KIREI

Green and Inclusive Economic Recovery through Circular Economy in Food & Beverages Related Sectors

Part 2 | System Dynamics Modeling

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1. Background and Objective of System Dynamics Modelling

This report will present a generic methodology of systems dynamics modelling for general products. The method will later be tailored to the palm oil industry. We are focusing on the inter-relations between production, consumption (demand), export, and import. Later we will add some interventions to this generic model base on the results of the Waste & CO2 Reduction Life Cycle Assessment Study.

According to Sterman (2004), system dynamics is a method for studying complex systems, based on the theory of nonlinearity, dynamics and feedback control. Martin (1997) defines System dynamics as a methodology used to understand a system that changes over time. System dynamics is a methodology for studying and managing complex feedback systems, such as business and other social systems. System dynamics takes the additional step of constructing computer simulation models to confirm that the structure hypothesized can lead to the observed behaviour and to test the effects of alternative policies on critical variables over time. Feedback control is a basic concept of system dynamics.

Complexity, dynamics, non-linearity, and feedback further characterize system dynamics. Detail complexity is the complexity of the system because of the many elements or components of the system, so the more elements or components, the more complex the system is. Dynamic complexity is the complexity of the system due to the many interrelated components in the system, which means that the more interrelationships between the elements or components, the more complex the system (Soesilo, 2007). System dynamics illustrate that system performance is always changing with changing times. There is no widely accepted definition of non-linearity in the scientific world. in simple terms, the non-linearity of the system is defined as all non-linear systems (Gibson, 1963).

According to Forrester (1971), feedback is system output that returns to system input to affect system work. In the view of O'Conner (1997), feedback is a fundamental system, without feedback, there is no system. Feedback is defined as system output that is returned or becomes system input to affect system performance.

According to Gilpin (2011), the state is the dominant actor both in the domestic economy and in the international economy because the course of economic development is determined by the market and state policies. Competition, interests, and political goals in cooperation between countries have been stated in several agreements, including regional agreements and bilateral trade agreements between two countries. The state is the dominant factor in determining policy, in the process of determining policy the state must protect the interests of the domestic industry and must also protect the national interest. Comprehensive information on the conditions and developments of the related industry must be mastered so that the formulated policies prioritize the national interest.

In international political economy, the interests and policies of the state are determined by the political elite, pressure from interest groups and the national system of political economy. The

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foreign economic policy reflects the national interest defined by its elites. Therefore, the direction of the market can still be determined by the interests of the state which is the goal of the economic activity itself.

Each political-economic system has different characteristics, they have priority given to four aspects namely prosperity, order, justice, and freedom. The government must be able to manage all these aspects to become a policy that prioritizes the interests of the domestic industry. Studies in several developing countries show a strong relationship between the political system in developing countries and the expansion of a market-oriented capitalistic economy.

It should be noted that a large industry in Indonesia absorbs a lot of labor (labor intensive), so the impact of global trade that is not controlled effectively will have wide implications for labor problems in Indonesia, which is one of the performance criteria in this model. The central role of the government here is very dominant in maintaining national interests related to employment, economic stability, and domestic security.

Information on industrial conditions studied at the domestic level is very important in formulating global trade policies, especially information on the cost structure for related industries in the country and the cost structure for related industries in other countries.

2. Methodology for System Dynamics Modelling

In general, a sequential exploratory study was used in this study. It begins with either a stage of quantitative or qualitative data collection and analysis. The output will be used in the next stage of inquiry, and later, these results will feed into an interpretation stage. The study procedure builds on the framework of the systems thinking and modelling (STM) intervention process. The five phases in the STM process are illustrated in Figure 1. Given the time constraint of the working period, the depth of analysis in this study covers the first three STM phases, which are Problem Structuring, Causal Loop Modelling, and Dynamic Modelling.

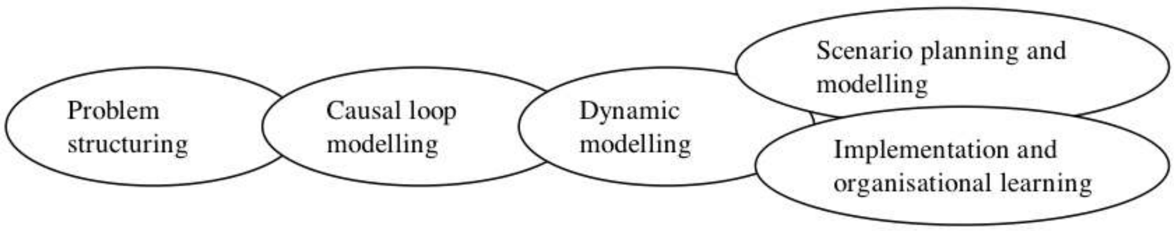

Figure 1. The five phases of systems thinking and modelling (STM)

1. Problem structuring
   The analytical purpose of the problem structuring phase was to define the system's boundary. The main activities were literature reviews (i.e., scientific journal articles) and consultations with a multi-disciplinary group of experts based in the LCDI Secretariate in Bappenas and other institutions.
2. Causal loop modelling
   The analytical purpose of the causal loop modelling was to visually assess the interactions of the components in a system (i.e., variables influencing the state variables) and their feedback relationships within the boundary of the system of interest. The main activities were to develop a causal loop diagram (CLD) by triangulating information from the literature and participatory model building with experts from the LCDI Secretariate in Bappenas and other institutions. The depth of analysis was subject to the complexity of the system boundary (i.e., the number of variables and interactions captured in the CLD) and the study time constraints.
3. Dynamic modelling
   The analytical purpose of dynamic modelling was to allow computer-aided simulation of the dynamics conceptualized under the causal model. The main activity in this phase was stock-and-flow modelling to simulate the accumulation and the rate of change of materials or information. This study was limited to developing a prototype stock-flow model structure using the CLDs as a 'seed structure' to simulate problematic system behaviours (i.e., trends) contributed by the feedback loops identified in the previous phase.

3. Indonesia and World CPO Profile

Before the researcher continues to find data and so on, we need to check the profile of the Indonesian Crude Palm Oil (CPO) industry. Table 1 is the palm oil production data for 2021/2022 for several countries. Based on Table 1, we can conclude that Indonesia is one of the main stakeholders in the CPO Industry in the world. Indonesia can provide CPO in 2022 in the amount of 44,500 tons/year. Indonesia's competitor in SEA is Malaysia with 18,700 tons/year of production.

Table 1. CPO Production for Several Countries

No	Country	Production (ton/year)	Domestic demand (ton/year)	Export (ton/year)	Import (ton/year)
1	Indonesia	44,500	15,675	26,874	-
2	Malaysia	18,700	3,440	15,878	1,300
3	Thailand	3,120	2,510	608	-
4	Colombia	1,615	1,139	454	156
5	Nigeria	1,400	1,665	18	424
Source		(Statista.com, 2022)	(Indexmundi.com, 2022)	(Indexmundi.com, 2022)	(Indexmundi.com, 2022)

Table 2. Indonesia CPO Productions from 2010 - 2020

Year	Production	Domestic Demand	Export	Import
2010	22.496.857	6.234.000	16.291.856	46.720
2011	23.995.973	6.940.000	16.436.202	23.344
2012	26.015.519	7.835.000	18.845.020	616
2013	27.782.004	9.020.000	20.577.976	65.561
2014	29.278.189	7.065.000	22.892.224	299
2015	31.070.015	8.310.000	26.467.564	7.572
2016	31.487.986	12.750.000	22.761.814	2.658
2017	34.940.289	11.056.000	27.353.337	2.518
2018	42.883.631	13.491.000	27.898.875	806
2019	47.120.247	16.747.000	28.279.350	93.285
2020	44.759.147	17.349.000	25.935.257	957
Source	(BPS - Statistics Indonesia, 2021)			

From Table 2 can be seen that Indonesia had big number in Export than Import. The CPO industry turns out to be an export-oriented industry. So the amount of Indonesian CPO production will depend on foreign demand. This domestic production will directly affect the number of workers.

