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Assessment of Potential Impacts from Emission Mitigation Policies in Indonesia

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I. Introduction

1.1 Background

Indonesia economy is kept advancing and gradually among the best economies in the Group of Twenty (G20), and it also becomes the largest economy in the Association of Southeast Asian Nations (ASEAN). However, it still struggling to transform its economic structure and become a developed country (Legowo, 2017). Thus, make Indonesia government develop several masterplans to boost Indonesia economic growth and development. Started from The Acceleration and Economic Development (*Masterplan Percepatan dan Perluasan Pembangunan Ekonomi Indonesia*/ MP3EI) in 2011 which stated that Indonesia needs to expand its economic development by using its demographic potentials, the abundance of its natural resources, and by its geographical advantages (Indonesia Ministry for Economic Affairs, 2011). As the president changed, the term of MP3EI also not widely used again but then replaced by *Nawacita* (nine priorities) that have a similar focus to improve the economic condition. The *Nawacita* is then translated into the 2015-2019 National Mid-Term Development Plan (*Rencana Pembangunan Jangka Menengah*/ RPJMN).

In the same time, Indonesia is also facing some environmental issues. From the agriculture, forestry, and land use (AFOLU) sector, Indonesia still experiences high and rapid deforestation/ forest degradation along with seasonal forest fire caused by El-Nino or human activities. Those make Indonesia the world's fifth-largest emitter of green house gases (GHGs) and the most significant contributor to forest-based emissions (Chrysolite et al., 2017). As a country with a dense population, Indonesia also needs to make sure the food sustainability of the people by maintain the sustainability of its agriculture production. However, there is also a land competition for building in the Java area, and within the commercial plantation outside the Java area.

In the energy sector, Indonesia also faces some challenges. One of the biggest challenges that should be facing is to manage the energy sufficiency to meet the national needs. Along with a higher and bigger economic condition, the needs for energy will also increase. However, crude oil, that becomes one of the main primary energy supplies for Indonesia slowly getting limited. Under that condition, the use of coal is assessed to be increased as there are more stocks available, but it may significantly increase GHG emissions. Another way is to utilize renewable energy like geothermal, as Indonesia itself is one of the countries with the biggest geothermal potential. However, the technology development for renewable energies is mostly imported. The geographical challenges of Indonesia also make supporting infrastructure installation harder and more expensive. It makes the progress of renewable energy utilization becomes very slow.

Moreover, under the Nationally Determined Commitment, Indonesia needs to reduce its total emission by 29% (voluntary) or 41% (involuntary) by 2030 compared to the BAU level. Indonesia needs to achieve that emission target and at the same time, also considering all the challenges that possibly arise. The government needs to consider the cost and impact of doing the mitigation policies to its economy and environment. This study, using the Computable General Equilibrium (CGE), will try to assess the impact of the emission mitigation policy on Indonesia economy.

1.2. GHG Emission and Emission Reduction Target

GHG emission reduction policy in Indonesia is evolving for several times. In 2009, Indonesia through President Bambang Yudhoyono delivered his speech at the G20 summit in Pittsburgh, United States and state that Indonesia commits to reduce 26% reduction in GHG emission below Business as Usual (Bau) level by 2020 by unilateral actions and further reduction until 41% below BaU if equate international support is available. This commitment then translated into Presidential Regulation of the

Republic of Indonesia No. 61/ 2011 and later known as RAN-GRK (*Rencana Aksi Nasional Untuk Gas Rumah Kac*a/ The National Action Plan for GHG Emissions Reduction) (Thamrin et al., 2011). Although this policy gains some critics nationally because it is considered too ambitious and too rushed without considering the national condition that Indonesia still in developing phase (Zuhra, 2017), but the target then revised in 2015 and even became stricter than it is on the RAN-GRK.

Before the 21st Conference of the Parties (COP 21) organized by United Nations Framework Convention on Climate Change (UNFCCC), member countries, including Indonesia, agreed to expanded emission reduction commitment for post-2020 which known as Intended Nationally Determined Contributions (INDC). Indonesia's INDC was released on September 24th, 2015 and targeted to reduce emission to 29% below BaU level and 41% with international support. According to this document, Indonesia emission is expected to increase from 1,805 MtCO2e/year in 2020 to 2, 881 MtCO2e/year by 2030. With 29% and 41% reduction commitment in 2030, then it follows that Indonesia targeted to reduce emission until 1,336 MtCO2e/year unconditionally (29% reduction) and 1,700 MtCO2e/year conditionally (41% reduction) (Government of Indonesia, 2016). Hereafter, this emission reduction target is called as Indonesia NDC. Although the target year of emission reduction in NDC is later than RAN-GRK. Although the target year is getting a little bit longer, the voluntary emission reduction is become higher (Table 1.1). Nevertheless, Indonesia INDC is still become the most crucial documents regarding emission reduction target, because this document will be translated into revised National Action Plan on Reducing GHG Emissions (Revised RAN-GRK) and will become a policy base for every ministries and institution to control and reduce their GHG emission.

Table 1.1 Comparison between RAN-GRK and Indonesia NDC

Indicators	RAN-GRK	Indonesia NDC
Target Year	2020	2030
Emission Reduction Target	Voluntary: 26% Involuntary: 41%	Voluntary: 29% Involuntary: 41%
BaU emission projection	2020: 1791 MtCO2eq 2030: 2881 MtCO2eq	2020: 1980 Mton CO2eq 2030: 2869 Mton CO2eq
Main focal point	Ministry of National Development (*Kementerian Perencanaan Pembangunan Nasional/ Bappenas*)	Ministry of Environment and Forestry (Kementerian Lingkungan Hidup dan Kehutananan/ KLHK)

The Indonesia NDC gains more critics because the target is higher than what stated in the RAN-GRK. Some parties assessed that Indonesia has a lack calculation on the impact on emission reduction target on the economic. There is also no lack of details of the methodology and quantitative measurements (Damassa et al., 2016). The baseline approach used by Indonesia is considered to have a limited indicator by only reducing total GHG emissions, without being accompanied by development indicators, such as GDP whereas emissions are generated from all economic sectors, such as transportation, industry, electricity, buildings, households, food, and other sectors (Wijaya and Chrysolite, 2017).

Indonesia itself still struggling to measure the sectoral impact of its GHG mitigation impact. Nationally, the government started to develop sectoral Monitoring, Reporting, and Verification (MRV) system, but it still faces some obstacles for implementation at the local level. This is a reason why an impact assessment of mitigation policy is still needed by the Indonesian government, as Indonesia still cannot find the exact measurement to measure their policy impact and have not enough tools to consider whether they need to revise their policy or not.

1.3. Previous Related Studies and the Significance of the Study

There are several studies related to GHG actions in Indonesia. However, those studies are not yet considering mitigation in all sectors. The mitigation in the AFOLU sector started to be introduced by (Hasegawa et al., 2016). By using the global AIM/CGE that combined with the AFOLU model, this study shows that if Indonesia would meet the latest INDC target, around 58% of total reductions should come from the agriculture, forestry and other land-use sectors by implementing forest protection, afforestation and plantation efforts. The study also shows a high carbon price in 2030. Thus, reach the 2030 target would be economically challenging. However, there are no details about the exact economic impact of the mitigation in this sector.

By using the similar technologies and assumptions for the agricultural sectors used in the Hasegawa et al. (2016), the study is the extended by introducing the national target and using the national statistic and create a country model for Indonesia for the mitigation policy for Indonesia. It was found that by comprehensively introduce the mitigation action in agricultural sectors and implement the carbon tax policy to manage the emission level, Indonesia will experience 2.98% of GDP loss in 2030 compared to BaU level (Malahayati and Masui, 2018a). However, this analysis only considers the agriculture sector and still not consider the mitigation actions in the forestry, land use, and other sectors. The technology lists are then re-examined to find which technology that more common to be used in Indonesia along with its cost. The list of potential mitigation technologies in agricultural sectors in Indonesia is then stated in Malahayati and Masui (2018a). These listed technologies for agriculture are then used for the 2nd part of this study and combined with the other mitigation technologies to see further impact. Moreover, those studies are only focused on agriculture or/and forestry sector.

There is also related research but for energy sector done by Siagian et al., (2017). The result summaries are: 1.) The GDP changes are positive: 0.6% and 0.3% for CM1 and CM2, respectively, due to a substantial increase in the use of coal in the baseline scenario. Of course, this result is counterintuitive because emission reductions usually generate negative impacts on the macroeconomy. However, this CGE analysis also done partially with other mitigation such as AFOLU, waste, and IPPU. 2.) Emission reductions would also be satisfied through the electrification of end-user consumption where the electricity supply becomes decarbonized by deploying renewables for power generation, mostly can be gained by the deployment of geothermal power plants.

A more comprehensive study that using more details data is done under the Deep Decarbonization Pathway Project (DDPP). In Indonesia DDPP report, it is stated that Indonesia has the technical potential to profoundly reduce its energy-related CO2 emission, to a level that will significantly contribute to the global efforts to prevent 2°C temperature increases in 2050. The three decarbonization scenarios in that study ("Renewable Energy," "Renewable Energy + Carbon Capture Storage (CCS)," and "Economic Structural Change") will all achieve about the same CO2 emission level of 402 million tons in 2050, or it can be translated to 1.3-ton CO2/capita. Unfortunately, the study only measures the emission reduction part, without looking further on the economic impact and still separate the analysis with the AFOLU sector (Siagian et al., 2015). In the separate documents of DDPP for AFOLU sector, it is stated that the rate of emission until 2050 would remain high and would not be much different from the present emission. This emission can be reduced only by the improvement of land and forest management as well as optimization of the use of low carbon stock land for agriculture and timber plantation development along with enhanced mitigation policies and measures. Thus, the emission from this sector can be reduced significantly, and by 2050, this sector can become a net sink. It is also stated that one of the main obstacles is that this mitigation will costly, but there is also no economic impact introduced yet (Boer et al., 2016). However, as the documents are listing quite detail technologies and mitigation target, this study also borrows several datasets from these documents.

Because there is still limited information related to the impact of the emission mitigation for Indonesia, the government are struggling to manage and prepare the exact amount of the budget needed for the mitigation policy implementation. The Indonesia Ministry of Finance, for example, was tried to arrange budget for mitigation project. However, due to data and report limitation, the ministry finally uses the previous study conducted by ADB that using the Integrated Assessment Model (IAM) that calculate the impact of emission mitigation policies in South Asia(Ministry of Finance, 2015a). While the technology and the condition of Indonesia are unique and rather to be specific compared to the other South-Asian countries, the assumption and the results may not fully fit the national condition. Considering the urge of knowing the potential impact of the national emission mitigation impact, it is crucial to make a national model examine the policy impact on the economy. Thus, the government can use as one scientific insight to revise the policy or take the further step related to the mitigation policy. Another novelty of this study is that this study involves a more comprehensive sector, so it hopes it can disclose further studies and discussion on this topic.

1.4. Hypothesis and Research Objective

Based on the previous studies, with some improvement and data update, it is predicted that Indonesia will still experience lower GDP compared to the BAU level when the GHG mitigation policies are introduced. This is because the mitigation will need some cost and time to fully established. In the previous studies, the GDP loss may around 3%-6% or more by 2030 compared to the BAU level depend on the level of emission mitigation policies and the length of the policy implementation period (Malahayati and Masui, 2018a) . From the perspective of AFOLU, the emission from the land conversion will remain high. As Indonesia rely on commercial plantation very much, the conversion to this sector, especially to the palm oil plantation will remain high even if the government improve the yield of the crops. Thus, reforestation and forest conservation should be introduced to control the land conversion rate.

In the energy sector, the emission will be increased annually because the production and use of coal to offset the decline of national crude oil supply. This is also predicted that the emission from the energy sector will exceed the emission from the AFOLU and reach ≈58-60% of total emission in Indonesia by 2030 under the BaU level (AFOLU will contribute for around 30% of total emission)(Boer et al., 2018). There is a hope from the introduction of renewable energy use. As it is targeted to use new and renewable energy should reach at least 23%, and gas should reach a minimum target of 22% in 2025. Along with the introduction of energy efficiency, the emission from the energy sector can be reduced and will give a significant contribution to achieving the emission target in 2030.

The main objective of this study is to measure the economic impact of emission mitigation policy in Indonesia by considering main mitigation actions on AFOLU and energy sector while also considering other mitigation from activities (agriculture, waste, and IPPU). The impact not only assessed on the total GDP but also for the sectoral level. In the end, there also some policy implication that can be recommended for the government to achieve the mitigation target.

1.5. *Organization of the Study*

This study is separated into two main parts, the first part is focused on the CGE development for Land Use Change and Forestry (LUCF) and the second part is assessing the mitigation in all sector with more focused on the energy supply and demand. To examine those two parts, this study is divided into several chapters.

The introduction and highlight of this study are introduced in *Chapter 1* as the Introduction chapter. There is also the highlight of study objectives and the novelty of the study. In *Chapter 2*, there is an explanation of the emission profile in Indonesia and the explanation of the mitigation technologies. The assumption and general explanation of the datasets are also explained in this chapter

Chapter 3 is explaining the general structure of the Computable General Equilibrium (CGE) and how the agents and the sector are interacting with each other. *Chapter 4* is the explanation for Part 1. CGE for mitigation for the Land Use Change and Forestry is assessed. This chapter also shows the result and the policy recommendations of this part. Moreover, in *Chapter 5*, the mitigation policy for the overall sector is assessed. Also, there is the result and policy recommendation for this part. Finally, *Chapter 6* will strengthen the conclusion and answering the research question. In this chapter, there is also some recommendations and suggestion for future studies.

2. Present State in Indonesia

2.1. Indonesia Economic Condition

The manufacturing industry is the sector that gives the highest contribution to Indonesia Gross Domestic Product (GDP). This is supported by the rapid growth of non-oil and gas processing industry, especially the food and beverage industry. Trade and Reparation share the second most significant contribution, then followed by agriculture, forest, and fisheries (Figure 2.1).

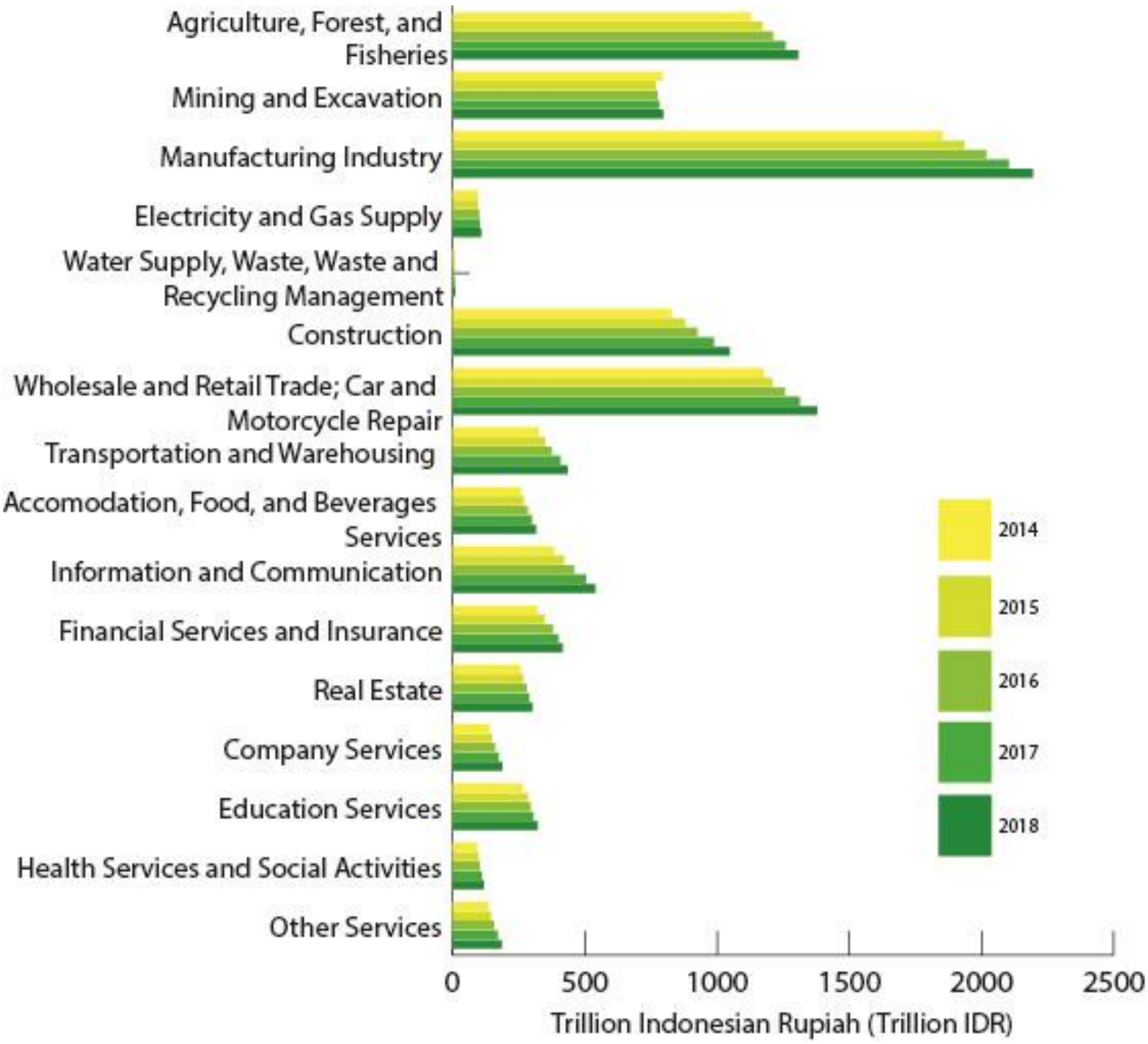


Figure 2.1. GDP Based on 2010 Constant Prices According to Business Fields (Billion Rupiah), 2014-2018.
Source: BPS, 2017

Agriculture and forestry itself hold a crucial role in the Indonesia economy because this sector supports the economy by intensively provide the raw materials for other sectors, especially the non-oil and gas processing industries. Based on Social Accounting Matrix (SAM) multiplier analysis, forest and plantation sector gives the biggest cumulative multiplier effect to another sector, especially to the industry in Indonesia compared to another sector (Malahayati, 2018). It leads to high deforestation, forest degradation, and land-use change in Indonesia. Around two-fifths of nation-wide deforestation are caused by large-scale oil palm and timber plantations. Another one-fifth of deforestation is caused by the unplanned deforestation that converts the forest into grasslands. The other factors are including small-scale agriculture and small-scale plantation, and forest fire (Austin et al., 2018).

In the energy sector, the relatively high growth of GDP has affected the GHG emissions generated from energy consumptions and supply. The final energy consumers in Indonesia are the household, industry, and transport sectors. In 2016, the shares of these sectors were, respectively,33.7%, 30.6%, 30.2% (Siagian et al. 2015).

In addition, the government also sets several economic growth projections. In the technical draft of Midterm Development Plan 2020-2024, Indonesia targeted to reach 6% of economic growth per year (Alaydrus, 2019). However, along with the global economic condition, the statistical data shows that it is hard for Indonesia to reach that target, so economic growth is then corrected to be around 5% (Agusman, 2019a).

For this study, the actual data from 2010-2017 can be gained from the official statistics. While, for the projection 2017 afterward, is projected by assuming the economic growth is around 5.1% from 2018-2025 and 5.2% from 2025 afterward (Figure 2.2).

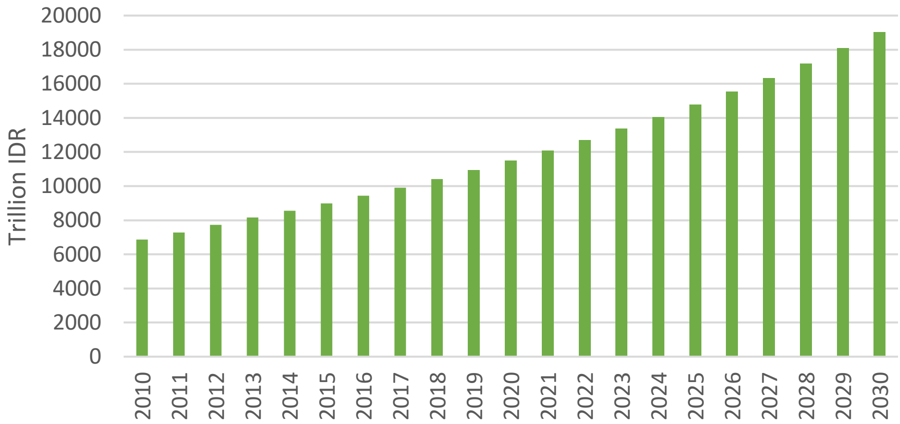


Figure 2.2. Historical GDP and GDP Projection.
Source: Author calculation based on Badan Pusat Statistik (2019a) and Agusman (2019)

2.1.1 Indonesia Input-Output Table

Input-Output Table portrays a macroeconomic system of interrelated goods and services. Each row in the matrix describes the intermediate demand and final demand. While the supply side is captured by the column of the matrix. However, the preparation of Input-Output Table is a time-consuming process. In Indonesia, this table only constructed every 4-5 years, but it is based on the assumption that although the current price is change and the production process are changing by each year, the economic structure is not changing significantly during the table construction (Badan Pusat Statistik, 2016). In this study is using the Indonesia IO Table 2010. The original sectors are consisting of 185 sectors, and for this study, the data is aggregated into 38 sectors (Table 2.1).

Table 2.1. Input Output Table sector classification

Sec	Code	Sector	Sec	Code	Sector	Sec	Code	Sector
1	PAD	Paddy	20	OIL	Oil refinery and LNG	Value Added	LAB	Labour
2	COR	Corn	21	CHE	Chemical Industry	Value Added	CAP	Capital
3	CAS	Cassava	22	FER	Fertilizer and Pesticide	Final Demand	h_c	household consumption
4	OAG	Other Agriculture	23	NON	Non-metal industry	Final Demand	h_i	household investment
5	RUB	Rubber	24	CEM	cement	Final Demand	g_c	government consumption
6	PAL	Palm Oil	25	IRO	iron and steel industry	Final Demand	g_i	government investment
7	OPL	Other Plantation	26	MET	Metal-based Industry	Final Demand	stc	stock change
8	LIV	Livestock	27	OIN	Other Industry	Final Demand	exp	export
9	WOO	Wood	28	ELE	electricity	Final Demand	imp	import
10	OFO	Other Forest	29	GAS	The results of natural and artificial gas, supplying steam / hot water, cold air, and ice products			
11	MAR	Marine and Fisheries	30	WAT	Water Supply			
12	COA	Coal and Lignite mining	31	WAS	Waste			
13	CRU	Crude Oil	32	BUI	Building			
14	NAT	Natural gas and geothermal	33	TRA	Transportation			
15	MIN	Mining	34	TRD	Trade, Hotel, and Restaurant			
16	FOO	Food, beverages, and tobacco	35	AMU	Amusement and telecommunication			
17	APP	Apparels	36	FIN	Financial Services			
18	WIN	Wood Industries	37	GOV	public services			

The IO Table also gives an insight into total supply and demand. In general, on the Indonesia IO table 2010, the total demand and supply in the national economy are IDR 14,827 trillion. On the demand side, the total intermediate demand is IDR 6,425 trillion (43%), while for total final demand is IDR 8,402 trillion (57%) which consists of final domestic and export of IDR 6,734 trillion (80%) and IDR 1,668 trillion (20%) respectively. Whereas, from the supply side, the value of domestic goods and services is far greater than the imported components used to fulfill demand. The value of domestic goods and services is IDR 13.109 trillion (89%), and the import value is IDR 1.538 trillion (10%), and the tax on net products is IDR 180 trillion (1% (Badan Pusat Statistik, 2015).

2.1.1.1. Total Supply of Goods and Services in Indonesia

In Indonesia IO Table, there are three commodity groups that have the largest contribution to the total supply of goods and services in Indonesia, such as the manufacturing industry (33.3%), followed by construction (13.2%); and large and Retail Trade, and Car and Motorcycle Repair (10.5%). Another sector that gives quite high domestic supply is agriculture, forestry, and fisheries (9.1%) and mining (7.2%) (Figure 2.3).

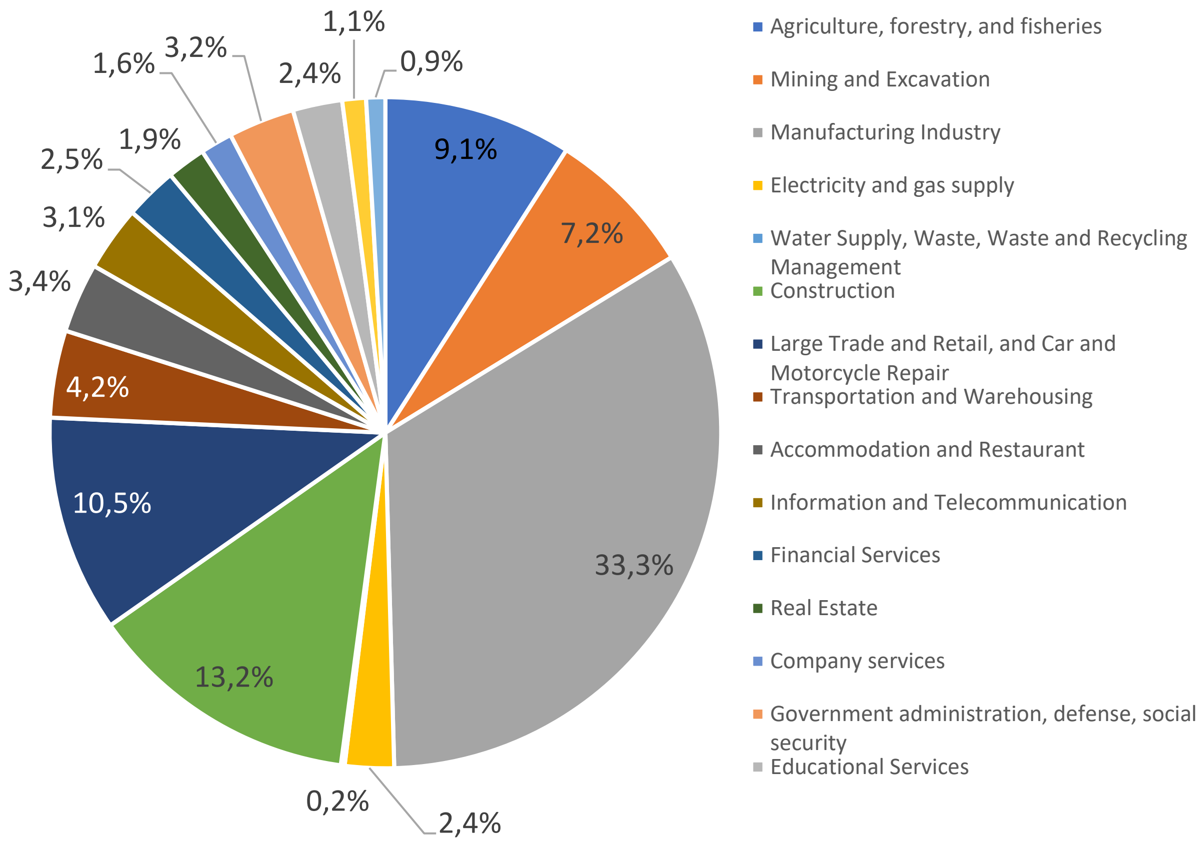


Figure 2.3. Summary of Domestic Output Proportion on Indonesia Input-Output Table 2010.
Source: Badan Pusat Statistik (2015)

2.1.1.2. Total Demand of Goods and Services in Indonesia

In general, the total demand consists of intermediate demand and final demand. Final demand is consisting of household and government consumption, fixed capital formation, inventory change, and export. Based on Indonesia IO table, the biggest component of demand in Indonesia comes from intermediate demand (43%) followed by household consumption (26%) and Export (11%). It means that around 43% of the total demand is used for re-production process (intermediate demand) while the other 57% is used for the final consumption. The final demand itself still dominated by household consumption, and only 5% from the total demand comes from the government (Figure 2.4).

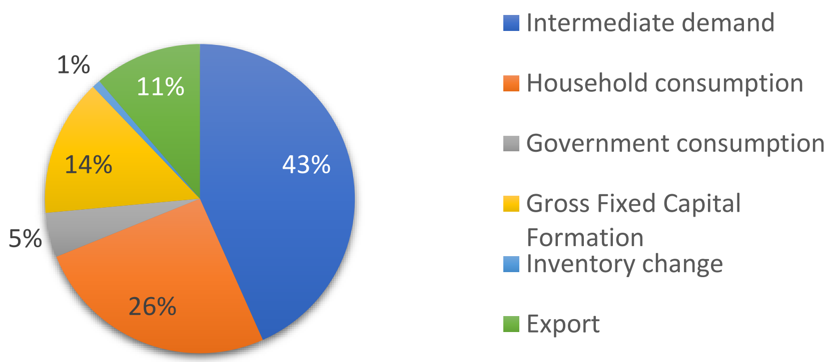


Figure 2.4. Total Demand proportion on Indonesia Input-Output Table, 2010.
Source: Badan Pusat Statistik (2015)

From the total intermediate demand, manufacturing industries give the biggest share (53%) to be used as the input in the economy, followed by agriculture, forestry, and fisheries (13.9%) and mining (10.33%) (Figure 2.5).

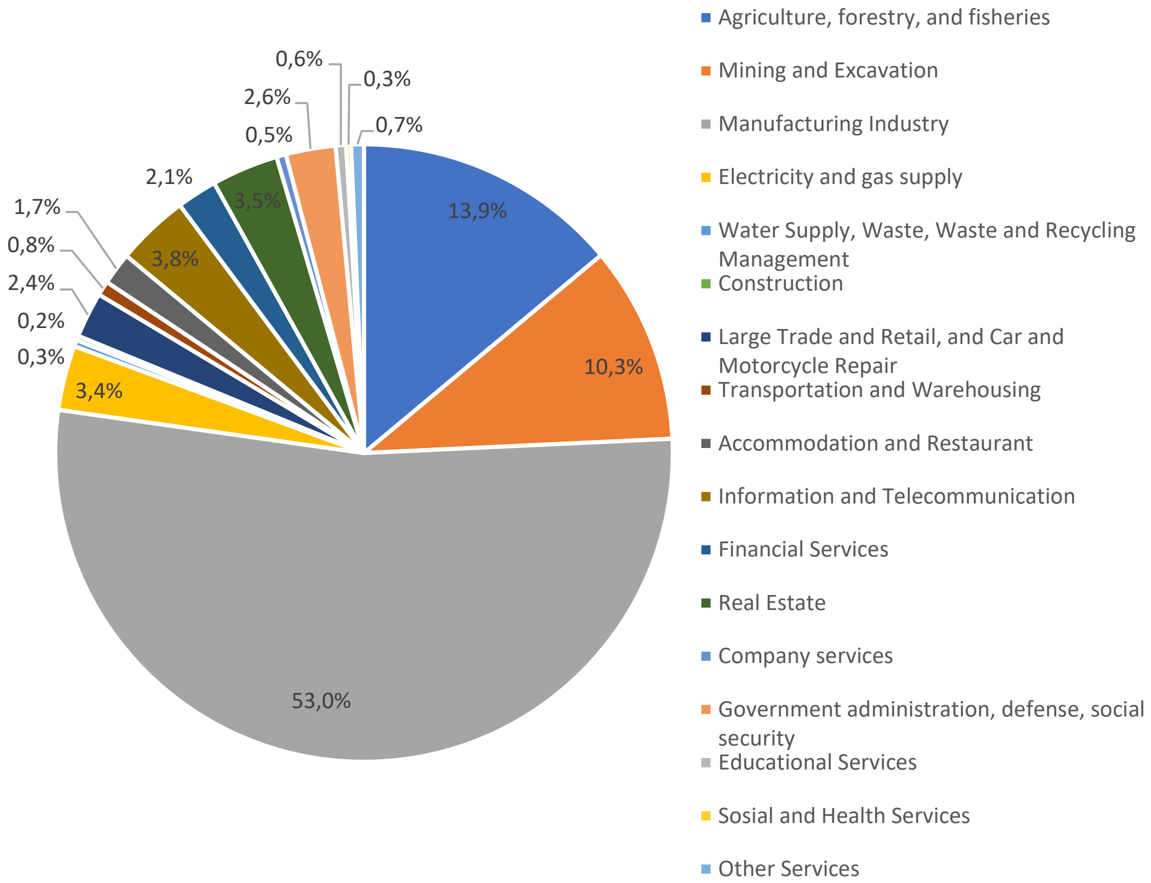


Figure 2.5. Intermediate demand proportion on Indonesia Input-Output Table, 2010.
Source: Badan Pusat Statistik (2015)

2.1.2. Export and Import

The information about export and import is also included in the Input-Output table. Thus, the export and import value are following the value in the input-output model. However, because the IO Table only give information on the target year, the export and import growth rate is needed. The growth from 2011-2017 is following the statistic. While from 2017 afterward, the growth is assumed to be following the same growth as the GDP (5.1% per year from 2018-2025 and 5.2% per year from 2025-2030) (Table 2.2).

Table 2.2. Growth Rate of Export-Import

No.	Year	Import Growth (%)	Export growth (%)
1.	2011	31%	29%
2.	2012	8%	-7%
3.	2013	-3%	-4%
4.	2014	-5%	-4%
5.	2015	-20%	-15%
6.	2016	-5%	-3%

Source: calculated from Badan Pusat Statistik, (2019a) and Badan Pusat Statistik, (2019b)

2.1.3. Population

Population data is needed for the labor projection in the model. In this study, the population data is gained from the official statistic published by Badan Pusat Statistik Indonesia (2013) that provided the data of the population by 2015 and then projected to 2035. the data is then updated in Badan Pusat Statistik (2018) that give the statistic from 2015-2017 and projected into 2045. However, the data between this two publication. So, to keep the consistency, data from 2010-2014 is using the data from Badan Pusat Statistik Indonesia (2013), but the ratio is extrapolated from Badan Pusat Statistik (2018) (Table 2.3).

Table 2.3 Population and Population Projection

Year	Population (Million People)	Growth/year	Notes
2010	238.5	1.3%-1.4%	Using Badan Pusat Statistik Indonesia (2013) but the ratio is extrapolated from Badan Pusat Statistik (2018)
2015	255.6	1.1%	
2020	269.6	1%	
2025	282.5	0.9%	
2030	294.1	0.8%	

From Table 2.3, the population growth is projected to be slowed down by 2030, and it is predicted that the Indonesian population will reach 294 Million people by that time. The population dataset also can be modified to fit the modeling purpose, e.g., in part 2 of this study, the population is separated between the agricultural labor and non-agricultural labor. Because in that part, the energy sector is introduced into more detail while the productivity of agricultural and non-agricultural labor will be different.

2.2. Mitigation Policy in Indonesia

In 1999, for the first time, Indonesia presented its National Green House Gases (GHG) inventory under the 1st National Communication to the UNFCCC. One of the most important point from that document was Indonesia is one of the countries that vulnerable to climate change. From that, Indonesia started to commit to deal with the climate change impact, one of each is by mitigating the GHG emission (Ministry of Environment Indonesia, 2010).

Indonesia committed to voluntarily reduce its GHG emission in 2009 along with G20 meeting in Pittsburgh. This action was also intended to provide an example and encourage other countries to reduce global warming that causes climate change jointly. In this meeting, Indonesia committed to reduce GHG emissions by 26 percent in 2020 from the Business as Usual (BAU) level with own business and reach 41 percent if it receives international support (Bappenas, 2012).

In 2010, Indonesia reported Second National Communication (SNC) that represent national GHG inventory for the years 2000 to 2005 (Ministry of Environment Indonesia, 2010).To keep on track with all those commitments, Indonesia issued the President Regulation No.61/2011 and mandated to all ministries and parties to support the government commitment to reduce emission by 26% by 2020 from BAU level. Along with that, the government also published RAN-GRK which contains points-points that should be taken to achieve the emission reduction target (Bappenas, 2012).

To maintain the sustainability of the policy, in 2015, Indonesia agrees to sign for the Paris Agreement and for the first time submitted its first INDC on 24 September 2015 (Masripatin, 2017). In the INDC, a little bit different with the RAN-GRK, in the INDC the target year in 2030 and the emission reduction target is 29 percent by 2030 from the Business as Usual (BAU) level voluntarily and reach 41 percent if it receives international support (Government of Indonesia, 2016).

In 2016, Indonesia published its first Biennial Update Report (BUR) that also become an extension of SNC because it's provided not only the information of GHG inventory, but also the needs for financial, technical, and capacity support to achieve the mitigation target. In 2017, the government issued the Ministry Regulation No. 73/2017 on Article 9 about the institutional arrangement on national GHG inventory that expected to ease the monitoring of GHG emission in each institution. Finally, in 2018, Indonesia submitted the 2nd Biennial Update Report as the follow-up of previous reports that also including the plan of Monitoring, Reporting, and Verification (MRV) and the progress of the national REDD (Reducing emissions from deforestation and forest degradation) (Boer et al., 2018).

2.3 Indonesia GHG Profile

The Indonesia GHG inventory is calculated and projected by using the IPCC guidelines 2006 and IPCC Good Practice Guideline (GPG) for the land-use change and forestry. The calculation and the projection of the emission are then reported as the Biennial Update Report (BUR) and National Communication to report its emission condition. Based on the 2nd BUR, the most recent report that stated the GHG inventory in Indonesia, in 2014-2016 the emission is increased significantly because of an increase of emission from the LUCF sector. This is because a big forest and peat fire occurred in Indonesia during that time. However, the emission is decreased again (Figure 2.6).

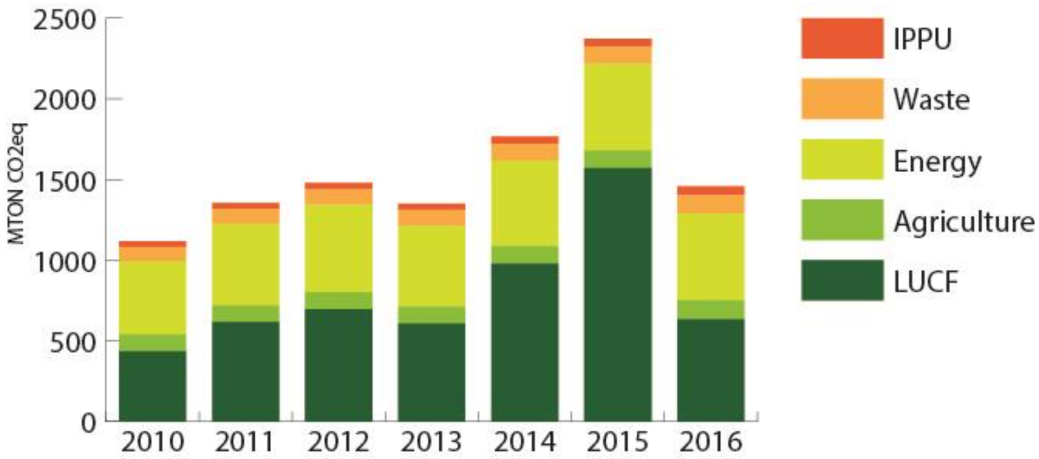


Figure 2.6. Actual Emission in Indonesia, 2010-2016.
Source: Boer et al. (2018)

In 2016, Indonesia emission reached 1.461 Mton CO2eq, and the emission from the LUCF is still the highest compared to the emission from the other sector. It is contributing to 43.6% of emission from the total emission, followed by the energy sector that contributes to around 36.% of emission from the total emission. If the LUCF is not considered, the energy sector will contribute to around 65.4% of emission (Figure 2.7). This data shows that the emission from the LUCF and energy are the main national problem.

