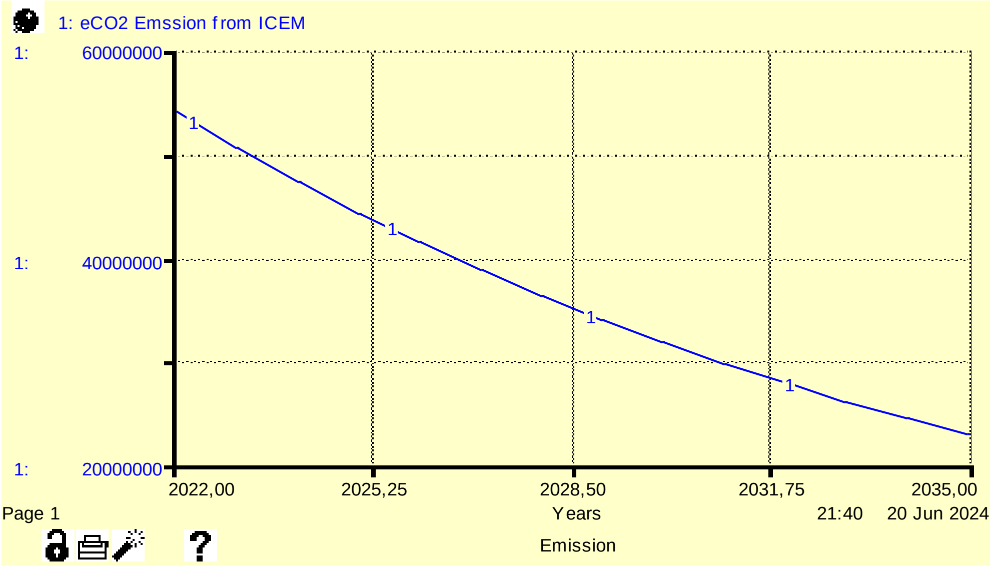

1: eCO2 Emssion from ICEM
1: 60000000
1: 40000000
1: 20000000
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:40 20 Jun 2024
Emission