4. Data Collection

During this study, we collected several data (Table 3) as input for this model and illustration the existing situation. Several data that we collect namely:

Table 3 Data Collection for Modelling Input

Data	Description	Unit
The need for production workers per ton of CPO	Number of workers to produce CPO per tonne	person/ton
Domestic CPO Price	National CPO Price	USD/ton
Export CPO Prices	Export CPO Prices	USD/ton
PLTBm efficiency	Biomass Power Plant efficiency	%
Share of Electricity Production from Business-as-Usual (BAU) Biomass	The amount of biomass energy per total energy used as a source of electricity generation for CPO production	%
Share of Electricity Production from Biogas BAU	The amount of biogas energy per total energy used as a source of electricity generation for CPO production	%
Electricity Share Production from BAU Gas	The amount of gas energy per total energy used as a source of electricity generation for CPO production	%
Share of Electricity Production from BAU Diesel	The amount of diesel energy per total energy used as a source of electricity generation for CPO production	%
Share of Electricity Production from BAU Coal	The amount of coal energy per total energy used as a source of electricity generation for CPO	%

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Data	Description	Unit
	production	
PLTBg efficiency	Biogas Power Plant efficiency	%
Palm Oil Mill Effluent (POME) Biogas Calorific Value	Energy value per unit volume of POME biogas	BOE/m3
Palm Shell Calorific Value	Energy value per unit ton of palm shell	BOE/ton
Calorific Value of Empty Bunches	Energy value per unit tonne of empty fruit bunches	BOE/ton
Yield Biogas from POME	The volume of biogas that can be produced per tonne of POME	m3/ton
Palm Shell Yield	Percentage of palm shells produced per tonne of CPO	%
Empty Bunch Yield	Percentage of empty fruit bunches produced per tonne of CPO	%
POME Yield from CPO	Percentage of POME waste generated per tonne of CPO	%
Biomass Emission Factor	CO2 emissions generated per unit of energy from biomass	ton of CO2/BOE
Biogas Emission Factor	CO2 emissions produced per unit of energy from biogas	ton of CO2/BOE
Share Gas for CPO production	Proportion of gas to total energy consumed for CPO production	%
Share for CPO production	Proportion of electricity to total energy consumed for CPO production	%
Share for CPO production	The proportion of coal to total energy consumed for CPO production	%
Emission Factors for Oil Palm Plantation Activities	Emissions generated from plantation activities per hectare of oil palm plantations	ton of CO2/ha
Coal Emission Factor	CO2 emissions produced per unit of energy from coal	ton of CO2/BOE
Share Diesel for CPO production	Proportion of diesel to total energy consumed for CPO production	%
FFB (fresh fruit bunches) Productivity Level	Production of fresh fruit bunches per hectare of garden per year	ton/ha/ year
CPO Wastewater Emission Factor	CO2 emissions produced per tonne of CPO liquid waste	ton of CO2/ton of CPO
Gas Emission Factor	CO2 emissions produced per unit of energy from coal	ton of CO2/BOE
Diesel Emission Factor	CO2 emissions produced per unit of energy from coal	ton of CO2/BOE
Land Transfer Emission Factors	Emission factors from land conversion to oil palm	ton of CO2/ha
Production capacity depreciation rate	CPO refinery production machine depreciation per year	%/ year
CPO Solid Waste Emission Factor	CO2 emissions produced per tonne of CPO solid waste	ton of CO2/ton of CPO
Emission Factor of Empty Bunches	CO2 emissions produced per unit energy from empty fruit bunches	CO2

Data	Description	Unit
Palm Shell Emission Factors	CO_2 emissions produced per unit of energy from palm shells	CO_2
Yield from FFB	Percentage of CPO produced per tonne of fresh fruit bunches	%
CPO Production Energy Consumption	The energy required per tonne of CPO produced	BOE/ton
CPO Production Capacity	CPO refinery capacity	ton
Oil Palm Plantation Area	Oil palm plantation area	Ha

5. System Dynamics Model

5.1 Causal Loop Diagram

To conduct analysis with a system dynamic, we need to formulate the model. The model is constructed based on the relation between variables. To make easier the model formulation step, we build the conceptual model first. The conceptual model for system dynamics formulation is using Causal Loop Diagram (CLD). After the CLD is constructed, we determine the mathematical equation and value of each variable. Then, we simulate the model to gain insights into the policy that we want to implement in the real case.

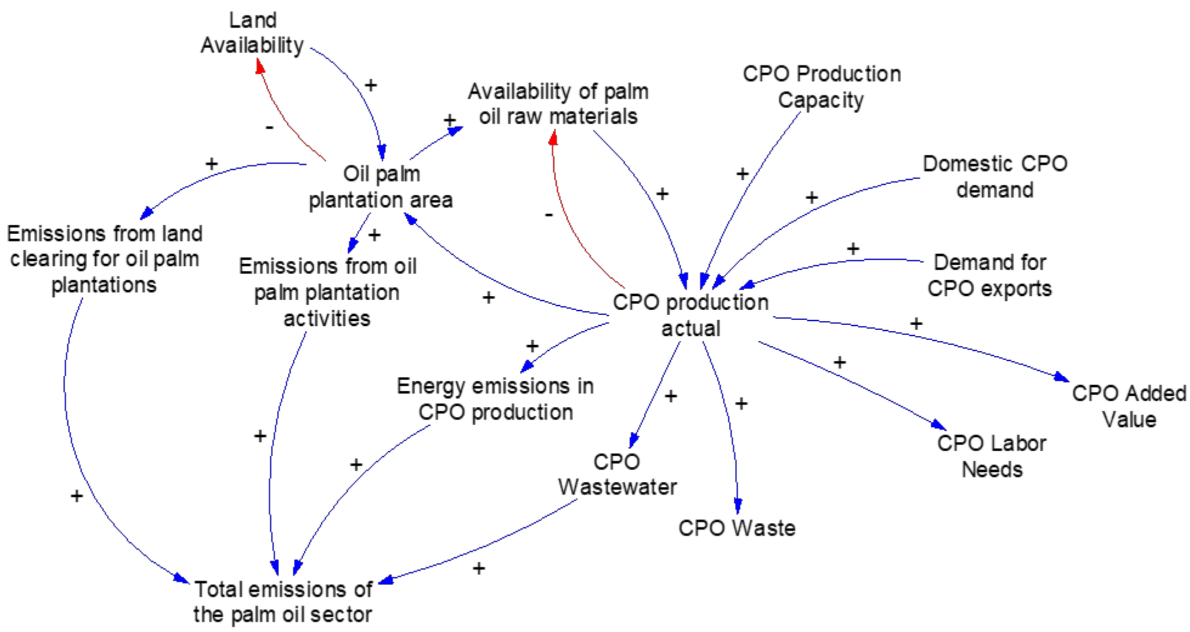

Figure 2. Causal Loop Diagram

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In the following CLD, it can be seen that the area of oil palm plantations will affect land conversion and land availability. The area of oil palm plantations will affect emissions from land clearing for oil palm plantations and emissions from oil palm plantation activities. On the other hand, the area of oil palm plantations will affect the availability of palm oil raw materials which will affect the actual production of CPO and at the same time the actual production of CPO will affect the area of oil palm plantations so that it will form a positive feedback. Actual production of CPO will also be affected by CPO production capacity, domestic CPO demand, demand for CPO exports, and CPO added value. On the other hand, the actual production of CPO will affect energy emissions in CPO production, CPO wastewater, CPO waste and CPO labor requirements. Meanwhile, the total emissions of the palm oil sector are influenced by emissions of waste and wastewater, CPO production energy, emissions from oil palm land activities and emissions from opening oil palm plantations. The structure of the flow diagram for each variable will be explained in more detail in the next sub-chapter.

5.2 Stock Flow Diagram - Macro Structure

The development of the CPO model follows the business flow of the Results of the Waste & CO2 Reduction Life Cycle Assessment Study, which consists of Palm Oil Resources, CPO Milling Process, and CPO Refinery Production.