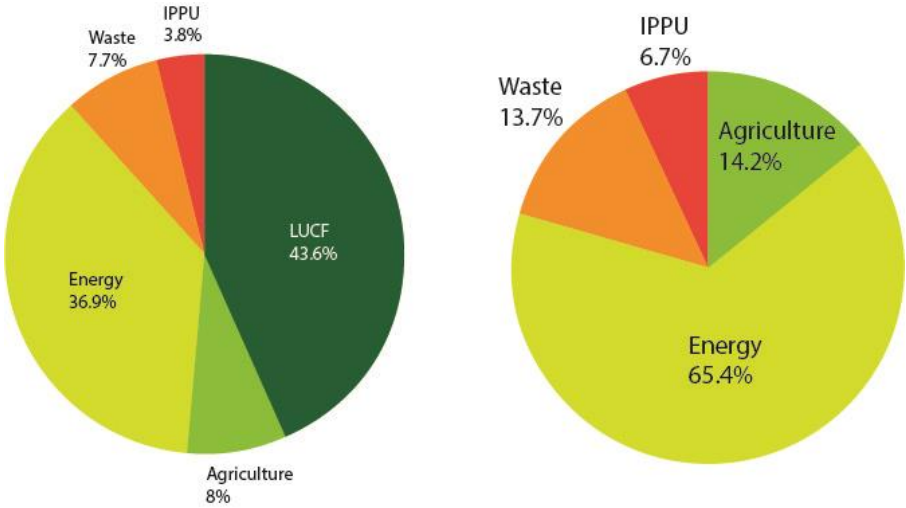


Figure 2.7. Emission in Indonesia in 2016, with and without LUCF sector.
Source: Boer et al. (2018)

Moreover, the actual data is more than it is that projected in the baseline that stated in the Indonesia Biennial Update Report (BUR), especially for the 2015-2016. The BUR document, the emission from LUCF are projected to be relatively stable throughout the year, while the energy sector is projected to increase significantly and exceeds the emission from the LUCF (Figure 2.2). This is because Indonesia has a wide area of peat and very vulnerable with the large temperature change, like what happened during the El-Nino. Moreover, there is also a high rate of forest degradation and deforestation, and the opened land make the land also easier to be burnt. These conditions make the emission from the LUCF is hard to be predicted. However, the emission from the energy is projected to keep increase significantly in line with economic growth. While the emission from the agriculture and IPPU sectors are projected to be stable throughout the year, waste becomes another sector that projected to increase more by 2030 (Figure 2.8).

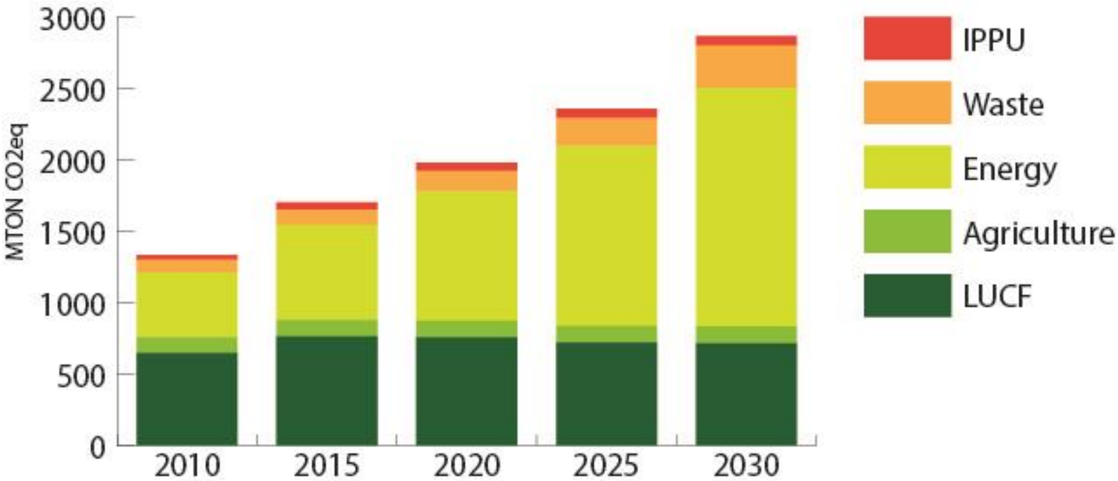


Figure 2.8. Emission projection 2010-2030.
Source: Boer et al. (2018)

2.4 Emission Sources

2.4.1. Agriculture

Agriculture sector gives the biggest share for non-CO2 emission, especially the methane (CH4) and nitrous oxide (N2O) emission. Indonesia itself consider ten emission sources from the agricultural sector. The main emission from this sector mostly comes from the rice cultivation, and direct N2O emission comes from soil management (Figure 2.9).

2.4.1.1. *Rice Cultivation*

Rice cultivation gives a big contribution to methane emission. This is because most of the rice field in Indonesia is a flooded rice field that makes a supportive environment to form methane. Moreover, the paddy rice structure also contributes to transport and emit the methane emission to the atmosphere. Around 90% of methane in transmitted and then emitted through the aerenchyma network and intercellular space of the paddy (Prihasto, 2006). The ability for the paddy rice to emit and transport the methane will vary depending on its age, physiology and morphology structure, and the root activity.

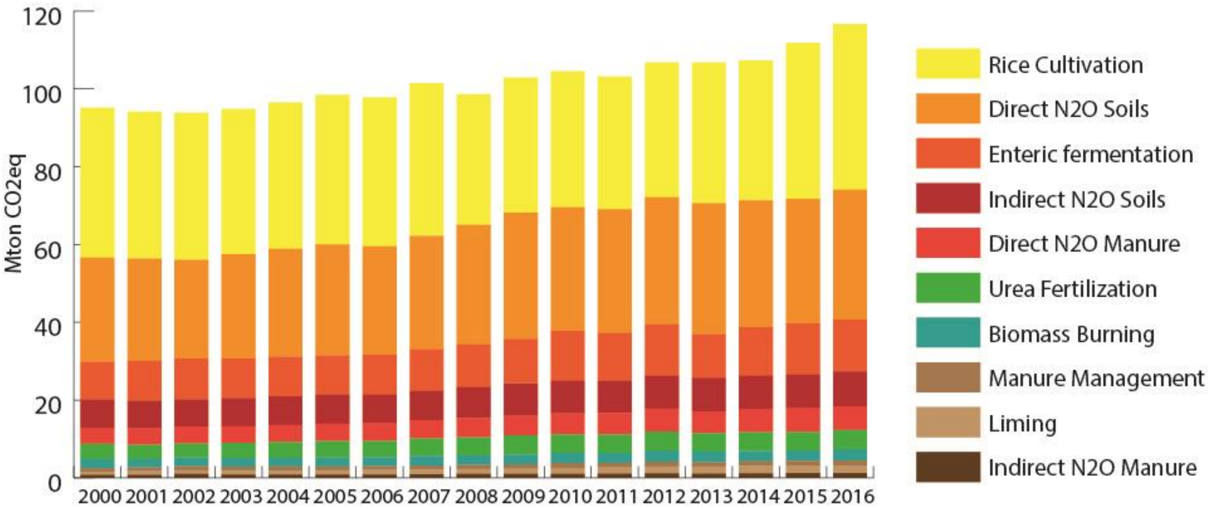


Figure 2.9. Sectoral Emission from Agriculture 2000-2016.
Source: Boer et al. (2018)

2.4.1.2. *Soil Management*

Out from paddy, the land also managed and cultivated for other crops and cultivars. During the cultivation process, there are several soil treatments that are causing emission. Soil management mostly produces N2O emission, mostly related to the microbial production process in soils, sediment, and water bodies, especially during the N fertilizer use and manure management. From soil management, the N2O emission can be distinguished as direct and indirect N2O. Direct N2O emission is related to fertilizer application at a given site, while the indirect N2O emission comes from soils at landscape and catchment scales owing to the cascading of nitrogen (Butterbach-bahl et al., 2013). Basically, both direct and indirect emission is caused by chemical fertilizer. While in Indonesia, the chemical fertilizers are still widely used, and even in most Java area, the chemical fertilizer is already exceeded the recommended dosage (Daeng, 2017), the emission from this sector also still considered high compared to other sources in agriculture.

2.4.1.3. *Liming*

The use of lime in agriculture is to reduce soil acidity and improve plant growth in managed systems, particularly in agricultural lands and managed forests. This method is done by adding carbonates to soils in the form of lime (e.g., calcic limestone (CaCO3), or dolomite (CaMg(CO3)2) leads to CO2 emissions as the carbonate limes dissolve and release bicarbonate (2HCO3-), which evolves into CO2 and water (H2O)(Cecile De Klein et al., 2006). In Indonesia, liming is mostly used for the plantation crops (e.g., palm oil, rubber, etc.) and also used into the peatland when it is utilized for the agriculture activities (Boer et al., 2016).

2.4.1.4. *Biomass Burning*

Biomass burning emissions from grassland was calculated based on harvested upland rice. Data on harvested upland rice area was used under the assumption that the data can be used to represent the shifting cultivation area where biomass burning might have occurred. While emissions from biomass burning in cropland were calculated based on harvested rice area and rice production(Boer et al., 2017).

2.4.1.5. Urea Application

Urea [$(NH_2)_2CO$] fertilizer application may emit CO2 emission through urease process. Urea that applied to the soil is hydrolyzed by urease and produces ammonium ions (NH_4^+), bicarbonate (HCO_3^-) and hydroxyl ions (OH^-). The bicarbonates may have a chemical reaction with the hydrogen ion (H^+) in the soil and produce carbonic acids (H_2CO_3). These carbonic acids can be dissolved in soil water and convert into CO_2 (Kim et al., 2017). As a fertilizer that largely used in any crops, in Indonesia, the calculation of the urea application not only considering the annual crops like paddy or corn but also perennial crops like palm oil.

2.4.1.6. Livestock

The sources of GHG emissions of livestock sector include GHG emissions from enteric fermentation and manure management. This emission will be depending on the total livestock population and feed.

a. Enteric Fermentation

Enteric fermentation contributes the highest share of emission from the livestock sector in Indonesia. Enteric fermentation itself is produced in herbivores, mostly in ruminants. The enteric fermentation process happened in the ruminant's rumen, microbes decompose and ferment plant materials, such as celluloses, fiber, starches, and sugars. The amount of methane that is exposed depends on the type of digestive tract, age, weight, and also the quality and quantity of the feed consumed (Dong et al., 2006a).

b. Manure Management

Manure management can both emits CH4 and N2O. CH4 produced during the storage and treatment of manure, and from manure deposited on pasture. The emission of methane depends on the type of manure management system, which can be divided into "liquid" and "dry" systems. The liquid system is using water to handle the manure. This system, including the use of tanks and lagoons to store manure until applied to cropland. Dry systems include solid storage, dry feedlots, deep pit stacks, and daily spreading of the manure. Moreover, unmanaged manure from grazing activity also falls into this category (Jun et al., 2000).

Manure management also can emit nitrous oxide (N2O) both directly and indirectly. Direct emissions occur through the processes of nitrification and denitrification, while indirect emissions occur through volatilization, leaching, and runoff. Nitrification process occurs aerobically and converts this ammonia into nitrate, while denitrification occurs anaerobically, and converts the nitrate to N2O (Moeletsi and Tongwane, 2015). While the indirect N2O emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NOx (Dong et al., 2006b) .

2. 4. 2. Land Use Change and Forestry (LUCF)

Generally, the emission from the LUCF comes from two land types: mineral land and the peatland. In fact, the emission from peatland is higher than the emission from the mineral land because there is some emission from the peat decomposition that accumulated throughout the year and the peat fire which harder to be predicted. Based on the GHG inventory based on the 2nd Biennial Update Report of Indonesia, the emission from LUCF itself, in general, is projected to be stable. However, because of the geographical condition of Indonesia that has a wide peatland area and located on the equator line, Indonesia becomes vulnerable with some natural phenomenon like El-Nino. El-Nino causing the air dryer and the temperature higher and makes it is easier for Indonesia to experience the forest and peat fire. The condition is worsened by high forest and land opening. This is what happened during 2014-

2016, with the peak in 2015, that Indonesia experiencing the forest and peat fire and make the emission from LUCF increase significantly Figure 2.10.

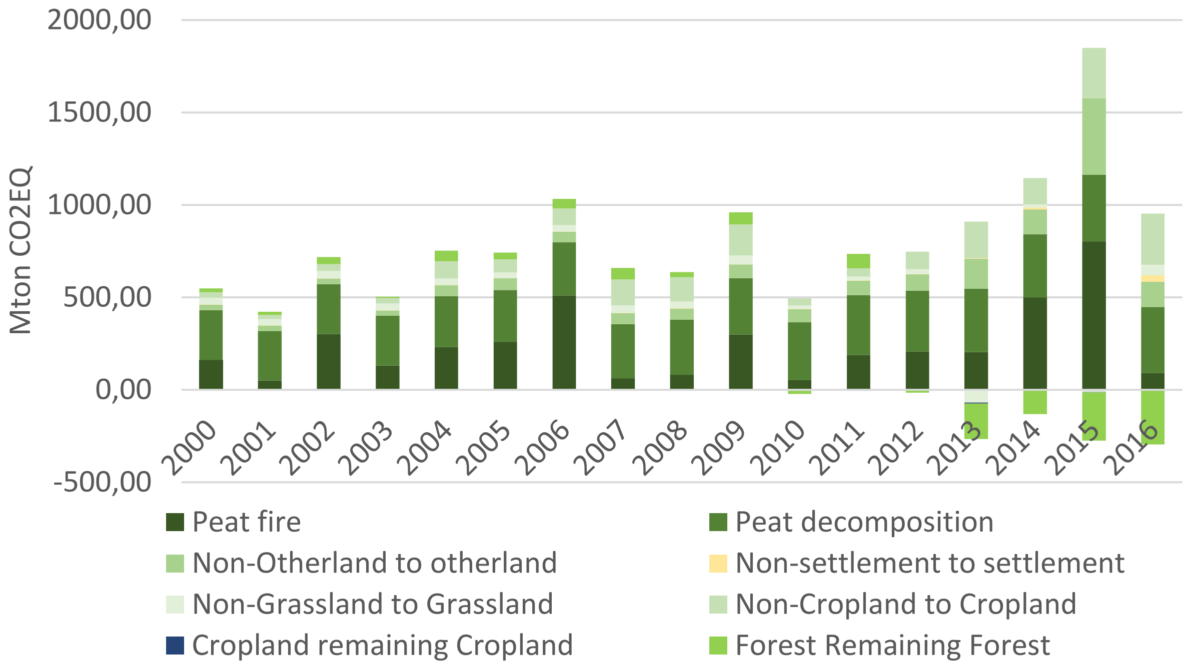


Figure 2.10. Actual Emission from the LUCF 2000-2016.
Source: Boer et al. 2018

Moreover, it is assumed that after 2015, there is no more peatland is opened for economic activity and exploited. Thus, the emission projection for LUCF from 2020-2030 is projected to be stable (Figure 2.11.)

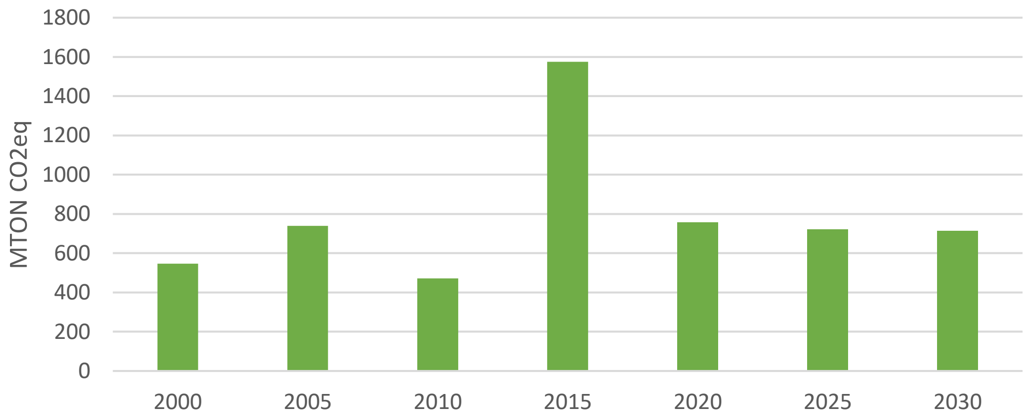


Figure 2.11. The emission projection by 2030

The treatment of emission calculation in land use is different from the other sector due to several factors such as (Iversen et al., 2014):

Land use can act as a sink or a source; unlike other sectors, the land sector can hold the role as both emitters and for removals of CO2.

Significant natural effect; the emission from the land use can be highly related to the natural effects like drought, floods, etc. It is also making the calculation become more difficult, because there is no clear distinction between emission from natural or anthropogenic effects In Indonesia, as the IPCC states that it is difficult to distinguish causal factors in the land sector that result in emissions or removals. For example, emissions from fires may originate from either natural cause (e.g., climate cycles, lightning), or indirect and direct human causes (e.g., past forest harvest activities, the unintended spread of deliberately set fires or, in some parts of the world, climate change),

Trends can be cyclical; While other types of emissions may also have cyclical trends, for example, those that tend to follow economic ups and downs or variations in seasonal weather, emissions from land-use can experience more regular cycles related to timber harvesting (e.g., those linked to forest age structure) or replacement of perennial tree crop systems. Such cycles can cause difficulties if the length of a time of a mitigation commitment is shorter than a full cycle or if a single base year (that does not reflect the average emissions over one cycle) is used as a reference level, particularly for smaller countries that cannot average out effect over large areas of land. For more information, see the Section on Baselines and Reference Levels.

Legacy effects; Both natural disturbances and management decisions, actions that affect the age distribution of plantation forests (e.g., harvesting or reforestation), can have a long-term effect on carbon fluxes, including sequestration rates, from decades to hundreds of years later. There are even more significant legacy effects associated with the draining of peatlands that continue to emit large quantities of CO2 for decades as layers of organic soil accumulated over millennia are subject to aerobic decomposition. The legacy impacts on emissions are not exclusive to the land-use sector.

Non-permanence; Non-permanence relates to the risk that terrestrial carbon can be released into the atmosphere due to natural and/or anthropogenic (i.e., human) causes. This is of concern when the CO2 removed from the atmosphere enters the accounting system to demonstrate compliance with the committed emission reductions (e.g., as part of a national commitment) and is subsequently released and emitted into the atmosphere.

Emissions and removals are distributed; The largest source of emissions, the energy sector, tends to originate from "point-sources" (e.g., a power plant, a cement factory, etc.). In contrast, land spans large areas and involves multiple stakeholders in its management, which has consequences for both the management, and estimation, of emissions and removals. Measures to manage emissions tend to become more difficult with more actors involved; this is particularly true in countries where land tenure is unclear, and the land is used by multiple communities. Estimation of emissions and removals also becomes more difficult and, in many cases, cannot be done in the same manner as other sectors that use production data from national statistics. For the land-use sector, countries often do not have national statistics, e.g., for soil carbon, and therefore use proxies for carbon stocks and their fluxes for different land uses in order to estimate emissions and removals.

Moreover, based on the Intergovernmental Panel on Climate Change (IPCC) guidelines there are two common methods to calculate the emission from the LUC: 1.) Gain and Loss Method and 2.) Stock Change Method (Aalde et al., 2006). In this study, the stock difference method is used because the gain and loses method is hard to be implemented in Indonesia for several reasons: 1.) The geographical condition of Indonesia that involves an extensive area and diverse soil type and climate. 2.) As a country that often experience forest fire, Indonesia also faces difficulties to calculate the biomass losses from a forest fire, because the soil, weather, and climate in each place might be different (Santosa et al., 2014). The Stock difference method is more convenient to be used in Indonesia. This method is estimating the carbon stock difference at a time interval. Each land cover will have different emission factor due to the difference in its density and cultivar that usually planted in each land type. In this method, it is assumed that when converting from one land use to another land use, the carbon stocks over time will reach the average carbon stocks of the new land use, and emissions and removals of CO_2 can be estimated on this basis (Iversen et al., 2014). For Indonesia, due to the climate and soil types are varied between each island, the carbon stock value is based on the average from the calculation and research conducted in each province.

In general, the carbon stock change calculation using the stock-difference method can be written as:

$$\Delta C = \frac{C(t2) - C(t1)}{(t2 - t1)}$$

Where:
ΔC = annual carbon stock change in the pool, tonnes C/year
C(t1) = carbon stock in the pool at time t1, tones C
C(t2) = carbon stock in the pool at time t2, tones C

2.4.2.1. Deforestation and Forest Degradation

Deforestation is the process of converting forest land to another land use. While forest degradation is the process of losing carbon stock from forest land. When a forest degraded, the forest remains as a forest, but the tree cover density and the carbon stock are reduced (Kissinger et al., 2012). Deforestation and forest degradation can be happened due to several drivers. Moreover, the drivers can be classified as the two most prominent groups as direct and indirect drivers (Hugel et al., 2016).

1. Direct drivers (proximate causes); caused by human activities or immediate actions that directly make an impact on forest cover. In forest degradation, it is mainly caused by timber extraction (legal or illegally), forest fire, livestock grazing, and fuelwood collection. Direct drivers for deforestation mainly for commercial agriculture to established cash and estate crops, mining, and urban expansion(Murdiyarso, 2008).
2. Indirect drivers (underlying causes/ driving forces); complex interactions of social, economic, political, cultural, and technological process that drive to deforestation or forest degradation. Example of indirect drivers is fluctuation in currency exchange rates, subsidies or fiscal incentives in certain crops, and poverty at the local level.

In Indonesia, the deforestation and forest degradation are mainly because of the land utilization for the cash crops, especially the commercial plantations.

2.4.2.2. Peat Land

a. Peat Decomposition

Indonesia has the largest tropical peatland area in the world. This peatland holds an essential ecological function, including water flow regulation and carbon (C) balance and storage (J.O. Rieley et al., 2008). Draining the peat can cause the escalation of CO_2emission by aerobic bacteria. The peatland exploitation may reduce the water level of the peat and make the peat surface subsides. As the peat surface sank, it loses its functions as the carbon storage and hydrological control, which stores water during the rainy season and releases the CO_2 gradually during the dry season (Agus, 2015).

b. Peat Fire

Although peatland only takes place in a water-saturated environment that makes it has very high moisture content and is thus naturally protected from burning. However, natural drought (e.g., El-Nino) and human activities to open the peat may lower the peat's water level and reduce its moisture. It makes the peat becomes susceptible to smoldering fires, while the organic matters inside the soil make the peat fire is harder to be handled (Hu et al., 2018). Massive peat exploitation already breaks the peat environment; this condition is then worsening because Indonesia is in the equator line that makes it is more vulnerable to drought during the El-Nino. The condition makes Indonesian emission usually increase drastically every 4-5 years (Field et al., 2016).

2.4.3. Energy

In Indonesia, the emission from the energy sector is calculated from two main sources: Fuel combustion and Fugitive emission from fuel production (Republic of Indonesia, 2015). Fuel combustion consisted of emission from the energy industries, manufacture, transportation, commercial, and residential sector. By comparing all the emission sources in the energy sector, during the 2000-2016, the emission from energy mostly comes from the energy industries (Figure 2.12).

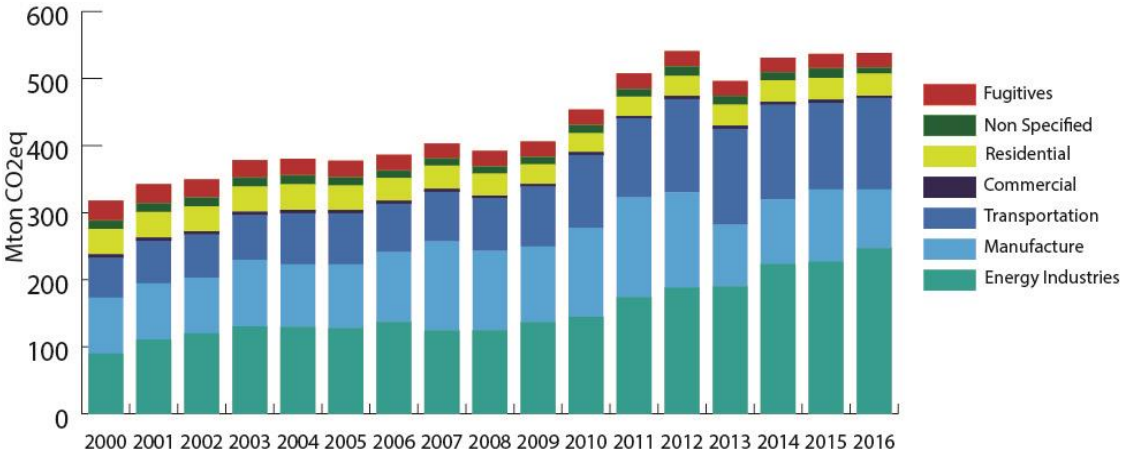


Figure 2.12. Sectoral Emission in the Energy Sector, 2000-2016.
Source: Boer et al. (2018)

2.4.3.1. Fuel Combustion

Based on IPCC 2006, the definition of this emission source is emissions that come from the intentional oxidation of materials within an appliance that is designed to raise heat and provide it either as heat or as mechanical work to a process or use away from the appliance (Garg et al., 2006a). The emission from this process is mostly the CO2. However, some carbon is released as carbon monoxide (CO), methane (CH4) or non-methane volatile organic compounds (NMVOCs). However, in the case of fuel combustion, the emissions of these non-CO2 gases contain tiny amounts of carbon compared to the CO2 estimate. This is because the total carbon in the fuel depends on the fuel alone, while the non-CO2 emissions are depending on many factors such as technologies, maintenance, etc. which, in general, are not well known. However, if a country already has a complete database and methodology, the non-CO2 emission also can be calculated (Garg et al., 2006b).

In Indonesia, emission from the fuel combustion is including the emission that emitted by the energy industries (producers), manufacturing industry, transportation, and other sources such as households, commercial, agriculture, construction, and mining. Since Indonesia still not implemented the Carbon Capture Storage (CCS), there is no carbon capture process considered in the emission calculation.
Energy Industry; this sector shared the most significant proportion of emission in the energy sector. The emission from the energy industry includes all electricity production, petroleum and gas industry, and the production of solid fuels. Emission from power generation include all emissions from all fuel used for electricity generation from main activity producers except those from combined heat and power plants. Power generation in Indonesia can be done by the state-owned company (*Perusahaan Listrik*

Negara/ PLN) and private. However, in the emission calculation, an only state-owned company that put into consideration (Boer et al., 2017).

Manufacturing Industry; Emissions from the combustion of fuels in industry. Also includes combustion for the generation of electricity and heat for own use in these industries. Almost all industries fall into this category. The fuel consumption data of those industries are gained from the fuel sales data. GHG emission from fuel combustion in non-fuel mining and quarry are also calculated in this category. *Transportation*; GHG inventory for the transportation is based on the aggregate fuel consumption data that grouped according to the type of fuels instead of the type of utilization. Moreover, the transport sector also gives a significant share to the emission in line with the increase in private transport mode ownership (BPPT, 2018).

Other sectors; GHG emissions from residential as well as from commercial are generated from combustions of LPG, pipe gas, and kerosene. The calculation is done without separating the sub-sector (e.g., agriculture, commercial, mining) but disaggregated according to the type of fuels, such as motor gasoline, Automotive Diesel Oil (ADO), Industrial Diesel Oil (IDO), kerosene, and fuel oil (FO). Motor gasoline, ADO, and kerosene are mostly used in motorized equipment for agriculture activities, including fisheries. FO is used in fisheries while ADO and IDO are often used in construction and mining sub-sectors.

2.4.3.2. Fugitive Emissions from Fuel Productions

Fugitive emissions from fuel productions only included CH4 gas released from coal mining and GHG emissions released from oil and gas production facilities (up-stream), refining and processing, and distributions.

a. Coal Mining and Handling

Coal contributes around 83% of total fossil fuel stock in Indonesia. However, the use of coal is limited to several sectors, such as power generation and industry. Low capacity of the power plant and industry become one reason why coal use still not optimized yet. Most of the coal is exported rather than used domestically. In 2012, 79% of total coal production was exported (Kementerian Energi dan Sumber Daya Mineral, 2013a). All Indonesian coal mining is either surface or open mining. Therefore fugitive emissions from coal mining only limited during mining activities (Republic of Indonesia, 2015).

The emission from coal mining comes from the geological processes of the coal formation. The formation may also produce methane (CH4), and carbon dioxide (CO2) that may also be present in some coal seams. This seam gas will remain trapped in the coal seam until the coal is exposed and broken during mining. CH4 is the major GHG emitted from coal mining and handling(Garg et al., 2006c).

b. Crude Oil and Natural Gas

Fugitive emissions on oil and gas systems including equipment leaks, evaporation and flashing losses, venting, flaring, incineration and accidental releases (e.g., pipeline diggings, well blowouts and spills) (Garg et al., 2006c).

Crude oil; In Indonesia, crude oil still dominated in the primary energy supply in Indonesia due to its high demand on the market. The national price of crude oil is relatively low because there is still high subsidy provided by the government, especially for the transportation sector. This trend is mostly because the available policy to do diversification of energy still not running effectively. However, this condition is alarming because the oil reserves in Indonesia is keeping decreasing. Indonesia oil reserves are predicted the only amount 0.2% from entire world's oil reserves in 2012, and with this value, it is predicted that it will be fully utilized and exploited in the next 12 years (Kementerian Energi dan Sumber Daya Mineral, 2013b). Indonesia government tried to handle this problem by increasing the number of explorations. However, this policy is constrained by some of the non-technical constraints (e.g., licensing, land transfer, socio-economic conflict, etc.). The non-technical problem dominated 47% of oil exploration constraints in Indonesia, followed by the financial problem (24%), lack of infrastructure (21%), and others (8%)(Kementerian Energi dan Sumber Daya Mineral, 2013b). To prevent the energy crisis caused by the decrease of crude oil stocks, the government tried to introduce the use of natural gas.

Natural Gas; Unlike oil, natural gas production has shown a gradual increase over the last two decades. Compared to the world, Indonesia is in the 14th position as a country with the highest natural gas reserve. It is only mean that Indonesia only stores 1.6% of the total of the world's gas reserve. Along with the oil reserve stock recession, the government actively introduce gas as an alternative to reduce the high dependency on oil. However, national gas infrastructure networks are still not integrated well and causing some province to face difficulties to access the gas (Kementerian Energi dan Sumber Daya Mineral, 2013c). Moreover, Indonesia's gas industry has also transformed to supply liquefied natural gas (LNG) markets, thus making the nation become one of a leading LNG exporter in the world. This situation may increase a higher natural gas exploration in the future (Ministry of Finance, 2015a).

2.4.3.3. Energy Supply and Energy Demand

a. Government's Energy Supply Projection

The primary energy supply stated in the RUEN is including both all the energy source that produced domestically and imported. There is also a projection of the potential of new and renewable energy (Figure 2.13).

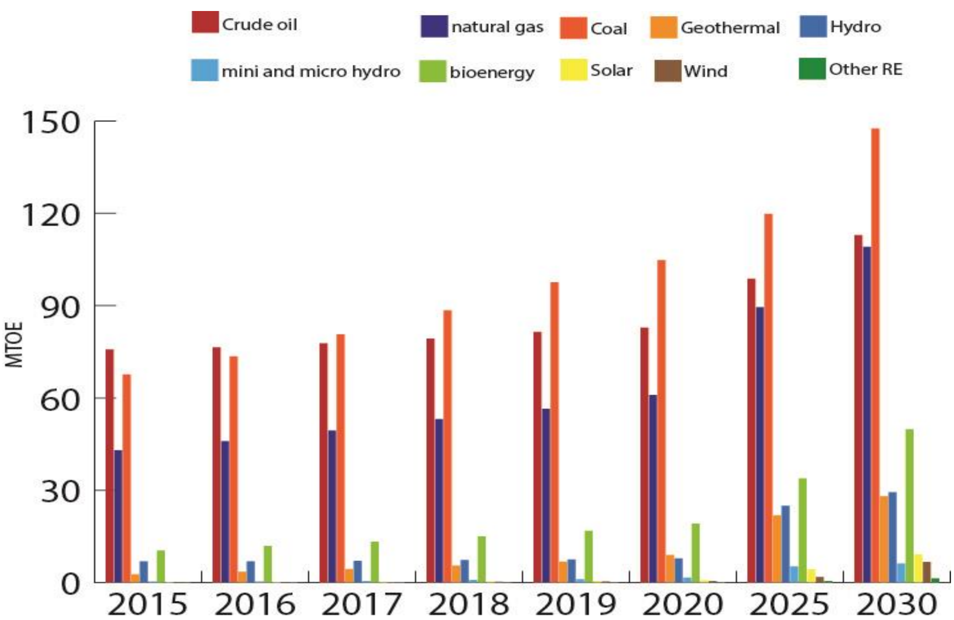


Figure 2.13. Projection of Indonesia Primary Energy Supply under RUEN by 2030.
Source: Dewan Energi Nasional, 2017

More detail of the national primary energy supply in Indonesia is summarized as below:

Crude oil; Primary energy supply to meet domestic petroleum needs consists of crude oil and fuel imports. Nationally, the crude oil stock already started to be depleted. Around 52% of crude oil supply in Indonesia are imported goods and planned to be reduced gradually, and it is projected to be replaced by the coal.

Natural gas; The primary energy of natural gas also includes LPG requirements which are met by the production of LPG refineries and LPG imports. National LPG production has not experienced an increase due to limited LPG raw materials. Thus, more than 50% of domestic LPG supply is currently met with imports.

Coal; is projected to be harvested and utilized mostly for the power generation and industrial sectors. The use of the coal is planned to be optimized for domestic use to reduce the energy import. The coal is considered as the most promising energy source to be utilized after the stock drop of gas and oil in the country. Thus, coal is projected to dominate the energy supply since 2017. However, Indonesia also cannot fully rely on coal for a long time because it is also projected that the coal reserves will also be exhausted in several years. BPPT (2018) projection shows that if no new coal reserves are found, then the proven-reserves of medium to high-quality coal are projected to be exhausted by 2038, and the total- reserves of medium to high-quality coal will be exhausted by 2048. In addition, coal also supplied to be exported, and most of the produced coal is exported than for domestic use (Figure 2.14).

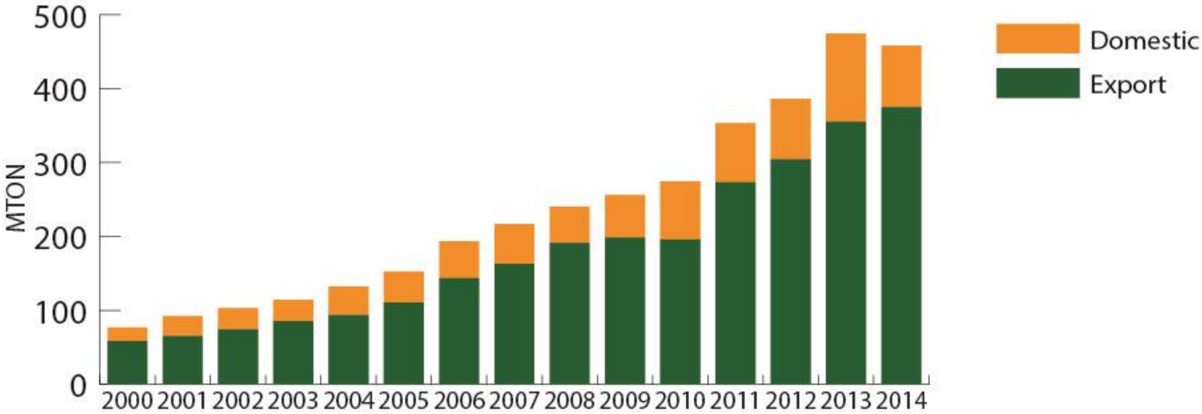


Figure 2.14. Coal Supply for Export and Domestic Use, 2000-2014.
Source: 2000-2009: Bappenas (2016), 2010-2014 Kementerian Energi dan Sumber Daya Mineral (2015b)

Renewable energy; in the RUEN, the primary energy supply for the renewable energy is also highly projected because it calculated not only the *committed project,* project that already planned to be developed, and *potential project,* project that identified to have prospects to be developed. As a country with wide plantation and agricultural land, the biofuel potential (including biomass, biodiesel, and biogas) are also high. The utilization of new and renewable energy resources has not been optimized due to its high production cost and worsen by the subsidy policy on fossil energy

b. Government's Energy Demand Projection

To give the upper limit and as the comparison of the final energy supply, the statistic and the projection of final energy demand from the National Energy Plan (RUEN) is used. From the statistic, it is found that the final energy demand comes most from the industry sector, followed by transport and household sector (Figure 2.15).

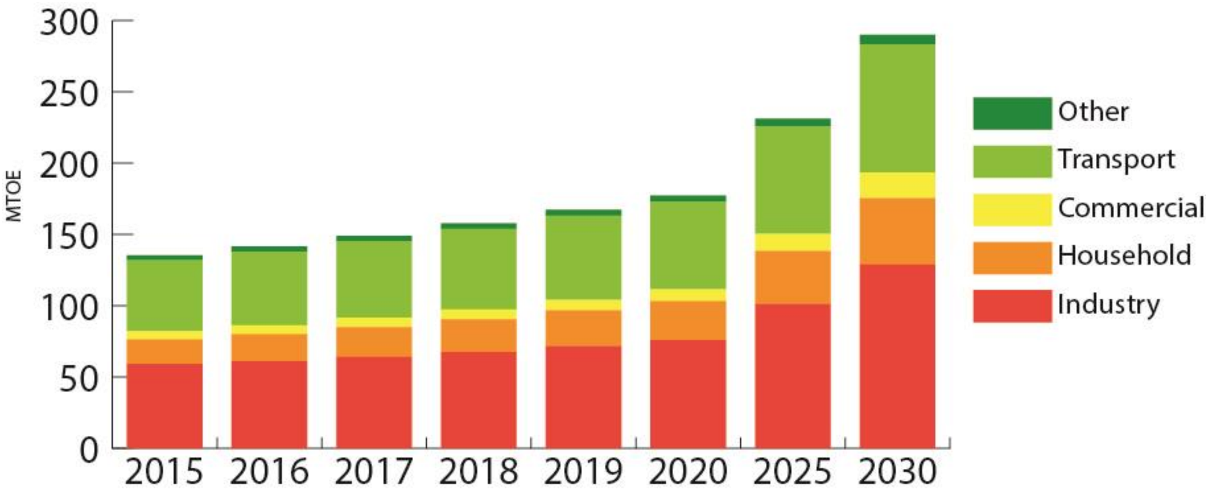


Figure 2.15. Energy Demand y user 2010-2017.
Source: Dewan Energi Nasional (2017)

Each sectors having a different pattern in the energy demand (Figure 2.16), this pattern is needed to explain the simulation result (Dewan Energi Nasional, 2017):

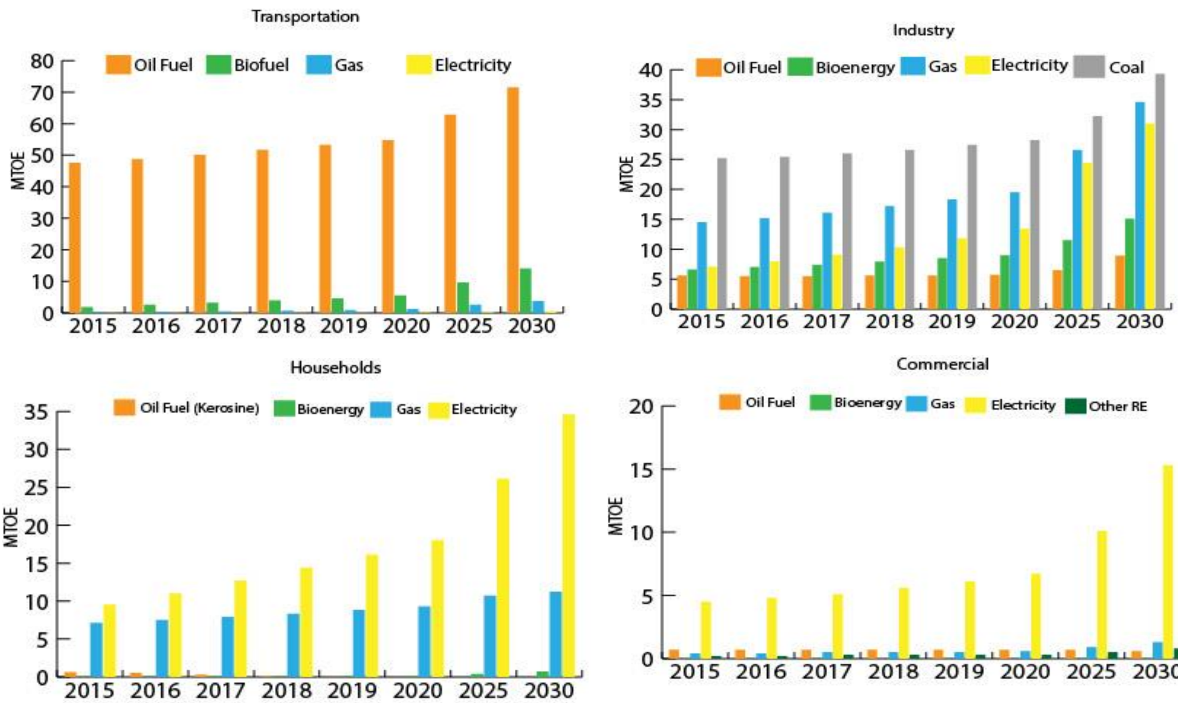


Figure 2.16. Projection of Final Energy Demand.
Source: Dewan Energi Nasional, 2017

Transportation; More than 90% of the final energy demand from the transportation sector is still dominated by fuel oil. To reduce the use of oil, the government plan to mix the oil with the biodiesel and bioethanol. However, the government also not projected the use of the biofuel in the transport sector will increase significantly because it is only planned as the mixture for the fuel, while the transportation technology in Indonesia still not enough for fuel substitution. While the use of gas and electricity in transportation only available in several big cities.