Appendix 14. Workforce Population Rate Maximum Extreme Value Test

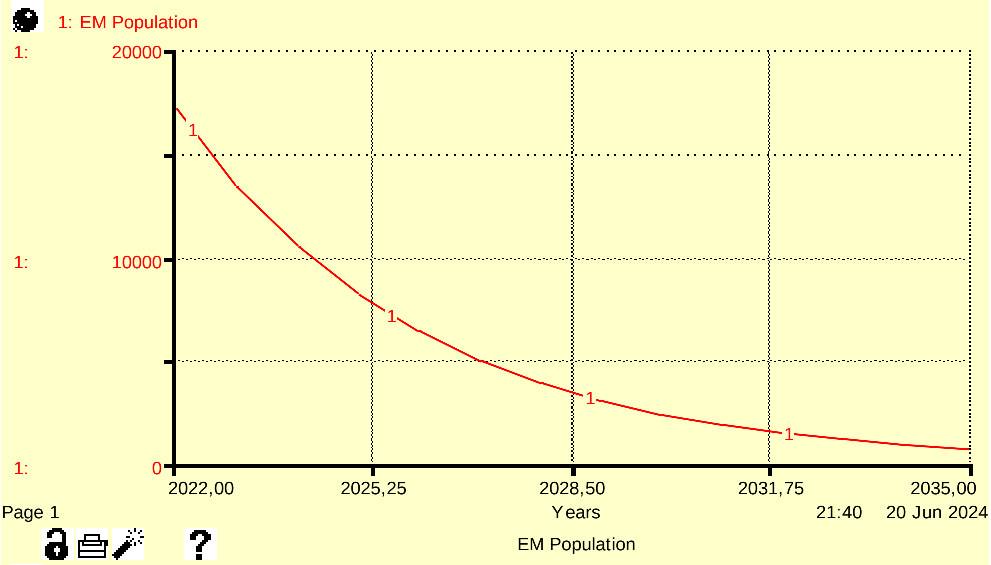


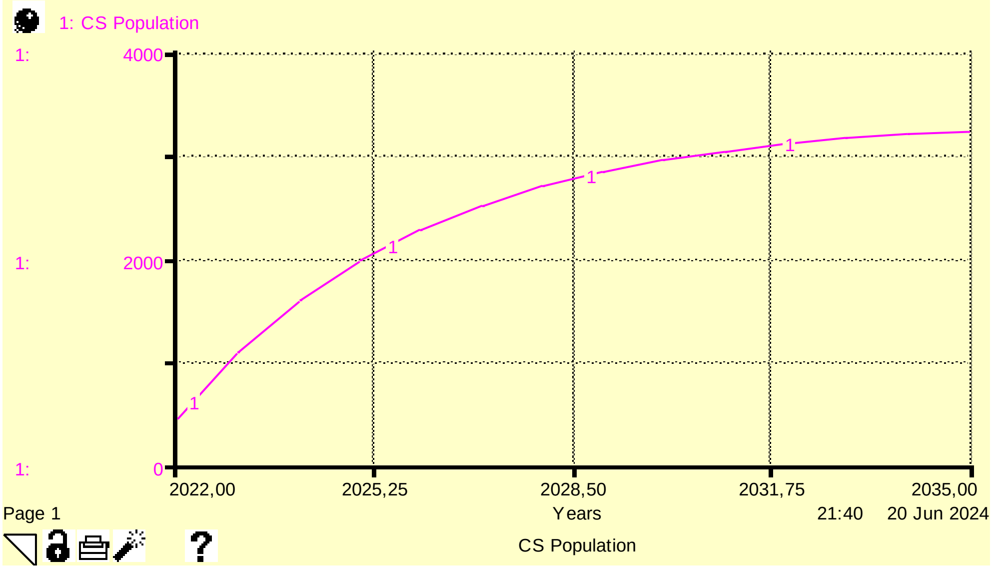


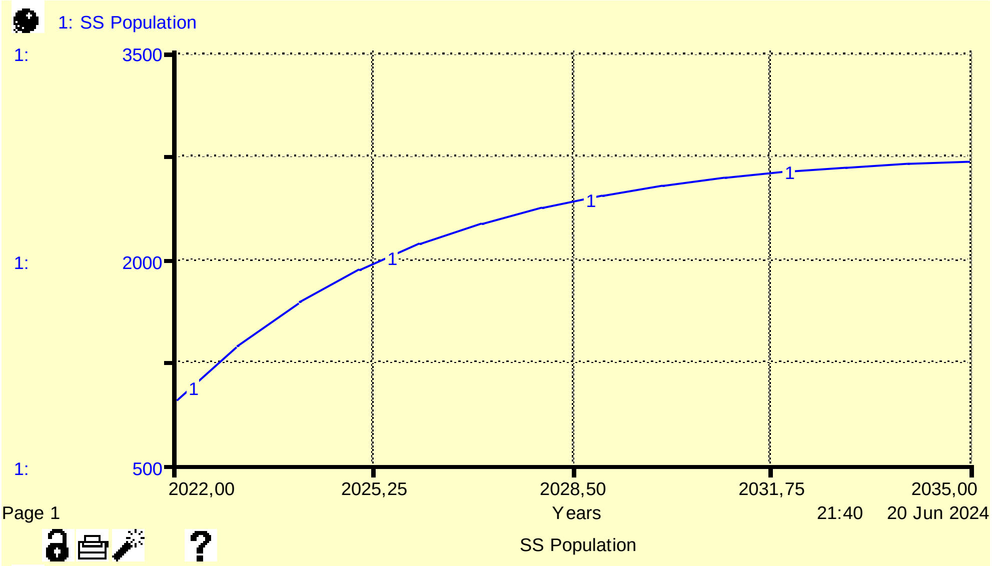


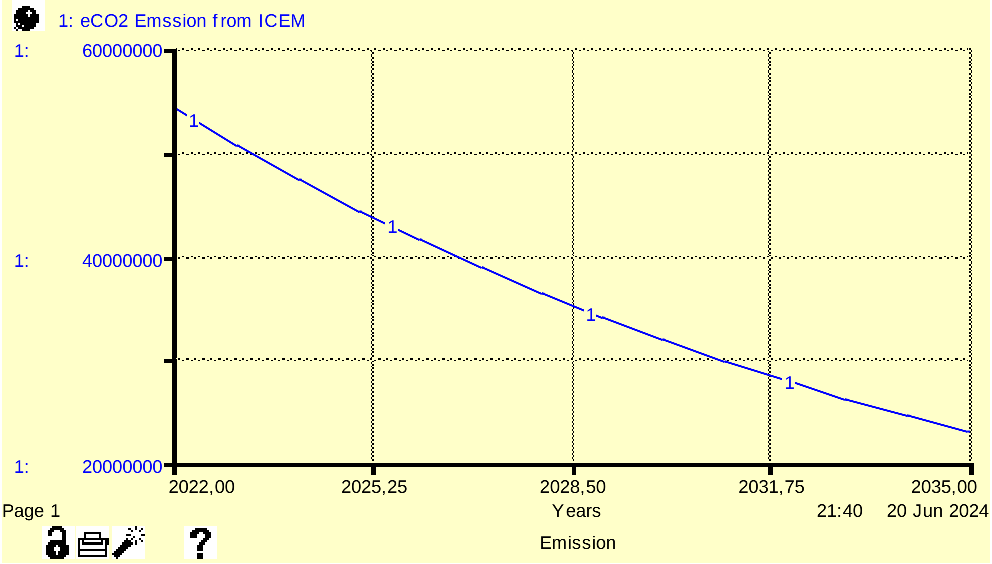


Appendix 15. Workforce Population Rate Minimum Extreme Value Test

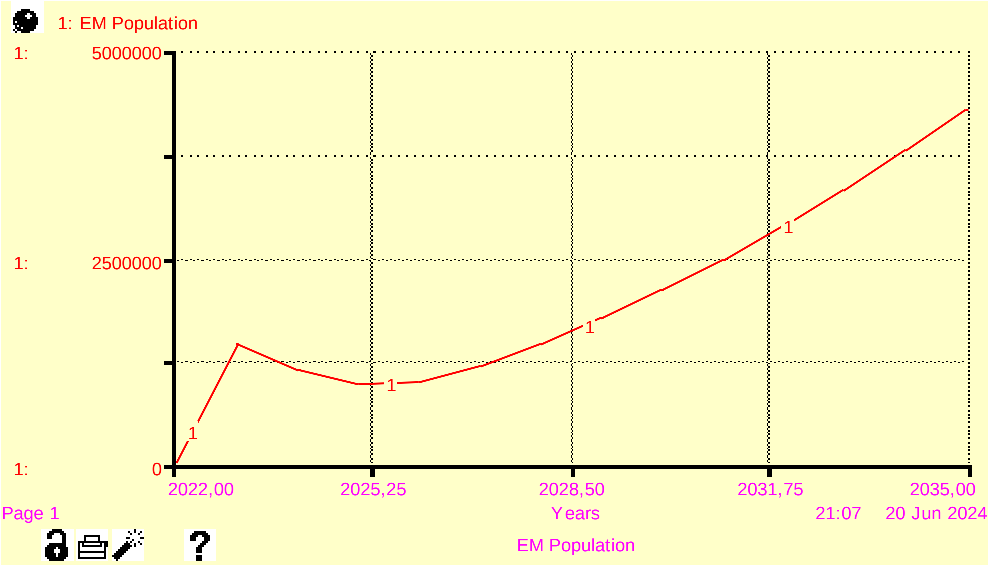


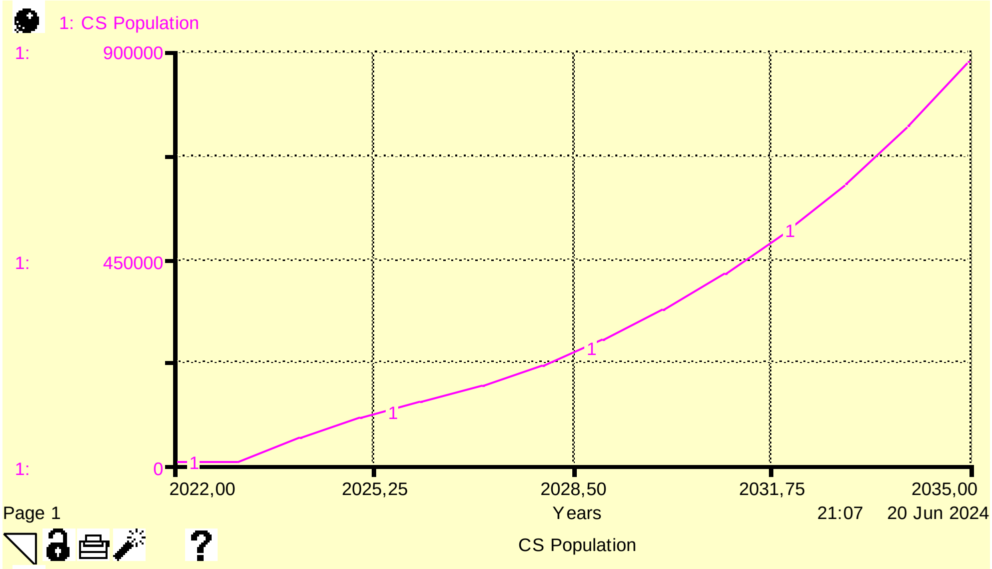


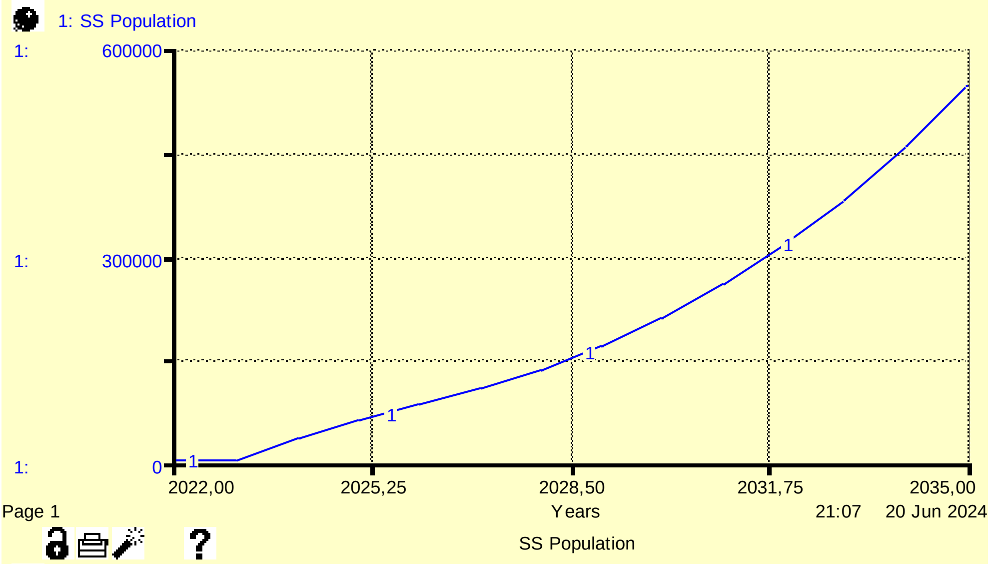


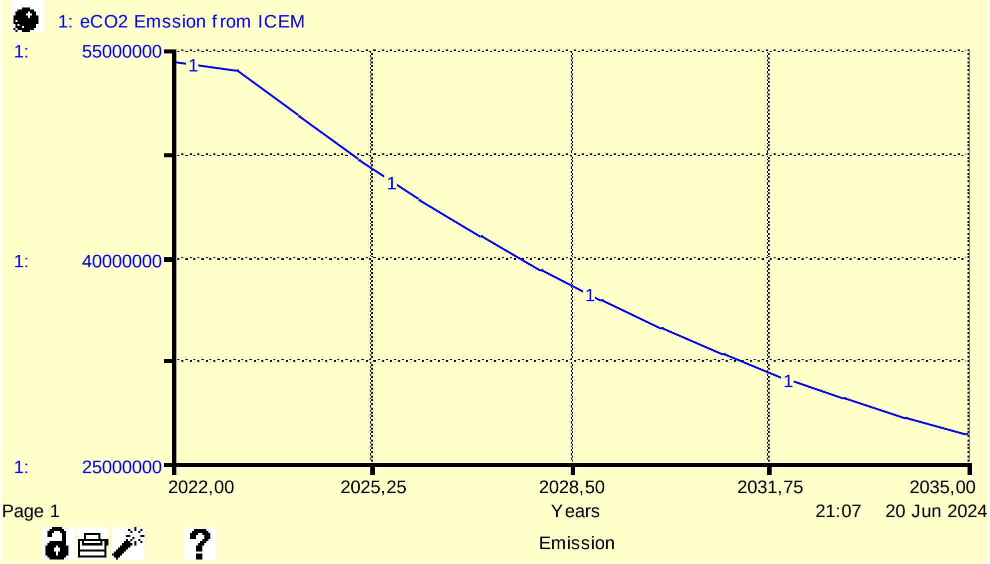


Appendix 16. EM Purchase Incentives Maximum Extreme Value Test