5.2.1 CPO Resources

The structure of this model (Figure 3) is taken into account as an analysis to project the availability of land that can be used as oil palm plantation land, as well as to project actual FFB production. The addition of oil palm plantation area is influenced by the need for additional oil palm land. The need for oil palm land is influenced by the desired fresh fruit bunch (FFB) production, the productivity level of FFB, the potential for fresh fruit bunch (FFB) production, CPO demand forecasts, and the yield of CPO production from FFB. Meanwhile, actual FFB production is influenced by actual oil palm plantation area, maximum FFB production potential, and desired FFB production.

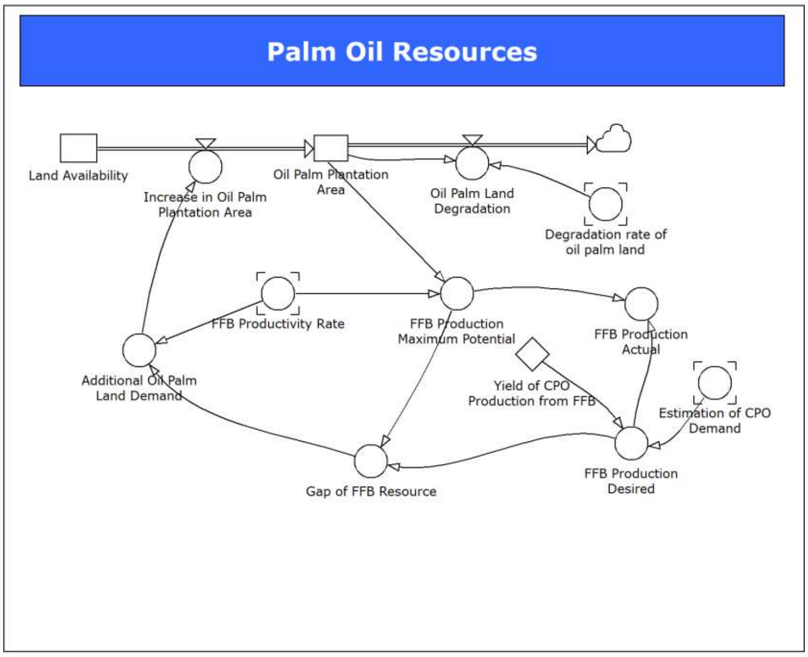

Figure 3. Palm Oli Resources Structure Model

5.2.2 CPO Milling Process

In this model structure (Figure 4) is used to project CPO milling capacity and total fresh water requirement for CPO milling process, as well as total wastewater production. CPO milling capacity is influenced by the need for additional milling capacity, actual FFB production, maximum process potential. The total freshwater milling demand is obtained from the actual FFB milling and the average freshwater milling demand. Whereas in determining the total production using the yield wastewater fraction of feedstock milling.

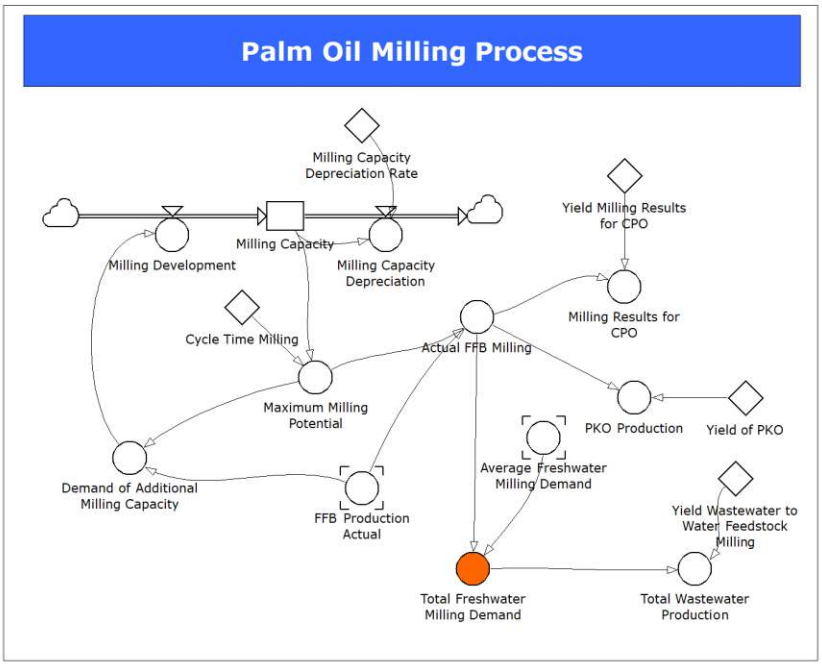

Figure 4. Palm Oil Milling Structure Model

5.2.3 CPO Refinery Production

The CPO Refinery Production model structure (Figure 5) is used to determine capacity in the CPO Refinery process. The need for additional CPO production capacity in the refinery process is influenced by milling results for CPO and the maximum refinery production potential of CPO. CPO refinery capacity will affect the level of production capacity utilization and actual CPO production capacity.

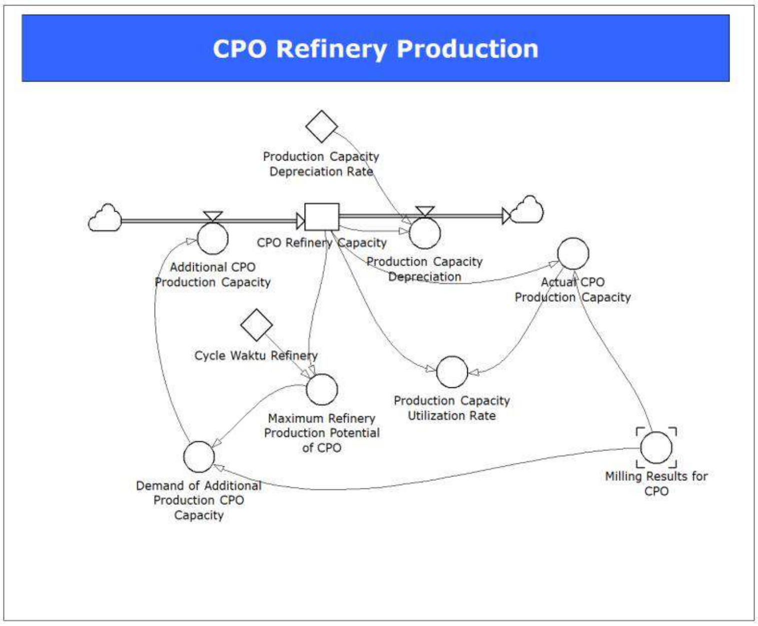

Figure 5. CPO Refinery Production Structure Model

5.2.4 CPO Supply-Demand

The CPO Supply-Demand model (Figure 6) is used to determine the total CPO demand and total CPO consumption. To be able to know the total amount of CPO produced, it can be adjusted to the CPO Demand which is analysed through the model structure related to CPO Supply-Demand. The total CPO demand is influenced by the desired domestic CPO demand and the desired CPO export. Meanwhile, total CPO demand is influenced by actual CPO production capacity and total CPO demand. Note that the input data for CPO requests are data on all CPO production.

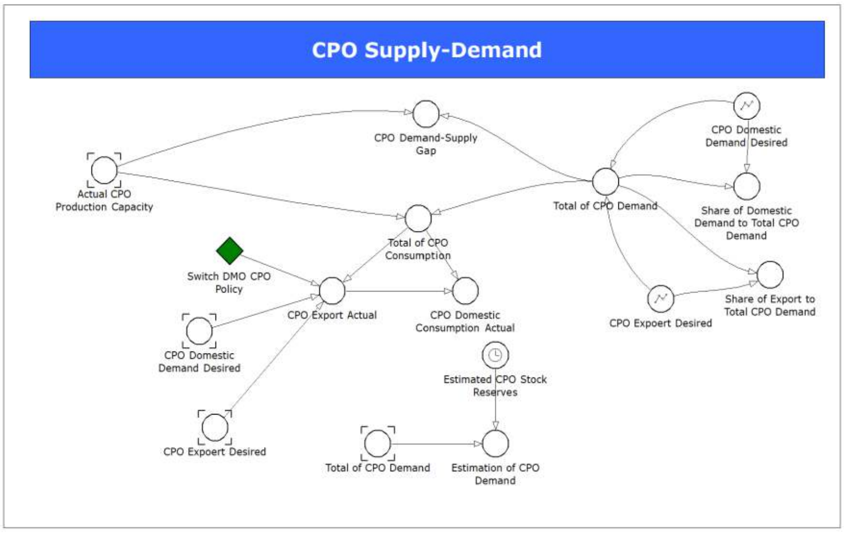

Figure 6. CPO Supply-Demand Structure Model

5.2.5 Waste and CPO Emission

In the structure of the waste and CPO emission model (Figure 7), total potential CPO emissions have been analysed from land conversion activities, oil palm plantation activities, total energy consumption for CPO production, CPO wastewater and CPO waste.