Industry; the use of coal and gas is projected to increased year-by-year. The energy diversification for the energy sector also quite high in the industry sector, but it is only limited to the biodiesel and commercial biomass. Furthermore, the highest energy user from the industry is chemical industry (especially the petrochemical), food and beverage, cement, non-metal, steel, and iron, then pulp and paper.

Household and Commercial; the energy consumption pattern for the Indonesia household is dominated by electricity and gas. This pattern is similar to the commercial pattern that the demand pattern is dominated by electricity.

Most sectors are demand for high electricity supply; thus, the information of the power generation also need to be examined to gain the insight of power generation in the target year. Furthermore, because there is high demand for coal in industry and high demand of electricity, which mostly generated by coal source, it can be estimated that in the simulation the coal supply may be high to satisfy the final energy demand.

c. *Government's Power Generation Projection*

As mentioned before, coal will be mostly utilized for the industries and power generation. This is in line with the projection of power generation in Indonesia. The energy source of power generation is gained from the General Plan for Electric Power Supply 2019-2028 (*Rencana Umum Penyediaan Tenaga Listrik*/ RUPLT) (Kementerian Energi dan Sumber Daya Mineral, 2019). In the other side, the use of oil for the power generation is projected to subside since 2021 and started to be replaced using renewable energy like geothermal and hydro (Figure 2.17).

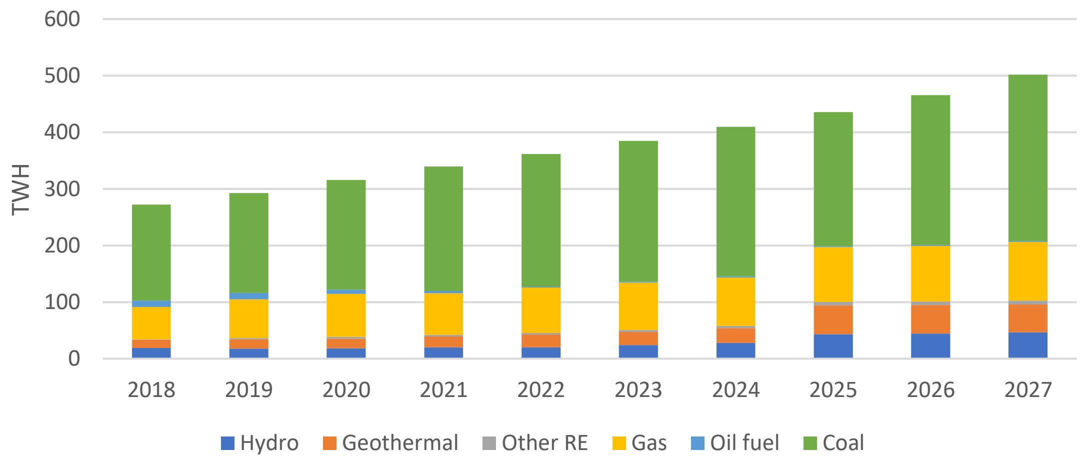


Figure 2.17. Power Plant Mix 2018-2027.
Source: Kementerian Energi dan Sumber Daya Mineral, 2019

Although Indonesia wants to utilize more coal for the power generation, considering its stock and availability, from 2025 the government tried to utilize more renewable energy, especially from geothermal and hydro.

Besides the energy supply and the projection of power plant mix, the information of price also needed so the model can simulate which energy that will be chosen the most to generate the electricity. The information of cost is gained from Basic Costs for Provision of National Electric Power in 2015 stated in RUEN (Table 2.4). Because the price data in Table 2.4 is still not including all the power plant in the model, the additional information from another document is added. Based on Minister of Energy and Mineral Resources No 1772 K/20/MEM/2018, the average of basic provision of National Electric Power is around 1025 IDR/ KWH. This value is assumed to be the price of coal pp by considering most of the power plants in Indonesia are a coal-generated power plant. The model tends to choose the cheapest options by also considering the primary supply. This condition may make the coal keep be chosen to generate the electricity or the overly estimated the use of biomass and waste pp because the primary energy supply data is also consisting the imported energy and the potential one.

Table 2.4. Basic Costs for Provision of National Electric Power in 2015

No	Power Plant	Represented Power Plant	Price (IDR/KWh)
1	Diesel (PLTD)	Oil pp	3992
2	Gas and steam (PLTGU)	Gas pp	1843
3	Gas (PLTG)		806
4	steam (PLTU)		661
5	Coal		1025
1	Solar (PLTS)	Renewable pp	8786
2	Geothermal (PLTP)	Renewable pp	1058
3	Hydro (PLTA)	Renewable pp	388
4.	Bioenergy	Waste-biofuel	3000

Source: Dewan Energi Nasional (2017)

To avoid this happen, the model also adjusted to not exceeds the projection of installed capacity and power plant expansion plan (Kementerian Energi dan Sumber Daya Mineral, 2019). Looking up the trend, the coal pp is already highly installed nationally (Figure 2.18).

Another problem is related to data availability. As can be seen from Figure 2.19, the data for the planned renewable energy power plant is limited and fluctuated. There is no exact information about the plan for waste, biomass, solar, and wind power plant expansion land. However, this information is used in the model as the “upper limit” of the powerplant generation to prevent the over-use of fossil fuel for the power generation, as the price of it is lower than the renewable energy sources, but the capacity of fossil fuel is limited.

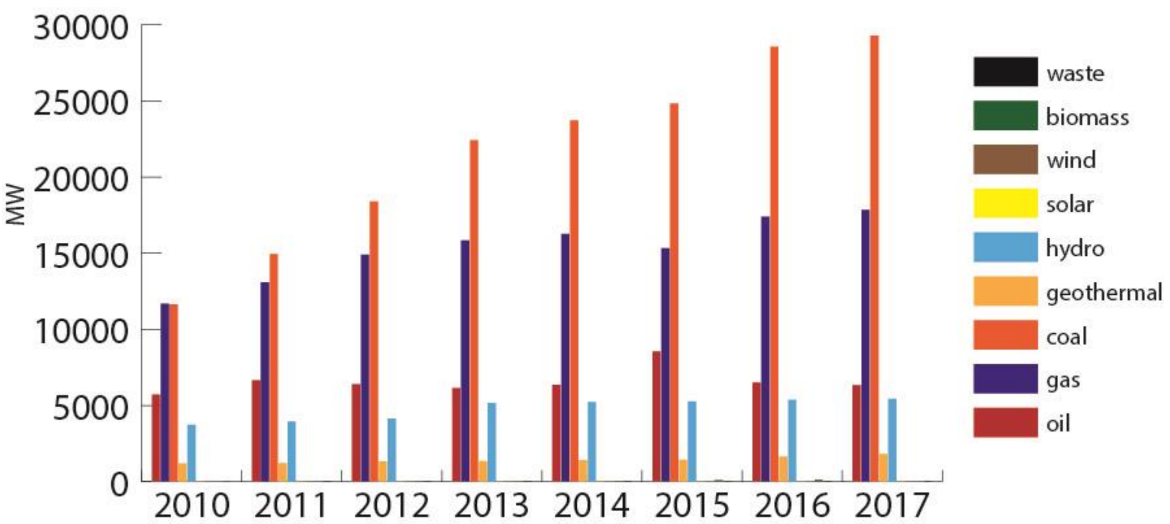


Figure 2.18. Power Plant Installed Capacity (MW).
Source: Kementerian Energi dan Sumber Daya Mineral 2015, 2016, 2017, 2018

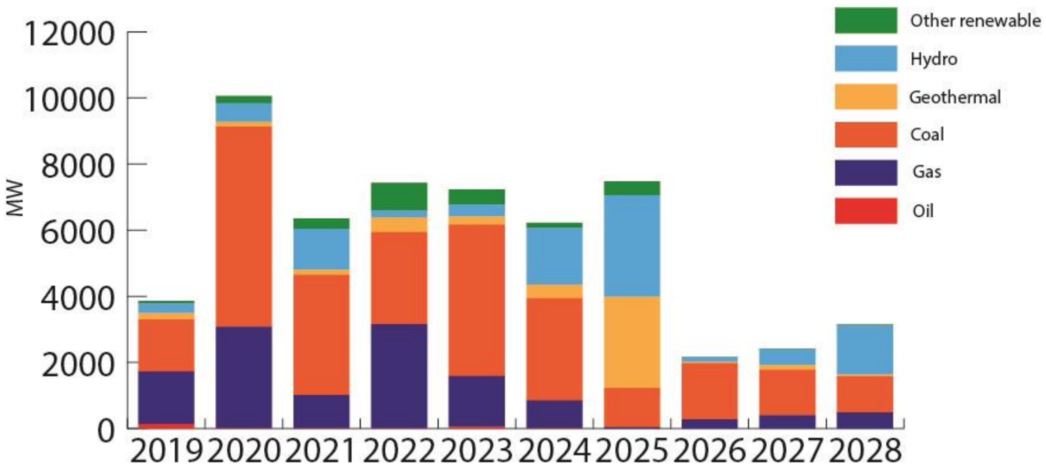


Figure 2.19. Power Plant Expansion Plan (MW).
Source: Kementerian Energi dan Sumber Daya Mineral (2019)

Furthermore, from the power plant expansion plan, the government tried to focus on building more coal pp, and for the renewable, there is an indication to build more geothermal pp, and hydro pp. Thus, the simulation result should also in line with this dataset.

2. 4. 4. Other Sectors (IPPU and Waste)

Other GHG sources in Indonesia are Industrial Process and Product Use (IPPU) and waste.

IPPU; The sources of GHG emissions from the industrial sector included GHG emissions from industrial process and product use (IPPU) activity. In Indonesia GHG inventory, the emission from IPPU is classified into 8 main categories namely: (a) mineral industries; IPPU emissions from mineral industries include those emissions related to chemical processes activities in cement (clinker production), lime, glass production activities and industries that use carbonates in their processes, (b) chemical industries; GHG emissions from chemical industries include those emissions related to chemical processes activities in ammonia, nitric acid, carbide, petrochemical and carbon black productions, (c) metal industries, (d) non-energy products from fuels and solvent use, (e) electronic industries, (f) product uses as substitutes for Ozone Depleting Substances (ODS), (g) production of other products and utilization, (h) other industries (Republic of Indonesia, 2015).

In the Indonesia Biennial Update Report (BUR) IPPU emissions that reported are mostly come from the emissions related to industrial process during conversion processes (usually involved chemical processes) and selected product manufacture and use. However, the emission-related to the product uses as substitutes for ODS are not reported due to the data and methodology limitation.

Waste; The emission sources from the waste sector in Indonesia were calculated by considering four categories, such as (a) municipal solid waste (MSW) treatments in solid waste disposal site (SWDS) or landfill, biological treatment/composting unit, open burning site, and incinerator, (b) domestic liquid waste treatment (collected and treated in centralized domestic Waste Water Treatment (WWT) as well as un-collected such as septic tank, latrine, etc.), (c) industrial wastewater treatment, and (d) industrial solid waste treatment. Also, like the agriculture sector, waste is contributing more to the non-CO2 emission. Although the emission from the waste is relatively low compared to another sector, however, it also projected that the emission from this sector would be increased year-by-year. The biggest share of emission from waste comes from wastewater treatment, followed by the incineration and open burning waste (Table 2.5).

Table 2.5. GHG Emission from Waste Sector in 2016 (000 Tones)

GHG Source	CO2	CH4	N2O	other
Solid Waste Disposal		1714.7		50.0
Biological Treatment of Solid Waste				1.6
Incineration and Open Burning Waste	2939.0	89.0	1.0	5.1
Wastewater treatment and Discharge		3248.0	9.0	71.1
Other	1.04	5.0		106.0
TOTAL	2940.0	5056.7	10.0	233.9

2.5. Mitigation Technologies

2.5.1. Agriculture

2.5.1.1. Paddy Cultivar

Nearly 30% of Indonesian paddy cultivar is *Ciherang* cultivar. *Ciherang* paddy is popular since its officially commercialized in 2000. This paddy is considered resistant enough with pest and can be planted both during rainy and dry seasons. As lowland rice, this cultivar also fits the most condition in Indonesia (Fau, 2018). However, different cultivar will also release a different amount of methane due to their structure and the way they transport and emit the emission. Before the wide use of Ciherang cultivar, IR 64 was highly used by the farmers. Although the Ciherang cultivar is already low emission, the introduction cannot be done at once, because it should consider some factors such as the climate, soil type, and so on.

In the calculation of emission for rice cultivation in Indonesia, the soil correction factor also considered. During the cultivation process, the straw and soil materials separation are not always enough. Some of the organic matter will leave under the soil and need to be calculated during the emission calculation (Table 2.6).

Table 2.6. Emission from Several Rice Cultivar in Indonesia

No	Variety	Average emission (kg/ha/session)	No	Variety	Average emission (kg/ha/session)
1	Maros	73.9	**23**	**IR 64**	**202.3**
2	Wayrarem	91.6	24	Cisadane	204.6
3	Limboto	99.2	25	BP360	215
4	**Ciherang**	**114.8**	26	Hipa6	219
5	Cisanggarung	115.2	27	IR 72	223.2
6	Tukad Balian	115.6	28	Mekongga	234
7	Martapura	125.7	29	Siak Raya	235.2
8	Muncul	127	30	Tukad Unda	244.2
9	Air Tenggulang	140	31	Fatmawati	245
10	Indragiri	141.1	32	Mendawak	255
11	Punggur	144.2	33	IR42	269
12	Way Apoburu	145.5	34	Inpari 1	271
13	Dodokan	145.6	35	Inpari 6 - ete	272

Table 2.6. Emission from….(Continued)

14	Memberamo	146.2	36	Aromatic	273.6
15	IR 36	147.5	37	Hipa 6 -ete	301
16	Sei Lalan	152.6	38	Rokan	308
17	Batang Anai	153.5	39	Hipa 5 Ceva	323
18	Tukad Petanu	157.8	40	Inpari 9 (lo	359
19	Cisantana	186.7	41	Gilirang	496.9
20	Margasari	187.2	42	Batanghari	517.8
21	BP205	196	43	Banyuasin	584.8
22	Hipa4	197			

Source: The Republic of Indonesia, (2015)

2.5.1.2. Irrigation and Water Management

The flooding-rice field is commonly used nationally as a water management method to water the rice-field. This condition makes paddy rice becomes the most significant methane emitters in Indonesia (Anas et al., 2008). It makes water management is one of the essential mitigation technologies in Indonesia. Water management will also affect the chemical process under the soil, and the organic matters left inside the soil. This is also why the soil correction factor also needs to be considered. The problem is, around 40% of irrigation in Indonesia is broken, and it makes the irrigation system is not efficient in most part of Indonesia(Ahmad, 2018). The field is left flooded without any significant water level settings and creates high methane emission. Water management through the sustainable irrigation system is one important key to control the emission. However, the cost of fixing and managing the irrigation also costly (Marpaung, 2013). Majority of the irrigation system is under the Ministry of Public Work and Housing and although the government realizes the importance of fixing and adding an irrigation system, they the realization in the field is still non-maximum due to budget limitation. In the farmers level, they also not motivated to fix their irrigation due to the expensive cost of managing the field.

2.5.1.3. Fertilizer Use Management

There are several ways to reduce the emission by fertilizer management, such as:

Replace urea with ammonium sulfate; Inhibitory effect of sulfate in CH_4 formation causes 10–67% reduction in methane emission when ammonium sulfate is used instead of urea (van Groenigen et al., 2013).

High-efficiency fertilizer application; one of the main causes of high N2O emission from the soil is due to the high use of nitrogen fertilizer. In Indonesia, farmers tend to use too much nitrogen fertilizers because they believe that it can increase the yield and good for the soil. In rice planting, due to bad drainage which makes the rice field always logged, they also use a significant amount of nitrogen fertilizer because rice has the low ability on absorbing nitrogen in logged condition (Triyono et al., 2013). However, in a study, it is said that there is no significant relation between Nitrogen fertilizer use with yield, so the most important thing is to increase the efficiency of the fertilizer to be easier absorbed by the plants or increase the ability of plants to absorb the nutrition from the fertilizer (van Groenigen et al., 2013). The use of high-efficiency fertilizer will reduce the amount of fertilizer used by the farmers and at last, will reduce the emission without reducing the total yield.

Replacing fertilizer with Manure-N and residue; Nitrogen in manure occurs mainly in organic forms (e.g., proteins) and as ammonium (NH4). Organic nitrogen is needed by the plants because it is not immediately planted available. Replacing inorganic N fertilizer will be more emission friendly and useful to improve the natural condition of the soil. The nitrogen will be used by the plant before emitted to the air. However, manure also one of the methane emission sources, so to block CH4 emission from manure and optimize the absorption of the nitrogen by the plant, Manure-N should be used immediately when the plant needs it, and also it should be avoided logged by water in the drainage. Otherwise, the plant cannot absorb nitrogen optimally, and it will increase the emission of CH4 (Pettygrove et al., 2003).

2.5.1.4. Biogas and Composting

Covered anaerobic digesters and Biogas; Covered anaerobic digesters and Biogas; An anaerobic digester is a closed tank which deters oxygen through the manure. Furthermore, the manure will be broken down naturally by occurring bacteria. Because the rate of methane production is dependent on ambient temperature, it is not considered cost-effective to produce biogas for energy in northern climates. It is the least expensive of the four types and is effective in reducing odors, even in cold climates (Aguirre-Villegas et al., 2016). One of the end products is biogas. Biogas itself can be utilized to generate electricity and heat or can be processed into renewable natural gas and transportation fuels.
In Indonesia, some projects are already introduced to build the biogas in the household scales; one of the most popular programs is BATAMAS. But some projects in this program are then stopped because people are still unfamiliar with the maintenance of the digester and the maintenance cost itself also costly (Budiman, 2018).

2.5.2. Energy

One crucial target of the Indonesia government in the energy sector is to reduce oil consumption. This is due to the declining domestic oil production capacity. For energy security reasons, the government has been attempting to move away from oil by promoting energy that is abundantly available in the country, i.e., coal, natural gas, and renewable energy. These attempts have resulted in high growth of coal supply (12.6% per year), much higher than the growth of oil (2.4% per year) and natural gas (3.8% per year)(Boer et al., 2017). Moreover, there is also a very high energy subsidy that goes for subsidized the oil and give a big burden for the national budget, that makes the government feel the urge to reduce the supply and demand of the oil.

Furthermore, the electricity demand is projected to be doubled by 2025, then the coal used for power generation is also will be optimized. On the Electricity Supply Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik* (RUPTL)) 2019-2028, Indonesia stated that the share of coal use for the energy mix would be at least 54.6%, this is 0.2% increase compared to the target on RUPTL 2018-2027.
To deal with the increase of demand for energy, there two main scenarios to mitigate the emission from the energy such as renewable energy utilization and energy efficiency.

2.5.2.1. Renewable Energy utilization especially for the Electricity Generation

One of the important mitigations technologies for the energy sector is the utilization of renewable energy. Under the Government Regulation No. 79/2014 on Indonesia National Energy Policy, Indonesia targeted to utilized New and renewable energy at least 23% in 2025 and 31% in 2050 (Boer et al., 2018). Indonesia itself has some potentials for new and renewable energy (NRE) such as hydro, geothermal, biomass, solar, wind, to sea wave. For example, in the case of geothermal, Indonesia is positioned in the 3rd position as a country with the biggest geothermal reserve in the world. As an archipelago country, Indonesia also has significant potential in the development of hydro and micro-hydro energy. However, in reality, less than 10% of those potential already utilized (Kementerian Energi dan Sumber Daya Mineral, 2013d). This is because there are lots of challenges faced to introduce the use of NRE (Maritje, 2013), such as:

1. Cost to produce NRE is relatively more expensive than conventional energy production.
2. Mostly of NRE technologies are still imported and not domestically produced.
3. The location of NRE resource spots in Indonesia are spreading throughout Indonesia; each spot also usually only has limited or small energy resources. In this case, it is also costly to deliver the energy from the NRE spot to the area that has higher energy demand.
4. Non-technical barrier; e.g., social acceptance, land tenure, and regulation. Sometimes, there are also some regulation clash between each ministry, for example some geothermal spots are located in the nature conservation area, and it means that geothermal in that place cannot be utilized because intersect with the regulation of conservation area and forest stated by the Ministry of Environment and Forestry (Lauranti and Djamhari, 2017).
5. The quantity and quality of human resources who expert and understand in renewable resources still limited.

Another biggest potential that can be developed for energy is the use of biomass. As the biggest producers of biomass producers in the world, the potential of biomass from palm oil is also very huge. Not including another biomass source such as paddy, cane, rubber, cassava, coconut, and corn. However, most of the biomass is used internally for the concerned industry (e.g., paper and pulp and palm oil industry) or exported. It makes the government facing some difficulties to gather all the biomass for the energy or power utilization use (Kementerian Energi dan Sumber Daya Mineral, 2015a).

Again, there are still lots of challenges that need to be solved by Indonesia for new and renewable energies development. In summary, all the challenges of the renewable energies are summarized on the Table 2.7.

2.5.2.2. Energy efficiency

The energy efficiency activity is the main mitigation technology from the energy sector. The first step that the government takes was energy conservation audits and labeling. Under the RAN-GRK. Indonesia started to state mandatory energy management practice for the energy-intensive user and can reach improvement of energy efficiency potential (no and low cost) by 10%. In the household level, there is an action for energy efficiency improvement through the implementation of energy efficiency appliances. For those, the government has issued a series of regulations and tools such as i. Energy Act No. 30/2007 Government Regulation No. 70/2009 concerning Energy Conservation; and ii. Ministerial Regulation of MEMR No. 6/2011 concerning The Labelling of Energy Efficient Appliances (Bappenas, 2012).

Table 2.7. Summaries of Challenges faced by Indonesian Government Related to the Renewable Energy Development

Renewable Energy	Technology	Economic	Social	Other
Solar	Most of the component, especially the solar cell, are still imported	High investment cost.	Land ownership and land acquisition	
Wind		High investment cost		Around the equator line, wind power is relatively small.
Geothermal		• High exploration cost. • For geothermal powerplant→ the selling price from geothermal pp is considered small and cannot cover the exploration and production cost.		• A geographical challenge as geothermal itself is "site-specific" energy sources. • Licensing issues; some geothermal resources are in a conservation area, and the exploration should be done carefully with the control from the Ministry of Environment.
Hydro and micro-hydro			When it comes to the hydro and micro-hydro, the maintenance is usually done by local people and them still unfamiliar with the maintenance of it.	High deforestation makes the water flow is uncertain. Geographical challenges; far from the place with high energy demand.
Bioenergy (including biomass, biogas, biofuel, waste)	• Some technology needs to be imported. • Waste; lack of waste separation system.	High energy subsidy for oil fuel makes bioenergy cannot compete for the price of oil fuel	Bioenergy that managed by local people (e.g., biogas) are usually lack of maintenance.	• Land competition between food crops and biofuel crops. • The productivity of biofuel crops in Indonesia still low. (Agustian et al., 2014)

Source: Kementerian Energi dan Sumber Daya Mineral, 2016 except that mentioned

2.5.3. Other Sectors

a. IPPU; the main emitters in the industries are steel, cement, and chemical industries. Thus, the mitigation technologies are highly related to these industries such as 1.) Reduction of clinker to cement ratio, 2.) Feedstock utilization and CO2 recovery in the primary reformer in the petrochemical industry, and 3.) enhance the energy efficiency in the industries. There is also Ministerial Regulation No.51/ 2015 that state the guidelines for the Development of Green Industry Standards. The guideline contains provisions regarding requirement criteria of the green industry, including the definition of standards for raw materials, energy, auxiliary materials, waste management, and corporate management for the green industry.

b. Waste; although the emission from the waste is not significant, the emission is projected to be increased. To control the emission from the waste, the government tried to make the regulation to convert waste into energy through the Presidential Regulation No.35/2018. The government also creates several sets of regulation to enhance the industry to treat their waste more efficiently. The main problem is there is still a lack of monitoring system for this system, although there are several sets of regulation, there is still limited information about how actually the waste that already treated and not.

3. General Structure of Computable General Equilibrium (CGE)

A Computable General Equilibrium (CGE) is a computer-based simulation to describe the whole economy and its sectoral interaction by using a system of equation. CGE model is often to be used for policy analysis as it tried to connect all the sector in the economy. The model also can be constructed based on the real-world data of a single country or multi countries. The simulation usually started with the business-as-usual followed by the introduction of some policy shocks (e.g., climate change mitigation policy) and the model will generate a new general equilibrium after the shock (Babatunde et al., 2017).

This model is a recursive dynamic model that only considers the equilibrium condition within a year. In other words, if there is a technology introduced (e.g., energy-saving technologies) that has a payback period more than a year, this technology will be not selected. If this technology wants to be promoted, the payback period can be changed. Moreover, for the capital, the capital stock is determined by the previous year's capital stock, capital formation, and capital depreciation.

In this study, the CGE is used for two main studies: 1.) CGE for analyzing the mitigation impact on the Land Use Change and Forestry (LUCF) and 2.) CGE for analyzing all the sectors.

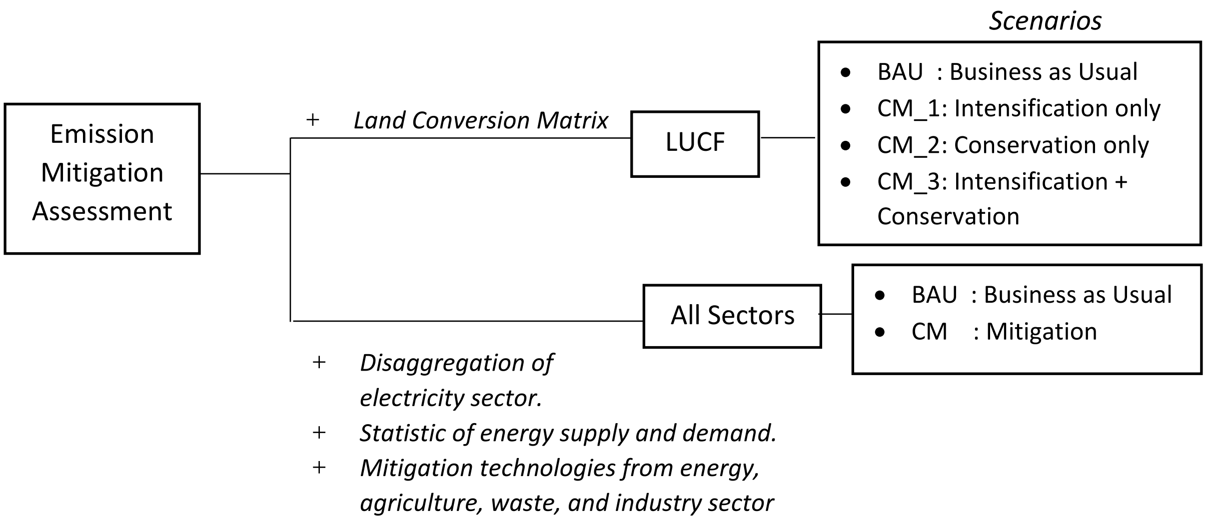


Figure 3.1. The flows of the study

In the CGE for LUCF part, there is no modification on the IO Table, but the table is then combined with another matrix called land conversion matrix. In the CGE for the overall analysis, the IO Table is slightly modified by disaggregating electricity sector (sector no. 28) into five categories: coal pp, oil pp, gas pp, renewable pp (excluding biomass and waste) and biomass-waste pp.

Furthermore, the reason for part 1 and part 2 separation is because of the lack of information on cost for the LUCF. The sector definition between LUCF and agriculture are overlapped between each other. More detail information that available are mostly the mitigation cost for the agriculture sectors (e.g., fertilizer and seed price, irrigation infrastructure, etc.) but there is very limited information about the cost that comes from the land conversion. This becomes more complicated because most of the land conversion is often a non-economic activity, and the activity is done privately or by involving family members without any economic transaction. Of course, there are several studies that tried to count the land-use conversion cost, but most of it is for commercial plantation like palm oil and rubber. But there is still a lack of information for the cost for the cropland.

3.1 General CGE structure

In general, the CGE will involve multiple agents in the economy that interact with each other, and all the agents are then mediated in the market through the price mechanism Figure 3.2.

In the economy, the producers are tried to maximizing profit by utilizing all the production factors and resources gained from the market. In the production sector, the producers can introduce one or more set of technology to make their production more efficient. All the production factors, including labor and capital, are provided by the household sectors. In this study, the land also introduced as a production factor, and this resource also assumed to be provided by the households. The household sector will gain some income by providing those factors through the market and tried to maximize the utility. While the government also received income transfer by levies tax from the households and then invested it in the capital formation form.

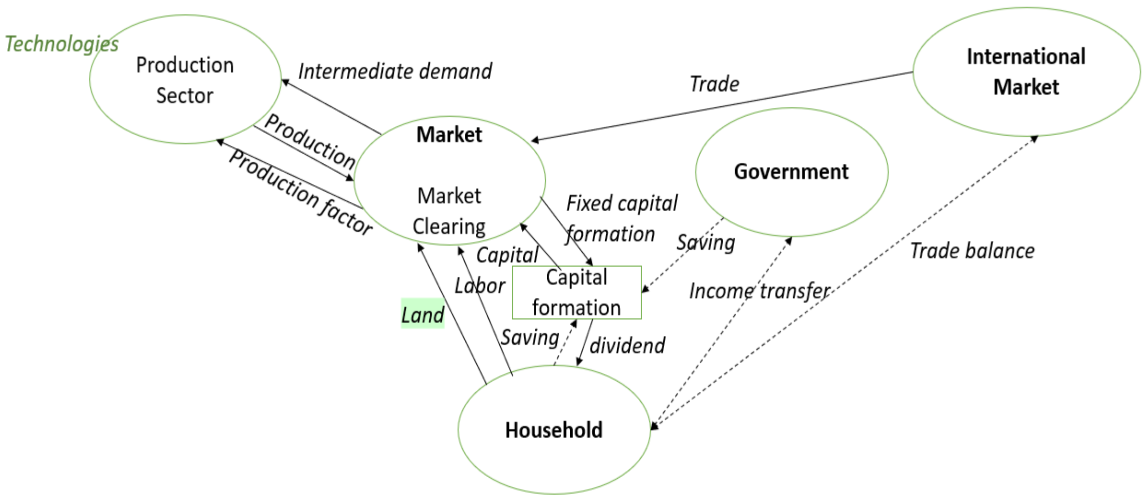


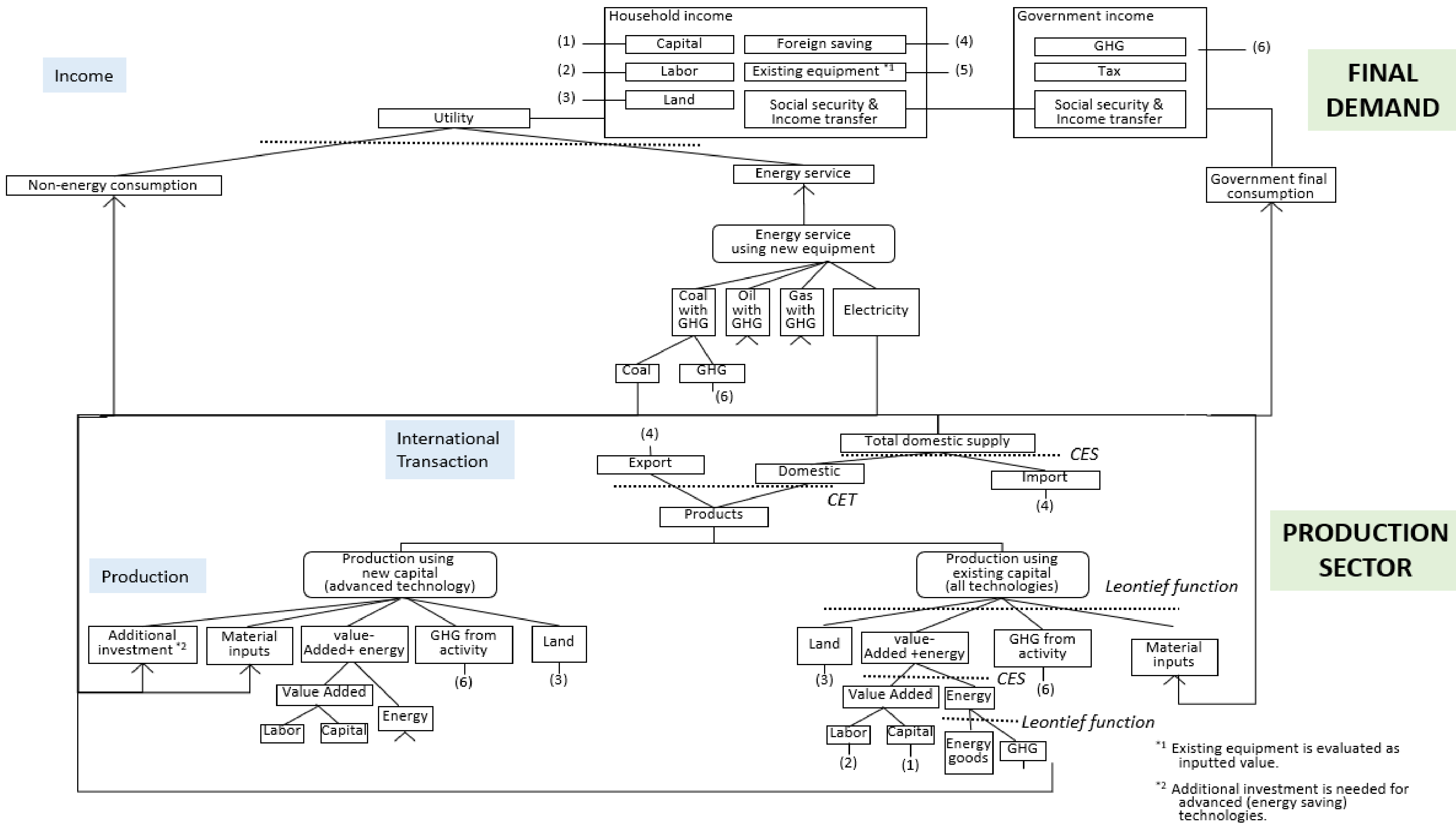
Figure 3.2. CGE Structure in General

For the international trade; the model is assuming small-open country assumption. Thus, it is assumed that the economy is small that will not give a significant impact to the rest of the world. Also, the goods domestically produced/ consumed and those that imported/exported are assumed to be imperfectly substitutable. Moreover, the Market is gathering all the products and production factors and connect all the economic agents. In the market, supply and demand of every factor and commodities are balance through the price mechanism.

3.2. Model Structure

There are 38 sectors in this model. These sectors are aggregated from the more detailed Indonesia input-output table, which has 185 sectors, including ten sectors categorized as "land-based" sectors and became the focus of this study. These ten sectors are sectors that are using the land as inputs to produce their output. The model captures the equilibrium of supply and demand in the economy. In the economy, those sectors link between each other, and in this model, the connection of each sector are as described in Figure 3.3. The model consists of three main blocks, such as production block, income/ household block, and international transaction block. Each block relates to a specific type of elasticity of substitution.

In the production block, each production sector inputs capital, labor, materials, energy, and outputs related product based on IO table. The production also can be produced by existing and the new capital. The new capital comes from additional investment in any sector. Moreover, after capital is installed into a sector, this capital becomes existing capital in that sector. The efficiency will also improve in proportion to the new capital.