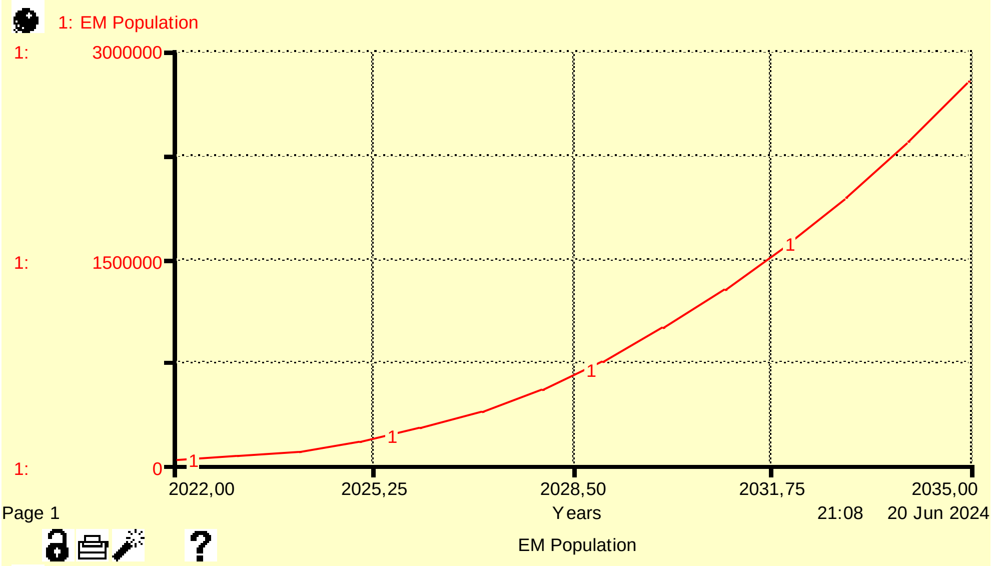


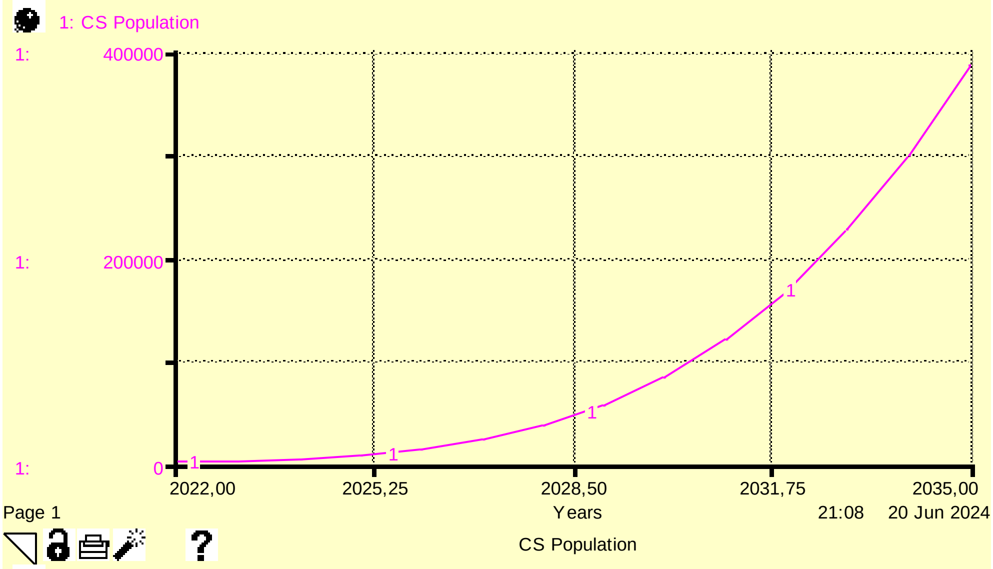

1: CS Population
1: 900000
1: 450000
1: 0
2022,00
2025,25
2028,50
2031,75
2035,00
Years
Page 1
21:07 20 Jun 2024
CS Population

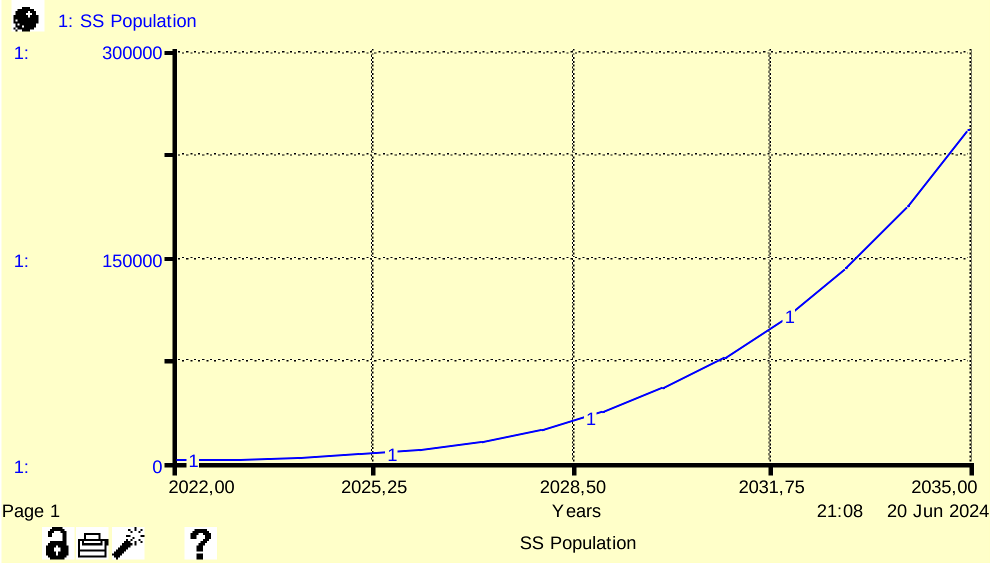

1: SS Population
1: 600000
1: 300000
1: 0
2022,00
2025,25
2028,50
2031,75
2035,00
Years
Page 1
21:07 20 Jun 2024
SS Population

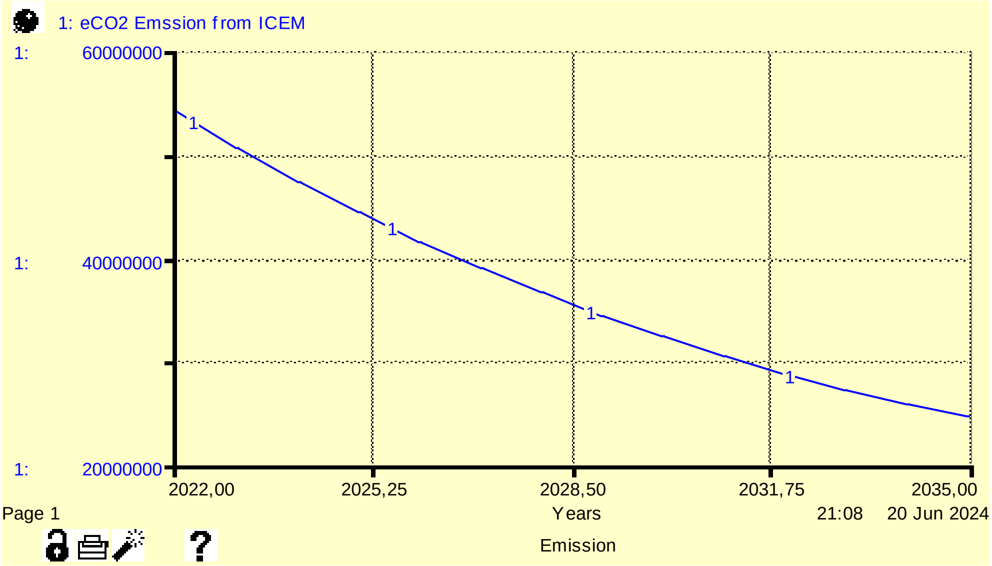

1: eCO2 Emssion from ICEM
1: 55000000
1: 40000000
1: 25000000
2022,00
2025,25
2028,50
2031,75
2035,00
Years
Page 1
21:07 20 Jun 2024
Emission