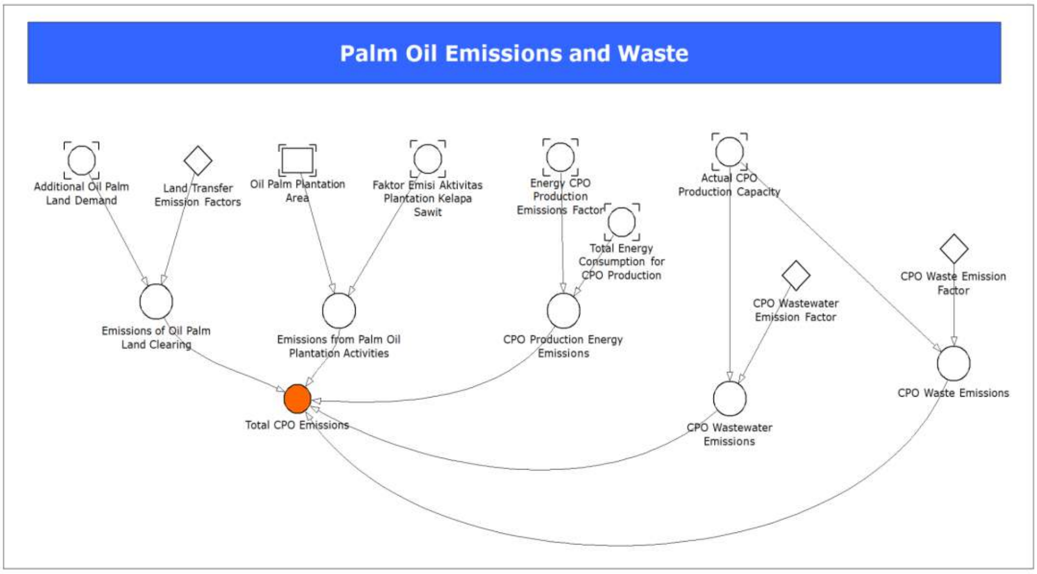

Figure 7. Waste and CPO Emissions Structure Model

5.2.6 CPO Added Value & Total Labor

The added value model structure (Figure 8) is used to analyse the emission intensity of the CPO sector resulting from the total CPO emissions compared to the total added value of CPO. While the total added value of CPO is generated from added value from CPO exports and added value from domestic CPO sales. Meanwhile, the structure of the number of workers takes into account the number of production workers per ton of CPO which is influenced by the total consumption of CPO and the need for labor per ton of CPO. In the CPO sector value-added model, the scenario does not add CPO value because it does not increase CPO demand as a waste & CO2 reduction effort.

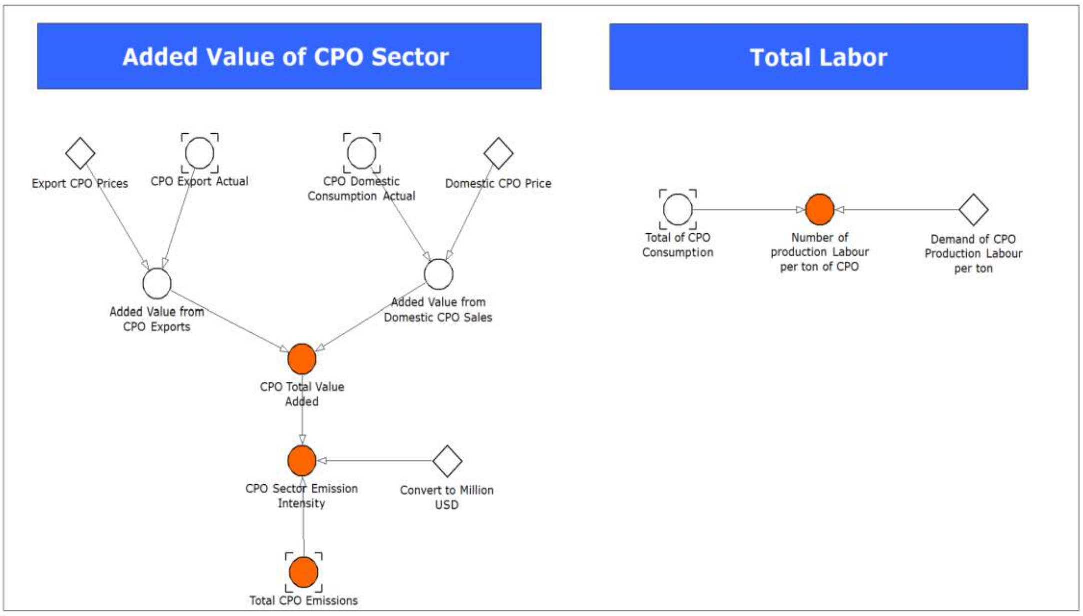

Figure 8. CPO Added Value & Total Labor Structure Model

5.3 Stock Flow Diagram - Policy Structure

5.3.1 Policy 1: Use of organic fertilizers and decentralization of CPO factories

This structure (Figure 9) is used as a model for analysis of policy interventions related to the use of organic fertilizers and the decentralization of CPO factories towards the implementation of a circular economy in the CPO plantation process. The intervention using organic fertilizers in the planting process will increase emission reductions compared to emissions using chemical fertilizers. Meanwhile, the CPO mill decentralization intervention in the planting process will be influenced by the distance between the plantation and the processing area, which will have implications for transportation emissions.

Switching from the use of chemical fertilizers to organic fertilizers can affect land degradation. So that if the use of organic fertilizers increases, the land degradation will be lower. Organic fertilizers can be in the form of solid fertilizers and liquid fertilizers by utilizing and managing solid waste from the CPO process because it can reduce the potential for methane gas. As an additional note that it does not highlight organic fertilizer from POME, because it still requires enrichment and more detailed data so that a more in-depth study can be carried out.

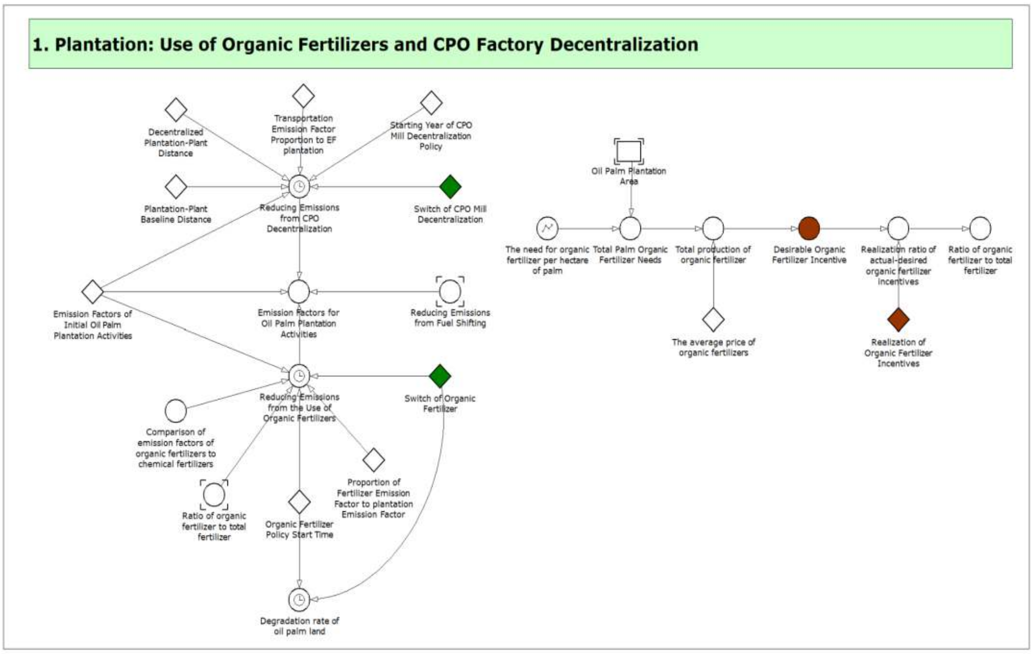

Figure 9. Plantation Policy 1 Structure Model

5.3.2 Policy 2: Increased planting productivity

The CPO planting increase policy (Figure 10) was analyzed based on the intervention target to increase productivity from the baseline as usual productivity and the year the plantation productivity increase policy was started.