- CES: Constant Elasticity of Substitution
- CET: Constant Elasticity of Transformation

Figure 3.3. CGE Structure for this study

3.2.1. Production Block

The first block is the production block. This block is consisting of a set of production factors including capital and labor that aggregated as value-added. The land also considered as an input, so it is also included in the *Production Block* in the model. The production in each sector is disaggregated into subsectors, using the existing capital stock and the new capital stock. Each subsector has a nested production function. The top of the nested production function is assumed to use the Leontief production function. The emission from the activities (GHGJA) is associated with the production activity in the economy. The equation in the production block can be written as:

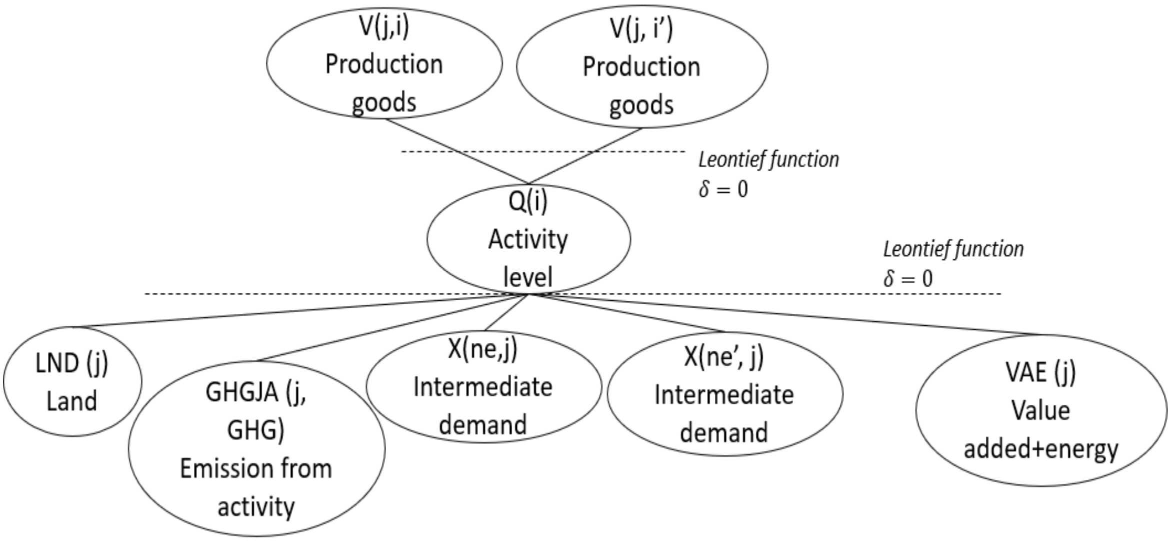


Figure 3.4. Production block

$$Max\ PQ \cdot Q - PVAE(j) \cdot VAE(j) \cdot PLND \cdot LND - \sum_{GHG} PGHG \cdot GHGJA - PS(ne) \cdot X(ne,j)$$
$$V(j,i) = Q(j) \cdot v_o(j,i)$$
$$Q\ (j) = VAE(j) + \sum_{ne}\big(X(ne,j)\big) + PLND \cdot LND(j) + \sum_{ghg} GHGJA(j,ghg))$$
$$VAE(j) = ava(j) \cdot Q(j)$$
$$X(ne,j) = ax(ne,j) \cdot Q(j)$$
$$LND(j) = alnd(i) \cdot Q(j)$$
$$GHGJA(j,ghg) = efa_{ghg(j,ghg)} \cdot Q(j)$$

Where:

Q(j)	:Activity level of sector j/ composite production in sector j
V (j,i)	: Production goods i in sector j
VAE(j)	: Value Added including energy in sector j
X(ne, j)	: Intermediate input of non-energy goods (ne) in sector j
LND(j)	: Land input in sector j
GHGJA(j,GHG)	: GHG emissions from activity in sector j
efa_ghg	: emission factor of GHG
v_o	: output coefficient of goods i In sector j
$ava(j)$	: adjustment parameter for the value-added
$ax(ne,j)$	: adjustment parameter for the intermediate input
$alnd(i)$	: adjustment parameter for land
PLND	: price of land
PGHG	: Price of GHG
PS(ne)	: Price of supplied goods (non-energy)
PQ(j)	: Price of composite production in sector j

The next nested function in the production block is the value-added. In this model, the value-added consists of capital, labor, and energy. In this nesting part, the capital (K(j)) and labor (L(j)) are aggregated into the value-added (VA(j)) and energy composite (ENJ (j). While this block involves capital, the capital will experience depreciation at some level each year. For this study, the depreciation rate is assumed at the level of 5%. The equation of this part can be written as:

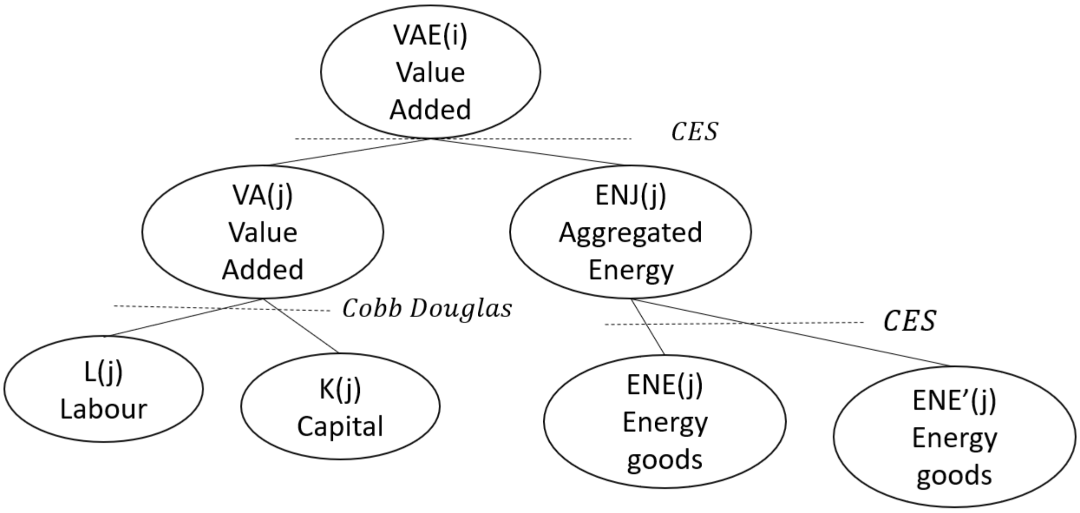


Figure 3.5. Value Added block

$$VAE(j) = a^{VAE(j)} \cdot \left(s_{ENJ(j)} \cdot ENJ(j)^{-\rho^{VAE(j)}} + s_{VA(j)} \cdot VA(j)^{-\rho VAE(j)}\right)^{\frac{1}{-\rho^{VAE(j)}}}$$

$$ENJ(j) = VAE(j) \cdot \left(\frac{a^{VAE(j)^{-\rho^{VAE(j)}}} \cdot s_{ENE(j)} \cdot P_{VAE(j)}}{P_{ENE(j)}}\right)^{\frac{1}{1+\rho^{VAE(j)}}}$$

$$VA(j) = VAE(j) \cdot \left(\frac{a^{VAE(j)^{-\rho^{VAE(j)}}} \cdot s_{VA(j)} \cdot P_{VAE(j)}}{P_{VA(j)}}\right)^{\frac{1}{1+p^{VAE(j)}}}$$

Where:

VAE(j)	: Value-added- energy composite in sector j
VA(j)	: Value-added input in sector j
ENJ(j)	: Energy aggregation in sector j
PVAE(j)	: Price of value-added with energy in sector j
PVA(j)	: Price of value-added in sector j
PENJ(j)	: Price of energy aggregation in sector j
$s_{VA(j)}, s_{ENJ(j)}$	: Share parameters of VA and ENJ for value-added with energy in sector j
$\alpha VAE(j)$	: Adjustment parameter for value-added with energy in sector j
$\rho VAE(j)$	: Substitution parameter between VA and ENJ in sector j

$$VA(j) = \alpha_{VA}(j) \cdot L(j)^{s}_{L(j)} \cdot K(j)^{s}_{K(j)}$$

$$L(j) = \frac{s_{L(j)} \cdot PVA(j) \cdot VA(j)}{PL}$$

$$K(j) = \frac{s_{K(j)} \cdot PVA(j) \cdot VA(j)}{PK}$$

Where:

VA(j)	: Value added in sector j
K(j)	: Capital demand in sector j
L(j)	: Labor demand in sector j
PVA(j)	: price of value added in sector j
PK	: Price of capital
PL	: Price of labor
$s_{K(j)}$, $s_{L(j)}$	: share parameter of K and L to value-added in sector j
$\alpha_{VA}(j)$	: adjustment parameter for value added in sector j

While the energy composite part can be written as.

$$ENJ(j) = \alpha_{ENE(j)} \cdot (\sum_{em} s_{e(en,j)} \cdot E(en,j)^{-\rho}_{E})^{\frac{1}{-\rho_{E(j)}}}$$

$$E(en,j) = ENJ(j) \cdot \left(\frac{a_{ENJ(j)^{P}_{E(j)}} \cdot s_{E(en,j)} \cdot PENJ(j)}{PE(en)} \right)^{\frac{1}{1+\rho_{E(j)}}}$$

Where:

ENJ(j)	: Aggregate energy of sector j
E(en,j)	: intermediate demand of energy (en) in sector j
PENE(j)	: Price of aggregated energy in sector j
PE(en)	: Price of energy (en)
$s_{e(en,j)}$	: share parameters of energy (en) to the total energy in sector j
$\alpha_{ENE(j)}$	: Adjustment parameter for energy aggregation in sector j
$\rho_{E(j)}$	: Substitution parameter among energies in sector j

The energy itself also consists of the energy goods and its emission that connected by Leontief function. The energy input consists of intermediate energy input and CO2 emission. The elasticity of substitution between energy and CO2 is assumed to be 0 (Leontief function) is assumed. In the case that the total CO2 emission potential exceeds the CO2 constraint, the GHG price, PGHG, becomes the positive value.

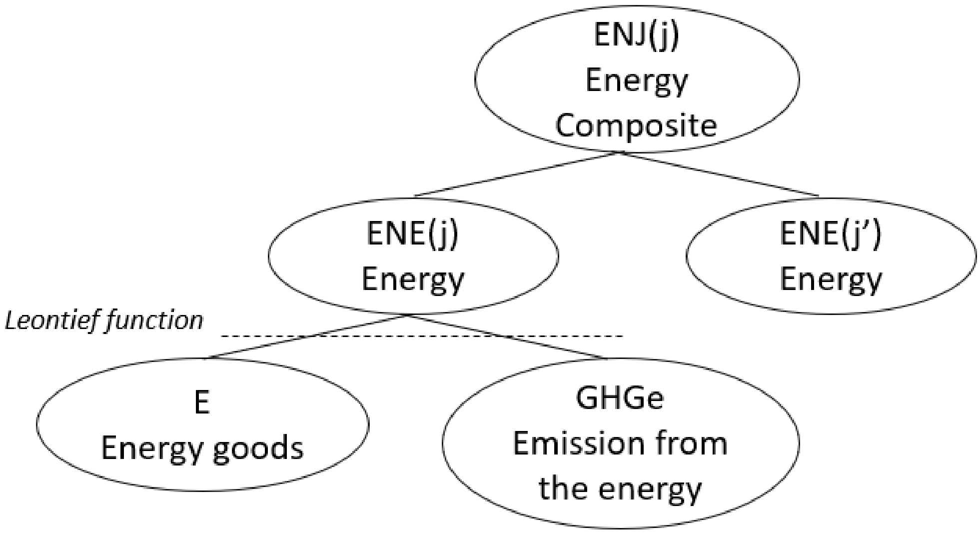


Figure 3.6. Division of Energy goods and emission from the energy

$$ENE(j) = \sum_{en} E(en, j)$$
$$E(en, j) = X(en, j)cmb_r(en, j)$$
$$GHGe\ (en, j) = ef_{GHG(en)} \cdot E\ (en, j)$$
$$PE(en, j) \cdot E(en, j) = PS(en) \cdot X(en, j) + PGHG \cdot \sum_{GHG} GHGJ\ (en, j, ghg)$$

With:

ENE (j)	: Total energy composite in sector j
E (en,j)	: Energy input with GHG in sector j
X (en,j)	: Energy input from intermediate input
GHGe (en,j)	: Emission from the energy sector
$cmb_r(en, j)$	: combustion rate for energy in sector j
$ef_{GHG(en)}$	: Emission factor of energy goods.

The combustion rate (energy rate) of energy goods $cmb_r(en, j)$ for this model is assumed to be 1, that means all the energy are all perfectly combusted.

3.2.2. Household and Government Block

3.2.2.1. Household Demand (consumption)

Households are tried to optimize their utility by consuming some goods and services by using their incomes gained from providing production factor to the market. The utility of the household is gained by consuming some goods, both energy and non-energy goods. The initial value of the household consumption is gained based on the information on IO Table. Moreover, the energy composite in the household also consists of energy goods and their emission. It can be written as:

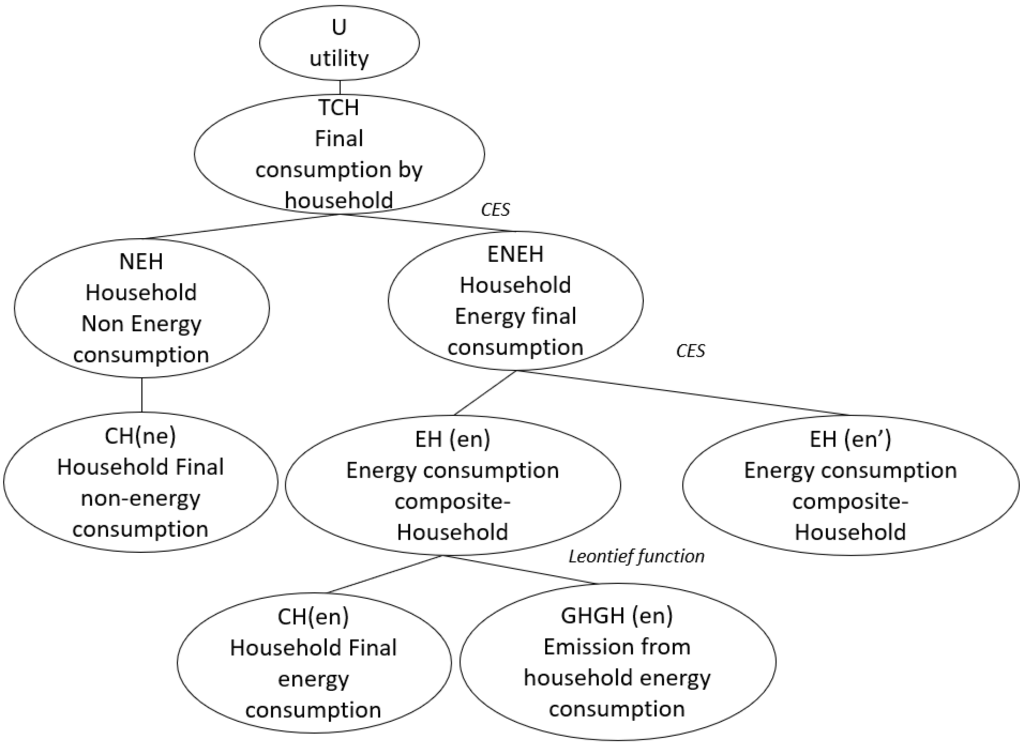


Figure 3.7. Division of Household Consumption Block

$$U = TCH$$
$$TCH = NEH + ENEH$$
$$NEH = a_{NEH} \cdot \prod_{ne} CH(ne)^{s_{CH}(ne)}$$
$$ENEH = \ a_{ENEH} \left(\sum_{en} s_{EH}(en) \cdot CH(en)^{-\rho ENEH} \right)^{\frac{1}{-\rho_{ENEH}}}$$
$$GHGH\ (en) = efe\ (en) \cdot CH(en)$$

Where:

U	: total demand in the household (utility)
TCH	: total final consumption by household
NEH	: total non-energy final consumption by household
ENEH	: total energy final consumption by household
CH (ne)	: Nonenergy demand in household
CH (en)	: Energy consumption by the household
GHGH (en)	: Emission from the household
$s_{EH}(en)$	: Share parameters of energy to total energy in household
a_{ENEH}	: Adjustment parameter for energy aggregation in household
$\rho ENEH$	: Substitution parameter among energies in household
$efe\ (ene)$	: Emission factor (energy)

3.2.2.2. Government demand (consumption)

The government also use their income (gained from tax) for consumption and investment. It can be written as:

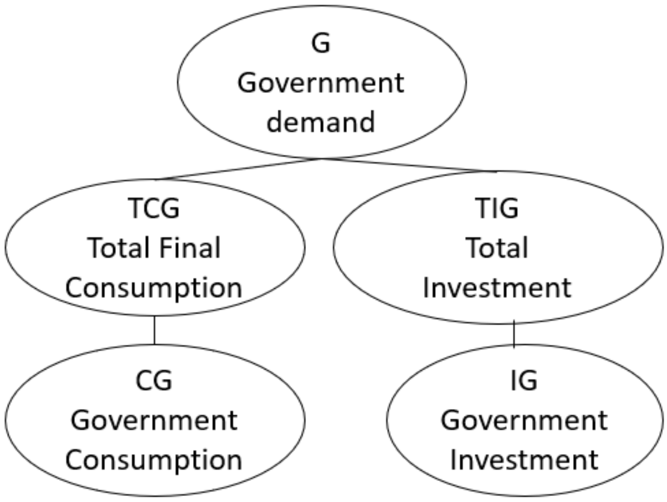


Figure 3.8. Division of Government Consumption Block

$$G = TCG + TIG$$
$$TCG = \sum_i CG(i)$$
$$TIG = \sum_i IG(i)$$

Where:
G : Total demand in government
TCG : Total final consumption by government
TIG : Total investment in government.
CG(i) : final consumption by government
IG (i) : investment by government.

The information on government consumption and investment are gained from the IO Table. In the case of Indonesia IO table, the information of government investment is not available, so it is assumed to be shared along with the investment of the household sector.

3.2.2.3. Household and Government Income

The Household sector receives income from providing some endowment such as capital, labor, and land. In this model, the household will share their income with the government by tax mechanism, while the government also can give an income transfer to the household (e.g., social transfer) to the household. The trade surplus is also assessed in the income level. In this model, the fixed capital formation is calculated from the future GDP growth in advance. In other words, the fixed capital formation in decreased from the total income. This income also becomes the constraint for the household to optimize its utility and for the government to optimize social welfare. The equation can be written as:

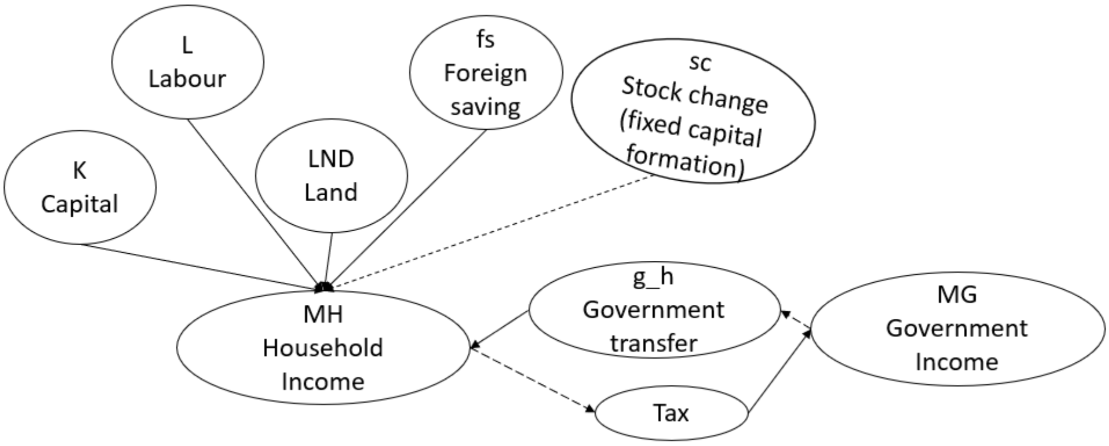


Figure 3.9. Household and Government Income

$$MH = \sum_j P_K \cdot K(j) + P_L \cdot L(j) + P_{LND} \cdot LND\,(j) + fs + (\sum_i -sc(i)) + \; g\_h$$

$$MG = (\sum_i \left(tx_{o(j)} - tx_m(i)\right) + \; (\sum_j \left(tx_{k(j)} - tx_l(j)\right) - g_h$$

$$g_h = \; \sum_i (tx_{m(i)} \cdot im(i) + \sum_i (tx_{o(i)} \cdot D(i) + \sum_j (tx_{k(i)} \cdot K(j) + \sum_j (tx_{l(j)} \cdot L(j) - \sum_i (cg(i) \cdot ig(i)$$

where:

MH : Household Income
MG : Government Income
K(j) : Quantity of Capital Input
L(j) : Quantity of Labour Input
LND(j) : Land
fs : foreign saving
sc(i) : stock change
g_h : transfer between household and government
tx_o(i) : output tax rate
tx_k (j) : capital tax rate
tx_l (j) : labour tax rate
tx_m(i) : import tax rate
im (i) : import quantity
D(i) : total supply
cg(i) : final consumption by the government
ig(i) : investment (fixed capital formation) by the government

All the prices in the model are relative prices, with zero (0) as the initial value. The price will change based on the supply and demand mechanism in the market.

3.2.3. *Relationship between Output, Export, Import, and Domestic Market*

The domestically produced goods are allocated for domestic use and to be exported. While the domestic supplied goods are coming from the imported goods and the goods that allocated for the domestic use (Figure 3.10).

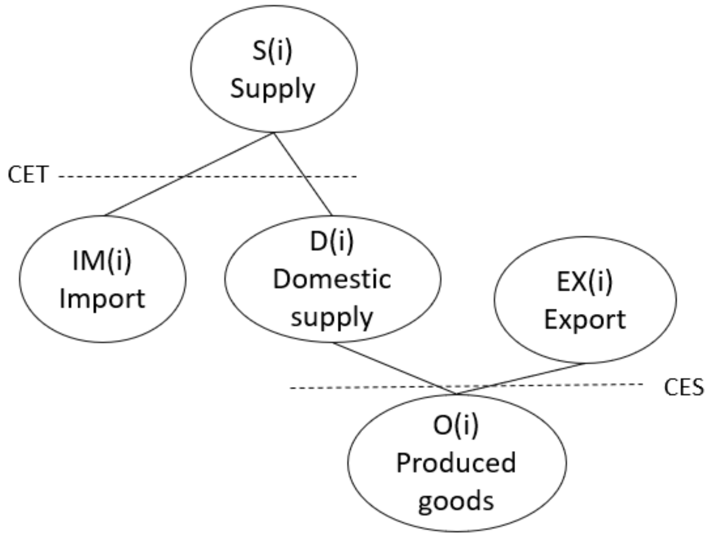


Figure 3.10. Relationship between Output, Export, Import, and Domestic Market

In this model, the elasticity assumption for international trade is using Armington' assumption for the import and domestic supplied goods, that there is an imperfect substitution between import and the supplied goods. The elasticity of transformation of produced goods between export and domestic is assumed to be constant under the CET function. From this function, the values of export and domestic goods are calculated from the total produced goods and their prices.

$$O(i) = a_{ex(i)} \cdot \left(s\_ex(i) \cdot EX(i)^{al_{ex(i)}} + s\_xd(i) \cdot D(i)^{al_{ex(i)}}\right)^{\frac{1}{al_{ex(i)}}}$$

$$EX(i) = O(i) \cdot \left(\frac{a\_ex(i)^{al_{ex(i)}} \cdot s\_ex(i) \cdot PO(i)}{PEX(i)}\right)^{\frac{1}{1-al_{ex(i)}}}$$

$$D(i) = O(i) \cdot \left(\frac{a\_ex(i)^{al_{ex(i)}} \cdot s\_xd(i) \cdot PO(i)}{PD(i)}\right)^{\frac{1}{1-al_{ex(i)}}}$$

Where:

O(i) : Produced goods i
EX(i) : Export of goods i
D(i) : Domestic produced goods i
PO(i) : Price of produced goods i
PEX(i) : Price of exported goods i
$a_{ex(i)}$: adjustment parameter for export
$s_{ex(i)}$: share parameter of export
$s_{xd(i)}$: share parameter of export-domestic goods
$al_{ex(i)}$: elasticity of substitution of export-domestic goods

The elasticity of substitution between imported goods and domestic goods is also constant but using the CES function and can be written as:

$$S(i) = a_{im(i)} \cdot \left(s\_md(i) \cdot D(i)^{-al_{im(i)}} + s\_im(i) \cdot IM(i)^{-al_{im(i)}}\right)^{-\frac{1}{al_{im(i)}}}$$

$$D(i) = S(i) \cdot \left(\frac{s_{md(i)} \cdot PS(i)}{a\_im(i)^{al_{im(i)}} \cdot PD(i)}\right)^{\frac{1}{1+al_{im(i)}}}$$

$$IM(i) = S(i) \cdot \left(\frac{s_{im(i)} \cdot PS(i)}{a\_im(i)^{al_{im(i)}} \cdot PIM(i)}\right)^{\frac{1}{1+al_{im(i)}}}$$

where
S(i) : Total supply of goods i
D(i) : Domestic produced goods i
IM(i) : Imported goods i
PS(i) : Price of supplied goods (i)
PD(i) : Price of domestically produced goods (i)
PIM(i) : Price of imported goods (i)
$al_{im(i)}$: substitution parameter between import and domestic use
$s_{im(i)}$: share of import
$s_{md(i)}$: share of domestic use
$a_{im(i)}$: adjustment of import and domestic use

The international commodity prices (pintx(i) and pintm(i)) and trade surplus (fs) are assumed to be exogenous parameters. The exchange rate (EXR) is described as:

$$PEX(i) = EXR(i) \cdot pintx(i)$$
$$PIM(i) = EXR(i) \cdot pintm(i)$$
$$\sum_i \big(pintx(i) \cdot EX(i)\big) + fs = \sum_i \big(pintm(i) \cdot IM(i)\big)$$

Where:
EXR : Exchange rate
PEX(i) : Price of Exported goods (i)
PIM(i) : Price of Imported goods (i)
pintx(i) : International commodity price for export goods
pintm(i): International commodity price for import goods.

3.2.4. Market equilibrium

As mentioned before, in the mode, all the supply and demand are equilibrium, and it makes the model consist of some set of equilibrium conditions. There are five equilibriums available in this model: Production market, market goods, the market of capital, the market of labor, and market of GHG.

3.2.4.1. Production market

In the production market, the total produced goods are equal with the total production that comes both by using the existing stock and new investment and the accumulation of some valuable waste that still be used in the production.

$$PQ \cdot Q(i) = \sum_j \big(PV1 \cdot V1(j,i) + PV2 \cdot V2(j,i)\big) + sc$$

Q(i) : Total produced goods i
V1(j,i) : Produced goods i by existing stock subsector in sector j
V2(j,i) : Produced goods I by new investment subsector in sector j
sc : Stock change
PQ : Price of total produced goods i
PV1 : Price of produced goods by existing stock
PV2 : Price of produced goods by new investment

3.2.4.2. Market goods

In the market good, the supply and demand for goods that consumed are balanced.

$$\sum_j V(j,i) = \sum_j X(i,j) + C(i) = S(i)$$

Where:
V(j,i)	: Production goods I in sector j
X(I,j)	: intermediate demand for goods in sector j
C(i)	:Final consumption of goods i
S(i)	: Total supply of goods i

3.2.4.3. Market of Capital

The supplied capital should be equal to the endowment of capital. As mention before, there are two kinds of capital, the existing and the new capital. The new capital is the capital of the investment, and it is available in any sectors. After installing new capital to a sector, it becomes existing capital in that sector. Thus, it can be written as:

$$K1(j) = end_{k01(j)}$$
$$\sum_j K2(j) = end_{k02(j)}$$

Where:
K1(j)	: existing capital in sector j
end_k01(j)	: Endowment of existing capital
K2 (j)	: new capital in sector j
End_k02(j)	: endowment of new capital

3.2.4.4. Market of Labor

Similar to the market of capital, the supplied labor in the sector are equal with the labor endowment and can be written as:

$$end_{lab} = \sum_j \big(L1(j) + L2(j)\big)$$

Where:
L1(j)	:labor in sector j (existing capital subsector)
L2(j)	:labor in sector j (new investment subsector)
end_lab: the endowment of labor

3.2.4.5. Market of GHG

For the Green House Gases (GHG), the total emission including from the activities and from energy sectors are summed and equal with the GHG endowment and can be written as:

$$END\ GHG_{GHG} = \sum_j \left(\sum_{en} \big(GHGJ1(en,j,ghg) + GHGJ2(en,j,ghg)\big) + GHGJA1(j,ghg) + GHGJA2(j,ghg) \right) + \sum_{en} GHGF(en,ghg)$$

Where:
GHGJ1(en,j,ghg) : GHG emission from energy type (en) in existing capital subsector of sector j
GHGJ2(en,j,ghg) : GHG emission from energy type (en) in new investment subsector of sector j
GHGJA1(j,ghg) : GHG emission from activity in existing capital subsector of sector j
GHGJA2(j,ghg) : GHG emission from activity in new investment subsector of sector j
GHGF(en,ghg) : GHG emission from energy type (en) in household sector

f. market of land

$$\sum_j \big(LND1(j) + LND2(j)\big) = end_{lnd}$$

LND1(j) : Land area in the existing capital subsector of sector j
LND2(j) : Land area in new investment subsector of sector j

The model then does a simulation exercise until 2030 as the target year. This target year is chosen because it is the same as the NDC target year. In the future, there will be an improvement in productivity and new technology introduced to the economy. To capture that in the model, there also another production function with new capital stock. The equation for this production block is the same; however, in this subsector, the capital is movable among the sectors. It is also assumed that the efficiency and other parameters for new investment are improved, compared with those for the existing capital. Moreover, each sector relates to others, and in the end, it is assumed that total demand will always be equivalent to total supply in the economy.

4. CGE for the Land-Use Change: Method, Data, and Result

4.1 Background

GHG emission in Indonesia is dominated by the emission from the Land Use Change and Forestry (LUCF). In 2016, LUCF contributed for 43.59% of total national emission (Boer et al., 2018). This is mainly because of the enormous deforestation dan land-use change in Indonesia. Indonesia already highly rely on land ever since the 1980s, started by high forest exploitation for timber harvesting and then shifted to land conversion for the establishment of the commercial plantation, especially for the establishment of the palm oil plantation. The manufacture industries also highly rely on the land-based sector to provide its input — the commercial plantation is giving a high economic multiplier to industry until now (Malahayati, 2018).

To control the emission from the LUCF, the deforestation rate should be reduced, and the reforestation/conservation policy should be implemented. However, considering its significant impact on Indonesia economy, those mitigation policies are feared to slow down economic growth. However, if the mitigation policy for the LUCF is not prepared and well established, the rapid land conversion, especially for the cash crops and plantation, are also feared to reduce the forest area significantly.

The study that measures the mitigation impact from the LUCF to the environment and economics are still limited. The reason of limited study related to mitigation for the LUCF in Indonesia is because the complication of the calculating the land-use change and the emission from this sector, especially for Indonesia that has varied land-use types and characteristics. Not to mention that the existence of peat decomposition and peat fire also give additional complication on the emission and economic calculation.

This study tried to assess the impact of GHG mitigation technology implementation to the economics and environment especially the forest land area because Indonesia also needs to maintain its forest area as one of the world's largest carbon sinks. Considering there are several land types, and each land types store different carbon stock, the CGE model in this study is combined with the land conversion matrix, so it can give consistent forecasting of land-use change and trend under each decided scenario. The emission from the land use also calculated endogenously by using the specific carbon stock for each land type.

Moreover, there are some notes and limitation in this part, listed as follows:
Mitigation Technology considered in this study is only mitigation in the land-based sector. There is no detail mitigation technology introduced in another sector. However, there is an assumption that to achieve the emission reduction target, the energy sector will adjust its productivity and efficiency. This may cause the GDP loss will be higher because the energy sector needs to adjust its productivity and efficiency in such a short period and without contribution from another sector to mitigate the emission. The investment to improve energy efficiency and productivity will take time. For example, in Indonesia, to build hydro and geothermal powerplant, it will take a minimum of 5-6 years to be established. However, this condition is assumed in this simulation.

Peatland; in this study, the land conversion is only considered happened on the mineral land, because it is assumed that most of the economic activity is done on the mineral land more than it is on the peatland. Because of that, it is assumed the peatland is not exploited further, but there are still some emissions left from peat decomposition in the previous year and the peat fire. Data for emission from peat are treated exogenously and still considered because this emission should be reduced along with the available mitigation package for the LUCF. Not only that, the price between peatland and the mineral land area also have a significant difference. From 2010-2016 the actual data is used, from 2016 afterward, the average emission value from 2010-2016 is used.

Conversion for industrial use; Land use change from the agricultural land and forest to the industry also not introduced yet due to the cost information limitation. This is because the price for the industry will totally different compared with the cost of land-use change between the crops. It is also because of the data limitation that the land conversion matrix used in this study does not have enough information related to the land conversion for the industry.

Cost, as the specific and details cost for the land conversion from one land type to another type, also from one crop to another crop. Thus, the initial price of each land category is set to be the same and will change depending on its supply and demand in the model.

4.2. Model Structure

The analysis for the LUCF done in two main steps: 1.) the static analysis, that analyzes the land-use change and the emission from the LUCF in the base year (2010). This static analysis is using the available land conversion matrix and carbon stock data. 2.) the dynamic model using the CGE model to simulate the impact of mitigation policy in the LUCF sector towards 2030 (Figure 4.1).

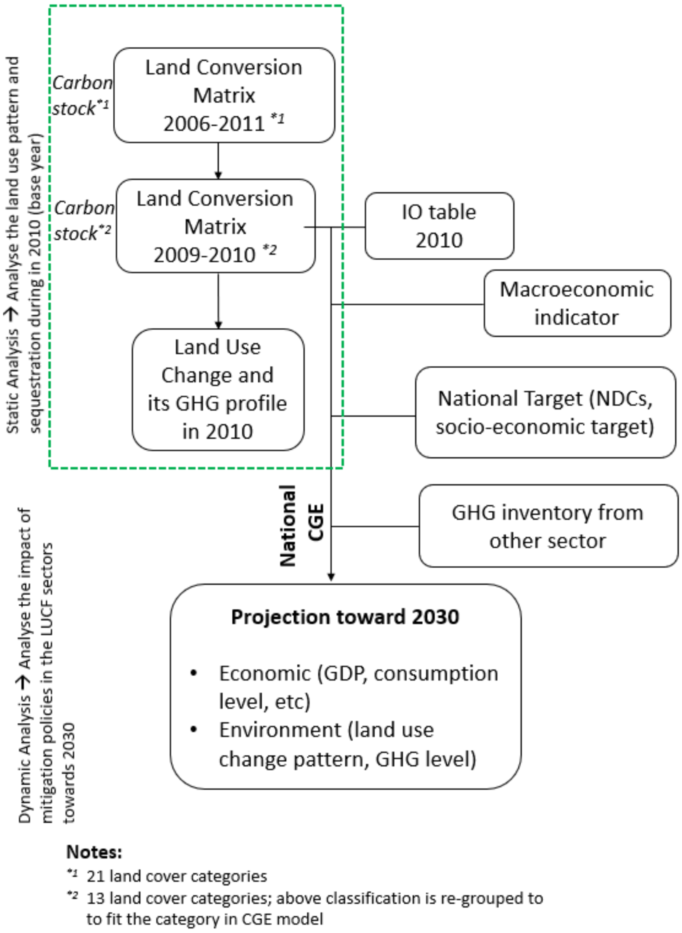


Figure 4.1. The LUCF Study Flow

In this CGE analysis, the land is treated as an input. Some activities in the economy will need land to produce outputs. To produce more output, at least two ways can be taken: 1.) increase the quantity of the inputs or 2.) make the inputs work more efficiently. In the case of the land as an input, "more efficient" here means more yield than can be realized by the land-based sector. In the simulation, the elasticity of substitution between each land category is set to be infinite, so the land can be substituted between each other, depending on the "price" of each land type. However, due to the lack of information of monetary price between each land types, the "price" of converting from one commodity to another commodity will depend on the labor and capital. The information on labor and capital itself is stated inside the input-output table (Figure 4.2). However, as an input, the land cannot be substituted with any other input, while each input is calculated under the Leontief function environment.

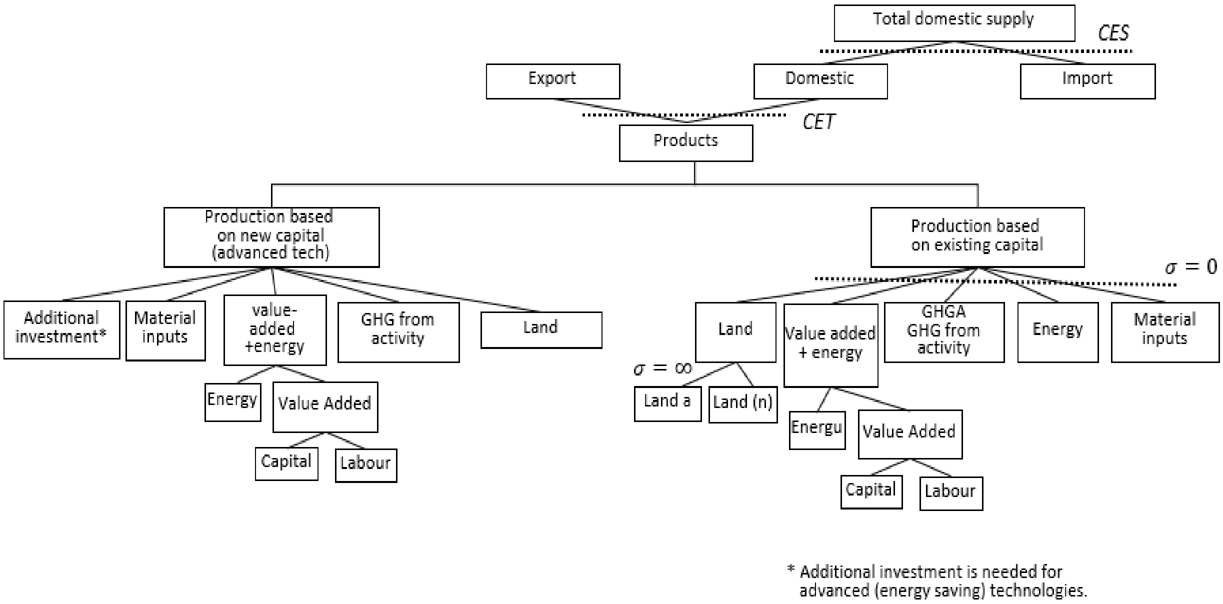


Figure 4.2. Land Allocation Treatment in the Model

Moreover, in the case of Business as Usual (BAU), the limit for the maximum proportion of each land type that can be converted is set to be around 7%. This number is calculated based on the Indonesia National Forestry Plan (*Rencana Kehutanan Tingkat Nasional*/ RKTN) for the maximum forest land that can be converted into another land use (Ministry of Forestry, 2011). When the reforestation and conservation policy is introduced, the land conversion proportion also reduced.

4.3. Data

4.3.1. Land Allocation Matrix and Carbon Stock

The information of land-use change trend from one land to another type is summarized on land allocation matrices. This study utilizes the land allocation matrices that published by the National Development Planning Agency. This matrix comes from several geographical information sources including spatial data on forest cover 2006-2011 by the Directorate General of Forestry Planning, the Ministry of Forestry, and data of the appointment area in each province based on the Minister of Forestry Decree, which was issued in stages from 1999-2012 (Santosa et al., 2014). The matrix is then summarized in the 21 x 21 matrix form to inform the land-use change from one land type to another type (Appendix A, Table A1).

However, to make this matrix fit with the IO Table and can be run simultaneously, the categorization in the matrix should be matched the categorization in IO Table. The base year on the matrix also needs to be adjusted as the matrix shows the land conversion in the 2006-2011 period, while the base year in IO Table is 2010, by assuming the same trend in land-use change and calculate the land-use change for 2009-2010. Thus, the new land matrix in the created, the new matrix is 13x13 matrix, but then the building and mining are exempted because it shares is too small compared to other land use and also the cost treatment for these land classifications will be totally different compared to land conversion between each crop. Especially for the building, it is both including the housing and the industrial building, and there is limited information related to the share of these building. The other land, including the degraded land, is also considered, but not included when doing economic calculation

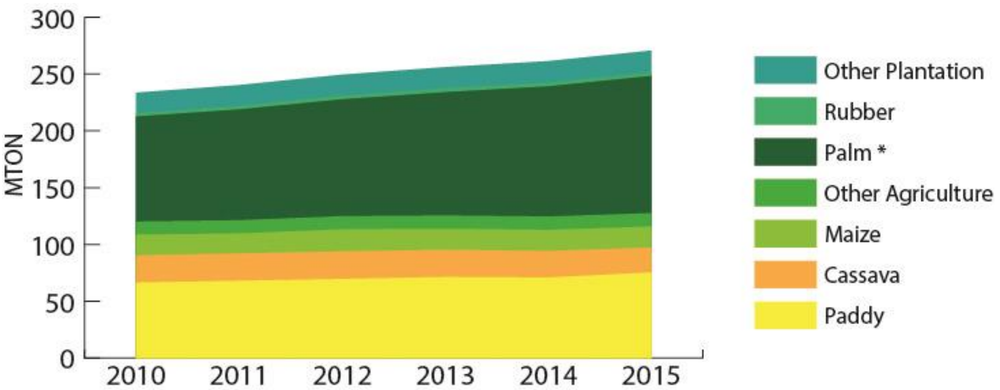
because we assume no economic activity is done in this land type. It left only ten land sectors to be calculated simultaneously in the model.
The rice field area is set for the paddy sector. While for the other crops, the adjustment and aggregation use the same proportion with total production in the IO Table. For forest land, wood (WOOD) is assumed harvested from the industrial forest and some mixed-dry agriculture (agroforestry). On the other side, the forest area (OFO) in the model are consist of all kind of forest, both primary and secondary forest. It is a sum from primary forest, secondary forest, primary and secondary mangrove forest, primary and secondary swamp, swamp, and some share from agroforestry (Table A2). The agroforestry (MD/ Mixed Dry Agriculture) in the original land conversion matrix are disaggregated into several land-use changes: corn, cassava, other agricultural crops, palm oil, rubber, other plantation, wood, and forest. The disaggregation is divided in proportion to the total output in the input-output table. This is because the CGE model cannot capture a very detail classification of land use type, while the sector classification also needs to be the same between the land conversion matrix and the CGE classification. Like the dryland agriculture (DL) on the original matrix, it is also disaggregated but only into cassava, corn, other agriculture.

In the CGE simulation, the building and mining are excluded while the open land is calculated exogenously. The reason for building and mining exclusion is because it's land-use change is not as significant as the other land-use change. Land conversion in Indonesia is mostly located in the Java area. While for the mining land, especially for mineral mining, the spot of the mining is specific and more often not converted into another land type in such a long period.

As mentioned before, each land type also has different potential to store the carbon stock; it will depend on its density — this study using the carbon stock that already published in Tosiani (2015). The document stated the carbon stock for 21 types of land categories. Again, to adjust with the model, the carbon stock is then normalized and adjusted to fit the land classification in the model. The carbon stock classification and its adjustment are written in Appendix A, Table A3.

4.3.2. Production and Yield Improvement

The production of the crops from 2010 to 2015 are gathered from multiple sources, mostly from the crops and estate crops statistic published by Indonesia ministry of agriculture. The production of paddy and palm oil still dominate the production of the national crop (Figure 4.3).



Notes: *) in FFB: Fresh Fruit Bunch

Figure 4.3. Production of some crops in the Model 2010-2015

Source: Badan Pusat Statistik (2019c),Kementerian Pertanian (2016b),Kementerian Pertanian (2016a), and Boer et al. (2016)

Palm oil is essential crops for Indonesia, the main problem of palm oil is based on statistic, the productivity of this crop is remained stagnant from 2010-2015, while the demand of palm oil as the raw materials for the industry and export are kept increasing. This that feared could threaten the forest land and increase the rate of deforestation (Figure 4.4).

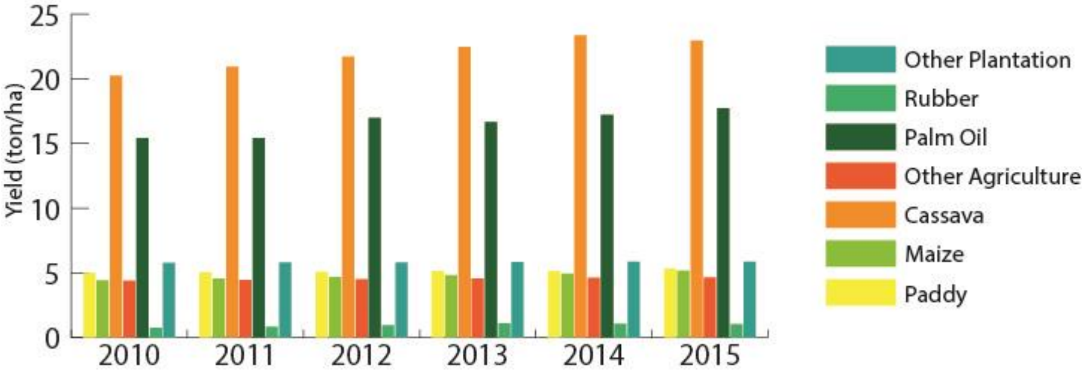


Figure 4.4. The yield of each crop, 2010-2015

The latest most comprehensive information about the projection of the crops yield is stated in the Deep Decarbonization Pathway Project (DDPP) for Forestry and Land Use of Indonesia (Boer et al., 2016), the summary is as follows (Table 4.1). This study follows the yield improvement of this document.