Appendix 17. EM Purchase Incentives Minimum Extreme Value Test

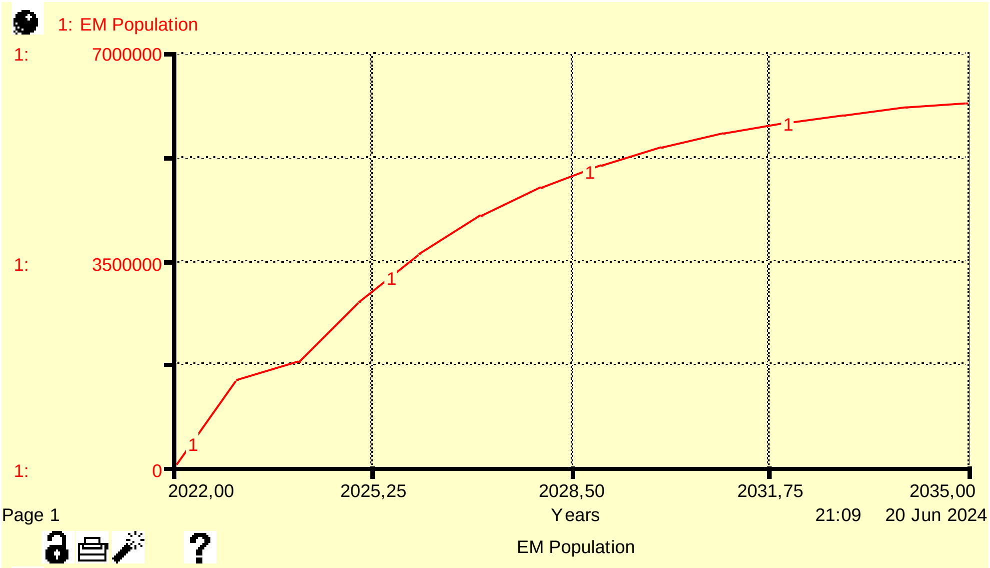


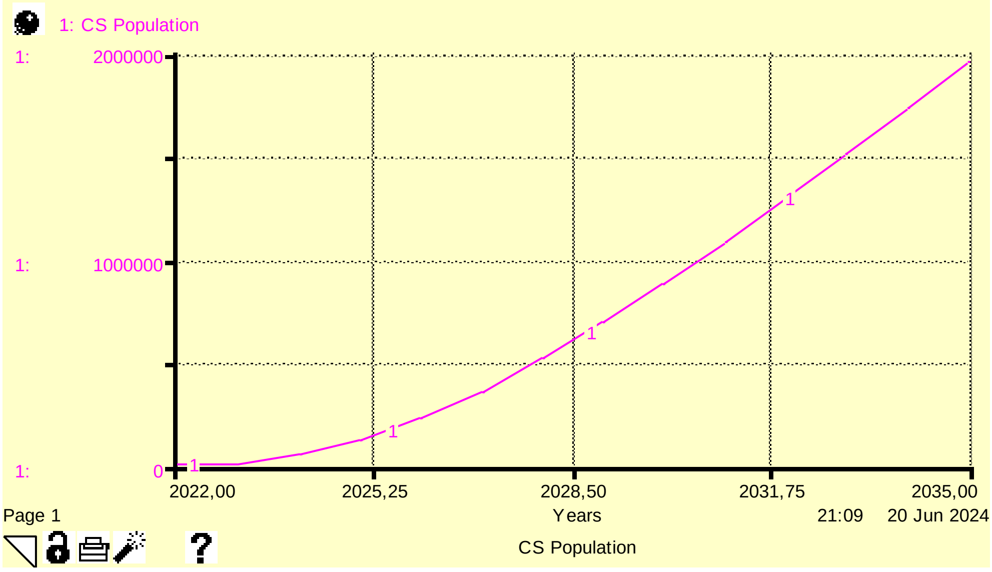


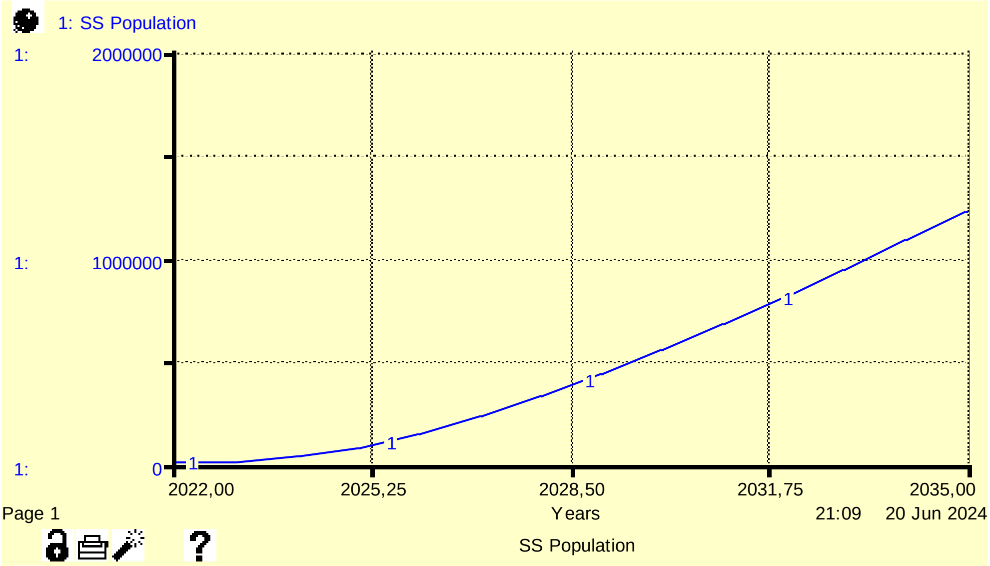


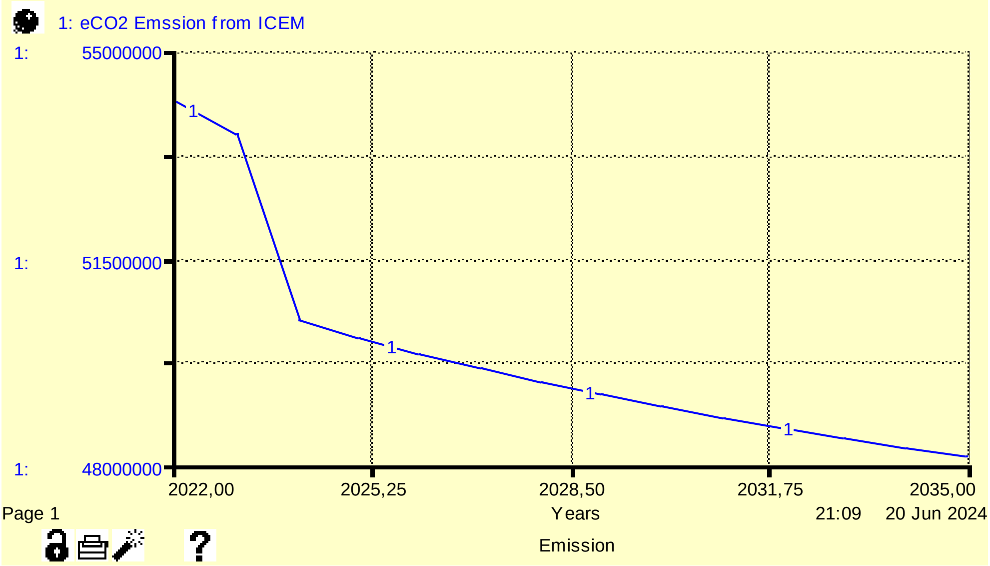


Appendix 18. Buying Power Maximum Extreme Value Test

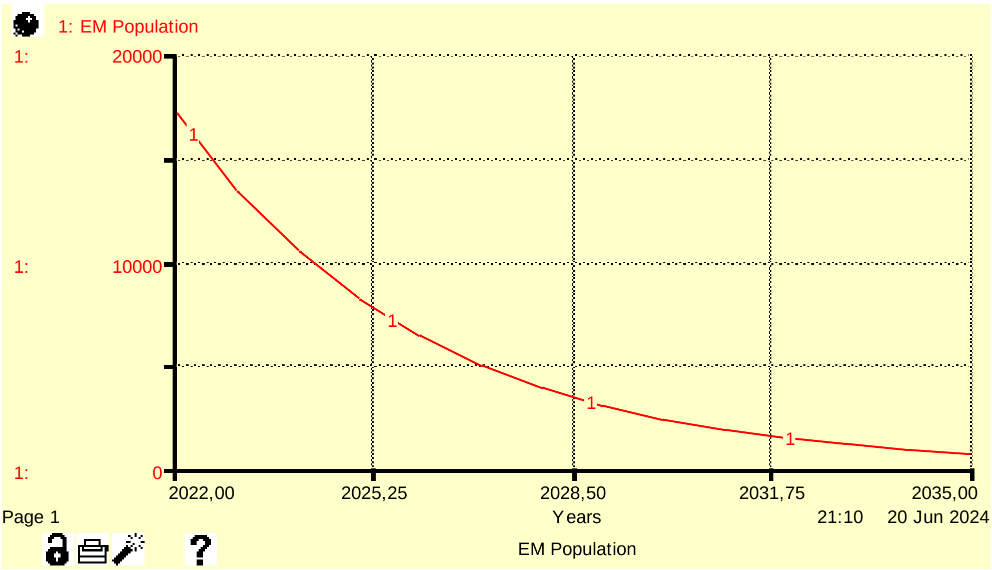


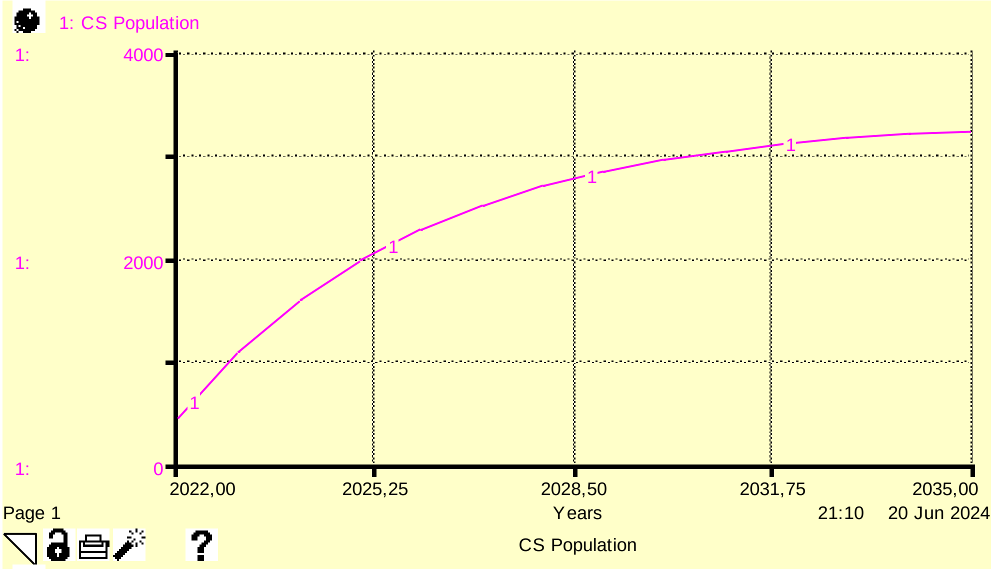


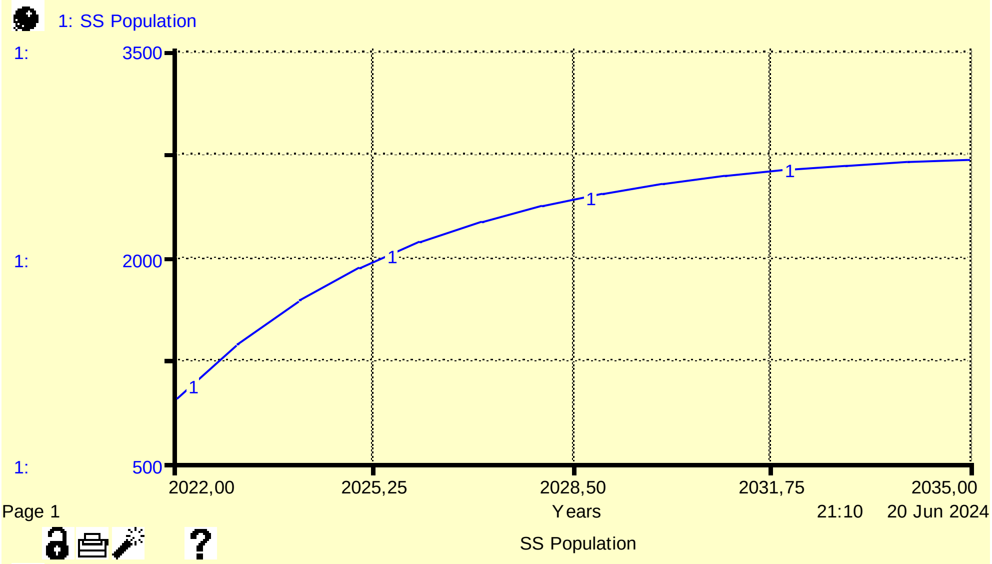