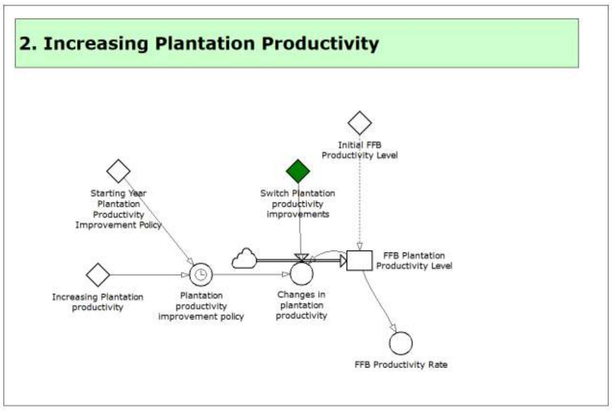

Figure 10. Plantation Policy 2 Structure Model

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5.3.3 Policy 3 & 4: POME Biogas & Empty Fruit Bunches and Palm Shell Biomass

The structure of this model (Figure 11) is used to analyze policy interventions for the management of liquid waste and solid waste in the CPO process through biogas and biomass processing. The processing of biogas from palm oil mill effluent is influenced by actual CPO production capacity, PME production and biogas yield from POME. Biomass potential is generated from solid waste production in the form of empty fruit bunches, palm shells and fibres which are affected by the actual FFB milling process.

Biogas and biomass products from solid waste of empty fruit bunches, palm shells and fibres as potential sources of electrical energy that affect the share of potential energy from biomass and biogas to total electricity demand. In addition, the potential share of electricity from biomass and biogas is affected by electricity consumption for CPO production, electricity production from PLTBm (Biomass Power Plants) - PLTBg (Biogas Power Plants), the efficiency of PLTBm and PLTBg, share utilization of biomass and biogas for electricity which is desired.

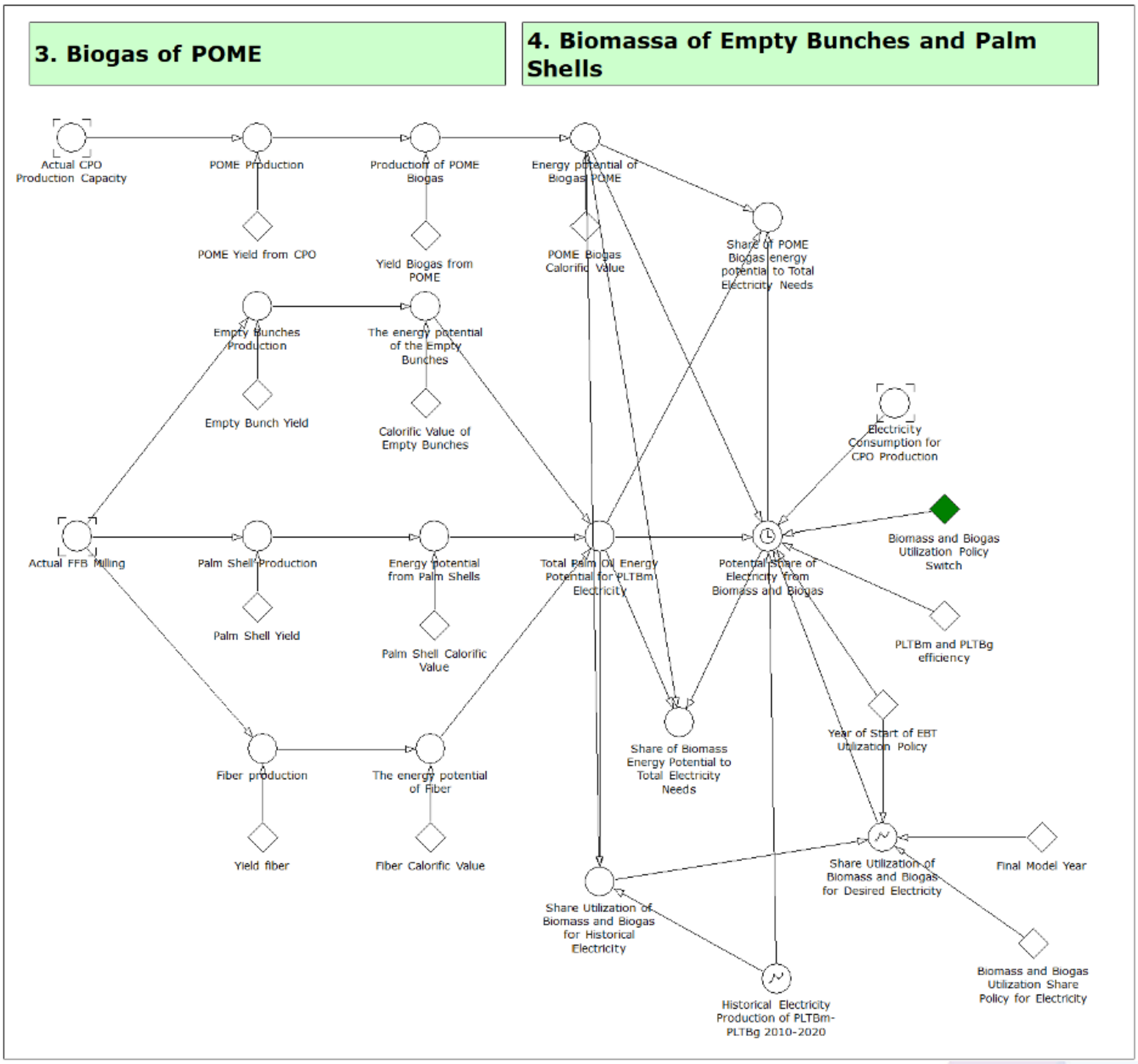

Figure 11. Policy 3&4 Structure Model

5.3.4 Policy 5: Waterless Milling

Waterless policy interventions in the milling process (Figure 12) can be analyzed through the structure of this policy model which considers the ratio of actual and desired waterless milling investment realization. Waterless milling policy investment needs are influenced by milling capacity, waterless milling investment needs per ton, milling time cycle, and the year the waterless milling policy starts. For milling capacity, it is assumed that 1 year is 200,000 USD calculated from a capacity of 10 tons/hour. However, investment data is still limited, CAPEX data does not include OPEX which can be used as further analysis.