In the CM1 and the CM3 scenarios, the yield is improved higher than in the BAU scenario. The difference between CM1 and CM3 is in the CM3 the yield improvement is implemented together with the conservation.

Table 4.1. Yield Improvement (ton/ha/ year)

No	Crops	BAU	CM1/CM3
1	Paddy[1), 2)]	0.5%	1.9%
2	Corn	0.3%	1.4%
3	Cassava	0.7%	1.5%
4	Other agriculture	0.9%	1.1%
5	Rubber	0.8%	1.3%
6	Palm Oil	1.5%	2.0%
7	Other Plantation	0.5%	1.0%
8	Wood [2), 3)]	0.6%	0.9%

Notes:

[1.)] *average of yield from paddy fields in Java, outside Java, and upland*

[2.)] *calculated by dividing the total production divided by total area. Hence, the crop rotation is also included in the calculation*

[3)] *for wood, the yield is in thousand m^3/ha.*

For reforestation, the reforestation rate is set to meet the government target in the 2nd Bilinearly Update Report (2nd BUR) such as the implementation of forest rehabilitation in 500,000 ha of priority watershed and forest rehabilitation in 1,954,000 ha of critical lands in the priority watershed. So, around 2.4 Million ha of land is set to be conserved by 2030 (Boer et al., 2018).

4.3.3 Scenario and Emission Reduction Target

There are three mitigation scenarios treated in this study, with one Business as Usual (BAU) scenario. The BAU scenario is running without any mitigation scenario. While the Counter Measure (CM) scenarios are the scenarios where there is an emission reduction target. Here, we set the emission reduction in 2030 as 29% lower compared to the BAU level. The difference between those three CM scenarios is in the treatment of mitigation action for the land. CM_1 is only assuming the yield improvement for each crop. The improvement of yield is expected to lower the deforestation and emission at some level, because the same total area may produce more products. The yield improvement also represents technology to reduce deforestation/forest degradation. However, in this scenario, there is no reforestation or conservation function introduced. Here, the cash crops may still utilize the same land and even use some forest area for their expansion. On the other hand, in the CM_2 scenario only, reforestation as a conservation function is introduced without the yield improvement. This scenario assumes that the government will allocate some area for reforestation and conservation. Moreover, the CM_3 scenario combines both yield improvement and the reforestation policy (Table 4.2)

Table 4.2. Simulation Scenarios used in the Study

No	Scenario	Yield Improvement	Reforestation and Conservation	Notes
1	BAU	No	No	Without carbon restriction
2	CM_1	Yes	No	
3	CM_2	No	Yes	Set to achieve 29% of emission reduction
4	CM_3	Yes	Yes	

4.4 Result and Findings

4.4.1. Condition in the Base Year

4.4.1.1. GHG Inventory and Projection

At first, because the land conversion matrix and the carbon stock are adjusted to have similar sector classification with the IO Table, it is essential to check that this treatment will not give a huge change and different from the original dataset and calculation. To check it, the net emission between before and after the aggregation is done. Before the aggregation, the net emission reaches 150.9 Mton CO2eq, while after the aggregation, the net emission is not given the different result and shows the net emission is 151.7 Mton CO2eq (Table 4.3). As the difference is small, the matrix and the carbon stock use are continued to be used.

Table 4.3. Emission comparison before and after the land conversion matrix aggregation (Mton CO2eq/year)

	Emission Total (A)	Sequestration Total (B)	Net Emission (A+B)
Before Aggregation (21 land categories)	197.1	-46.2	150.9
After Aggregation (13 land categories	374.3	-222.6	151.7

4.4.1.2. Land Use and Land Use Change in 2010

To examine the LUC in Indonesia, the analysis of land use pattern in the base year should be first examined. From Figure 4.5, it can see that the land-use conversion in Indonesia mostly happens in productive land and forest.

From this simulation, the OAG (other agricultural crops) land is the land converted the most, mostly to Palm Oil (PAL), Corn, (COR), and Other Plantation (OPL) land. This conversion can be caused by several reasons. The main reason for the conversion of agricultural land is because of income. The farmers tend to convert their land to another land use and plant other commodities that might give them higher income. While in Indonesia, commercial plantation gives a higher income, it is quite common for the farmers to convert their land into this. Another reason is that for some farmers, planting perennial crops (including mostly plantation crops) is not as complicated and exhausting as taking care of annual crops. This is also the reason why the conversion figure to rice field (PAD) is relatively low (Bhaskara et al., 2012).

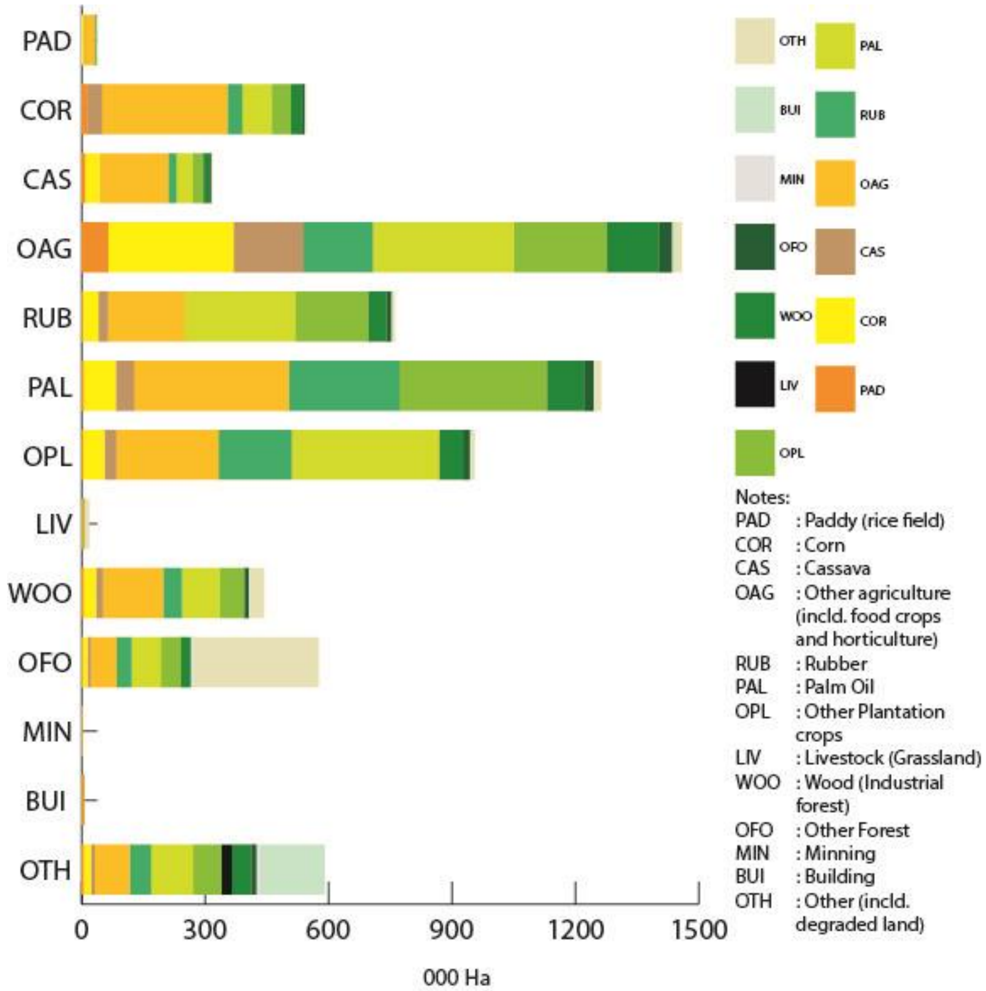


Figure 4.5. Land Conversion from Each Land Type in 2009/2010 (excluding its own sector)

Figure 4.5. also shows that land conversion from the rubber area (RUB) and other plantations (OPL) is also mostly converted into palm oil plantation. It is also another side effect of the economic attractiveness of palm oil that makes this commodity become the primary plantation commodity. While for palm oil itself, the conversion from this sector is more likely to be another plantation area or other agricultural crops.

Another concerning problem in the Indonesia case is there is a high tendency that deforestation is converting the forest into open land/degraded land (captured by OTH). This is in line with the assumption stated in DDPP that the unplanned deforestation is still higher than the planned deforestation in Indonesia. These unplanned forest losses are usually the result of illegal logging, forest fires, and forest encroachment. This unplanned deforestation mostly happened in the forest with no management institution on-site, including production forests that have been left by concessionaires, or have not been granted with licenses and protection forests (Boer et al., 2016)

The land conversion result is in line with the emission and sequestration caused by the land-use change. Figure 4.6 summarizes the total emission and total sequestration for each land type in 2010. Palm oil is mostly blamed as the most significant contributors of GHG emitters of CO2 emission; in fact, it also contributes to relatively high carbon sequestration. This is because some degraded land and agricultural land are then converted into palm plantation. This has caused the conversion from land with lower density land to higher density land.

A similar explanation pertains for the industrial forest (WOO) and other forests (OFO). The carbon stock of WOO and OFO are higher than the PAL, so they basically can store more carbon than any other land type. However, as can be seen from Figure 4.5, the conversion to forest area is not as high as another land that has higher economic profit.

This result has a meaning that the land conversion to the commercial plantation including palm oil, might be beneficial for the environment if it is using the degraded land and not exploiting the land with higher carbon stock density like a forest. Because of it, the central government of Indonesia tries to strengthen the Monitoring, Reporting, and Verification (MRV) and more forest governance and management for the forest. Central government keeps creating various policy tools to reduce the deforestation and allocating the forest concession, but at the district level, the local government often issues permits for any development including for palm oil and other commercial activities (Setiawan et al., 2016).

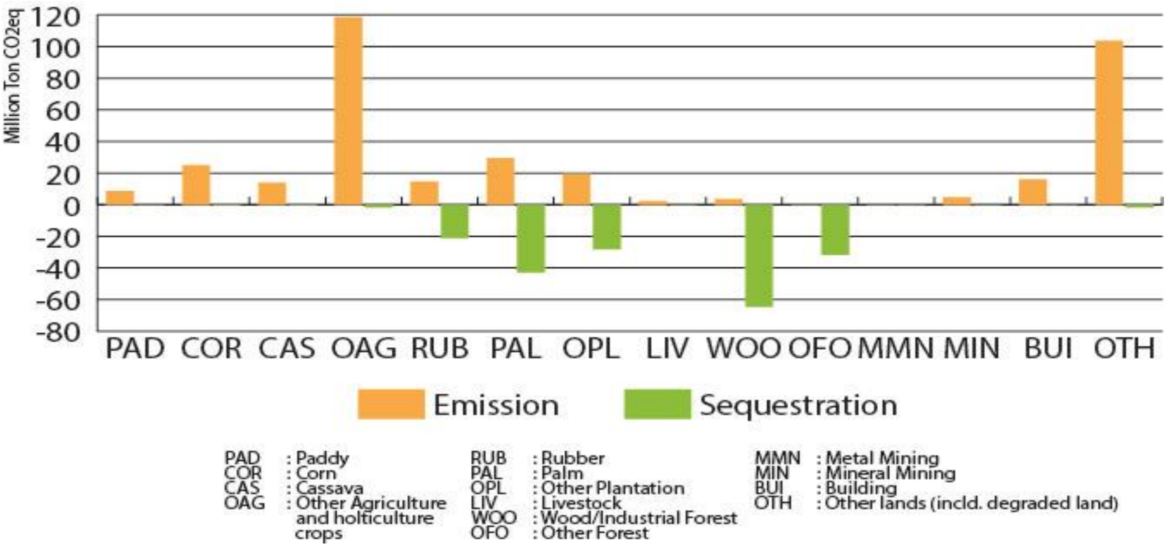


Figure 4.6 . Emission and Sequestration in each land type in 2010

4.4.2. CGE Simulation Result

4.4.2.1. Economic Impact

The simulation shows that any mitigation action will reduce the GDP at some level compared to BAU level. The lowest gap can be gained under the CM_1 scenario by only lowering 0.66% under GDP in the BAU level in 2030. Increasing the yield without any reforestation and conservation function will make economic activity by land exploitation more profitable, and it will not significantly stop land exploitation. While the other simulation shows a high GDP loss, in the CM_2 the GDP loss is projected to be around -5.43% and the CM_3 is projected to be around -5.22% in 2030 compared to the BAU level.

Under the CM_1, the GDP gap is the lowest because it shows no significant difference between each macroeconomic indicator (e.g., consumption, export, and import) compared to the BAU scenario. It strengthens our indication that is only improving the yield, will not significantly change the consumption pattern in Indonesia. While Indonesia itself is still heavily reliant on land resources, when the yield improved without any policy able to limit the land opening for cash crops and economic activity, there is a tendency to keep the pattern and keep using the land for the economic activity. On the other side, when the reforestation and conservation policy is introduced, the land endowment that can be used for the economic activity is decreasing and leads to the reduction of supply, consumption, and in the end, the GDP level (Figure 4.7).

Another reason for high GDP loss is because in this simulation the mitigation is started in 2015, while the emission itself already in the peak for this year. Introducing the conservation will limit the production in sudden. While there are no mitigation technologies introduced in other activities level, the whole emission reduction burden is borne to the LUCF that need to reduce the deforestation and/or keep some land to be conserved. Also, the energy sector also needs to achieve the efficiency that needed to maintain the emission level.

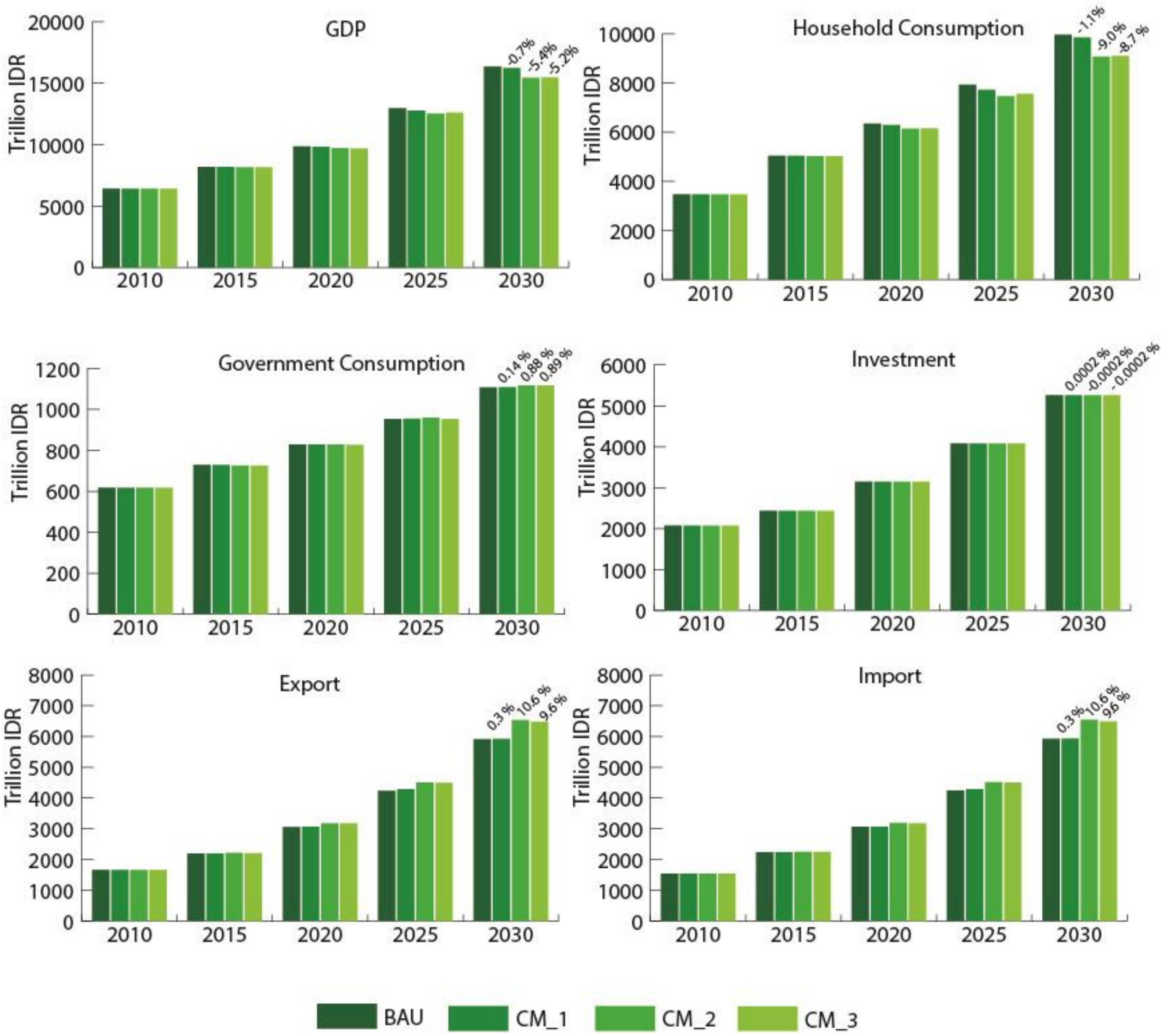


Figure 4.7. Simulation Result Summary for Several Macroeconomic Indicators, 2010-2030

Implementing the CM_1 scenario will only be possible if the energy sector can be very efficient, both in production and emission reduction, until it can emit very low emissions. However, this condition is still not possible to be realized in Indonesia with only 10 years left into the target year. Another consequence of implementing only the CM_1 is that the deforestation will remain high compared to the BAU because we predict it will not significantly slow down land exploitation. This will be explained further in the next section.

Considering the consequence of choosing the CM_1 scenario, we agree that the reforestation and conservation program should be introduced along with the other mitigation program. Here, the government needs to choose between CM_2 (reforestation without improving the yield of the crops) and CM_3 (introducing both the yield improvement and reforestation together). Our simulation shows that the CM_3 scenario will work better than CM_2.

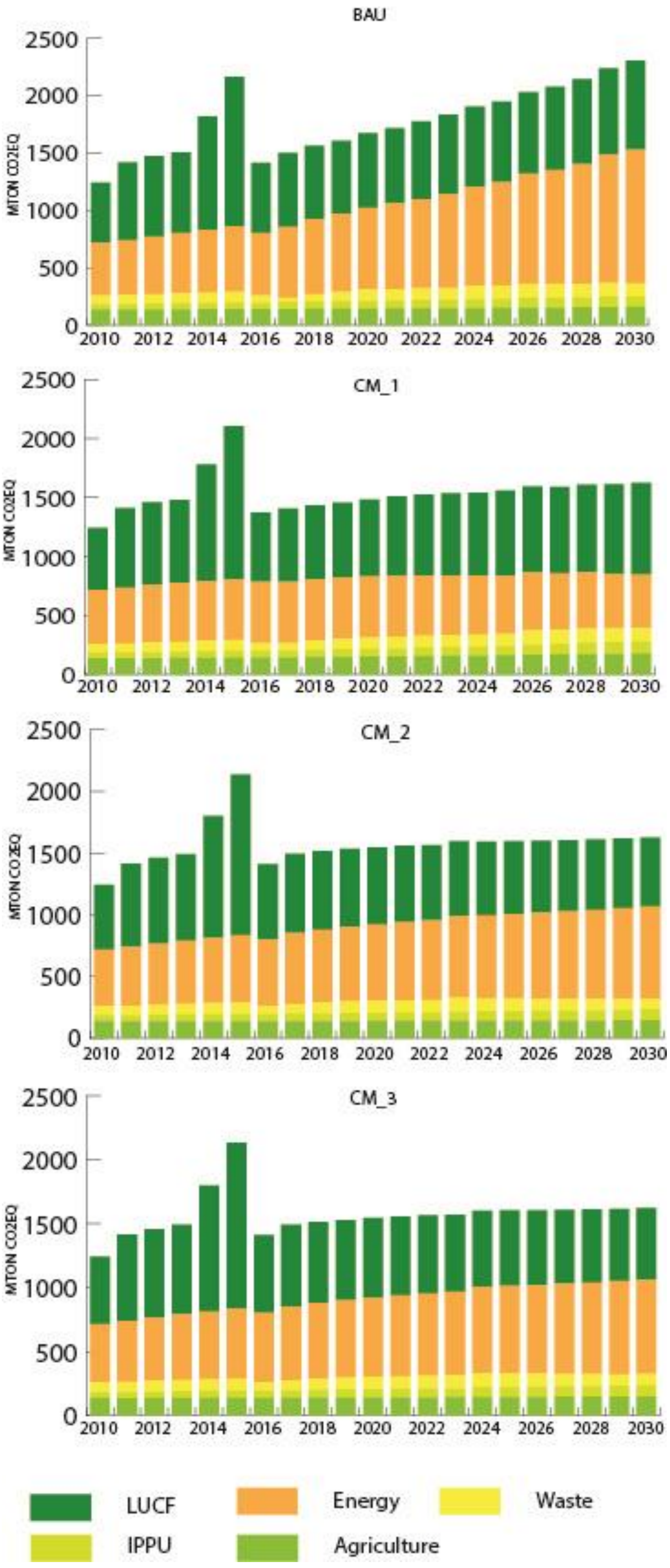
This simulation shows that it might be costly enough, introducing the reforestation program during the 20 years of the simulation period. However, this policy will also maintain the forest area and control the rate of land conversion into cash crops and commercial plantation. In the long term, this policy will be more beneficial for Indonesia. However, it is essential to implement both the reforestation and conservation along with the yield improvement, to minimize the economic gap that might happen.

4.4.2.2. Emission

As we set emissions in the target year to achieve the 29% reduction under the BAU level, total emissions for all the mitigation scenarios is the same in 2030. The difference is the proportion between the emission sources. As mentioned before, the CM_1 scenario is not effective enough to reduce emission from the LUCF, as shown in the figure, the emission level in BAU and CM_1 are not showing a significant reduction.

The emission from agriculture is in line with the yield and production improvement. The highest emission from agriculture is found in the CM_1 scenario, where the yield improvement is introduced without the conservation function introduced. However, the emission from agriculture is relatively stable year by year, a similar result for other emission sources from activity (IPPU and waste) (Figure 4.8).

If the CM_1 is established, to reach the target, the energy productivity improvement should be very high to be able to reduce the emission level. At least in this model, at least 8% of the average annual growth rate of efficiency for productivity and emission reduction is set to achieve the emission target in the CM_1 scenario. It is double if compared to another CM scenario, that only needs around 4% of productivity improvement. As can be seen in Figure 4.8, the emission in the energy sector on CM_1 scenario is lower compared to in another scenario, while there is no mitigation action from the activity are not introduced. The assumption is very strong for this and will be challenging to be realized in such a concise mitigation period. However, this result can be an insight for Indonesia that the mitigation action cannot be focused in such a partial sector, while it will give a huge burden and cost to that sector.



Notes: LUCF: Land Use Change and Forestry, IPPU: Industrial Process and Products

Figure 4.8. Emission Comparison under Each Scenario, 2010-2030

4.4.2.3. Land Use Change

To see the general pattern of the land use by 2030, first the land category is aggregated into four groups, 1) agriculture (paddy, corn, cassava, horticulture, and other agriculture), 2) plantation (rubber, palm oil, and other plantation), 3) timber plantation and 4) Forest. The forest holds the conservation function. When the conservation policy is introduced, the forest area that can be converted and used for any economic activity becomes lower.

When the CM_1 is introduced, the mitigation technology is only by improving the yield without reforestation/ conservation function. Increasing yield is expected to be able to withstand the rate of demand for land so that it can reduce the rate of deforestation and land change. However, based on the simulation result, the forest area between the BAU case and CM_1 case is not significantly different. Also, the commercial plantation expansion still very high between. Because the model itself assume the profit optimization, the simulation result expects that by improving the yield, the farmers will also be encouraged to plant more crops as it will give more profit for them. Although the yield for palm oil is improved higher than any other crops, the land area still dominated by this crop as it becomes one of the most profitable crops in Indonesia (Figure 4.9).

This simulation result gives an indication of Jevons paradox existence. The intensification effort to crops that raises profitability and returns provides incentives to maintain or even expand the area of those crops. However, the labor from other sector are might swift to the more profitable crops and may lessen the land expansion of the less-profitable crops and may reduce the production of these crops. This is also an answering of the GDP that slightly reduces in the CM_1 scenario (Byerlee et al., 2014). The yield improvement and any other intensification itself is only one of many factors that drive the land conversion and deforestation. So, this policy will not function effectively without improved governance and some incentives to preserve natural systems.

The reforestation and conservation function are introduced in both in CM_2 and CM_3 scenarios. However, in CM_3, the yield improvement also introduced. The sudden conservation policy introduction makes the land that available to be converted for the economic activity become more limited. The policies expected to restrain the rate of land-use change and maintain the total forest area (Appendix A: Figure A3); however, it brings a high impact on economic loss. This is because the reforestation and the conservation will affect the commercial plantation the most. Commercial plantation, especially palm oil (Appendix A: Figure A2), is a crucial sector that gives the high multiplier effect on the economy. When the land for plantation is limited, it compels the supply of plantation products to be reduced and slow down the economy. In this model, it is also assumed that there is no change in preference or economic pattern. So, the reduction of commercial plantation products may hit the economy very much. In case the reforestation and conservation are introduced together, it may help to reduce the GDP loss slightly.

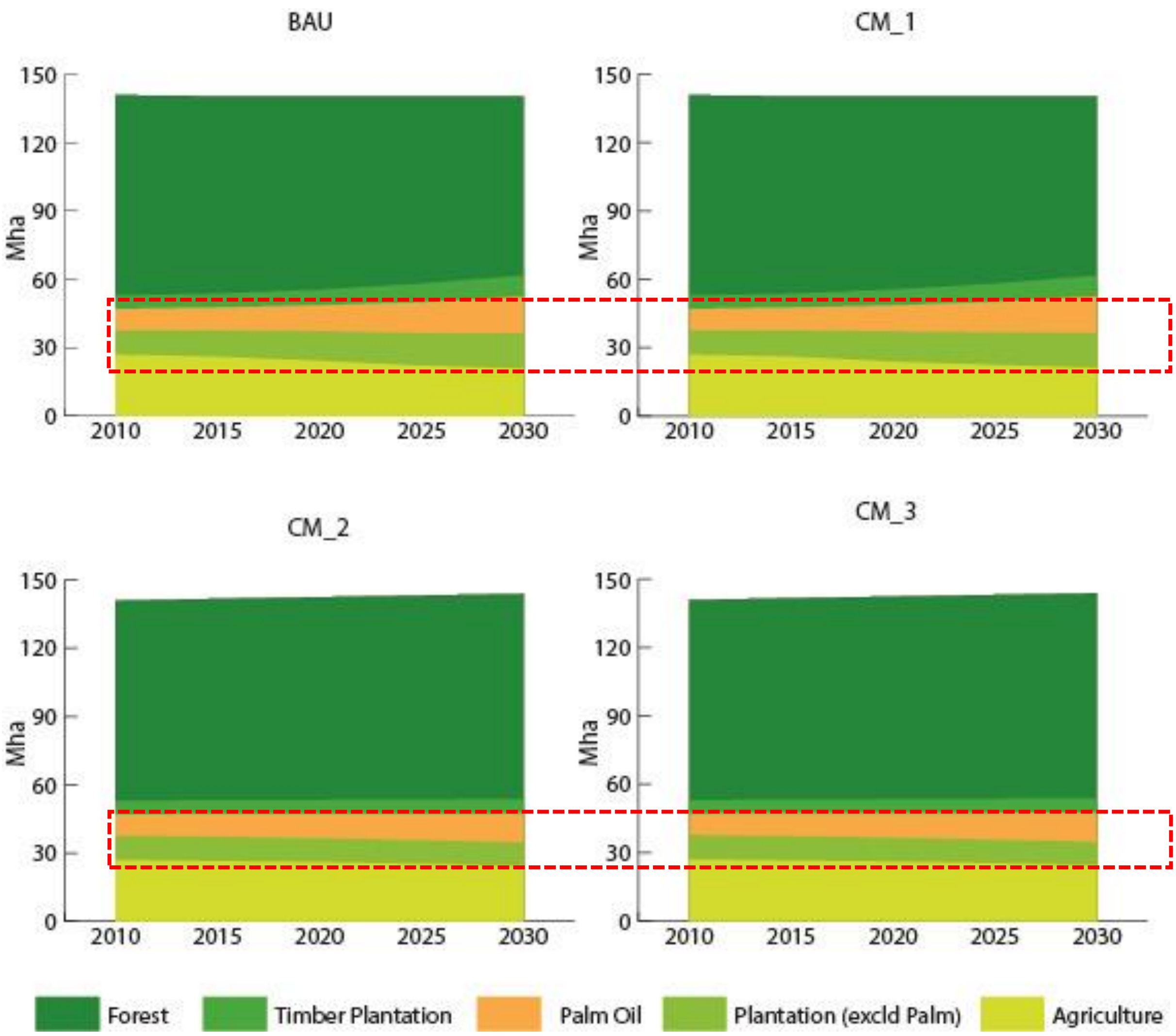


Figure 4.9. Summary of land conversion under all scenario by 2030

4.5 Conclusions

This part is trying to analyze the impact of potential GHG emission mitigation policies in the LUCF sector by utilizing the CGE model. There are three mitigation scenarios used for this part: 1.) CM_1: intensification only, CM_2: conservation only, and CM_3 intensification and conservation. For the economy, the CM_1 give the lowest GDP reduction compared to the BAU level (-0.7% in 2030) because it gives the lowest household consumption (only -1.1% in 2030 compared to the BAU). While in the introduction of conservation give lower reduction impact on GDP (-5.4% for CM_2 and -5.2% for CM_3 in 2030 compared to BAU level). The introduction of conservation increases the government consumption (0.88% and 0.89% for CM_2 and CM_3 respectively, in 2030, compared to BAU level). But that improvement cannot offset the significant drop in household consumption (-9% and -8.7% for CM_2 and CM_3 respectively, in 2030, compared to BAU level).

The conservation policy makes the land (that also count as a production factor in this model) that can be managed to become more limited, and it may lead to fewer production and makes the household consume less. The conservation also increases the government consumption and investment, especially to mitigate the emission after 2015, while the emission peak happened in 2015 due to the peat fire during the period. However, household consumption is dropped at a higher level than the increase in government consumption and investment. Although the CM_1 scenario gives the lowest GDP loss, however, this policy does not give a significant effect to manage the land-use change, especially to manage the deforestation rate.

The importance of commercial plantation for Indonesia makes the land conversion to it still dominate the land-use change in Indonesia. Because of that, the yield improvement, cannot significantly reduce the land utilization for the establishment of the plantation, especially for the palm oil. This is evidenced by the increase of total area for the palm oil plantation under the CM_1 scenario, when there is no reforestation and conservation is implemented, although the yield is improved highly compared to the other crops, it still dominated the area of plantation.

To restrain the rate of land conversion for the plantation, the reforestation and conservation should be introduced. However, the sudden introduction of the reforestation and conservation may drop the supply of the commercial crop by reducing the available land that can be converted for it. The land will also become more limited to be converted in any other economic activity. This policy will reduce the GDP at a higher level. By doing the conservation function, there is an indication that the GDP loss in the target year will be quite high. However, when the conservation is introduced together with the yield improvement, the GDP loss can be slightly reduced. In other words, conservation is useful to control the rate of land exploitation and maintain the total forest area. While the yield improvement is potential to maintain the production rate and, in the end, maintain the output and GDP.

Another reason for a very high GDP loss in 2030 compared to the BAU level in this study is there is a lack of introduction of mitigation details from the other sectors. If other technologies in other sectors are introduced the burden from the LUCF to mitigation emission may reduce along with additional investment from the other sectors. It is also an important note for the government to make sure that the mitigation should not only focus partially. In this study, because the focus is only mitigation on LUCF and the energy sector is assumed to reach its ideal efficiency to achieve the mitigation target, these two sectors are pushed very hard to achieve the emission target. The reforestation, land conservation, yield improvement, and energy efficiency programs take time to be established

There is also some information that needed to be added for the mitigation action from LUCF such as how much additional labor and capital that might be needed when the policies are introduced, e.g. when the conservation is introduced, how many additional labor that needed to ensure the concession and forest area, also how much is the cost difference between the land-use change from one crops to another crops. Again, in this simulation, the total cost is assumed to be the same between each crop's types.

4.6. Discussion

The GDP caused by the conservation in this simulation is very high; this is because only the mitigation is only focused on the LUCF. In the real world, it is more rational to involve all sector for the mitigation, especially realizing that the policies will give a significant impact to the economy. However, it also needs to be highlighted that the message from this part is to compare the impact of two main mitigation in LUCF in Indonesia: intensification and conservation and deliver and insight that there is a significant impact between each mitigation actions for this sector.

Most of the Indonesia government policy to mitigate the emission from LUCF is by the intensification. This can be captured by rejuvenation, especially for the commercial plantation. The government sets several regulations for rejuvenation, for example, President regulation No.24/2016 about the budget allocation for the palm oil plantation provides a specific point that the government will allocate specific allocation for palm oil plantation. For the rubber, Indonesia also has a deal with the International Tripartite Rubber Council (ITRC) to do more rejuvenation for the rubber plantation.

On the contrary, the policy for forest conservation is not much if it is compared to the intensification policies. For example, the president regulation No.86/ 2018 about the agrarian reform, did not mention the minimum and the maximum limit for Business-Use Right *(Hak Guna Usaha*/ HGU) and this can be used by some companies to expand their business without minding the land conservation. There is also forest moratorium policy that extended for several periods (2011, 2013, and 2015), but this regulation only states to maintain the conservation from the existed conservation area and never mention to increase the conservation from the secondary forest and another land type (Mongabay, 2017). In short, the conservation is remaining stagnant under the available conservation.

This study tried to deliver the message that the intensification cannot effectively lower the deforestation rate, and it is hoped that the government will implement the conservation along with the intensification effort to maintain the forest and land sustainability. Moreover, the model also assuming very strict limit for land conversion under the conservation condition. In reality, although the conservation policy is introduced, the forest, the secondary forest is still able to be converted. Also, some primary forest still allowed to be converted as long as the company gains the concession permit. However, because the land categorization in this model is limited, the model assumed a fixed proportion for each year to be converted and conserved.

5. CGE for Overall Assessment: Method, Data, and Result

5.1 Model Structure

In general, the structure of this part is like the structure in part 1 (CGE for the Land Use and Forestry). However, the dataset and mitigation are different. In this model, the main highlight comes from the introduction of more detail in the energy sectors. The energy supply and demand are simulated by considering the target for energy supply, energy demand, and the power generation. In part 1, the detail mitigation technology is only implemented for the LUCF. In this model, the mitigation details from agriculture, waste, IPPU, and energy are considered (Figure 5.1).

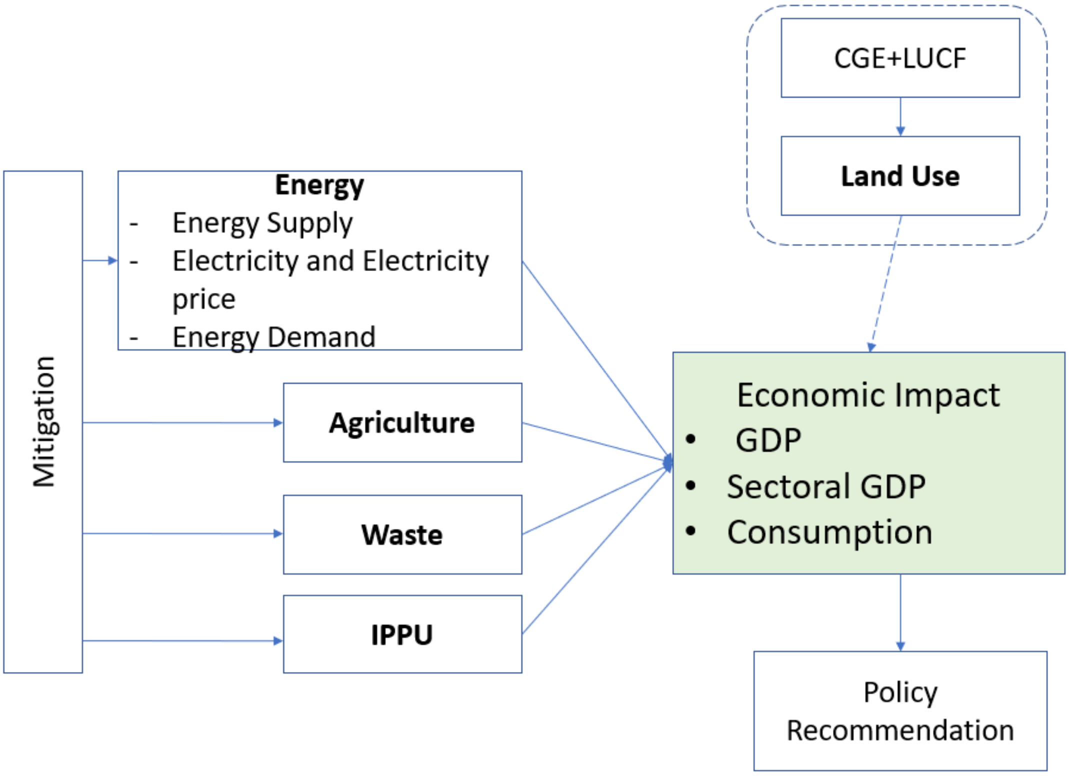


Figure 5.1. Simulation Flow for the Overall CGE simulation

However, this model did not provide detail information of LUCF. The emission and the area are calculated exogenously. To compensate for this limitation, the land area and the emission for the crops are fixed based on the previous simulation. The total area for each crop in the BAU scenario gained from the total area when there is no mitigation action is introduced (no yield improvement, no reforestation/conservation).Under the CM scenario, the land area inputted into the model already the simulation result after considering the mitigation technologies (with yield improvement and reforestation/conservation function).

The reason for this division treatment is: 1.) The emission calculation from LUCF is different compared to the emission calculation for another sector. 2.) When the reforestation and conservation is introduced, the forest area increased, and the model still assume it as an additional endowment, 3.) When all sectors are introduced, the cost is one variable that needed. The information on the monetary price of land-use change from one type to another type is very limited.

Another further modification of this model compared to the previous model; in this part, the energy sector becomes one of the essential components to be highlighted. The production of energy also used for the electricity generation, and it makes a further disaggregation for the electricity sector also done based on the energy source (Figure 5.2.). But there is also another limitation on the international price.

International price under the BAU and mitigation scenarios are assumed to be same; in other words, this study still not considering the change of preference and price of high-emission energy on the international market. Another treatment for the international price is it set as relative price with 1 (one) as the default number. This price is then changed (decreased or increased) depend on the supply and demand in the market.