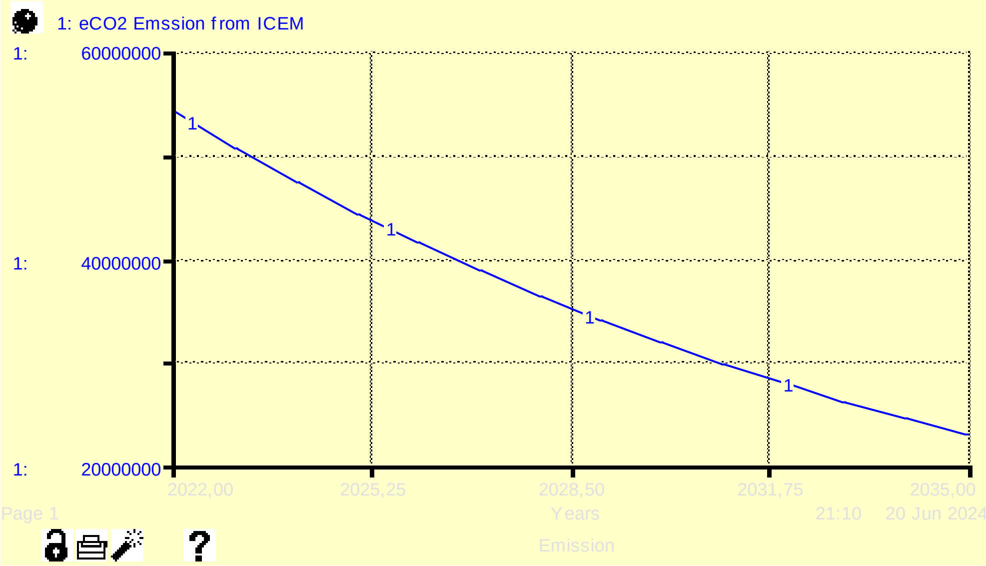


Appendix 19. Buying Power Minimum Extreme Value Test

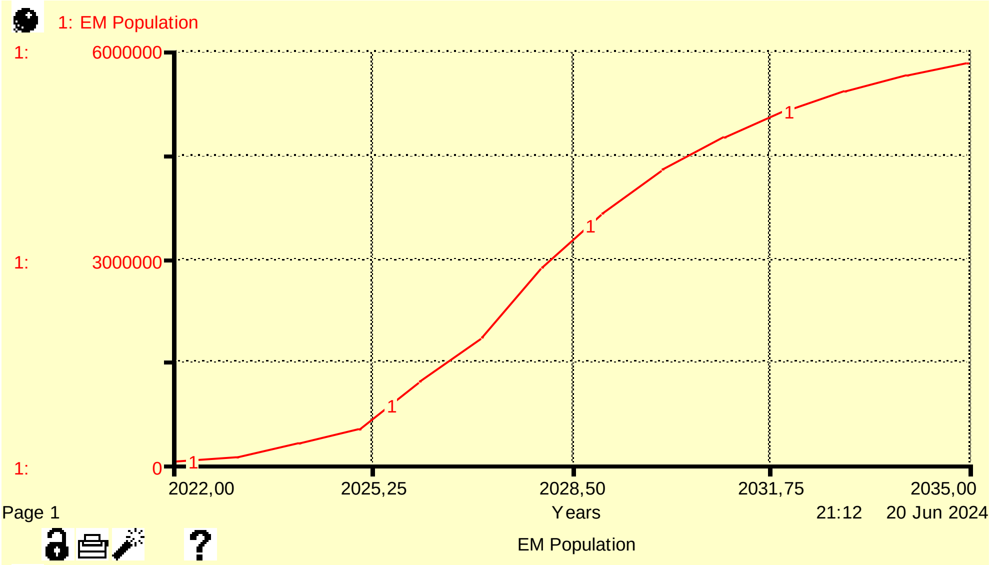


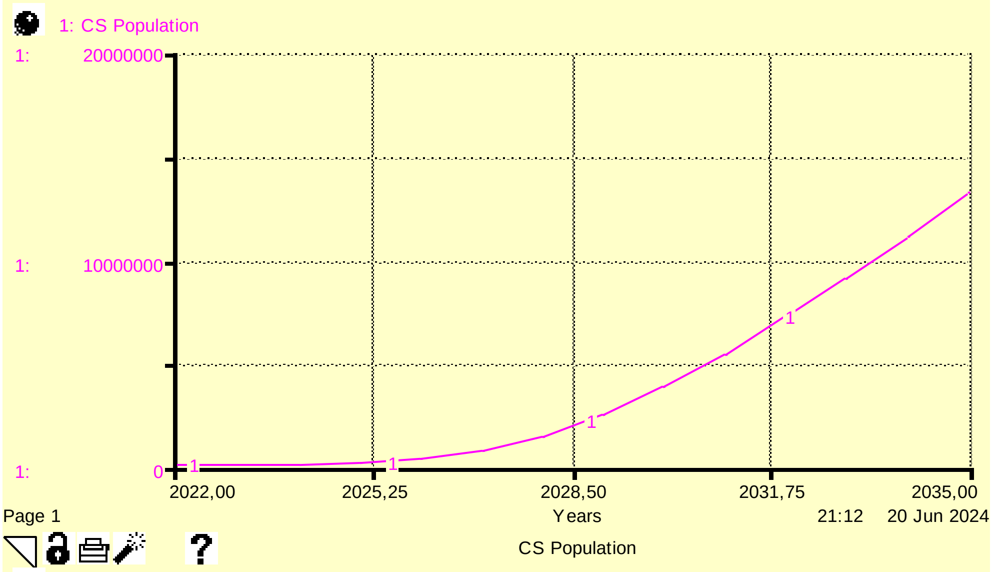

1: CS Population
4000
2000
0
2022,00
2025,25
2028,50
2031,75
2035,00
Years
Page 1
21:10 20 Jun 2024
CS Population

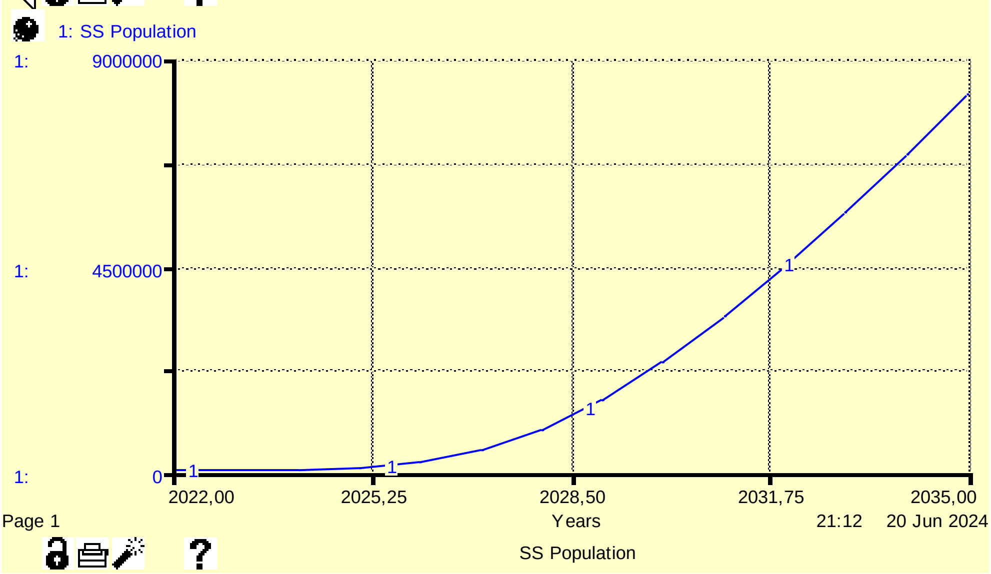

1: SS Population
3500
2000
500
2022,00
2025,25
2028,50
2031,75
2035,00
Years
Page 1
21:10 20 Jun 2024
SS Population