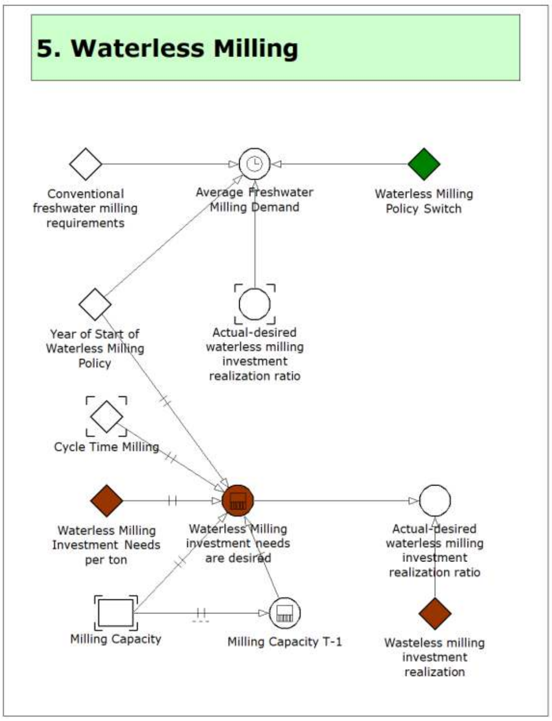

Figure 12. Policy 5 Structure Model

5.3.5 Policy 6: CPO Processing Technology Efficiency

The CPO processing technology efficiency policy (Figure 13) is analyzed through this policy structure by considering the start time of the CPO energy efficiency policy and industrial energy efficiency targets. Technology efficiency policies in CPO processing have an impact on the energy consumption of CPO production. Technological efficiency in CPO processing can be calculated from the assumption of the average manufacturing industry.

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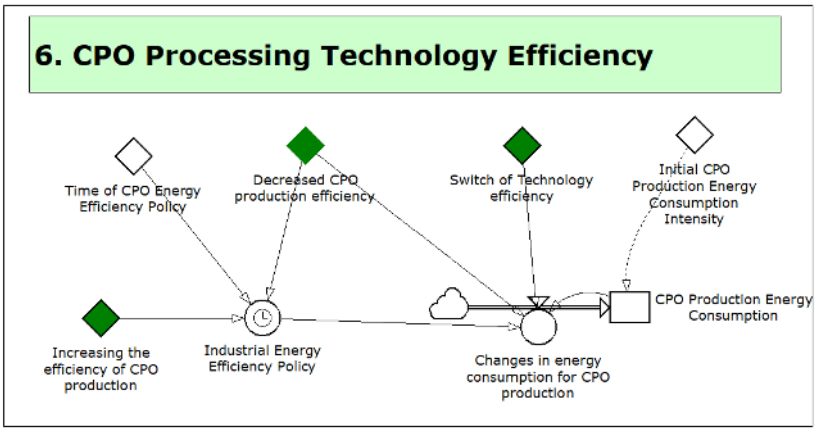

Figure 13. Policy 6 Structure Model

5.3.6 Policy 7: Shifting Diesel Fuel Trucks to BioCNG

Structure of Diesel-BioCHG Truck fuel shifting policy (Figure 14) to analyze the effect of Diesel-BioCNG Truck fuel shifting intervention on emission reduction. Reducing emissions from fuel shifting is influenced by the initial oil palm plantation activity emission factors, gas emission factors, diesel emission factors, the proportion of transportation emission factors to plantation emission factors and the year the BioCNG fuel shifting policy starts.

The gas emission factor is smaller than the diesel emission factor, so it will affect transportation emissions from the plantation to the factory where the new scope model is calculated for the transportation model to the factory. Meanwhile, policies are installed to accommodate transportation needs which are controlled by the industry itself.

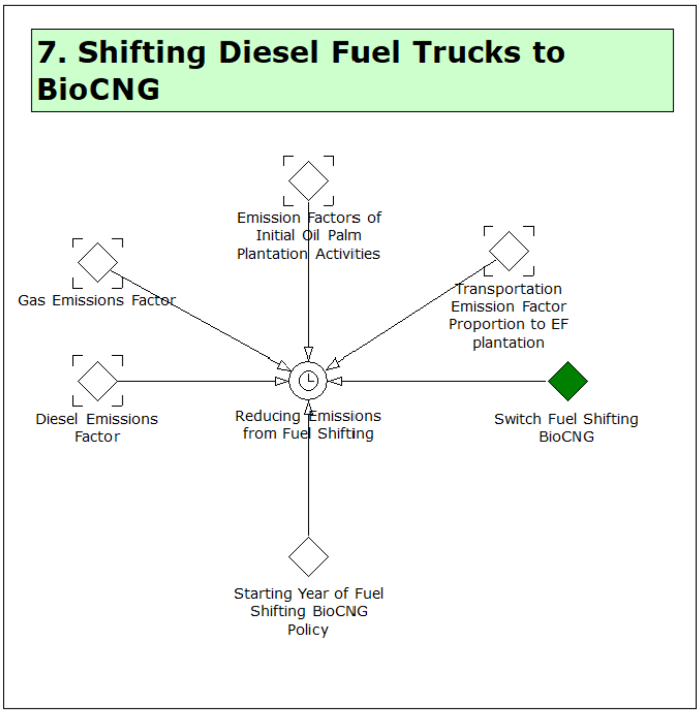

Figure 14. Policy 7 Structure Model

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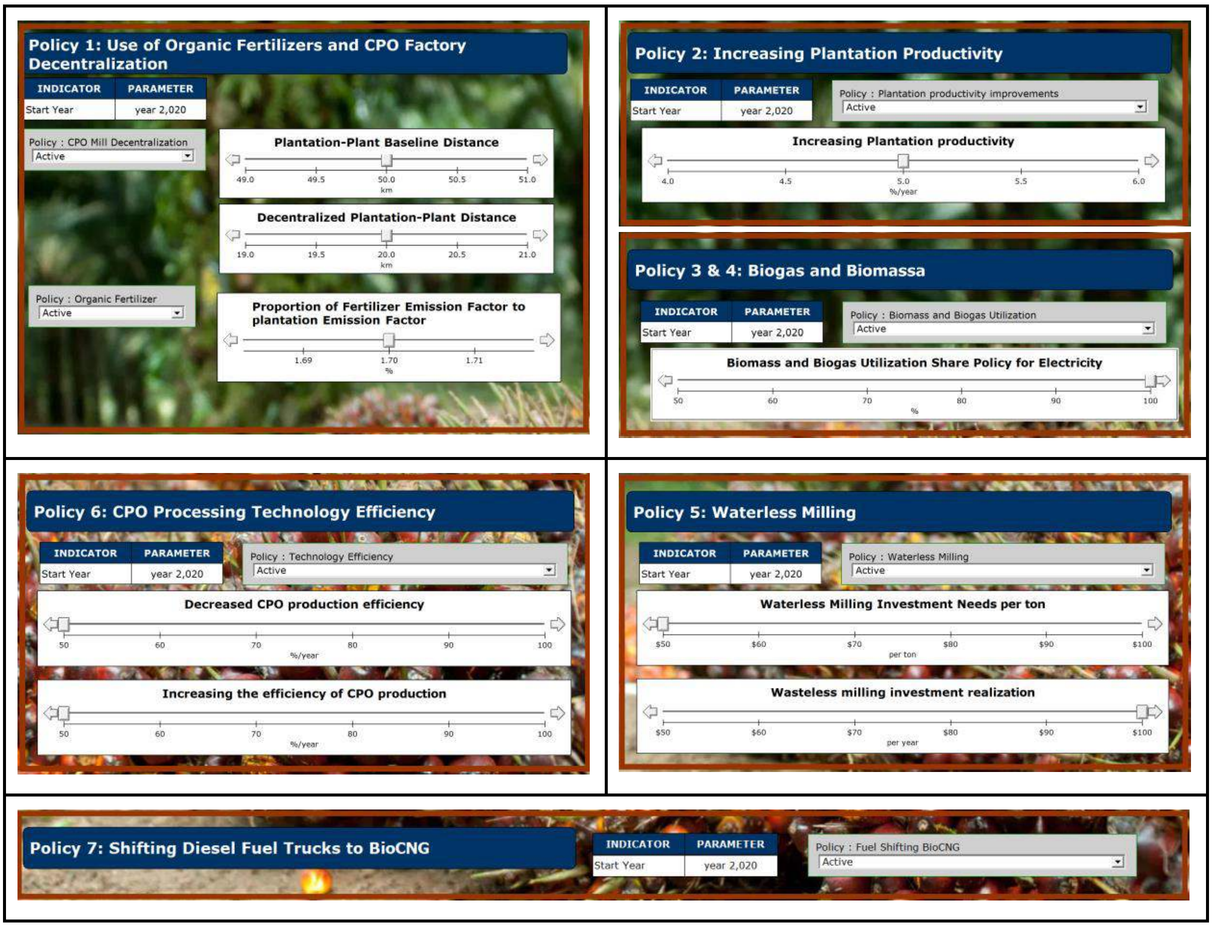
6. Simulation of Indicator and Policy Intervention