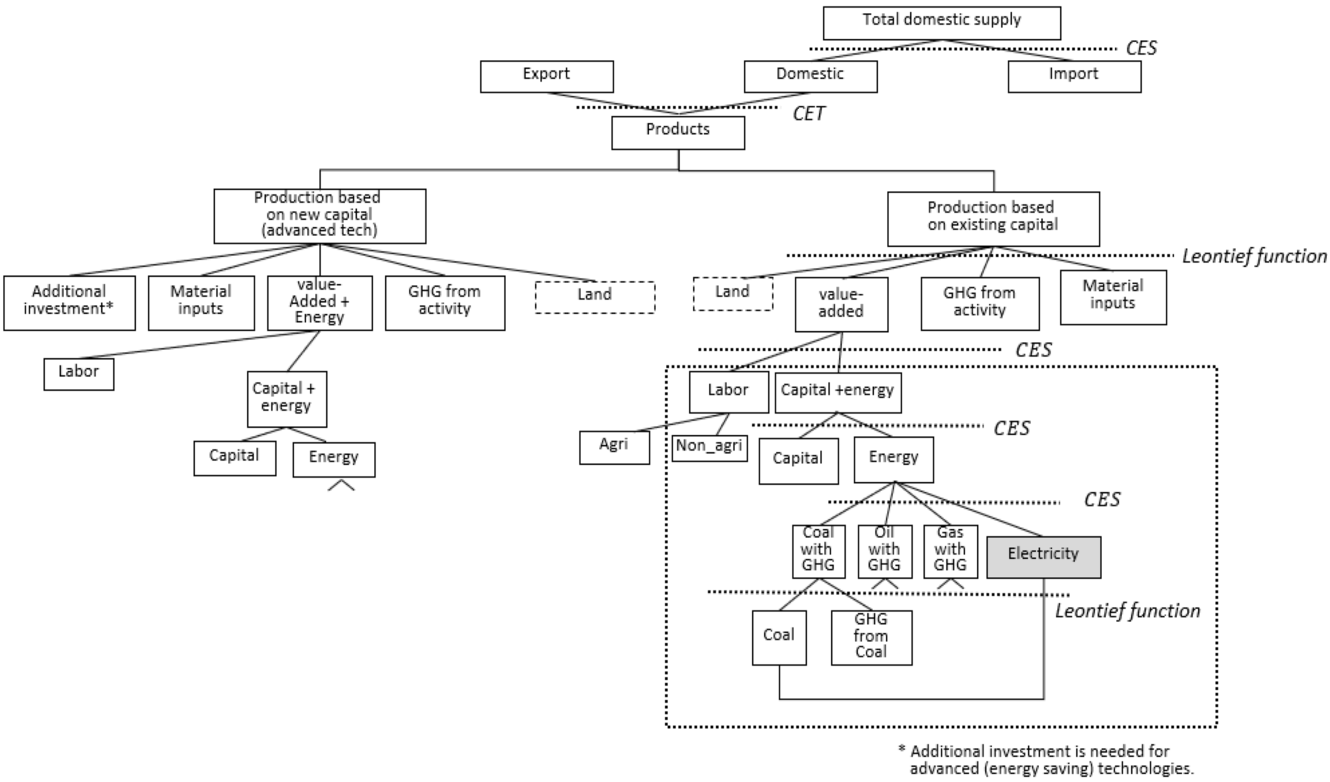


Figure 5.2. Diagram of Production Block and the Modification of the Energy Sector

Or it can be written as:

$$EPHUS(i) = \sum_{tec}\left(\sum_{j} QS\,(j, tec) \cdot vo\,(j, i) + QN(j, tec) \cdot vo\,(j.i)\right) + \big(IMP(i)\big) - EXP(i)$$

With:

$EP\ (i)$	: Primary Energy Supply
$QS\ (j, tec)$	: Production by Existing technology
$QN\ (j, tec)$	: Production by New technology
$v0(j, i)$	: Initial Produced goods I in sector j
PIM	: Import price
IMP	: Import
PEX	: Export Price
EXP	: Export
$rp\ (i)$	: reference price of goods i

The final energy demand is all the energy demanded by both the activity and the household. Final energy from the household is calculated from all the energy consumption in this sector, similar in the activity sector, the final energy is summed up from the energy that consumed both with the existing and new technology:

$$FEHUS = \sum QC\ (en, tec)$$

$$FEACT = \sum QS\ (en, tec) + QN\ (en, tec)$$

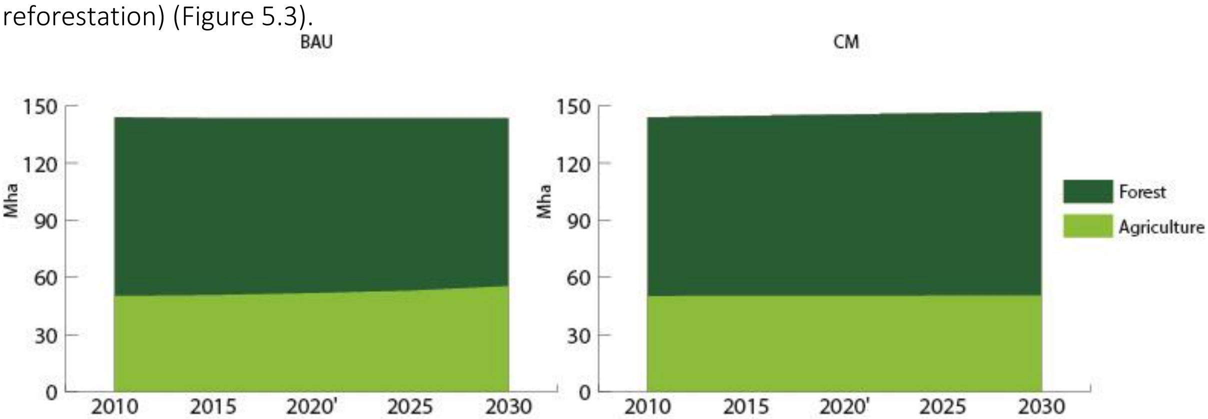
With:
$FEHUS$: Final Energy in the Household
$FEACT$: Final Energy in the Activity levels
$QC\ (en, tec)$: Total energy consumption in the household
$QS\ (en, tec)$: Total energy consumption with the existing technology
$QN\ (en, tec)$: Total energy consumption with the new technology

5.2 Additional Data

For constructing this model, there are several additional data and projection added. The additional data comes from the disaggregation of the input-output table. For the land area, population, energy supply, energy demand, and power generation, there are both statistical data and projection. The projection data are used as the comparison with the BAU scenario to make sure that the result does not give a big difference with the government official projection.

5.2.1. Additional Adjustment of Input-Output Table

The input-output table classification is set to have more disaggregation compared to the IO Table aggregation/disaggregation in Part 1 to accommodate more mitigation technology. There are 10 sectors that classified as a land-based sector (LAND). These sectors also need some area of land as input to produce their output. The value of the area that needed for these sectors is decided exogenously based on the previous calculation and statistic. In the CM scenario, the forest area is more than it is in the BAU scenario, because in the mitigation for the LUCF is considered (yield improvement and the reforestation) (Figure 5.3).



Notes: The agriculture land is including cropland, plantation, and livestock land
Figure 5.3. Land area in BAU and CM scenario

Another differentiator in this part also comes from the more comprehensive information from the energy sector. There are six sectors classified as energy sectors (ENE). Moreover, the electricity/ power sector is disaggregated into five. The non-renewable power is consisting of the coal power plant (coal pp), oil power plant (oil pp), and gas power plant (gas pp). While the for the renewable it is only disaggregated into two such renewable power plant excluding waste and biofuel (including geothermal pp, hydro pp, and micro-hydro pp), and biofuel power plant. The waste power plant is also included in this bioenergy power plant.

In part 1, the value-added only divided into capital, labor, and indirect tax. In this model, there is a separation between the indirect tax and the subsidy. This is considering several sectors are receiving a high amount of subsidy, especially for the energy sector. More than half of the subsidy in Indonesia is allocated for energy subsidy, especially for oil-fuel and LPG (Direktorat Penyusunan APBN, 2019).

5.3. Scenario and Emission Reduction Target

There are only two scenarios introduced in this model, such as 1.) BAU; Business as Usual and 2.) CM; Counter Measures where the emission is reduced 29% from BAU level in 2030 and along with that there are mitigation technologies from all sectors.

The mitigation technology here can come in two main forms: reduce the GHG emission and/or reduce the energy use. To achieve such reduction, some additional cost that comes from the increase of capital from the related sector will be needed. The assumption of mitigation technologies used in this simulation is described below.

5.3.1. Agriculture

Water Management; water management is highly related to the irrigation system to ensure the water supply for the crops, especially for the paddy, because paddy needs a flood condition during the growing phase. It makes water management is very crucial, especially for the paddy rice, it is assumed that 60% of emission from rice cultivation comes from water management. While the rice cultivation shares 33.49% of emission from agriculture, and it is assumed that water management share 60% of emission from paddy cultivation (share with changing to the low emission cultivar ~40%). By fixing the irrigation system, it predicted to reduce around 40% impact from water management (Elliott et al., 2014). The simulation was done for 15 years, and a rough calculation resulted in emission reduction from water management will be around 0.5%/ year for the paddy sector. Moreover, for other crops, the irrigation is not as crucial as the paddy sector, so there are assumed only 0.1%/year of emission reduction by introducing water management. To fix the irrigation system, it is assumed to have additional capital. For some crops, corn, cassava, other agriculture, rubber, palm oil, other plantation, and wood, the additional capital is assumed in the same proportion with the additional GHG reduction (~0.1%/ year). While for the rice, it might be more expensive and more complicated, so it is assumed the additional capital will be around 0.3%/ year.

For the low emission cultivar, especially for the paddy, it is assumed that there is a conversion from IR 64 cultivar into *Ciherang*. The average emission emitted by the *Ciherang* cultivar is almost 50% lower compared to IR 64. The average emission of *Ciherang* cultivar per ha per session is around 114.8 kg, and for IR 64 cultivar per ha per session is around 202.3 kg. It is ~ 43% reduction from the low emission cultivar. The emission from rice cultivation is not only from the paddy cultivar but also from water management. The water regime will be more dominant than the paddy cultivars, so it is assumed that 40% of emission from paddy sector is coming from the paddy cultivar. While the rice cultivation contributes around 33.49% of all emission in the agriculture sector, this value is then multiplied by 40% and 43%. Another consideration is that for some land type and climate, the IR 64 is still growing better than the *Ciherang* cultivar, so another assumption is added by mixing these two cultivars 50:50. While the assumption of emission technology started in 2016, the value is divided for around 15 years project and remain around 0.2% of emission reduction from the paddy sector per year. To reach this 0.2% of emission reduction/year, it is assumed that additional capital is needed. By checking the market price of IR 64 and *Ciherang*. It is found that the price for IR64 seed is around 100,000 IDR/10kg and *Ciherang* 110,000 IDR/10kg[1]. Around 10,000 IDR is needed to replace the seed while seed expenditure is contributing to around 2%-4% of total farmer's expenditure for production factor (Ardiyanto and Santoso, 2013; Siregar, 2011; Sugesti et al., 2015). By assuming the seed expenditure is 2% from total farmer's expenditure (Siregar, 2011). Additional of 0.2% will be expected by the additional cost arise.

[1] The price is checked on March 2019 for "Citra Tani purple label"

Combine urea with ammonium sulfate fertilizer; urea is very important for any crops because it can keep the leaves green and more productive for photosynthesis. Thus, this fertilizer is utilized in all agriculture and plantation sector. However, it may create high N2O emission. To minimize the emission from the urea utilization, the fertilizer can be mixed by any ammonium sulfate fertilizer like ZA that has lower nitrogen content. The urea nitrogen content is 26% while the ZA is 21%, so replacing the urea with ZA may lower 50% of the nitrogen emission. However, this is not such a wise option for the farmers, because they also tend to double the amount of ZA fertilizer when they totally replace the urea. By mixing the urea with ZA, it is assumed that total 25% of nitrogen emission from this activity can be reduced. However, the urea fertilization is contributing to around 4.5% of the total emission in agriculture. Based on this information, for 15 years emission mitigation project, the emission can be reduced for around 0.1%/ year from this technology.

Table 5.1. Mitigation Technologies for the Agriculture

Mitigation Technologies	Initial Years	Related Sector	GHG reduction rate (%.year)	Energy Reduction rate (%.year)	Additional Cost (increase rate to capital) (%.year)
Agriculture					
Water management	2016	Paddy	0.3		Building: 0.3
		Corn	0.2		Building: 0.1
		cassava	0.2		Building: 0.1
		Other agriculture	0.2		Building: 0.1
		Rubber	0.2		Building: 0.1
		Palm oil	0.2		Building: 0.1
		Other plantation	0.2		Building: 0.1
		wood	0.2		Building: 0.1
Low emission cultivar	2016	paddy	0.2		Paddy: 0.1
Mix the urea with ammonium sulfate fertilizer	2016	Paddy	0.1		Fertilizer: 0.5
		Corn	0.1		Fertilizer: 0.2
		cassava	0.1		Fertilizer: 0.2
		Other agriculture	0.1		Fertilizer: 0.2
		Rubber	0.1		Fertilizer: 0.2
		Palm oil	0.1		Fertilizer: 0.2
		Other plantation	0.1		Fertilizer: 0.2
		wood	0.1		Fertilizer: 0.2
High efficiency fertilizer	2016	Paddy	0.1		Fertilizer: 0.3
		Corn	0.2		Fertilizer: 0.3
		cassava	0.2		Fertilizer: 0.3
		Other agriculture	0.2		Fertilizer: 0.3

Table 5.1. Mitigation Technologies… (Continued)

		Rubber	0.2		Fertilizer: 0.3
		Palm oil	0.2		Fertilizer: 0.3
		Other plantation	0.2		Fertilizer: 0.3
		wood	0.2		Fertilizer: 0.3
Manure utilization for the Biogas	2016	Livestock	0.2		Building: 0.2
Liming	2016	Palm	0.03		Chemical industry: 0.03
		Rubber	0.03		Chemical industry: 0.03
		Other Plantation	0.03		Chemical industry: 0.03
		Wood	0.03		Chemical industry: 0.03

More efficient fertilizer; another way to reduce the emission from the soil, especially the N2O emission is by mix it with more efficient fertilizer. For some farmers, they usually use single-content fertilizers and mix it by themselves. Thus, the overdose condition mostly happens. While, in the market, they can use more efficient fertilizer like NPK (nitrogen (N), phosphorus (P) and potassium (K)). The emission can be reduced to some level. In a case, the farmer use Ammonium phosphates fertilizer, the nitrogen content from this fertilizer type is 18% while the NPK[2] only has 15% of nitrogen content by replacing the fertilizer to NPK, around 17% of direct nitrogen emission from soils. However, the price of NPK fertilizer is so much higher than any other kind of fertilizer, that fully replace it to NPK will be very costly for the farmers. So, it is assumed that the farmers still use 50% of their previous fertilizer. Direct N2O emission from the soil itself is assumed to contribute 30.4% of the emission from the agricultural sector. The implementation of this technology may reduce around 3% of emission from agriculture or around 0.2%/ year. It is assumed that the fertilizer industry also needs to increase some capital for producing more NPK fertilizer. In this study, the proportion of capital improvement is the same as the potential GHG reduction (~0.2%/year).

Manure utilization for the biogas; the emission from manure can be minimized if it is gathered and then utilized for the biogas development. By compiling the emission from manure management and direct N2O from manure, these sectors will contribute to 6.44% of emission from agriculture. By assuming that 50% of the total manure from this source can be gathered and used for the biogas, half of the emission can be cut, or around 0.2%/ year of emission reduction. To build dome digesters and support the biogas development, it is assumed that the same portion of additional capital is needed in the building sector (~0.2%/ year).

Liming is usually given for the plantation crops when the land is considered acid and cannot support the growth of the plant. The emission reduction by the reduction of liming use is projected to be around 1% per year in line with the reduction rate of the total area used for the commercial plantation. As there are three types of land that considered commercial plantation, this value is then divided into three. Thus, each sector will contribute to around 0.33% of emission reduction for liming use. Along

[2] The NPK used here is NPK 15 (N): 15 (P): 15 (K)

with that, it is assumed that the chemical industry needs to increase the capital in the same number (0.03%/ per year).

5.3.2. Industrial Process and Product Use (IPPU)

More efficient production process; The assumption is based on the annual trend of annual additional emission and reduction. Within the period 2000-2016, the emissions in the IPPU sector experienced an average of 0.2% annual increase. There are some technologies that focused on cement, chemical, and metal-based industries such as: enhancement on the use of alternative materials (blended cement program) for the replacement of clinker by decreasing the "clinker to cement ratio" from 80% in 2010 to 75% in 2030, efficiency improvement of ammonia production plant to reduce the use of natural gas as feedstocks as well as energy supply in the ammonia plant and CO2 recovery in primary reformer of fertilizer industry, (c) improvement of processing system in the smelter industries, (d) use of secondary catalyst in nitric acid production and (e) claim of GHG emission reduction potential in aluminum smelter. However, during 2015-2016, those technologies only able to achieve 0.16% of emission reduction(Boer et al., 2018) .

Table 5.2. Mitigation Technologies for the IPPU

Mitigation Technologies	Initial Years	Related Sector	GHG reduction rate (%.year)	Energy Reduction rate (%.year)	Additional Cost (increase rate to capital) (%.year)
IPPU					
More efficient production	2016	Chemical industry	0.2		Other industry: 0.2
		Cement industry	0.2		Other industry: 0.2
		Metal-based industry	0.2		Other industry: 0.2

Considering this trend, it is assumed that the mitigation is focused on three main industries: cement, chemical, and metal-based industries. The continuation and improvement of technology in these industries may reduce 0.2%/ year, respectively. Because there is still some limitation related to the cost information, so it is assumed that 0.2%/year capital improvement in machinery (other industries) sector.

5.3.3. Waste

Waste management installation; The assumption decision for the waste treatment is one of the hardest due to a very limited monitoring system of emission from the waste. The statistic shows that by using some potential waste technologies, the emission reduction in 2015 and 2016 is only accounted for 0.014% compared to the BAU level. This value is somehow too small because most are not recorded due to the poor monitoring facilities. This main reduction from the waste management of Municipal Solid Waste Treatment (MSW) by altering the open dumping to sanitary landfill and Landfill gas recovery.

Although 42.6% of the waste emission comes from industrial wastewater, the emission reduction from wastewater treatment also still not recorded well and it makes the contribution small compared to the MSW management (Boer et al., 2018). In Indonesia IO Table, solid waste is mostly calculated in the waste and recycling sector. While the wastewater is recorded in the water sector. For that, it is assumed that the GHG reduction rate of 0.1%/year in the waste and recycling service, and 0.05% in water supply sector. For that, there is also assumed that capital cost improvement is needed to construct a waste management facility. The assumption of capital improvement is in the same proportion as the emission reduction.

Table 5.3. Mitigation Technologies for the Waste

Mitigation Technologies	Initial Years	Related Sector	GHG reduction rate (%.year)	Energy Reduction rate (%.year)	Additional Cost (increase rate to capital) (%.year)
Waste					
Waste Management installation	2016	Water treatment	0.05		Building: 0.05
		Waste	0.1		Building: 0.1

For the LUCF, the land area and emission area calculated exogenously not endogenously in this model. To accommodate this limitation, the land area for the land-based sector is already fixed exogenously based on the previous assumption. In the BAU, the total area used for each crops area without considering the yield improvement and reforestation, here the forest area is decreased in parallel of land for the cash crops.

5.3.4. Energy

The emission from energy is included the emission from fuel combustion and fugitive emission. The mitigation technology will also be related to these two activities, but mostly the emission reduction in fuel combustion will contribute more as it involves more sectors (Figure 5.13). The assumption of mitigation action for the energy sector is summarized in Table 5.5.

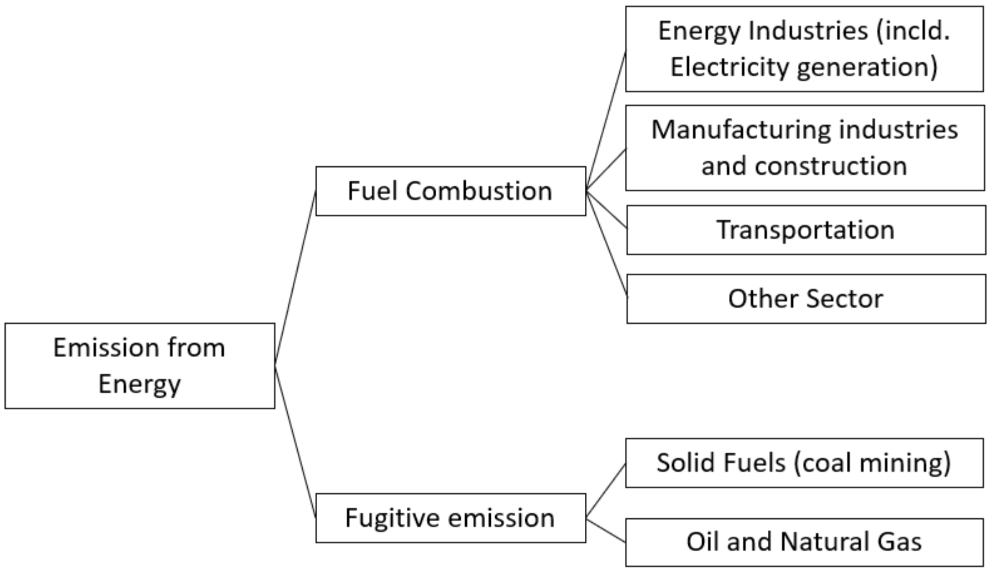


Figure 5.4. Emission Source from Energy Sector

Energy efficiency in the commercial sector; there is a target to achieve energy efficiency potential for at least 10% for large energy consumers. Commercial sectors (Trade, finance, services for public, building) are consuming the intensive amount of electricity. So, it is assumed that there is a 0.1%/year reduction in electricity consumption for these sectors. Not to mention that the industry also needs to provide appliances that more efficient to support this technology. The capital improvement is assumed at the same rate with the ratio of electricity consumption ratio.

Table 5.4. Mitigation Technologies for the Energy

Mitigation Technologies	Initial Years	Related Sector	GHG reduction rate (%.year)	Energy Reduction rate (%.year)	Additional Cost (increase rate to capital) (%.year)
Energy					
Energy Efficiency in Power Generation	2016	Coal pp		Coal mining: 0.1	Building: 0.2
		Oil pp		Crude oil mining: 0.1 Petroleum refineries: 0.1	Building: 0.2
		Gas pp		Natural gas mining: 0.1 Gas: 0.1	Building: 0.2
Reduce the use of oil in the transportation sector	2016	transportation		Petroleum refineries: 0.3	Other industry: 0.3
Energy efficiency in the commercial and household sector	2016	Building		Electricity: 0.1	Other industry: 0.1
		Trade		Electricity: 0.1	Other industry: 0.1
		Amusement		Electricity: 0.1	Other industry: 0.1
		Finance		Electricity: 0.1	Other industry: 0.1
		Services-Government		Electricity: 0.1	Other industry: 0.1
		Services-Private		Electricity: 0.1	Other industry: 0.1
		Other		Electricity: 0.1	Other industry: 0.1
	2016	Households		Electricity: 0.1, Petroleum refineries: 0.1 Gas: 0.1	Other industry: 0.3

Energy efficiency in the household sector; similar to the commercial sector, but the household sector also hoped to be able to reduce the consumption of oil (kerosene) and gas. The consumption reduction ratio is assumed by 0.1%/year for each energy type. This will also need capital improvement from the industry in line with the energy consumption reduction.

For **power generation**, the efficiency improvement is captured by the less use of primary energy, especially for the fossil fuel power generation. The coal power plant (pp.), oil pp, and gas pp are assumed to reduce the use of coal, oil, and gas for around 0.1%/ year. To support it, there should be some development and adjustment of the power plant to support the new technology, especially the development of Clean Coal Technology (CCT) that targeted to be widely introduced in Indonesia to reduce the use of oil and gas and use more coal while the cost for CCT will be relatively expensive compared to the energy consumption reduction. In this study, each fossil-fueled power plants are assumed to add 0.2%/ year of additional capital to support the new technologies.

5.4 Simulation Result and Findings

5.4.1. BAU case/ Parameter Adjustment

The parameter adjustment is made to check the reliability of the model. The BAU result for the GDP shows a very small difference between the simulation and the official statistics and the simulation result (Figure 5.5).

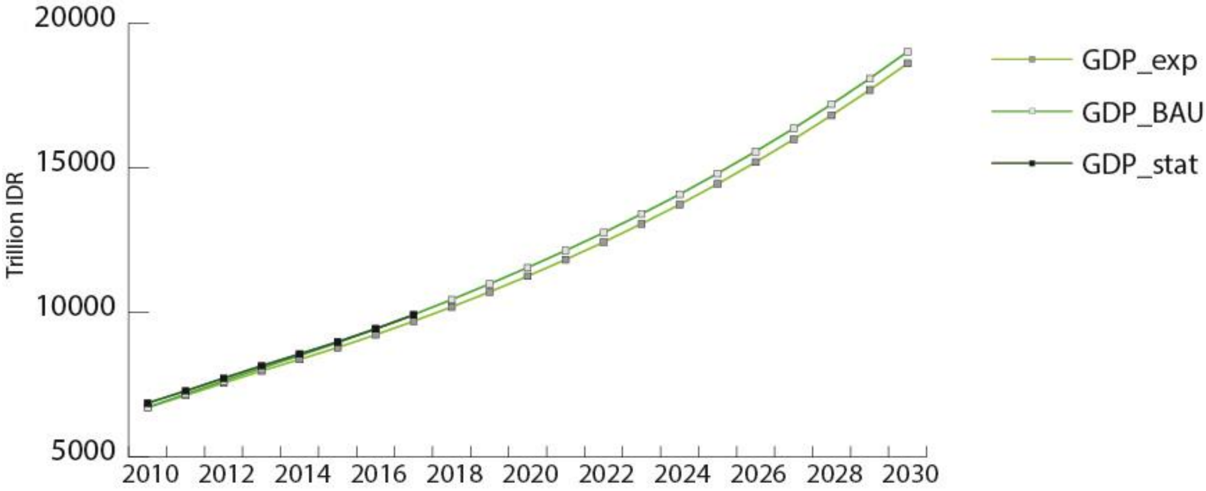


Figure 5.5. Comparison between GDP in BAU case (GDP_BAU), statistic (GDP_stat), and government GDP projection (GDP_exp)

Similar result with the GHG, the simulation result under the BAU level show similar result with the GHG official projection and statistic (GHG_stat) stated in 2nd Biennial Update Report (Figure 5.6).

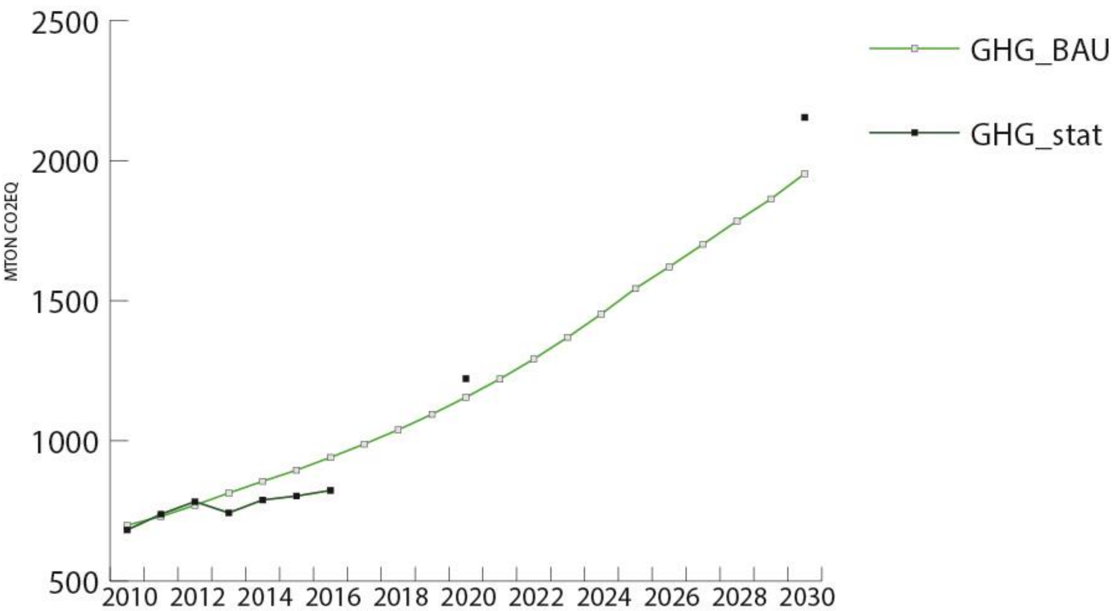


Figure 5.6. Comparison between GHG emission in BAU case (GHG) and government projection (GHG_stat)

5.4.2 Socio-Economic

5.4.2.1 Impact on the GDP

One of the most important economic results of this study is comparing the GDP loss. Compared to the BAU case, the model projected the GDP loss by introducing all the mitigation actions will be around 2.2% in 2030 compared to the BAU level (GDP BAU: 19025.7 Trillion IDR; GDP CM:18606.6 Trillion IDR) (Figure 5.7).

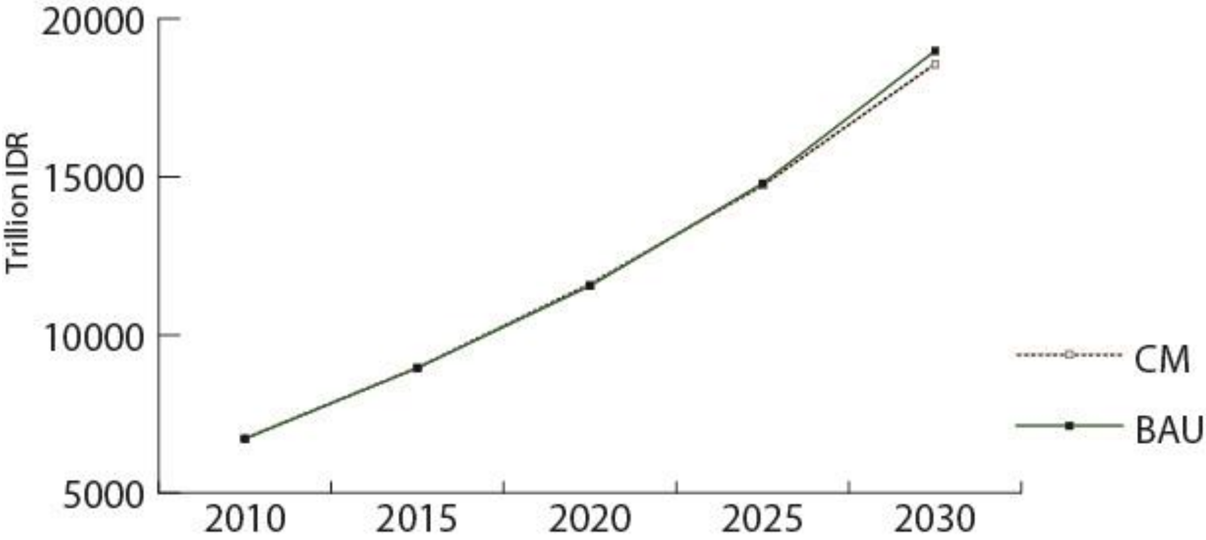


Figure 5.7. GDP under BAU and CM scenarios

This reduction is mostly driven by the reduction in household consumption along with the reduction of net export and household investment that might happen under the CM scenarios that arise because of the limitation of emission level. Although there is also an increase from government consumption, this increase cannot offset the lower consumption, investment, and net trade that happened in the household sector (Figure 5.8).

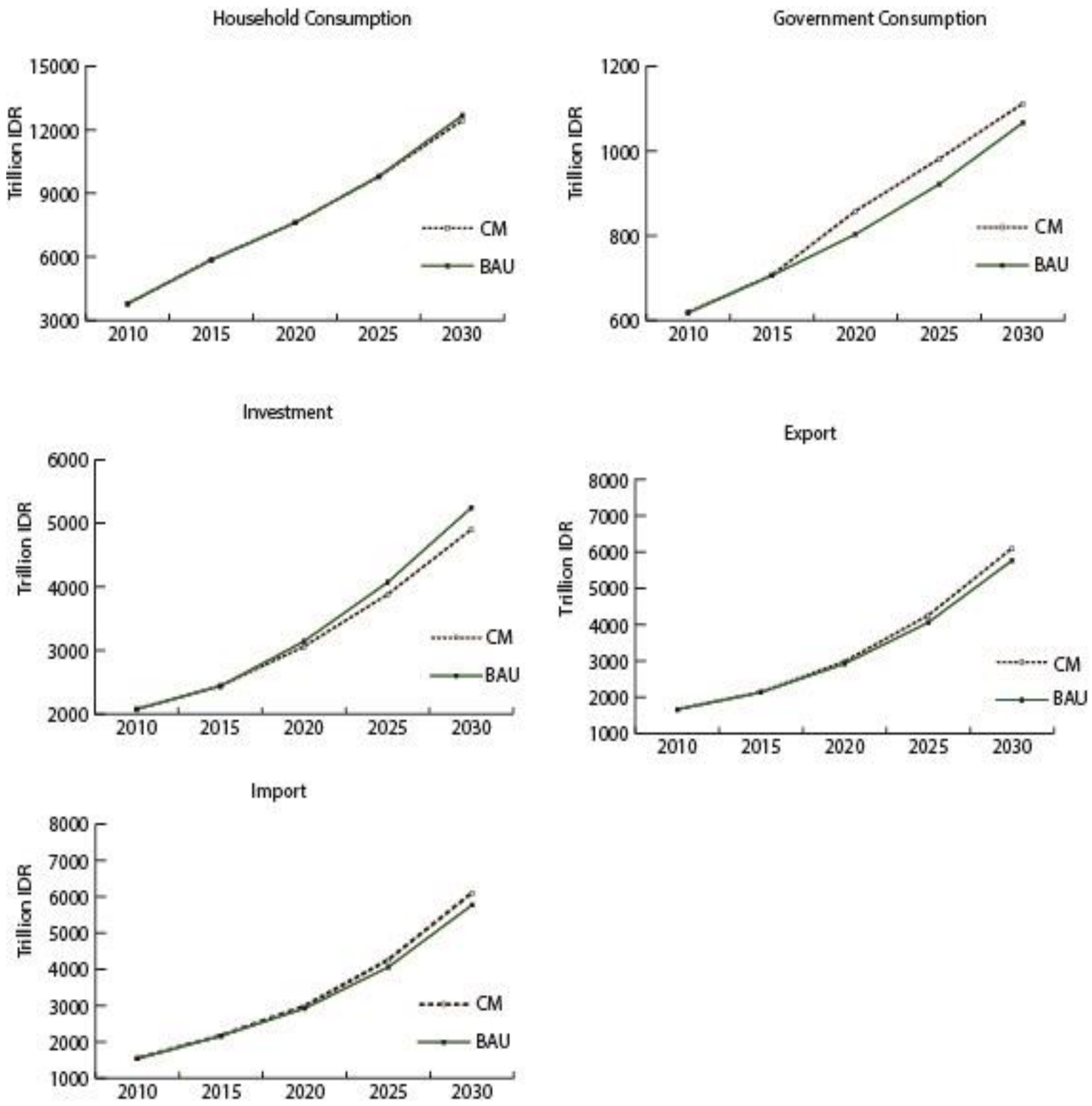
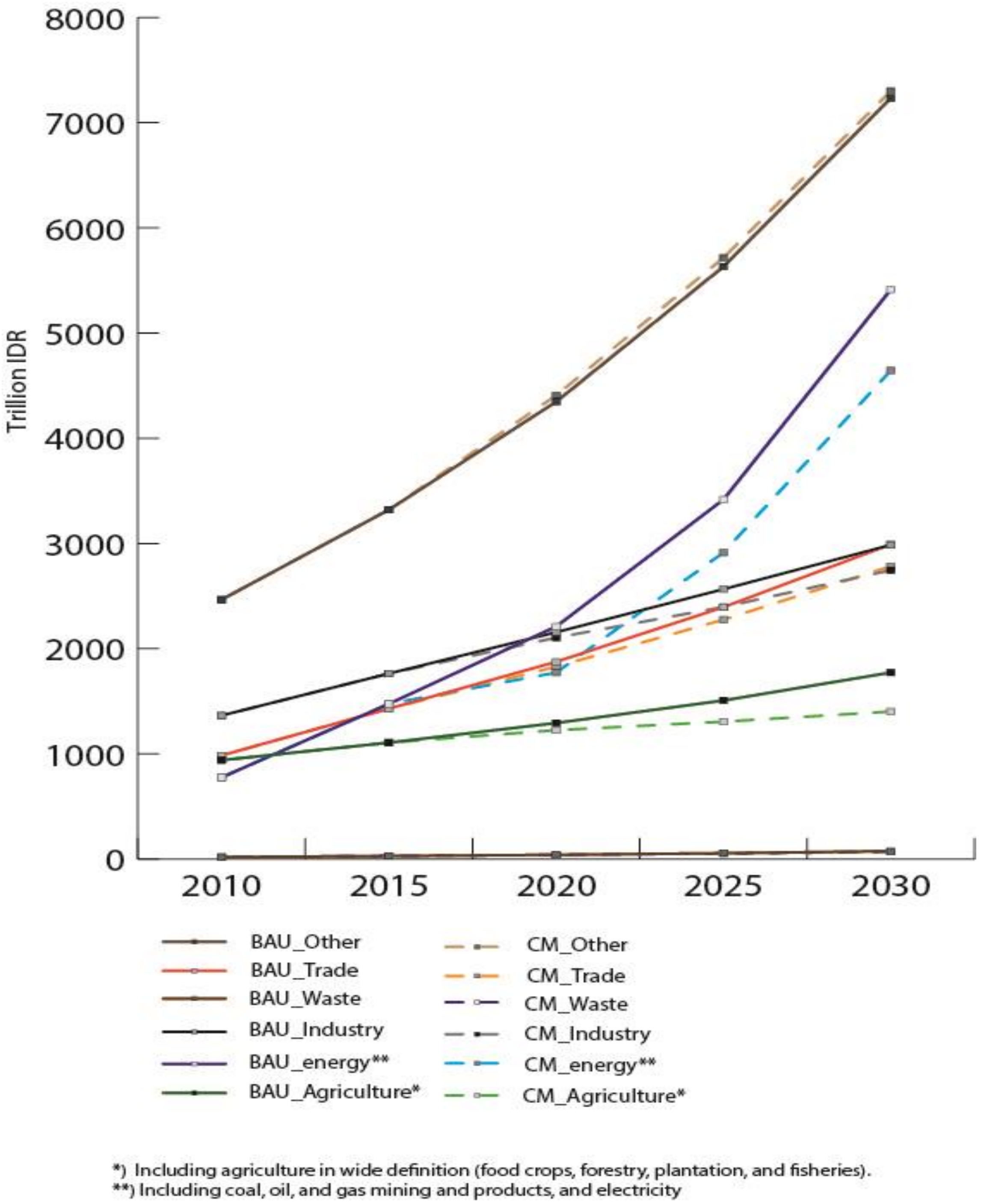


Figure 5.8. Some Macroeconomic indicators under all scenarios

By introducing the mitigation technology in all sectors and some improvement and investment for the energy sector, the sectoral GDP from the energy sector is improved, while the other sectoral GDP is lower in the CM scenario. This is because along with the economic growth, the demand for energy from all sectors is also increasing (Figure 5.9).