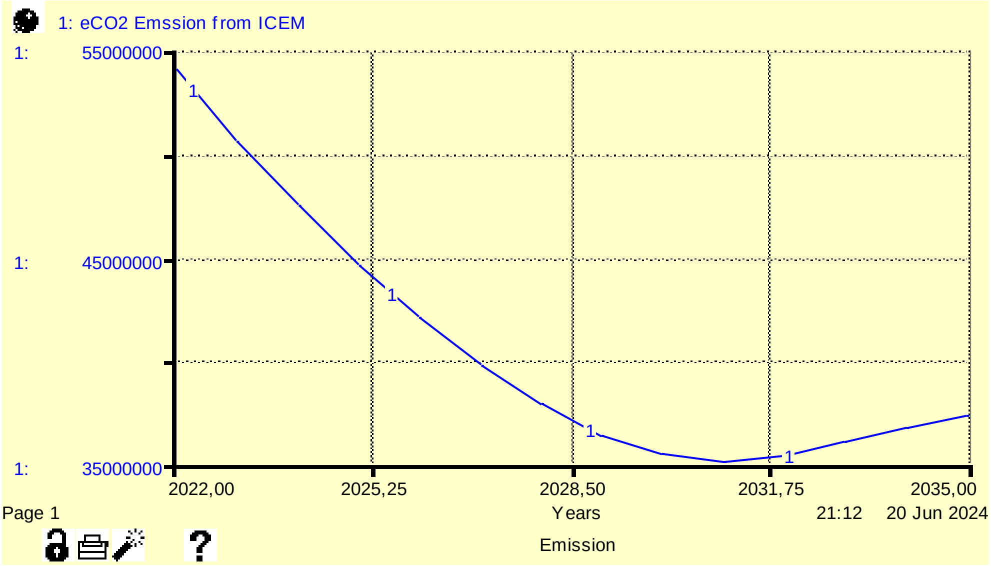

1: eCO2 Emssion from ICEM
60000000
40000000
20000000
2022,00
2025,25
2028,50
2031,75
2035,00
Years
Page 1
21:10 20 Jun 2024
Emission