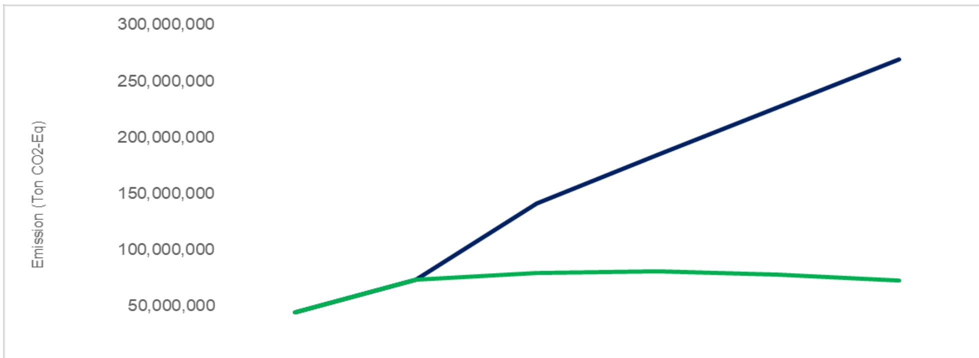
To know the illustration if one or some policies will be implemented in the real world, there will be a need to conduct simulation. This simulation is conducted by changing value on the decision variables. Policy analysis is exercised based on socio technical options of waste and CO2 Reduction Strategy from the Waste & CO2 Reduction Life Cycle Assessment study with the following conditions:



After the all the scenario was simulated, we get several information regarding to simulation result. To ease the understanding, we focus on the performance measurement indicators. There are 5 (five) performance measurement indicators.

- **Total of CPO Emissions**

Total CPO emissions (Figure 15) fluctuate due to changes in land use change (sequestration). The area of oil palm plantations will affect land efficiency. Total CPO emission consists of land conversion activities, oil palm plantation activities, total energy consumption for CPO production, CPO wastewater and CPO waste. If viewed from the results of a business as usual (BAU) simulation, the total emission of the CPO sector will relatively continue to increase in line with the increase in CPO activity of 269,532,359 tons of CO2-Eq in 2060. However, if policy interventions begin to be implemented from 2020, the total emission in the CPO sector is projected to be reduced to 72,995,407 tons of CO2-Eq or 72.3% compared to BAU conditions.

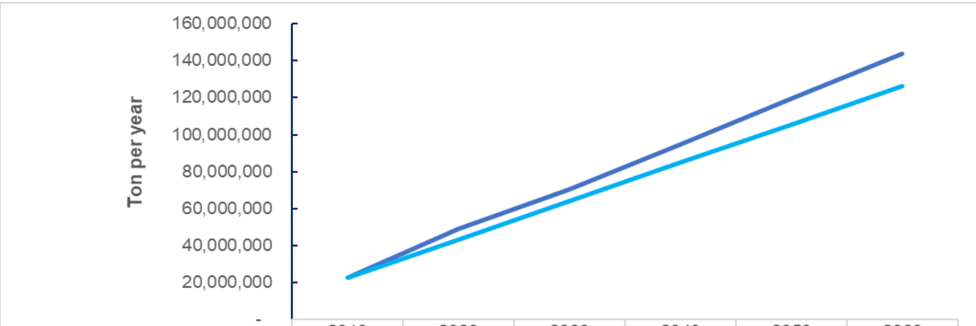


	2010	2020	2030	2040	2050	2060
Bussines-as-Usual	44,517,074	74,061,115	141,570,043	184,222,736	226,881,049	269,539,359
Policy	44,517,074	74,016,047	79,443,847	80,807,823	77,989,979	72,995,407

Figure 15. Total CPO Emissions

- **Total of CPO Demand**

Total of CPO Demand (Figure 16) will increase from year to year in line with population growth and export growth which will affect the total consumption of CPO. The model simulation has projected that the total CPO demand in 2060 will be 126,317,861 tons per year. Meanwhile, the actual production of CPO in 2060 is 143,756,184 tons per year.



	2010	2020	2030	2040	2050	2060
Actual of CPO Production	22,525,856	48,800,704	70,501,745	94,920,676	119,339,930	143,759,184
Total of CPO Demand	22,525,856	43,284,257	64,042,658	84,801,059	105,559,460	126,317,861

Figure 16. Actual of CPO Demand and Total of CPO Production

- **CPO Emission Intensity**

CPO Emission intensity (Figure 17) is calculated from the ratio of CPO Total Value Added to the total emissions of the CPO sector. In a business as usual simulation, CPO emission intensity is projected to stagnate, whereas if policy interventions begin in 2020 CPO emission intensity will decrease by 73% compared to BAU conditions in 2060. Emission intensity will decrease, which means the intensity will support green economy.

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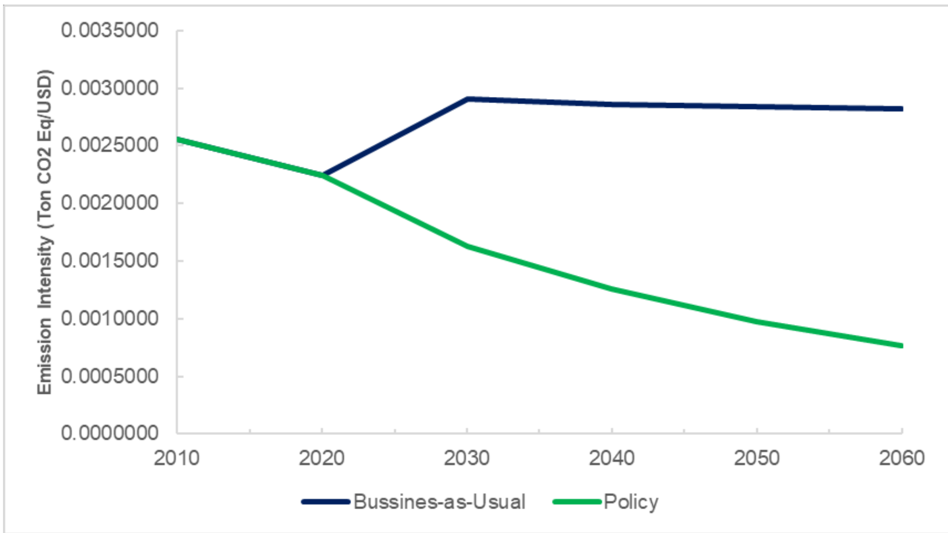

Figure 17. CPO Emission Intensity

- **Labor**

Labor for the CPO production (Figure 18) process are projected to continue to increase in accordance with the increase in CPO production. From the model results it can be seen that the total labor in 2060 is 348.637 labor per ton of CPO

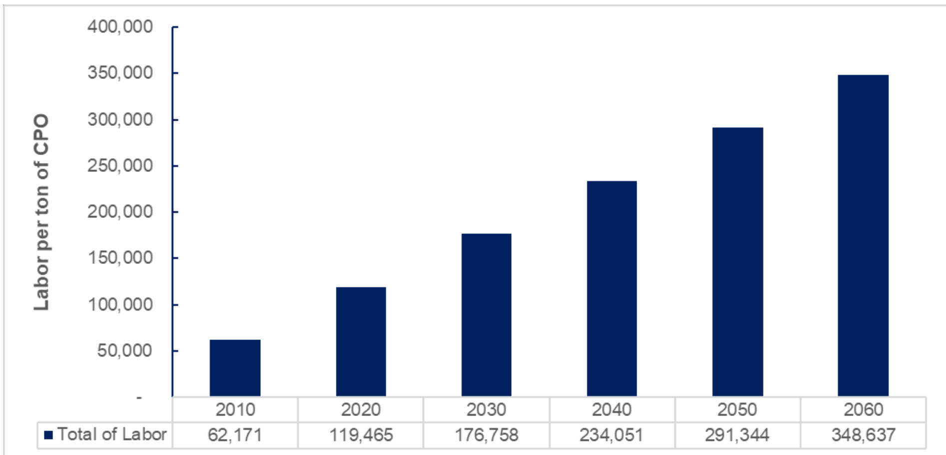

Figure 18. Labor

- **Freshwater Milling Needed**

The simulation results of freshwater milling policy interventions to increase the productivity of the CPO milling process have an impact on the need for investment in freshwater milling technology (Figure 19) which will increase from the business-as-usual simulation. The increase in investment requirements for freshwater milling technology in 2060 will reach USD 14,126,690 per year.