Notes: *Detail of sector aggregation can be found in Appendix C, Table C2*
Figure 5.9. Sectoral GDP comparison for each sector under all scenarios

Moreover, if we breakdown the sectoral GDP from the energy sector, there is a significant difference between the energy GDP from in BAU and CM scenarios. Under the BAU level, the sectoral GDP from the energy sector is dominated by the oil sector, both the petroleum refineries and crude oil mining. This is because high consumption of oil since 2004, and the condition become worse while the government also provide high subsidy for the domestic oil since 2008. Because the price is subsided, the consumption also becomes inefficient because consumers tend to be wasteful in consuming the oil resources (PwC Indonesia, 2014). The sector that highly consumes oil is the transportation sector. Because of the low price of the oil, Indonesian also tend to have more private transportation mode (figure 5.10)

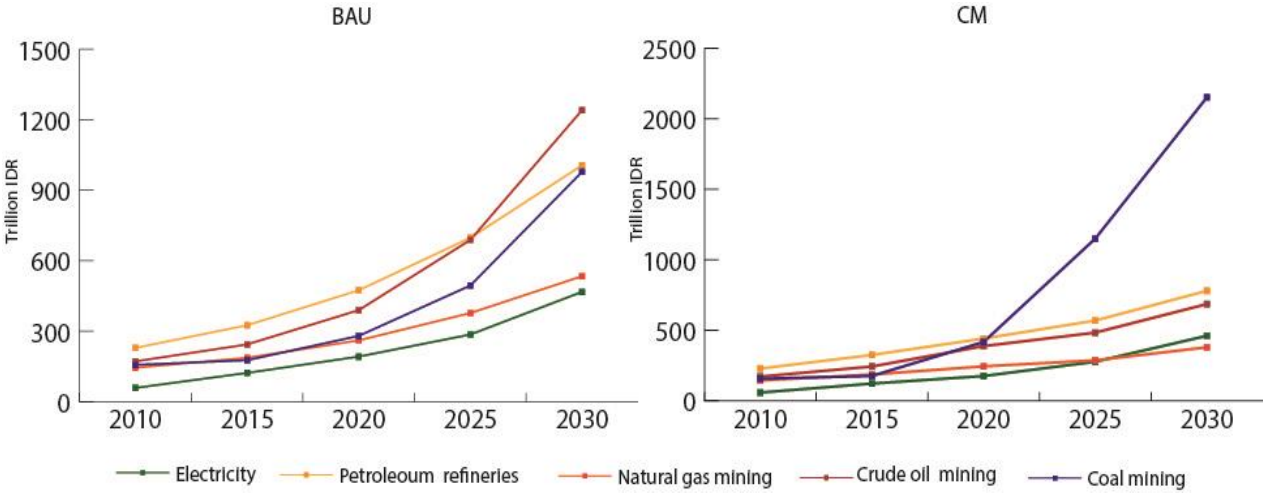


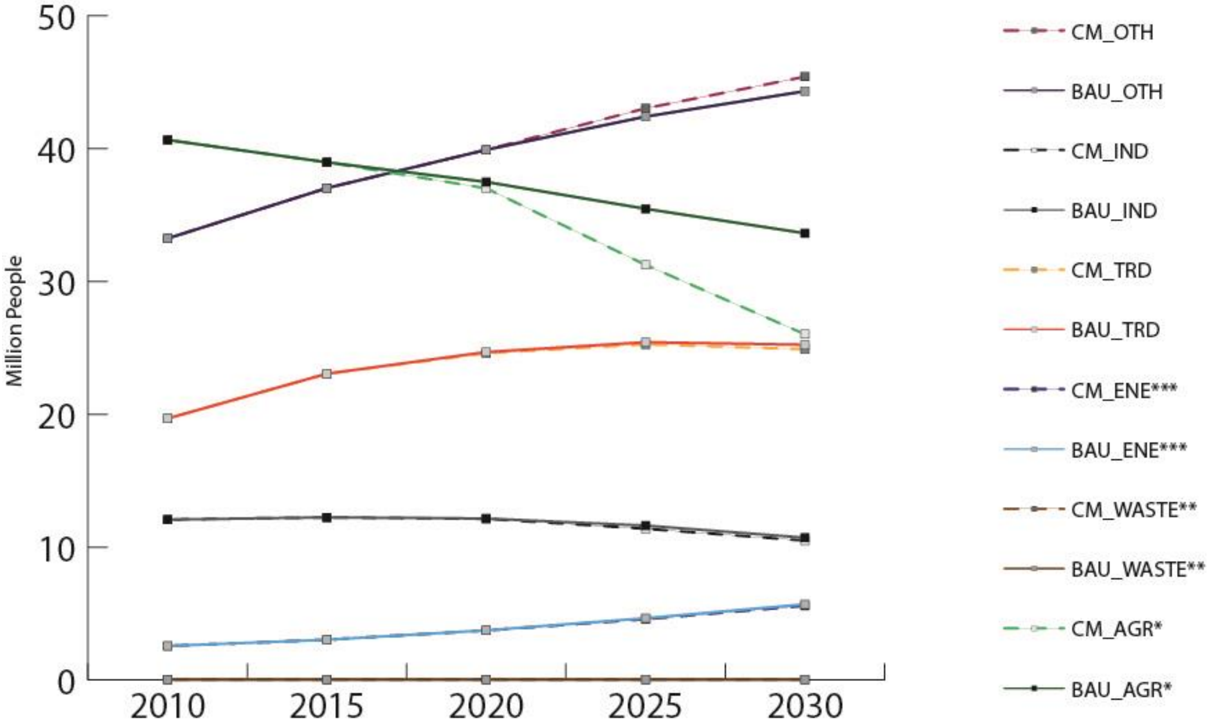
Figure 5.10. Sectoral GDP from the Energy Sectors.

While, when the mitigation policies are implemented as in the CM scenario, the sectoral GDP from oil is reduced, followed by the reduction of GDP from natural gas mining. However, it will be offset by a significant contribution from coal mining. This is estimated because Indonesia government plan to push the domestic production coal for domestic use, especially for the industry and power generation along to boost its export. There is also an increasing share from the electricity due to the higher consumption of electricity from all sector in the economy. The significant improvements are also because Indonesia's reserves of higher calorific value coal are declining. So, although the technology for Clean Coal Technologies and some other technologies are available, more coal still needed to compensate for its lower energy value (Mackenzie, 2018). This will create a condition where more coal exploitation might be needed.

5.4.2.2 Impact on the Labor

*A*griculture always gives a big contribution to absorb labor. However, along with the economic growth and some economic structural shift, the contribution is started to be decreased. With the mitigation implementation, the contribution is decreased more. This is because the number of lands that cultivated is decreased while some of the mitigation technologies in this sector (e.g. using more efficient fertilizer, using more efficient seed) are also need less labor.

The sectors that closely related to emission mitigation technologies are mostly reducing employment. Industry sector will reduce around 2.1% of labor absorption in 2030 compared to the BAU level, followed by the energy sector (-1.9% in 2030), trade (-1.3%) and waste (-0.5%) (Figure 5.11). This is because there is an assumption of efficiency improvement. While efficiency is improved, it will need less input, including labor. In the industry, the labor is reduced not only because of internal efficiency but also because of efficiency in the other industry that lower the demand to the industry.



*) AGR: Including all crops, plantation, forestry, livestock, and fisheries.

**) WASTE: Including recycle services and water supply due to the wastewater treatment mostly including in the water supply.

***) ENE: Including energy products and mining and power generation.

Detail of sector aggregation can be found in Appendix C, Table C2

Figure 5.11. Labor comparison for each sector under each scenario

5.4.3 Emission

The introduction of mitigation technologies in the energy sector in this simulation can reduce the emission for ~8% by 2030 compared to the BAU level (Figure 5.12).

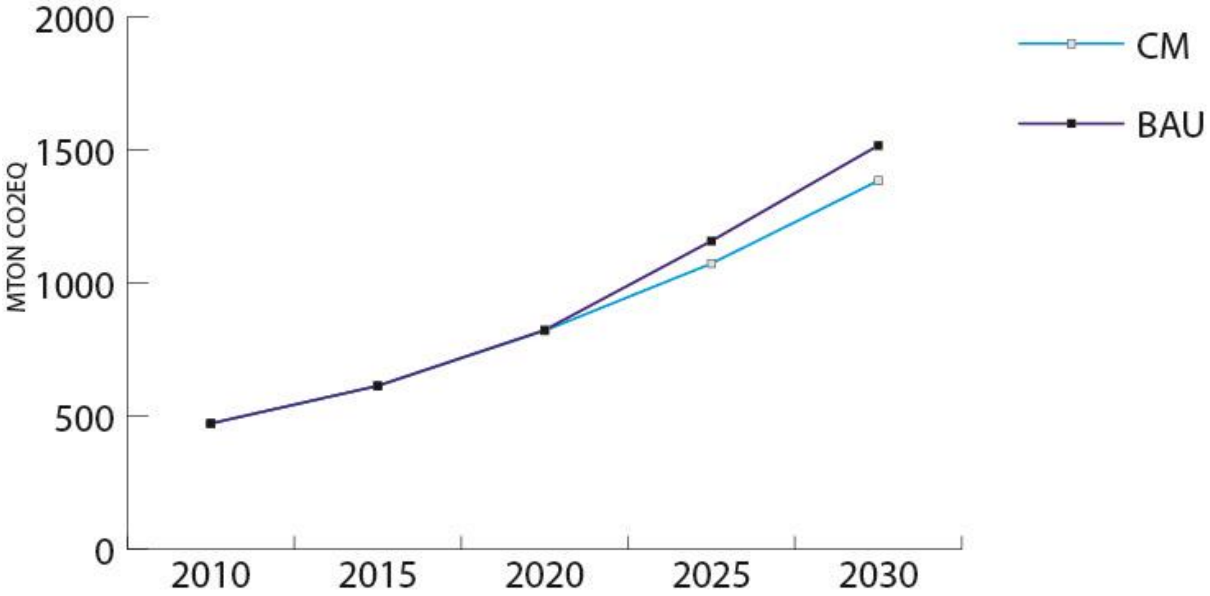


Figure 5.12. GHG emission from Energy sector under BAU and CM simulation

In the activity sector, the emission reduction is varying between each activity. The highest emission reduction comes from the agriculture sector. This result is because the information about mitigation in agriculture is more detail than another sector (Figure 5.13).

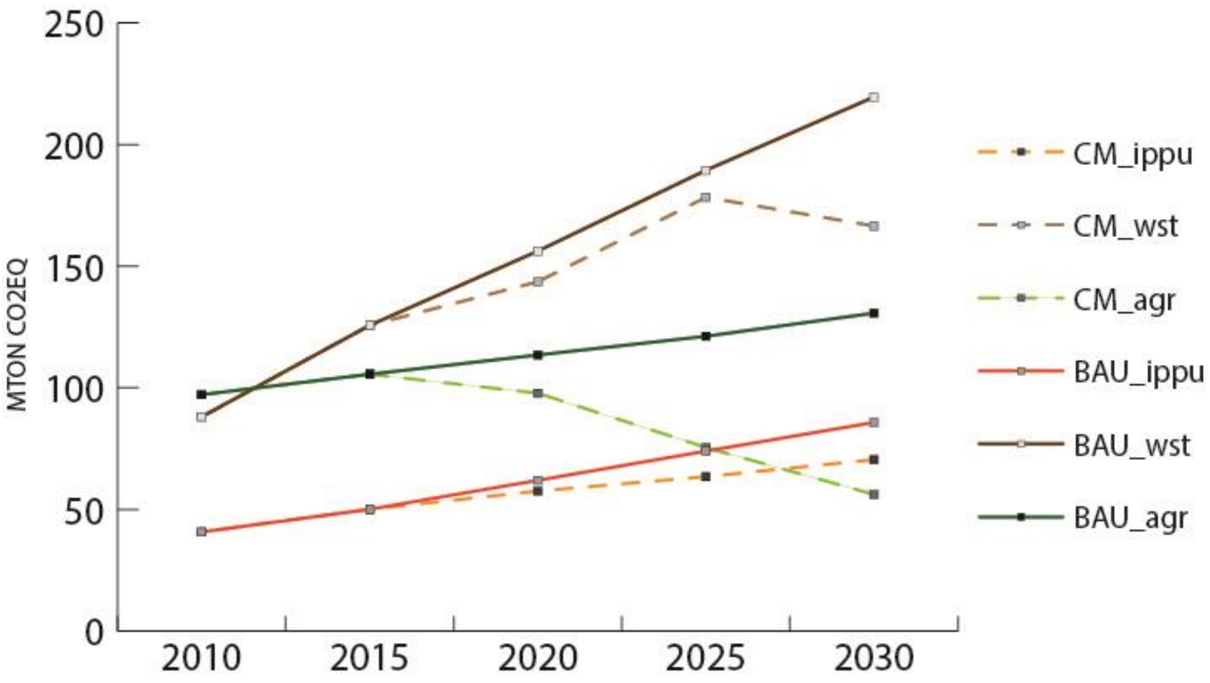


Figure 5.13. GHG emission from activities under BAU and CM simulation

5.4.4. Energy

5.4.4.1. Energy Supply

In line with government projection, the coal may dominate the energy supply. Different trend compared to the other energy sources; coal mining is increasing even under CM scenario.
This is because coal use is projected to be increased. Moreover, coal for Indonesia is also export goods, in line with a significant increase in the sectoral GDP for coal as in Figure 5.10, the result indicates the increase of the exported coal.

This is also because of the limitation of the model; the initial data used for this simulation is the energy supply in the base year (2010) and several supporting dataset of energy supply by 2016. During that period, Indonesia export more than 65% of its coal production. Because the international price is assumed to be the same for both the scenario, this trend is possibly continued during the simulation towards 2030. Due to the emission mitigation and the demand for coal is reduced (see subsection 5.3.4.2), Indonesia will decide to export more coal to compensate for it. This is also to minimize the GDP loss arise by the mitigation policies implementation.

In reality, the international price of coal may reduce. However, this assumption hasn't introduced in this study. The coal supply also increases to offset the reduction of other primary energy supply and especially the petroleum refineries that will be decreased in import and production (Figure 5.14).

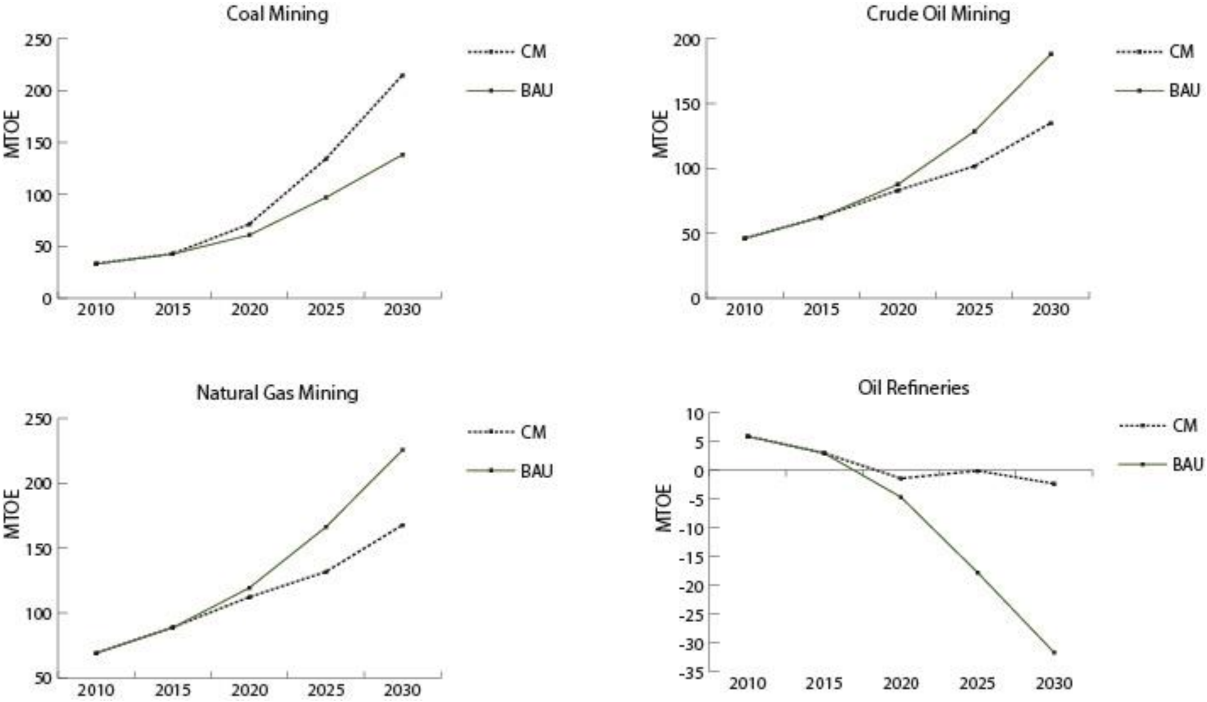


Figure 5.14. Simulation Result for Energy Supply (including export and import)

5.4.4.2. Energy Demand

The highest energy demand will come mostly from the industry sector, followed by the household sector and transportation. The energy demand from the industry is the highest because along with economic growth, the industry needs to produce more output and will need more energies to support its production activities. While the population is also increasing, the energy demand from the household sector also experiencing fast growth. However, along with the introduction of the mitigation scenarios, the demand is decreased notably for the industry and transportation sector (Figure 5.15)

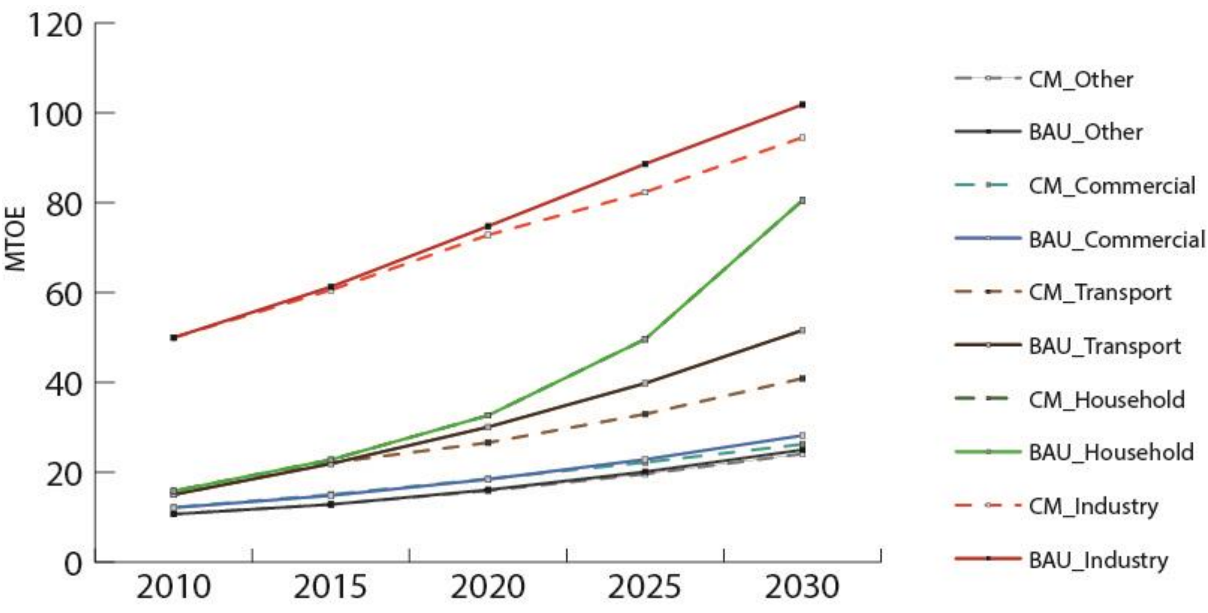


Figure 5.15. Energy Demand by the user under CM scenario

The demand for the oil refineries product also still high by 2030, followed by the need for coal mining products and natural gas. However, with the implementation of mitigation technologies, the demand for coal, natural gas, gas (town gas), and oil refineries will be reduced. This becomes one of the implications of energy efficiency in all sectors. The demand for crude oil mining is basically similar between the BAU and CM scenario because the crude oil stock in Indonesia is already reaching its maximum capacity. For electricity, although there is an assumption of energy efficiency for the electricity use, however the demand itself will keep increasing in all user, it makes the electricity demand in the CM scenario is only reduced slightly compared to the BAU scenario (Figure 5.16).

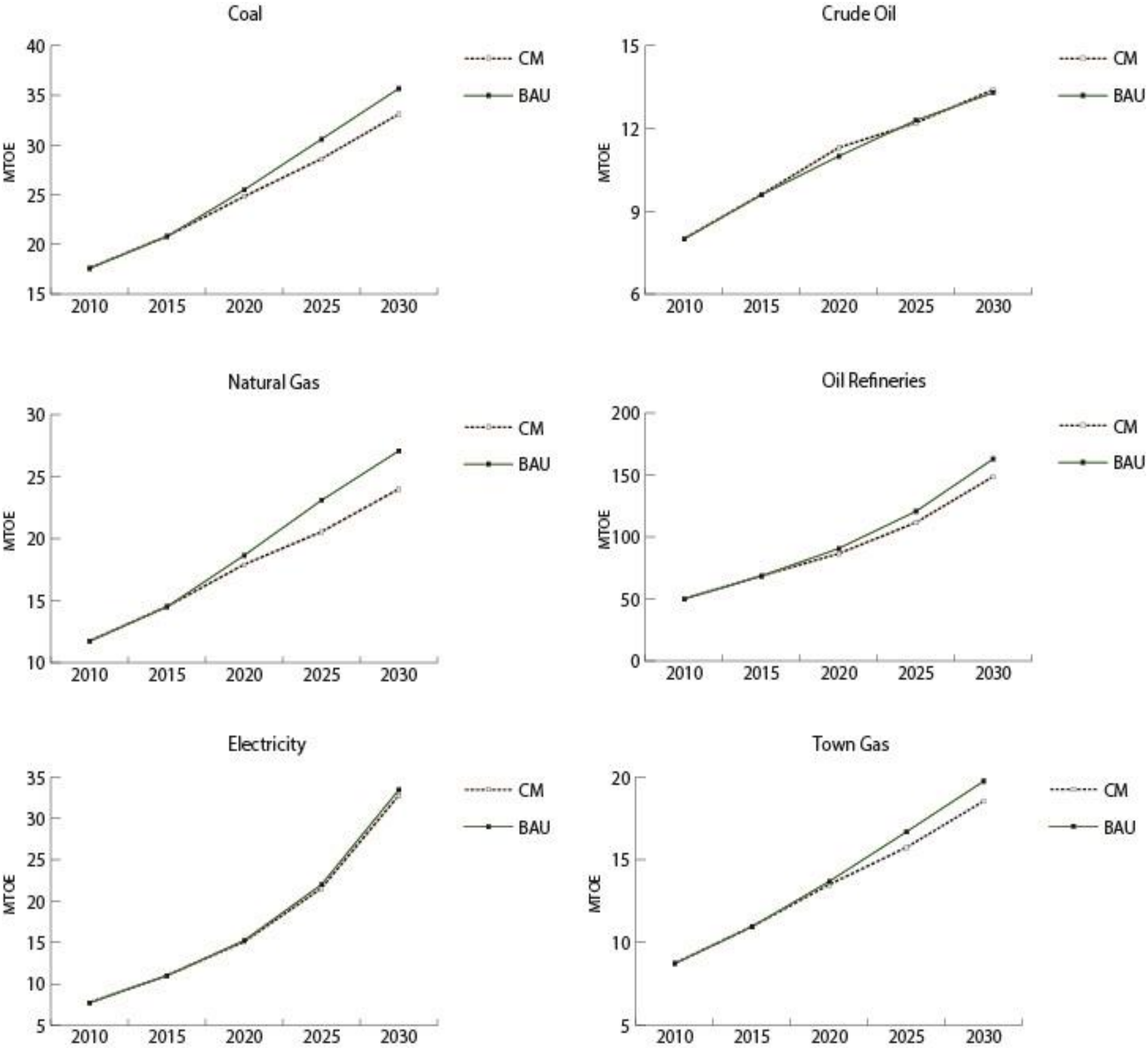


Figure 5.16. Simulation Result for Energy Demand by Energy type

5.4.4.3. Power Generation

The coal power plant also projected to dominate the power plant generation in Indonesia. The high growth of coal plants had resulted in a significant increase in coal share in the power generation mix. Moreover, because there is a target to utilize more renewable energy in the power generation mix, the renewable power plant also increased, mostly from the hydro pp and the geothermal pp. In the other side, although Indonesia has a huge potential in biomass, the share of the biomass-waste power plant is still very small and insignificant. This is because the installation of biomass and waste power plant are still very small compared to another power plant mix (Figure 5.17).

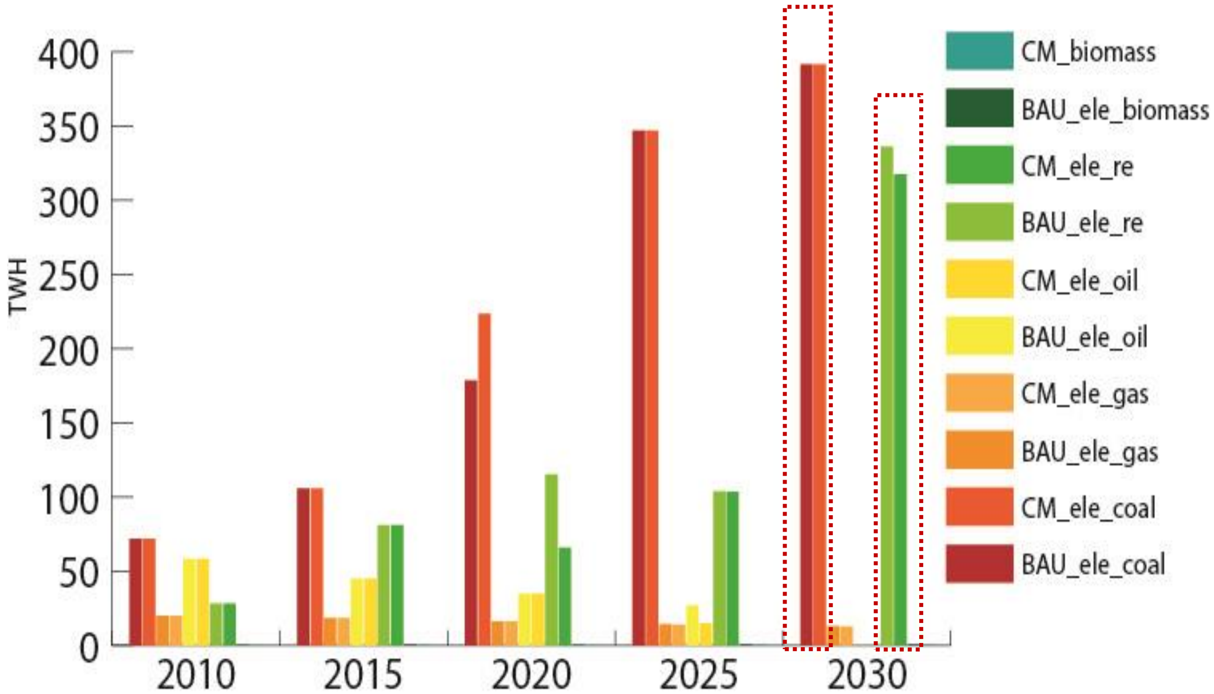


Figure 5.17. Simulation Result of Power Plant Mix under BAU and CM scenario

The use of coal, especially for the power generation is lead because of the development of Clean Coal Technology (CCT). The commercially established CCT technology for the coal power plant is using a supercritical boiler and ultra-supercritical boiler. Both technologies operate at temperatures and pressures above the critical point of water. The efficiency of the supercritical boiler can reach around 44%, and ultra-supercritical can reach around 50%, while the older type of coal power plant operates around 30% (Afework et al., 2018). The establishment of supercritical and ultra-supercritical powerplant is focused in Java. Moreover, there is also Circulating Fluidized Bed (CFB) boiler beside the supercritical power plant technology that more be focused on reaching Sumatera and East part of Indonesia. The CFB itself also can improve the power generation efficiency for around 40% (Hotta, 2012). Even more, in 2024, Indonesia also plans to start to develop an Integrated Gasification Combined Cycle (IGCC) technology, and it is estimated to be commercially ready by 2024 (PLN, 2015).

However, because the supply of coal itself also limited, the government also stated that the coal use should be limited and the use of renewable energy, especially the established hydro and geothermal needs to be more optimized. That becomes another reason that leads to the high utilization of the renewable power plant in 2030 is projected to increase significantly.

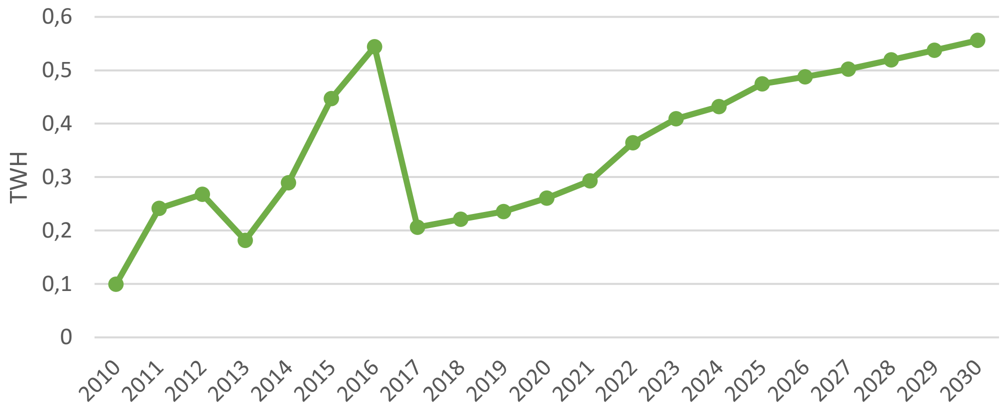


Figure 5.18. The Power Generation from Biomass and Waste Power Plant

Although very small compared to other renewable energy, the power generation by using biomass and waste also predicted to be increased (Figure 5.18). However, because of the installed capacity for these power plants also still very limited, and there is still a limited expansion plan for this powerplant, the growth is not as high as other renewable energies.

5.5. Conclusions

This part is trying to measure the potential impact of comprehensive emission mitigation policies for Indonesia by using the CGE model. There are two scenarios for this part: 1. BAU as the Business as Usual scenario and 2. CM, as the mitigation scenario. Under the CM scenario, all the emission mitigation in the energy and activities are introduced. Mitigation from the LUCF is introduced indirectly to this model by using the land use are gained from the previous chapter (CGE with LUCF). Under the CM scenario, the forest area is wider, and the cropland for the economic activities is more limited compared to it is at the BAU level. The energy also treated in more detail, especially by introducing more detail on the power sector.

The introduction of mitigation scenarios is predicted to create around 2.2% of GDP loss compared to BAU level by 2030 caused by lower household consumption and investment. Although there is an increase in government consumption, that improvement is not able to cover the loss in household consumption, that share the biggest proportion in Indonesia final demand. Along with the introduction of mitigation policies, it will also be reduced the sectoral GDP from agriculture, energy, and industry, but it is predicted that the sectoral GDP from other sectors that not directly affected by the mitigation policies will increase or at least experiencing lesser loss compared to the sector that directly affected by the mitigation.

For the labor, the model projected a significant fall of agricultural labor under the CM scenario. This is because under the mitigation scenario, the cropland is reduced, and there are also some sets of emission mitigation policies for agriculture. It can be an indication for the Indonesia government to prepare for the structural change and providing employment in other sectors, most likely to other sector and trade. Moreover, the energy, waste, and industry sectors are more capital intensive rather than labor-intensive, so it projected not to absorb high labor as high as agriculture, trade, and others.

From the energy sector, the mitigation action also reduced the domestic energy demand for almost all energy sources. This part also finds that the utilization of renewable energies will increase significantly for the power generation, especially after 2025, and slowly substitute the power generation by non-renewables. Other power generation from biomass and waste also projected to be improved under the mitigation condition. However, this improvement is still very small compared to other renewable energies (hydro, geothermal, and solar power plants).

5.6. Discussion

The introduction of all mitigation actions in all sectors is giving a smaller GDP reduction compared than only introducing the mitigation in LUCF. It also gives a smaller shock to household consumption. However, household consumption is still the most dominant part of GDP and give a significant effect on the GDP loss. By comparing all the sector affected by the mitigation policy, the agricultural sector is projected as the sector that affected the most. The sectoral GDP and labor of agriculture are reduced significantly under the CM scenario. This can be an indication for the Indonesia government to prepare for the structural change in the economy. The trade and other services can be alternative sectors that can accommodate this change and absorb the labor from the agriculture sector.

Besides, the coal also projected to still give an essential role in Indonesia in Indonesia. While there are mitigation actions in the energy sector, it will lead to the reduction of coal demand. The government may accommodate this domestic demand reduction by export more coal outside the country. However, what needs to be concerned here is, in this model, international prices are assumed to be the same in both the BAU and CM scenarios. In the future, the mitigation may not only do by Indonesia but also other country and may lead to a price drop on high-carbon energy sources like coal. In that case, coal will not profitable enough as export commodities, and even a developing country like Indonesia needs to design a scenario for new and renewable energies development.

The new and renewable energies development itself is still deficient in Indonesia, but the utilization is started to be improved, especially for the power generation. However, the utilization of renewable energies tends to less competitive compared to fossil fuel. In the case of power generation, this study predicted that the use of renewable energies for power generation increases significantly when the coal power plant already reaches its maximum capacity. The hydro, geothermal, and solar power plant is also projected to give a high contribution to the electricity generation, while there is slow growth for the biomass and waste power plant.

For future studies, the international price assumption also needs to be examined. This assumption will make a big implication, especially when it comes to the energy, the international price for high-carbon energy source may lower and the energy source like coal might be not profitable as the export goods.

6. Conclusion and Future Works

6.1. Conclusion

This study is trying to utilize the CGE model to examine the potential impact of GHG emission reduction for Indonesia. The study is divided into two main part: 1.) CGE for analyzing the emission mitigation for the LUCF and 2.) CGE for analyzing emission mitigation for all sectors.

The first part is focused more on Land Use Change and Forestry. This part was treated specifically because the emission calculation from the LUCF should consider the carbon stock difference between each land type.

Some important result from this simulation are:

1. For the economy, the CM_1 give the lowest GDP reduction compared to the BAU level (-0.7% in 2030) because it gives the lowest household consumption (only -1.1% in 2030 compared to the BAU). While in the introduction of conservation give lower reduction impact on GDP (-5.4% for CM_2 and -5.2% for CM_3 in 2030 compared to BAU level). The introduction of conservation increases the government consumption (0.88% and 0.89% for CM_2 and CM_3 respectively, in 2030, compared to BAU level). But that improvement cannot offset the significant drop in household consumption (-9% and -8.7% for CM_2 and CM_3 respectively, in 2030, compared to BAU level).
2. The intensification cannot be significantly slowed down the land-use change, especially the deforestation. The intensification only, as described in the CM_1 scenario, cannot reduce the expansion of commercial plantation, especially for the palm oil. This is the reason why the conservation is needed to be introduced in parallel with the intensification project. In other words, the intensification is helped to maintain the GDP, while the conservation is a help to maintain the forest area.
3. For this part, the CM_3 scenario (introducing the intensification and conservation together) is more recommended to be chosen by the Indonesia government.

The second part is trying to measure the potential impact of comprehensive emission mitigation policies for Indonesia by using the CGE model. There are also several findings that can be concluded from this part, namely:

1. The introduction of mitigation scenarios is predicted to create around 2.2% of GDP loss compared to BAU level by 2030 caused by lower household consumption and investment. Although there is an increase in government consumption, that improvement is not able to cover the loss of household consumption and investment.
2. the model also projected a significant fall of agricultural labor under the mitigation scenario. It can be an indication for the Indonesia government to prepare for the structural change and providing employment in the other sectors.
3. For the power generation, the use of renewable energy is predicted to increase significantly when the coal power generation already reaches its maximum capacity. This is because Indonesia has big potential for hydro and geothermal energy for the power generation.

Finally, there are several things that can be concluded while answering the research questions. The first and the most important conclusion in the GDP loss caused by the mitigation action is varied for around 2-5% regarding the how comprehensive the technologies are introduced. The more technologies and investment for the mitigation technologies are introduced, the lesser the GDP loss. In other words, Indonesia should consider implementing the mitigation technologies in all sectors rather than to do it partially to avoid higher GDP loss and to divide the mitigation burden to each sector although the technology in some sector is still not enough. In this study, for example, the mitigation from agriculture is assumed to be most established compared to other mitigation in energy, industry, waste, and LUCF. But introducing all the policies together still, give the lowest rate of GDP loss (~2%). This is significantly the lower compared to only introducing a partial mitigation policy. In the first part, the GDP loss is expected to be around ~5%. In the previous study, when the mitigation only introduced for the agricultural sector, the GDP loss is expected to reach ~3.5%. This brings very important message, as the Indonesia government tend to focus on establish the mitigation policies partially.

Moreover, aside from the GDP loss effect, the mitigation policies itself are found to hold essential roles for Indonesia, more specifically to encourage the utilization of renewable energies and maintain the forest and land sustainability in the future.

6.2. Discussion

The simulation the emission mitigation may create the GDP loss around 2-6% depending on the number of mitigation technologies that introduced. This value is considered very high for Indonesia; however, this number is caused by several reasons. 1.) The detail of the mitigation technologies; CGE itself is very sensitive with the parameter settings. Here, some technologies are simplified and aggregated. In the future, if the technologies are described one-by-one in detail, the more reasonable result might be achieved. 2.) The mitigation period introduced in this study is relatively short. The mitigation is assumed to be introduced in 2016, and 29% of emission reduction should be achieved in 2030. By only 15 years, Indonesia needs to achieve the target. To achieve this mitigation target, the demand needs to be reduced rapidly and, in the end, create higher GDP loss.

There are still several rooms for improvement. However, for this time, the research aims to deliver the messages that the government needs to implement the mitigation policies as soon as possible and involved all sectors in the economy and make sure to give attention to all sectors rather than only focus with one or two partial sectors, while it may create the emission reduction become more challenging to be achieved.

The first part of this study focuses on the mitigation action from the LUCF and tried to deliver the message that the intensification cannot effectively lower the deforestation rate, and it is hoped that the government will implement the conservation along with the intensification effort to maintain the forest and land sustainability. Moreover, the second part gives a more comprehensive insight that the mitigation may create several structural changes in the economy, especially for the employment trend. It was predicted that the agricultural labor will decrease significantly in the future and might be shifted to other sectors especially trade and other services. Also, the use of renewable energies for power generation will boost rapidly after the coal power plant achieve its maximum capacity.

6.4. Policy Implication

This study is assuming the market mechanism can perfectly move the people to follow the mitigation action. In reality, achieving the mitigation measures only by giving the regulation and by political force often not effective to change the behavior of the people. Therefore, the mitigation action will be better to be introduced through some incentive system. For example, in the case of Land Use Change and Forestry (LUCF), the mitigation can be introduced under the REDD (Reducing Emissions from Reforestation and degradation) fund scheme that usually available in developing countries. The farmers will be more motivated to manage the land is a sustainable way to get the access of the fund. In the end, the mitigation can be achieved.

Similar with the forestry, to encourage people to follow the mitigation actions, the specific financial incentive also can be introducing, for example shift the subsidy from fossil fuel to biofuel to make the people use more biofuel.

In conclusion, introducing the incentive scheme is easily understood by all the people instead directly mention the mitigation policies, especially in the case of developing country like Indonesia. By that way, the mitigation target will be easier to be achieved. Moreover, further monitoring system is needed to measure the progress and to make some adjustment or revision that can be added to the regulation.

In the case of Indonesia, the central government sometimes already prepare some budget along with the regulation to support the mitigation programs but are often hampered by discrepancies in regulation between central and local governments. Because Indonesia implements a decentralized government system, a good collaboration between the central and local governments is needed to realize a mitigation program. Also, control of the local government is also required relating to the regulation implementation.

6.4 Future Works

In the future, the model can be improved by making the model in part 1 (CGE-LUCF), and part 2 (all sector) are running simultaneously. One of the weaknesses of the model in part 2 of this study is the LUCF is simulated exogenously out from the model and the land endowment set to be fixed based on the scenario that implemented into the model. In case the model 1 and model 2 can be combined, there might be more insight that can be seen, for example, how much the national biomass potential, or how much the biofuel crops should be planted to meet the need for biofuel. This also leads to the potential for analysis of food and fuel because if there is an increase in the use of renewable energies, there is also a potential that the use of some form of renewable energy (e.g., biomass, biofuel), it will also affect the land use. Some farmers might prefer to convert their land more for the biofuel crops considering the possibility of a higher price in the future.

Further mitigation target also needs to be assessed in the future. In this study, the target is only the voluntary target. However, Indonesia plans to make a further reduction (41% from BAU level in 2030 by foreign help). By further reduction, Indonesia expects more foreign aid. However, the impact should be measured first to negotiate enough aid from the donors and to manage the national budget for the mitigation programs.

Moreover, the most challenging part of researching land use in Indonesia is the existence of the peat, as Indonesia is the house of the biggest peatland area in Asia. The emission accounting of the peatland also more complicated because it is including the emission from peat fire and peat decomposition. Some information based on geographical information system (GIS) may also be useful for giving more insight about the land use, e.g., potential area for the biomass power plant development, land use trend for the crops, or area that may experience high land conversion or deforestation. Other parts that can be improved in the future are:

1. With the more detail information of LUCF and GIS, the CGE simulation can be simulated simultaneously with the other sector. Other important crops and another land type (e.g., commercial building and/or industry) can also to be added on the simulation.
2. The comprehensive technology from each sector also still able to be improved. For example, in the case of waste treatment, the emission is coming both from solid and wastewater that have different treatment technologies with different emission potential. It will need more insight from another expert to give the technical details that more suitable to be introduced on the model.
3. The analysis in the energy sector also still have room to be expanded. For example, renewable energy still can be disaggregated into more detail along with its technical details and the cost for establishing the technology.
4. Related to the cost, in the future, the international price may need to be considered too. Especially when it comes energy, in the future, the demand for some products (e.g., high-carbon

product, or product from the unsustainable forest) might be reduced and will be hard to be sold in the international market.

5. The economic insight can be expanded, not only about GDP but other macroeconomic indicators and the impact between different income group; Because this study wants to examine the impact of mitigation to the economy, because there is a huge income happened in Indonesia, further analysis on how the impact of the mitigation to different income group will give another useful information.
6. CGE itself also very sensitive to any parameter change and adjustment. So, the sensitivity analysis may give further confirmation about how much the effect of the parameter change, and it may give another insight to the study.