Appendix 20. Ideal Facility to EM Ratio Maximum Extreme Value Test

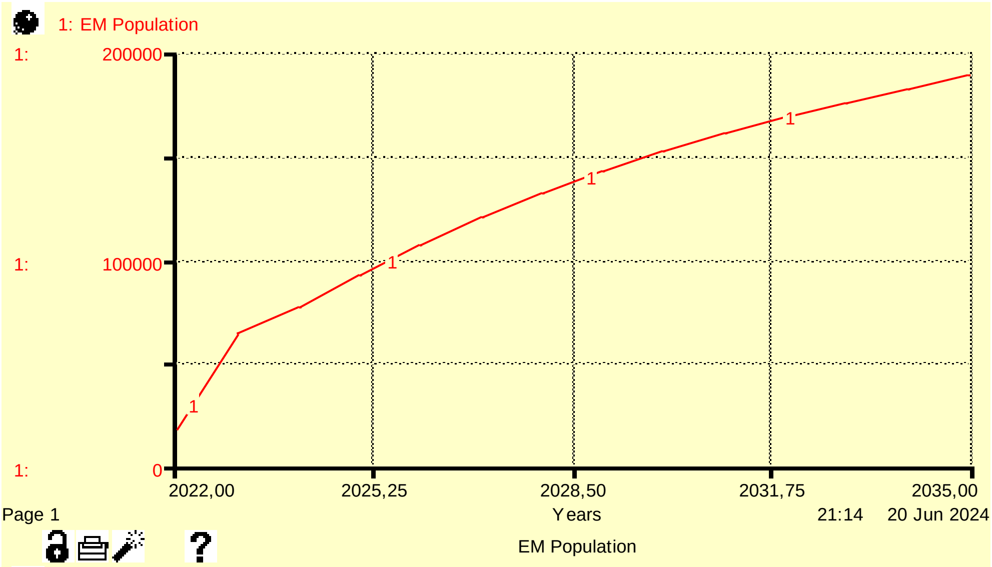


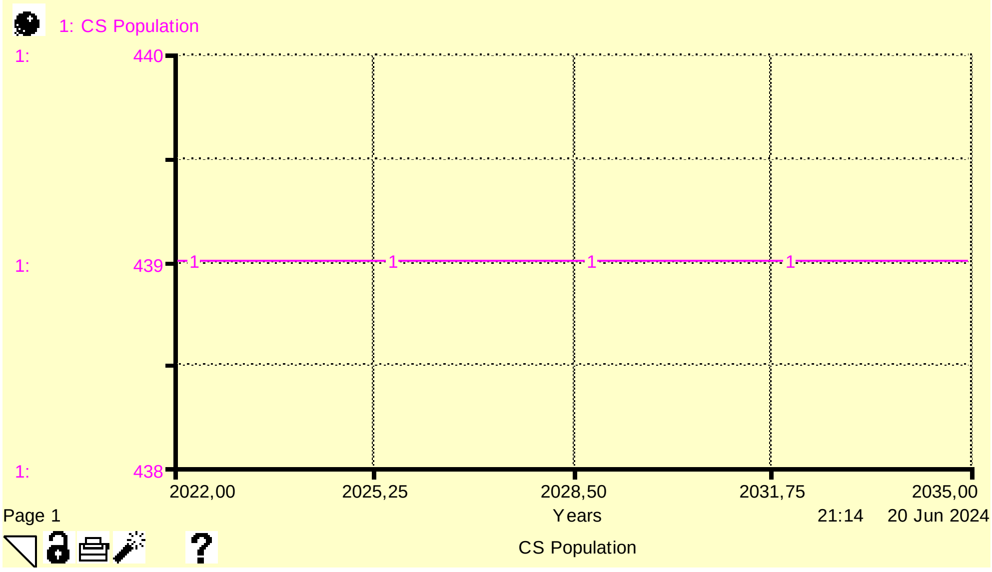


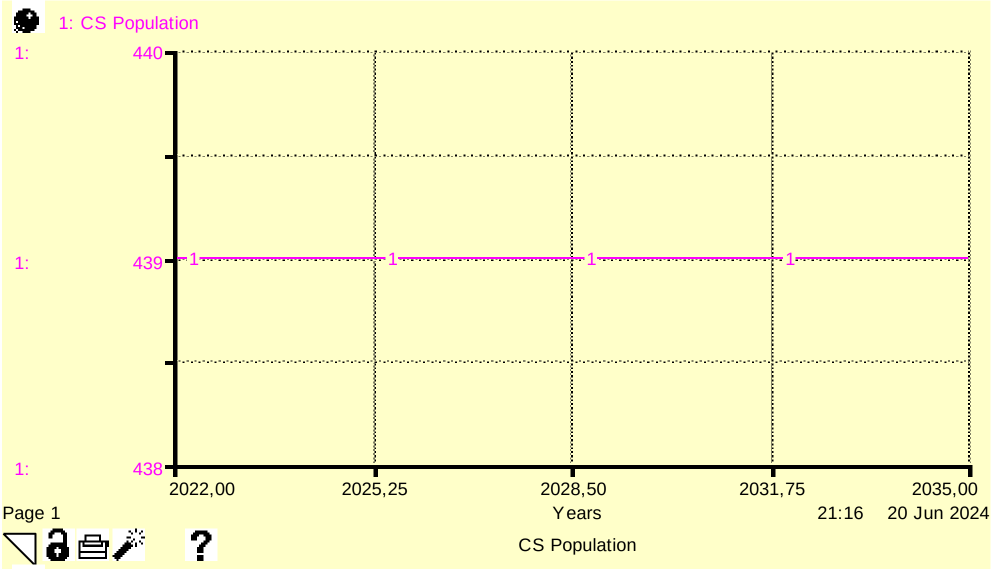


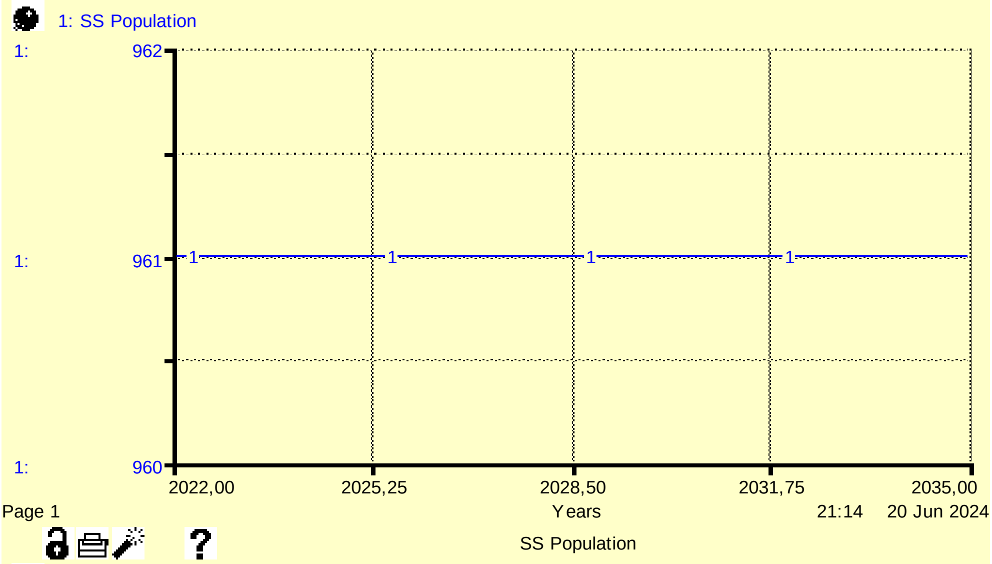


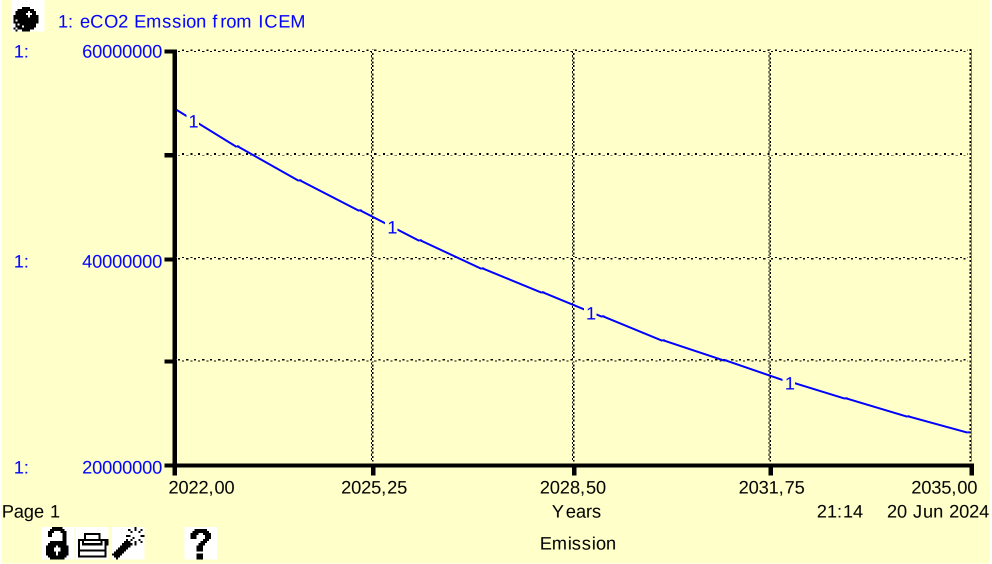
Appendix 21. Ideal Facility to EM Ratio Minimum Extreme Value Test



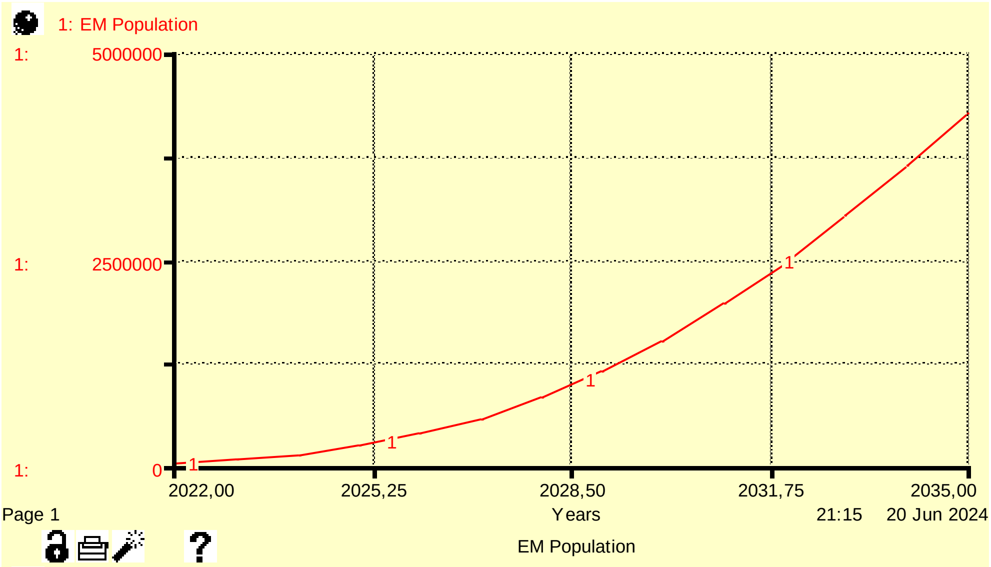


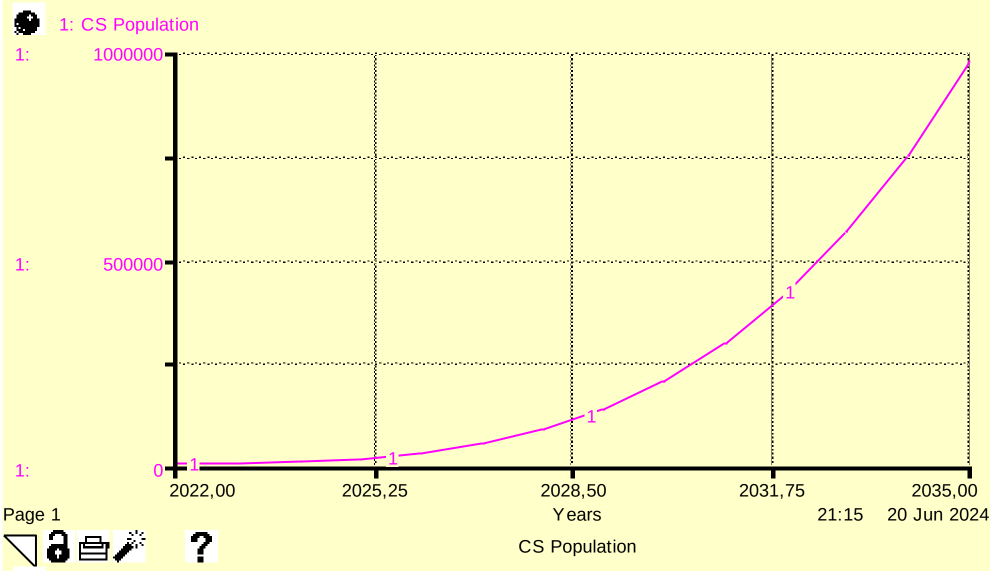

1: CS Population
1: 440
1: 439
1: 438
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:16 20 Jun 2024
CS Population

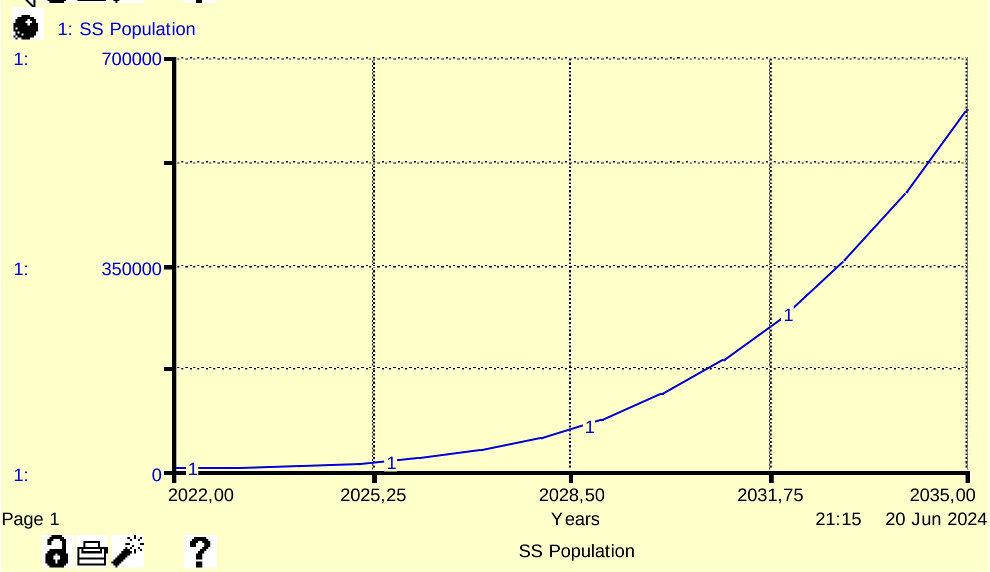

1: SS Population
1: 962
1: 961
1: 960
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:14 20 Jun 2024
SS Population

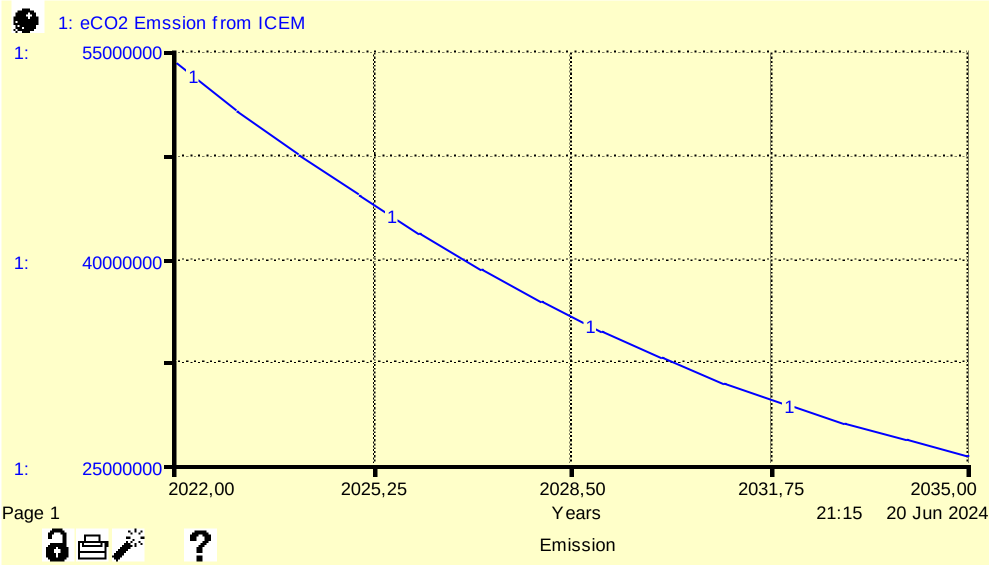

1: eCO2 Emssion from ICEM
1: 60000000
1: 40000000
1: 20000000
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:14 20 Jun 2024
Emission