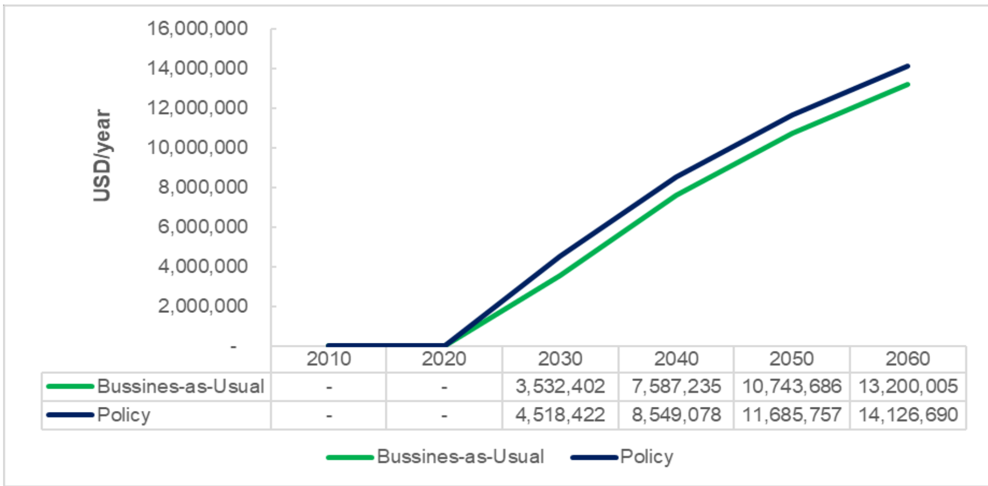

Figure 19. Waterless Milling Investment Desired

7. Conclusion and Recommendation

The results of the Waste and CO2 Reduction Life Cycle Assessment have identified potential policies that support circular economic activities in the CPO sector. Meanwhile, the study has also been analyzed and simulated through a system dynamics model that has considered the available quantitative and qualitative data, expert judgment and other discussions. After constructing a system dynamic model and conducting simulation for scenario analysis, we get several recommendations based our findings in this study. Then, these recommendations can be developed further and exercise the feasibility to implement it. We need to study further about the alternative of investment that can lower the carbon emission. The selected policy should be made in a timeline when the policy will be implemented. As an input in the implementation of policy potential in terms of the results of the analysis of models and enabling conditions, the strategy design also considers the strategy implementation period which is determined by expert judgment based on the time feasibility to achieve the strategy. Three categories of the strategy implementation period are the short term period (1 year), medium term period (5 years) and the long term period (25 years).

Table 3. Strategy for Improving

No	Policy	Period	Enabling Condition
1	Use of organic fertilizers	Short term	a. It is easy to find in oil palm plantations because it can be obtained from empty fruit bunches and palm oil mill effluent b. Efforts to avoid garden dependence on chemical fertilizers as well as anticipate reduced nutrient and organic matter levels in the soil, as well as help disease

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No	Policy	Period	Enabling Condition
			resistant plants c. Easy to apply to cropland
2	Decentralization of CPO factories	Medium term	a. Need support, collaboration and empowerment of smallholders b. Empowering smallholders to the owner as well as the worker of the facilities could be a way out to lower the emission and cost, as well as alleviation of poverty
3	Increased planting productivity	Short term	a. Soil health includes optimum and mutually supportive physical, chemical, and biological properties of the soil b. It is quite easy to apply to planting land c. Increase the availability of ground water
4	Wastewater management: POME Biogas	Medium term	a. Availability of funding and rate of return on investment, and lack of interest in investing or providing loans b. Application of technology that fits the market and makes it a profitable commercial project c. Perceptions of companies regarding the difficulty of working with PLN d. Limited information regarding technology, incentives, and human resources for operationalization
5	Waste management: Empty Fruit Bunches and Palm Shell Biomass		
6	CPO Processing Technology Efficiency	Long term	a. Investment in CPO process efficiency technology is needed b. Availability of funding and rate of return on investment, and lack of interest in investing or providing loans c. Limited information regarding technology, incentives, and human resources for operationalization
7	Waterless Milling	Long term	a. Investment in waterless milling technology is required b. Availability of funding and rate of return on investment, and lack of interest in investing or providing loans c. Limited information regarding technology, incentives, and human resources for operationalization

No	Policy	Period	Enabling Condition
8	Shifting Diesel Fuel Trucks to BioCNG	Medium term	a. Limited information regarding technology, incentives, and human resources for operationalization

In conclusion, based on the result and analysis from it, we can construct six recommendations for government:

1. Capacity building of stakeholders such as companies, government, NGOs (non-governmental organizations, and financial institutions. Knowledge sharing by companies that have successfully intervened in policies related to the economic circular, construction of training centres, application of international standards, development of guidelines and national standards by the government and safety standards for PLTBg and PLTBm.
2. The government encourage for the obligation to develop methane capture through ISPO (Indonesian Sustainable Palm Oil) establishing GHG emission standards that require methane capture installations; additional points in the PROPER (Company Performance Rating Program in Environmental Management) assessment for mills with methane capture facilities and GHG emission reports.
3. The government needs to build a pilot project that can serve as a training centre and make referrals to projects in neighbouring countries such as Thailand and Malaysia.
4. Looking for the more efficient options to conduct investment that lower the carbon emission. The more efficient options mean the alternative outside reforestation or combination of reforestation and another alternative. Another alternative that should be consider is investment in more advanced machinery which produce less carbon emission.
5. Prioritize the application of the intervention policies that implement the obligation to conduct investment that lower the carbon emission and carbon tax. It should be noted that both of policies should be implemented together at the same time to fulfill the better performance on labor, taxes collected by the government, and carbon emission reduction.
6. Consider changing the tax incentives to a subsidy or incentives that can reduce the average cost of investment to lower the carbon emission. The subsidy can be given during the investment process that reduce carbon emission or subsidy that can lower the product price of palm oil company in the domestic/foreign market. The subsidy sources can be taken from the carbon tax revenue, so the government can implement cross subsidy mechanism.

Then, for palm oil industry, we generate three recommendations:

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1. Support and participate the implementation of the policy. The policy will not deliver the outcome if the palm oil industry company as the one who implement in the real condition.
2. Give opinion and feedback before (policy construction process) and during the implementation of the policy. The industry party should assess the impact and outcome, especially in terms of cost and revenue, if the policy will be implemented. The process before and during the implementation should be in two directions from and to government and palm oil industry, so it can generate win-win solution for both parties.
3. Focus on balance sheet financing, bearing in mind that biogas projects are considered small for an investment project scale, making it less attractive for financial institutions to support project financing schemes. Ensure financial feasibility through a complete feasibility study, and pursue concessional loan options.

Furthermore, there is a recommendation for both government and palm oil industry. Government and palm oil industry parties should det up discussions to promote the policy that will be implemented and the capability of the industry to support that. The discussion should generate additional benefit to company who will implement the policy. For example, there will be eco-friendly logo or awarding that can be placed on the product of company or more support of government in terms of export palm oil product to specific countries that have high awareness in eco-friendly (i.e., Europe).

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