Appendix 22. Capability to Fulfill Ratio Maximum Extreme Value Test

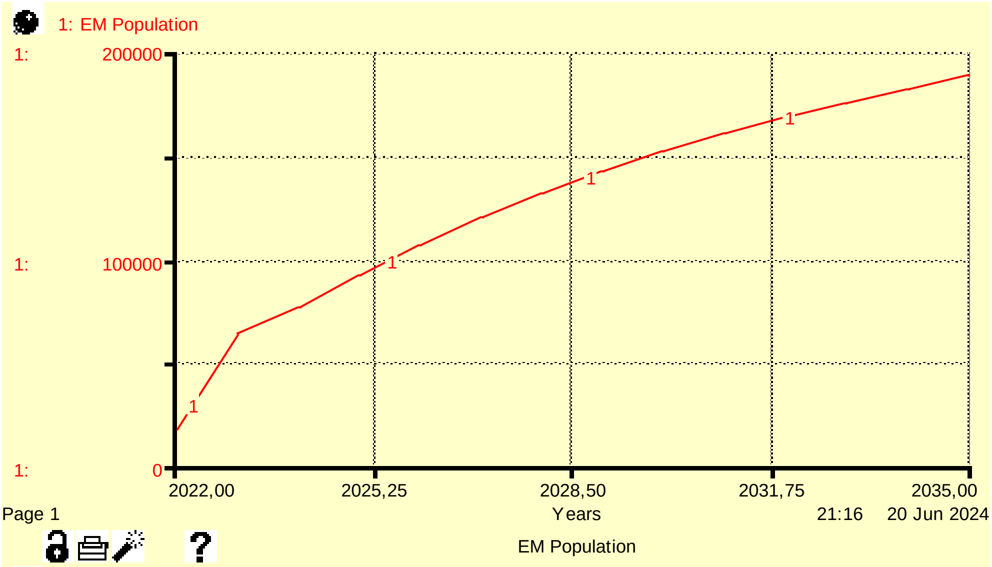


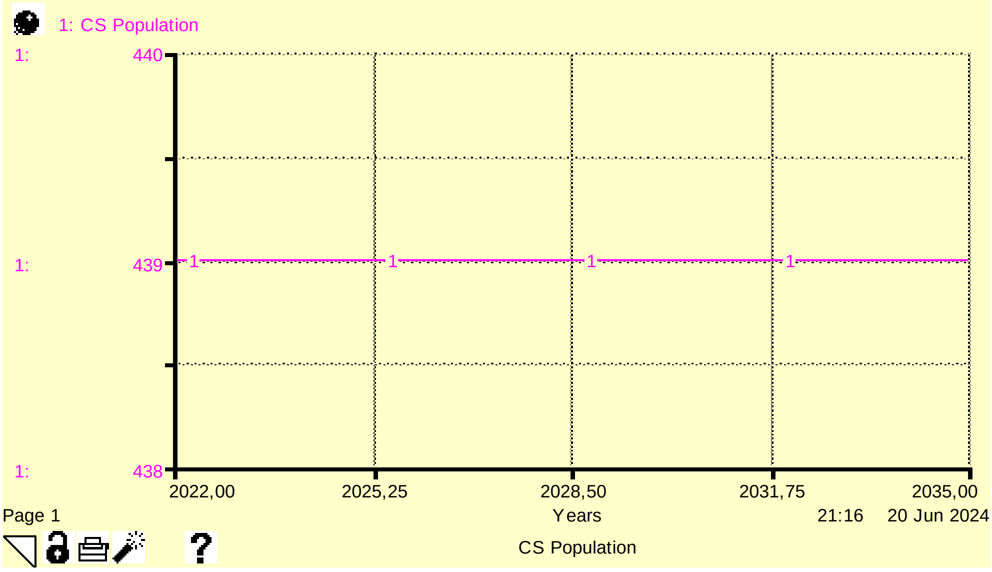


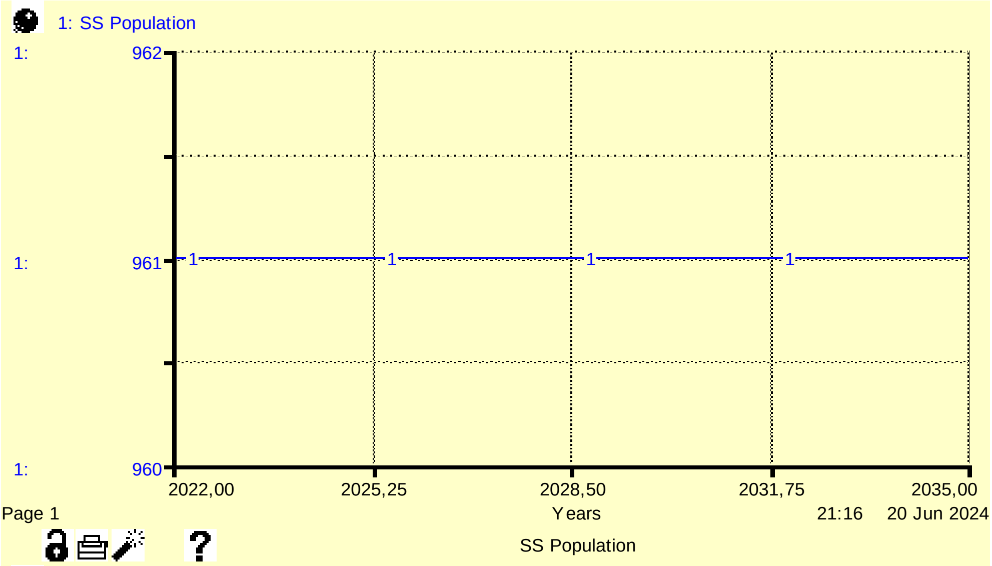


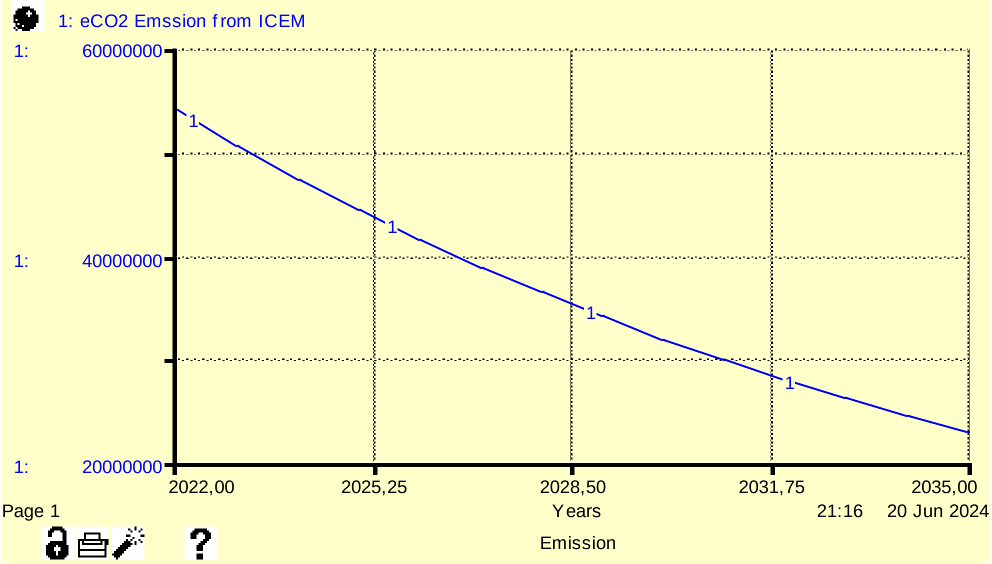


Appendix 23. Capability to Fulfill Ratio Minimum Extreme Value Test






1: SS Population
1: 962
1: 961
1: 960
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:16 20 Jun 2024
SS Population


1: eCO2 Emssion from ICEM
1: 60000000
1: 40000000
1: 20000000
2022,00
2025,25
2028,50
2031,75
2035,00
Page 1
Years
21:16 20 Jun 2024
Emission

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AUTHOR'S BIODATA

Rayhan Makarim was born in Tangerang on 19th of December 2001, the second of three children. The author has received formal education, namely at SD Islam Al-Azhar BSD, SMP Islam Al-Azhar BSD, and SMA Negeri 70 Jakarta. After graduating from senior high school in 2020, the author continued his education at Department of Industrial and System Engineering in Sepuluh Nopember Institute of Technology in 2020.

In the Department of Industrial and Systems Engineering, the author was active in the department's laboratory and organizational activities. The author is part of the department's laboratory assistant in Quantitative Modeling and Industrial Policy Analysis Laboratory. The author was the Secretary and Treasurer of the laboratory and was part of the Relations Department. The author was part of the department's student association, namely Himpunan Mahasiswa Teknik Industri ITS (HMTI ITS). The author was the Head of Industrial Engineering Fair Department that conducts various kinds of Industrial Engineering competition events for high school students and Industrial Engineering major related students and had the opportunity to become a mentor at several organizational trainings held by HMTI ITS.