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Appendix A

Table A1. Land Conversion Matrix- original

Land Conversion Matrix (Mha)		2011																					
		PF	SF	PM	PS	IF	SH	PL	HO	OL	SA	SM	SS	BU	DL	MD	RF	PO	AP	TR	MI	SW	TOTAL
	PF	38.71	1.12	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	39.88
	SF	0.01	37.34	0.00	0.00	0.03	0.84	0.20	0.00	0.30	0.00	0.00	0.00	0.00	0.04	0.33	0.00	0.00	0.00	0.00	0.02	0.00	39.13
	PM	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.16
	PS	0.00	0.00	0.00	3.25	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.41
	IF	0.00	0.01	0.00	0.00	3.66	0.08	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	3.92
	SH	0.00	0.02	0.00	0.00	0.08	13.10	0.33	0.00	0.10	0.01	0.00	0.00	0.00	0.07	1.05	0.01	0.00	0.00	0.00	0.04	0.00	14.80
	PL	0.00	0.00	0.00	0.00	0.02	0.02	7.03	0.00	0.04	0.00	0.00	0.00	0.00	0.03	0.04	0.02	0.00	0.00	0.00	0.00	0.00	7.19
	HO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	2.45
	OL	0.00	0.00	0.00	0.00	0.07	0.09	0.17	0.00	1.94	0.07	0.00	0.00	0.04	0.04	0.02	0.01	0.00	0.00	0.00	0.01	0.00	2.45
	SA	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.01	3.15	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	3.24
	SM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	1.01
	SS	0.00	0.00	0.00	0.00	0.01	0.00	0.14	0.00	0.07	0.00	0.00	2.94	0.22	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	3.40
	BU	0.00	0.00	0.00	0.00	0.01	0.13	0.10	0.00	0.04	0.05	0.01	0.00	5.05	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	5.41
	DL	0.00	0.00	0.00	0.00	0.02	0.01	0.08	0.01	0.02	0.00	0.00	0.00	0.00	8.21	0.11	0.40	0.00	0.00	0.00	0.00	0.00	8.85
	MD	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.03	0.07	0.00	0.00	0.00	0.00	1.32	23.61	0.06	0.00	0.00	0.00	0.03	0.00	25.43
	RF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.14	0.03	6.53	0.00	0.00	0.00	0.00	0.00	6.72
	PO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.00	0.00	0.77
	AP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32
2006	MI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.39
	SW	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	1.22
	TOT	38.72	38.50	1.11	3.25	3.89	14.50	8.23	2.49	2.68	3.28	1.02	3.09	5.35	9.91	25.25	7.05	0.79	0.01	0.32	0.52	1.20	171.17

Table A2. Land Conversion Matrix After the Adjustment

Land Conversion Matrix (Mha)		2010													
		PAD	COR	CAS	OAG	RUB	PAL	OPL	LIV	WOO	OFO	MIN	BUI	OTH	TOTAL
2009	PAD	6.88	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.92
	COR	0.01	2.61	0.04	0.31	0.04	0.07	0.05	0.00	0.03	0.01	0.00	0.00	0.00	3.16
	CAS	0.01	0.04	1.43	0.17	0.02	0.04	0.03	0.00	0.01	0.00	0.00	0.00	0.00	1.75
	OAG	0.06	0.31	0.17	13.55	0.17	0.34	0.23	0.00	0.13	0.03	0.00	0.00	0.02	15.01
	RUB	0.00	0.04	0.02	0.19	3.84	0.27	0.18	0.00	0.04	0.01	0.00	0.00	0.01	4.60
	PAL	0.00	0.08	0.04	0.38	0.27	8.03	0.36	0.00	0.09	0.02	0.00	0.00	0.02	9.29
	OPL	0.00	0.05	0.03	0.25	0.18	0.36	5.19	0.00	0.06	0.01	0.00	0.00	0.01	6.15
	LIV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	0.00	0.00	0.00	0.00	0.01	3.27
	WOO	0.00	0.03	0.02	0.15	0.05	0.09	0.06	0.00	5.58	0.01	0.00	0.00	0.04	6.03
	OFO	0.00	0.01	0.01	0.06	0.04	0.07	0.05	0.00	0.02	87.78	0.01	0.00	0.30	88.35
	MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.36
	BUI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.28	0.00	3.29
	OTH	0.00	0.02	0.01	0.08	0.05	0.10	0.07	0.03	0.05	0.01	0.01	0.16	22.30	22.89
	TOTAL	6.99	3.19	1.76	15.16	4.65	9.38	6.21	3.27	6.02	87.89	0.38	3.45	22.71	171.17

Table A3. Land Sector Aggregation

No	Code	sector	Aggregated Sectors
1	PAD	Paddy	Rice field
2	COR	Corn	Dry Land*, Mixed Dry*
3	CAS	Cassava	Dry Land*, Mixed Dry*
4	OAG	Other Agriculture	Dry Land*, Mixed Dry*
5	RUB	Rubber	Plantation*, Mixed Dry*
6	PAL	Palm Oil	Plantation*, Mixed Dry*
7	OPL	Other Plantation	Plantation*, Mixed Dry*
8	LIV	Livestock	Savanna
9	WOO	Wood	Industrial forest
10	OFO	Other Forest	Primary forest, secondary forest, primary shrubs, shrubs, secondary mangrove, secondary shrub, bushes, SW
11	MIN	Mining	Mining
12	BUI	Building	Settlement, Ponds, Airport, transmigration
13	OTH	Other	Open Land

*) decided based on output proportion on IO table.

Table A4. Carbon Stock (tC/ ha)

No.	Before Adjustment		No.	After adjustment	
1	Primary forest	132.99	1	Paddy	2.0
2	Secondary forest	98.84	2	Corn	19.8
3	Primary Mangrove	188.3	3	Cassava	19.8
4	Primary Swamp Forest	96.35	4	Other-Agriculture	19.8
5	Industrial Forest	98.38	5	Rubber	41.9
6	shrubs	30	6	Palm Oil	41.9
7	Plantation	63	7	Other-Plantation	41.9
8	building	4	8	Livestock	4.0
9	Open Land	2.5	9	Wood	73.7
10	Savanna	4	10	Other-Forest	112.5
11	Secondary Mangrove Forest	94.07	11	Mining*	0.0
12	Secondary Swamp Forest	79.67	12	Building*	0.0
13	Bushes	30	13	other land**	2.9
14	Dry Land Agriculture	10			
15	Mixed Dry Land Agriculture	30			
16	Rice fields	2			
17	Ponds	0			
18	Airport/ port	0			
19	transmigration	10			
20	Mining	0			
21	Swamp	0			

*) not considered in the model due to the small portion of area compared to the other land type
**) the emission from other land is considered inside the model. But not considered during the economic calculation

Figure A1. Agricultural Land Area under All Scenario

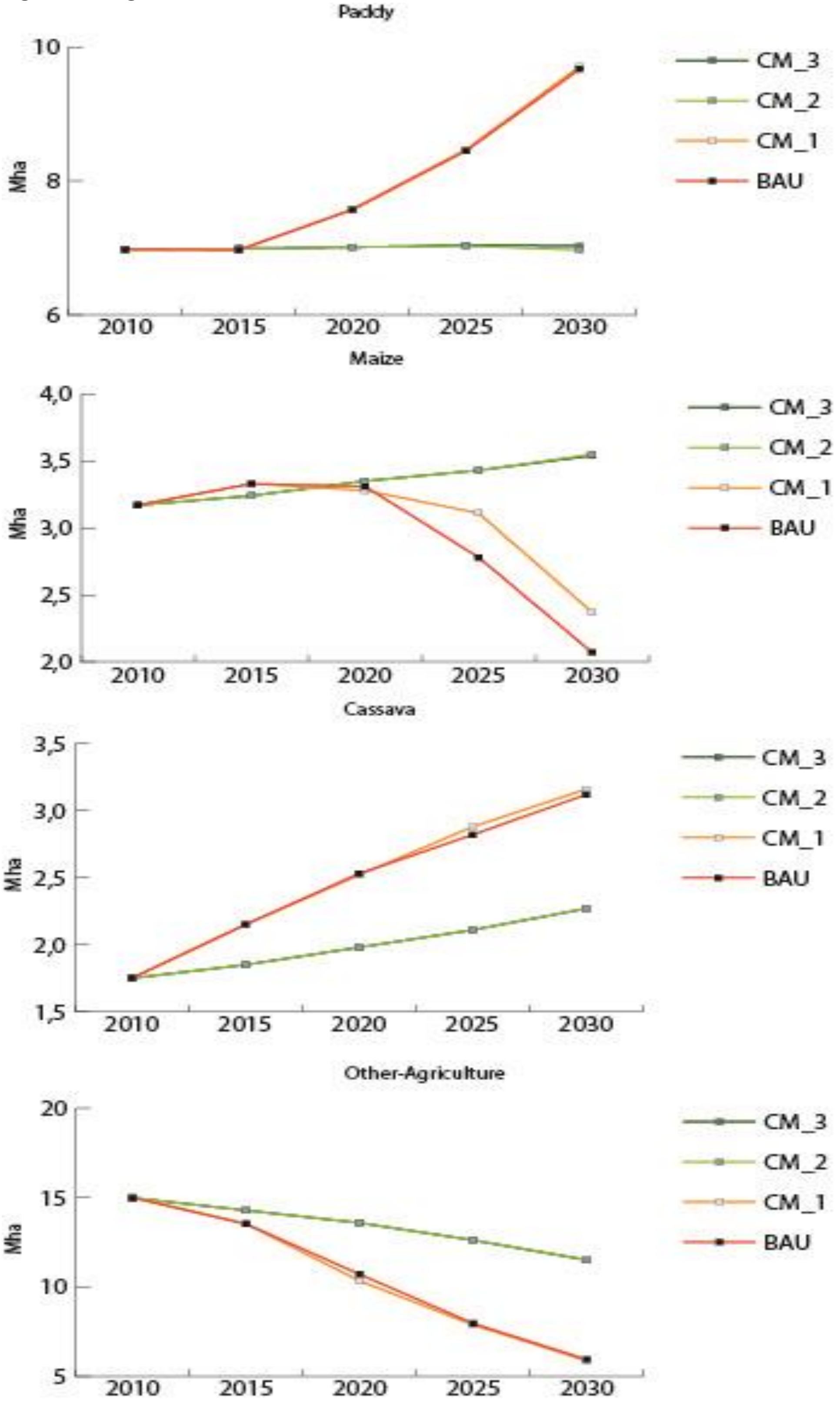
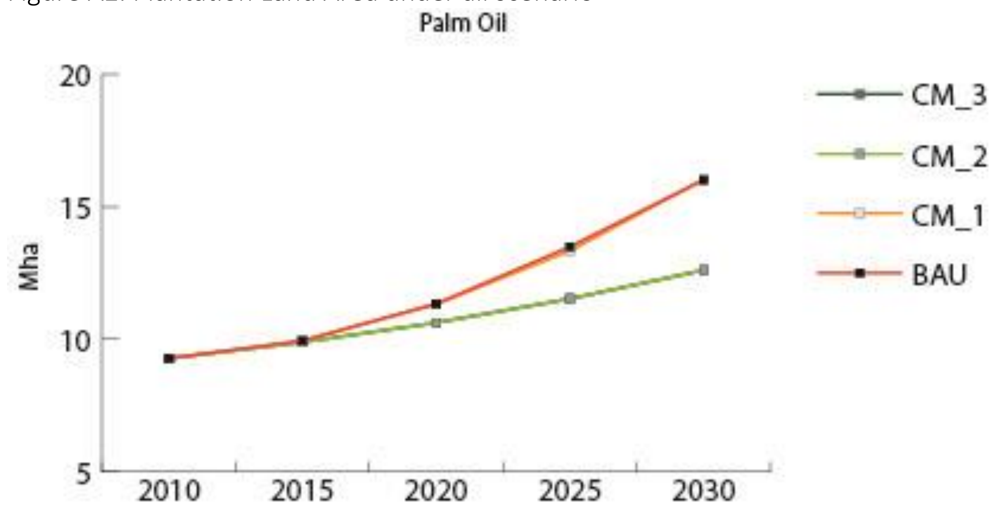
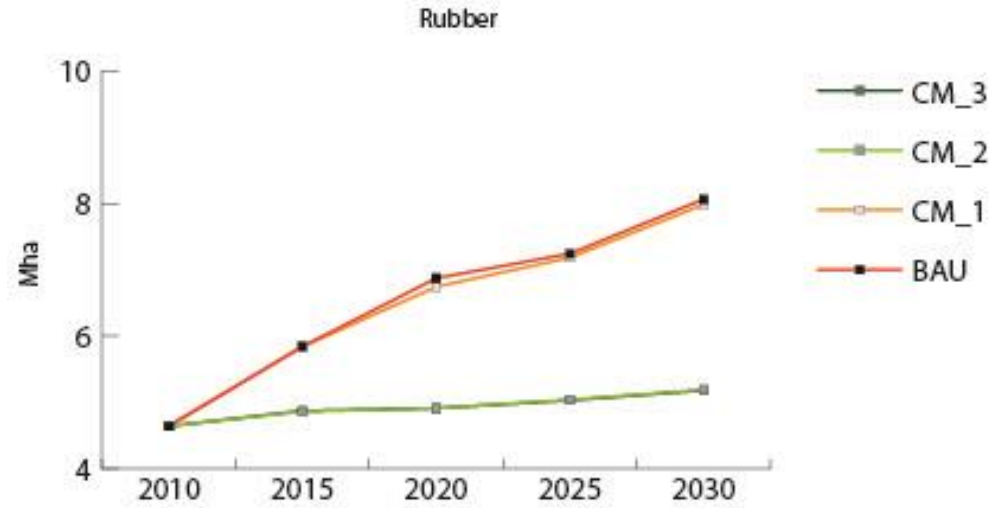


Figure A2. Plantation Land Area under all scenario





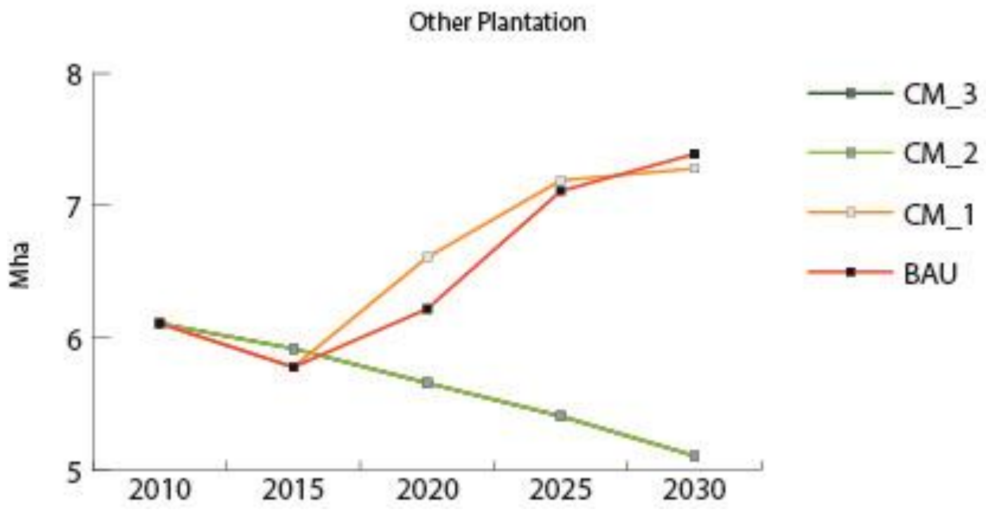
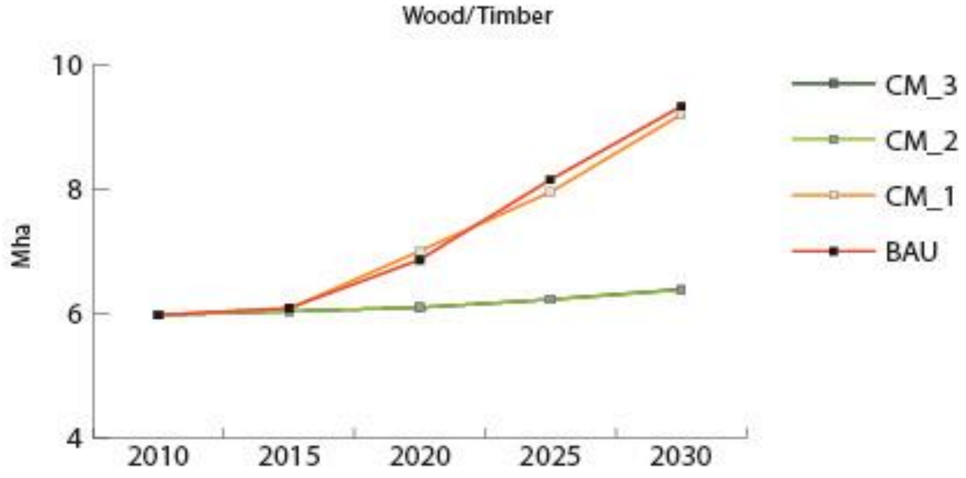
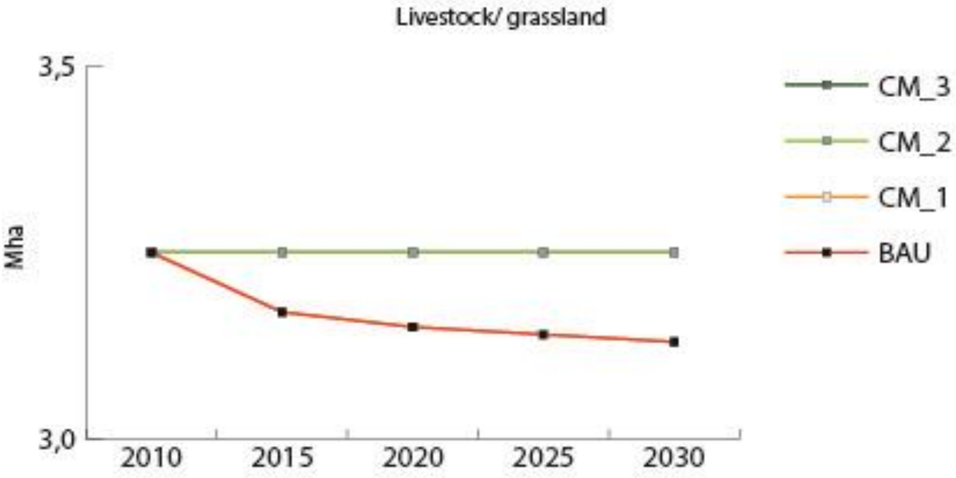
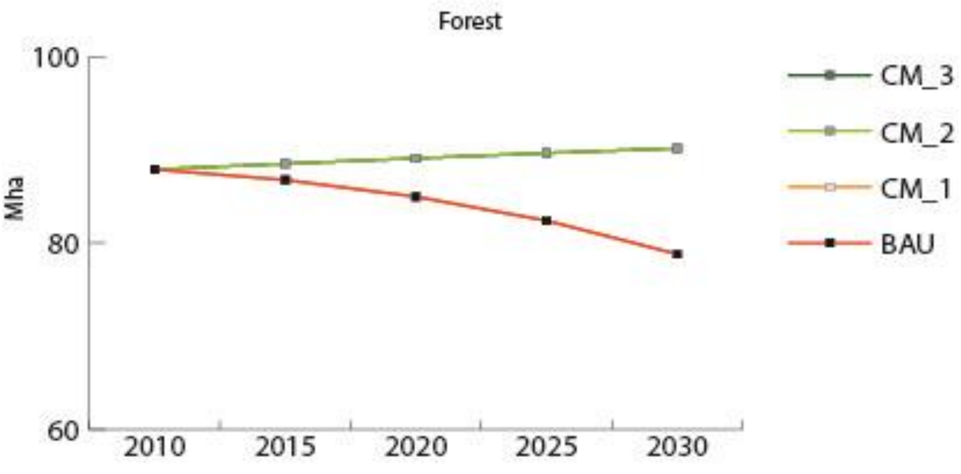


Figure A3. Timber plantation, Livestock/Grassland, and Forest Area under each Scenario

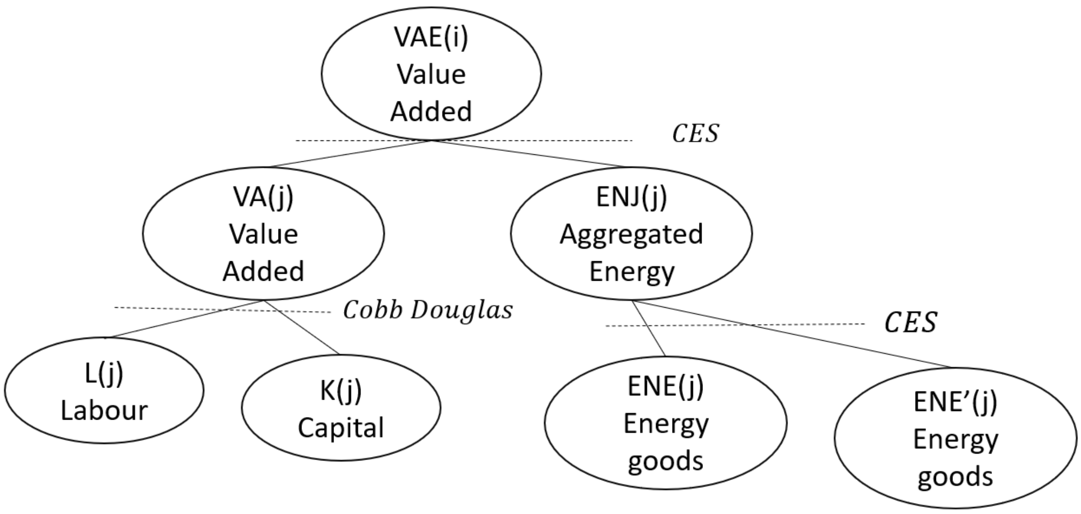






APPENDIX B. Detail of Parameter Value

a. Value Added



$$\sigma_{VAE(j)} = 0.7$$
$$al_{VAE(j)} = \frac{1 - \sigma_{VAE(j)}}{\sigma_{VAE(j)}}$$
$$s_{VAE(j)} = \frac{VAE(j)}{q(j)}$$
$$s_{VA(j)} = \frac{VA(j)^{al_{VAE(j)}}}{\left(VA(j)^{1+al_{VAE(j)}}\right) + \left(ene(j)^{1+al_{VAE(j)}}\right)}$$

$$s_{ene(j)} = \frac{ene(j)^{1+al_{VAE(j)}}}{VA(j)^{1+al_{VAE(j)}} + ENE(j)^{1+al_{VAE(j)}}}$$

$$a_{VAE(j)} = \frac{VAE(j)}{\left(\left(s_{va(j)} \cdot VA(j)^{-al}_{VAE(j)}\right) + \left(\left(s_{ene(j)} \cdot ene(j)\right)^{-al}_{VAE(j)}\right)\right)^{-\frac{1}{al_{VAE(j)}}}}$$

$$\sigma VA = 0$$
$$s_{K(j)} = \frac{K(j)}{VA(j)}$$
$$s_{L(j)} = \frac{L(j)}{VA(j)}$$
$$a_{VA(j)} = \frac{VA(j)}{\left(qK(j)^{s}_{k(j)}\right) \cdot \left(qL(j)^{s}_{l(j)}\right)}$$

$$el_{ENE} = 0.3$$

$$al_{ENE(j)} = \frac{1 - el_{ENE(j)}}{el_{ENE(j)}}$$

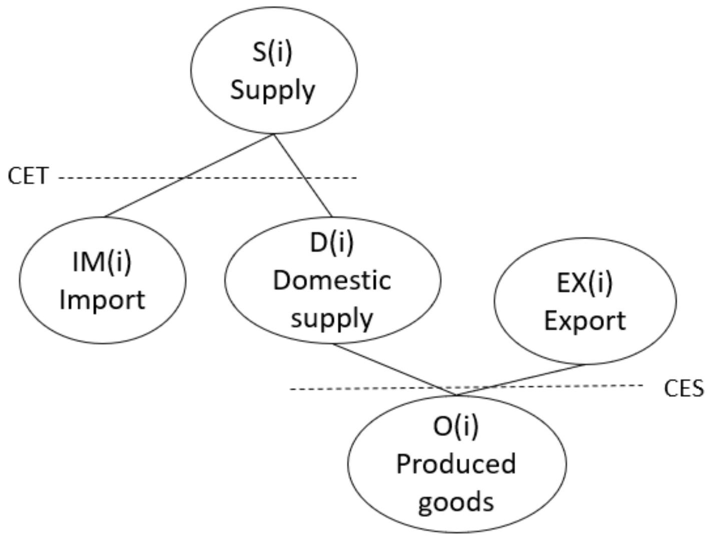
$$s_{ENE(ENJ,j)} = \frac{ENE(EN,j)^{\left(1+al_{e(j)}\right)}}{\sum_{en'} ENE(en',j)^{(1+al_{ene(j)})}}$$

$$a_{ENJ(i)} = \frac{ENJ(j)}{\sum_{ENJ}\left(ENE(en,j)\right)} \; ; \left(\left(s_{ene(enj,j)} \cdot ENE(en,j)\right)^{al}_{ene(j)}\right)^{-\frac{1}{al_{ene(j)}}}$$

Where:

$\sigma_{VAE(j)}$	: Elasticity of substitution between energy aggregation and value added
$\sigma_{VA(j)}$	: Elasticity of substitution between Capital and Labour
$al_{VAE(j)}$	: Substitution parameter between energy aggregation and value added
$s_{va(j)}$	: Value added share in value added
$a_{VAE(j)}$	: Adjustment parameter of value added and energy
$s_{K(j)}$	: Capital share in value added
$s_{L(j)}$	: Labor share in value added
$a_{VA(j)}$	: Adjustment parameter of value added
$\sigma_{ENE(j)}$	: Elasticity of substitution among energies
$al_{ene(j)}$	: Substitution parameter among energies
$s_{ene(enj,j)}$	: Energy share in energy aggregation
$a_{ENJ(i)}$	: Adjustment parameter of energy aggregation

b. International Trade



$$\sigma_{EX(i)} = 2;$$

$$al_{EX} = \frac{1 + \sigma_{EX(i)}}{\sigma_{EX(i)}}$$

$$s_{ex(i)} = \frac{ex(i)^{1-al_{ex(i)}}}{d(i)^{(1-al_{ex(i)})} + EX(i)^{1-al_{ex(i)}}}$$

$$s_{xd(i)} = \frac{d(i)^{1-al_{ex(i)}}}{d(i)^{1-al_{ex(i)}} + EX(j)^{1-al_{EX(j)}}}$$

$$a_{EX} = \frac{O(i)}{\left(s_{EX(i)} \cdot EX(i)^{al_{EX(i)}} + s_{XD(i)} \cdot d(j)^{al_{EX(i)}}\right)^{\frac{1}{al_{EX(i)}}}}$$

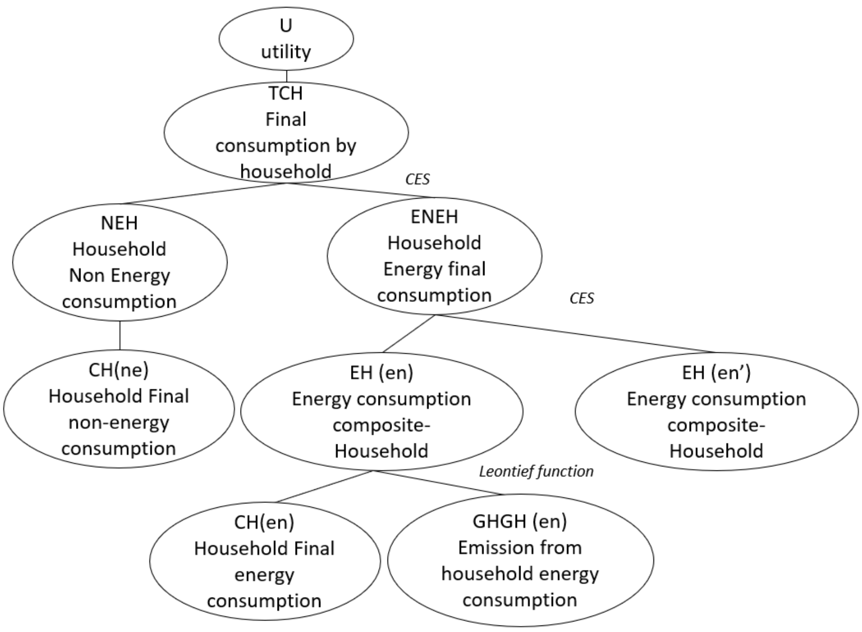
$$\sigma IM(i) = 2$$

$$al_{IM(i)} = \frac{1 - \sigma IM(i)}{\sigma IM(i)}$$
$$s_{im(i)} = \left(1 + tx_{m(i)}\right) \cdot qIM(i)^{1+al_{im(i)}} / \left(\left(1 + tx_{o(i)}\right) \cdot d(i)^{1+al_{im(i)}} + \left(1 + tx_{m(i)} \cdot qIM(j)^{1+al_{im(i)}}\right)\right.$$
$$s_{md(i)} = \left(1 + tx_{o(i)}\right) \cdot \frac{d(i)^{1+al_{im(i)}}}{\left(1 + tx_{o(i)}\right) \cdot d(i)^{1+al_{im(i)}} + \left(1 + tx_{m(i)}\right) \cdot qIM(i)^{1+al_{im(i)}}}$$
$$a_{im(i)} = \frac{s(i)}{\left(s_{MD(i)} \cdot d(i)^{-al_{IM(i)}} + s_{IM(i)} \cdot qIM(i)^{-al_{im(i)}}\right)^{-\frac{1}{al_{IM(i)}}}}$$

Where:

$\sigma_{EX(i)}$	: elasticity of transformation between export and domestic use
$\sigma_{IM(i)}$	: elasticity of substitution between import and domestic use
al_{EX}	: substitution parameter between export and domestic use
$s_{ex(i)}$	: share of export to total products of goods i
$s_{xd(i)}$	: share of domestic goods to total products of goods i
a_{EX}	: adjustment of export and domestic use
$al_{IM(i)}$	: substitution parameter between import and domestic use
$s_{im(i)}$	: share parameters of import to total domestic supply of goods i
$s_{md(i)}$	: share parameters of domestic goods to total domestic supply of goods I
$a_{im(i)}$	: adjustment of import and domestic use
d(i)	: total supply
qIM	: Import quantity
$tx_{m(i)}$	: import tax rate
$tx_{o(i)}$	: output tax rate

c. Household and Government



$$a_{NEH} = \frac{NEH}{\prod_{ne} CH(ne)^{s}_{CH(ne)}}$$

$$s_{CH(ne)} = \frac{CH(ne)}{\sum_{ne'} CH(ne')}$$

$$a_{ENEH} = \frac{ENEH}{\left(\sum_{en} s_{EH(en)} \cdot CH(en)^{-al_{ENEH}}\right)^{-\frac{1}{al_{ENEH}}}}$$

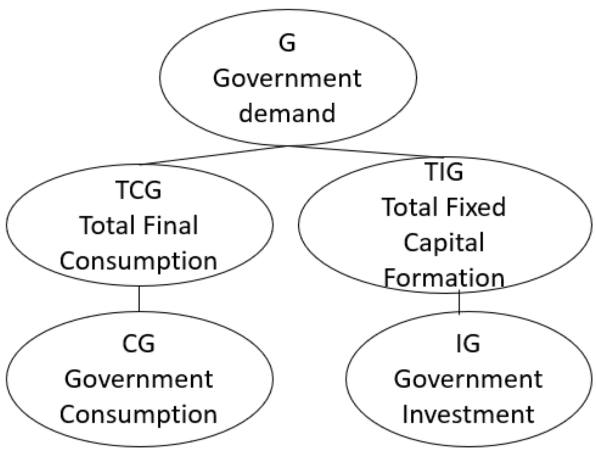
$$s_{EH(en)} = \frac{CH(en)^{1+al_{ENEH}}}{\sum_{en'} CH(en')^{1+al_{ENEH}}}$$

$$al_{eneh} = \frac{1 - el_{ENEH}}{el_{ENEH}}$$

$$\sigma_{eneh} = 0.5$$

Where:

$s_{CH(ne)}$	:	share of non-energy final consumption goods i to total non-energy final consumption
a_{ENEH}	:	adjustment of total energy final consumption
$s_{EH(en)}$	:	share of energy final consumption to total energy final consumption
ρ_{ENEH}	:	substitution parameter among energies in household



$$s_{TCG} = \frac{TCG}{TCG + TIG}$$

$$s_{TIG} = \frac{TIG}{TCG + TIG}$$

$$a_g = \frac{g}{(TCG^{s}_{TCG}) \cdot (TIG^{s}_{TIG})}$$

$$s_{CG(i)} = \frac{CG}{\sum_{ii} CG(ii)}$$

$$a_{TCG} = \frac{TCG}{\prod_i CG(i)^s_{CG(i)}}$$

$$s_{IG(i)} = \frac{IG(i)}{\sum_{ii} IG(ii)}$$

Where:

s_{TCG} : share of final consumption (government)
s_{TIG} : share of investment (government)
a_g : adjustment of government utility
$s_{CG(i)}$: share of final consumption goods i to total final consumption in government
a_{TCG} : adjustment of total final consumption in government
$s_{IG(i)}$: share of investment formation to total investment in government

APPENDIX C

Table C1. Aggregated Input-Output Table (Billion IDR)

Sector	*Code*	*Paddy*	*Corn*	*Cassava*	*other agriculture*	*Rubber*	*Palm oil*	*Other Plantation*	*Livestock*	*wood*	*other forest*
		01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*
Paddy	01	14186	0	0	0	0	0	0	8	0	0
Corn	02	0	3414	0	0	0	0	0	101	0	0
Cassava	03	0	0	963	0	0	0	0	35	0	0
other agriculture	04	0	0	54	5626	0	0	0	26	0	0
Rubber	05	0	0	0	0	1970	0	0	0	0	0
Palm oil	06	0	0	0	0	0	3089	0	0	0	0
Other Plantation	07	0	0	0	0	0	0	3508	285	0	0
Livestock	08	118	20	12	489	37	73	60	821	1	0
wood	09	0	0	0	2	1	0	1	0	1	0
other forest	10	0	0	0	2	0	21	0	0	0	1
Marine and fishery	11	0	0	0	0	0	0	0	22	0	0
Coal mining	12	0	0	0	0	0	0	0	0	0	0
Crude oil mining	13	0	0	0	0	0	0	0	0	0	0
Natural gas mining	14	0	0	0	0	0	0	0	0	0	0
Other mining	15	0	0	0	2	0	0	0	0	0	0
Food, beverage and tobacco	16	1	0	0	1	181	204	233	41163	20	5
Textile, foot and leather	17	167	26	21	319	222	93	93	3	69	17
Processed wood products	18	1	0	8	95	31	2	31	3	2	1
Pulp and Paper Products, and print	19	23	5	5	120	20	40	33	5	12	3
Petroleum refineries	20	46	8	6	156	455	935	718	87	1171	293
Chemical industry	21	214	39	22	74	419	845	624	566	37	9
fertilizer and pesticide	22	7326	1490	1357	9119	1420	2615	3985	0	2	0

Table C1. (Continued)

Sector	*Code*	*Paddy*	*Corn*	*Cassava*	*other agriculture*	*Rubber*	*Palm oil*	*Other Plantation*	*Livestock*	*wood*	*other forest*
		01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*
Non-metal industry	23	119	1	1	81	185	330	221	25	21	5
Cement	24	0	0	0	0	0	0	0	0	0	0
Iron and steel	25	0	0	0	0	0	0	0	0	0	0
metal based industry	26	297	48	44	150	126	241	237	23	44	11
other industry	27	728	114	64	435	402	658	626	49	670	163
Electricity (only commodity)	28	15	3	2	46	13	27	27	40	75	18
Gas (Town gas)	29	0	0	0	0	0	0	0	0	0	0
Water supply	30	4	1	0	2	2	3	3	41	1	0
Waste and recycling services	31	0	0	0	0	0	0	0	0	0	0
building and construction	32	2797	796	941	1435	1616	8703	2204	177	2548	626
Transportation	33	142	27	15	139	85	170	166	19	236	60
Trade, hotel, restaurant	34	1871	608	368	2455	593	1070	1394	8751	240	66
amusement and telecommunication	35	4	1	0	27	17	34	30	1	192	47
Financial Services	36	521	94	69	575	1498	5298	1969	279	329	81
Public services-Gove	37a	0	0	0	0	107	1279	214	1	0	0
Public services-private	37b	0	0	0	0	0	0	0	1	0	0
Other Services	38	4348	957	1134	1597	1528	9957	3239	403	1793	478
Capital	VA1	146030	29317	15428	110193	37157	68117	72671	72017	34919	8545
Labor	VA2	38872	5615	2978	23039	22832	38965	25457	41783	10545	2581
Indirect tax	VA3	-5073	-1080	-750	-4797	-32	-22	-1160	974	600	135
Subsidy	VA4	0	0	0	0	0	0	0	0	0	0
adjustment	adj	0	0	0	0	0	0	0	0	0	0

Table C1. (Continued.)

Sector	*Code*	*Marine and fishery* 11	*Coal mining* 12	*Crude oil mining* 13	*Natural gas mining* 14	*Other mining* 15	*Food, beverage and tobacco* 16	*Textile, foot and leather* 17	*Processed wood products* 18	*Pulp and Paper Products, and print* 19	*Petroleum refineries* 20
Paddy	01	103	0	0	0	0	187777	0	0	0	0
Corn	02	98	0	0	0	0	24654	0	0	0	0
Cassava	03	13	0	0	0	0	5852	0	0	0	0
other agriculture	04	0	0	0	0	0	42852	0	0	0	0
Rubber	05	0	0	0	0	0	0	388	1	0	0
Palm oil	06	0	0	0	0	0	94913	0	0	0	0
Other Plantation	07	0	0	0	0	0	60615	8977	1206	0	0
Livestock	08	1	0	0	0	0	40388	1286	0	0	0
wood	09	4	41	0	0	17	420	13	20485	4350	84
other forest	10	17	0	0	0	0	174	585	5162	924	0
Marine and fishery	11	2915	0	0	0	0	37887	0	0	0	0
Coal mining	12	0	4449	10	2	35	1	24	0	0	1320
Crude oil mining	13	0	0	16333	13900	0	0	0	0	0	153582
Natural gas mining	14	0	0	15722	14647	0	0	0	0	0	76854
Other mining	15	0	15306	7583	2124	9557	1026	34	25	0	45
Food, beverage and tobacco	16	7331	230	393	158	366	229608	3834	523	369	561
Textile, foot and leather	17	71	261	172	20	102	323	80505	293	310	3
Processed wood products	18	10	0	0	0	35	66	11	15608	14	19
Pulp and Paper Products, and print	19	5	156	1180	160	145	5471	628	108	64796	15
Petroleum refineries	20	5414	4550	1946	150	8855	3879	3819	1967	4965	8655
Chemical industry	21	66	1307	134	37	8643	5574	8612	4181	10297	482
fertilizer and pesticide	22	63	1	0	0	12	52	1	0	3	0
non-mental ind	23	56	33	36	16	432	568	16329	2921	2784	705
Cement	24	0	0	0	0	0	0	0	25	0	1

Table C1. (Continued.)

Sector	*Code*	*Marine and fishery*	*Coal mining*	*Crude oil mining*	*Natural gas mining*	*Other mining*	*Food, beverage and tobacco*	*Textile, foot and leather*	*Processed wood products*	*Pulp and Paper Products, and print*	*Petroleum refineries*
		11	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
Iron and steel	25	0	0	0	0	0	0	5	48	34	0
metal based industry	26	23	1	6	0	179	904	886	803	1498	410
other industry	27	905	6430	2509	348	10239	4133	3815	1916	3962	4366
Electricity (only commodity)	28	147	164	899	92	119	2233	2915	570	2361	1155
Gas (Town gas)	29	0	0	0	0	6	1305	1374	498	713	186
Water supply	30	23	29	334	12	40	607	406	52	399	28
Waste and recycling services	31	0	0	77	3	0	5	3	0	2	0
building and construction	32	371	5195	7383	1611	9714	3106	1732	278	1612	1896
Transportation	33	91	6675	3616	782	8006	4559	3161	1668	12327	3851
Trade, hotel, restaurant	34	3198	1003	1087	82	2066	100626	14829	14707	4858	886
amusement and telecommunication	35	1	428	1037	102	1027	8845	4382	1145	2894	2846
Financial Services	36	801	2815	8142	1521	2489	8269	4706	1525	5362	1445
Public services-Gove	37a	0	748	2368	284	95	931	355	0	614	848
Public services-private	37b	5	9658	5269	1953	1407	318	347	25	1534	385
Other Services	38	4786	3278	2307	748	4426	4653	2489	1172	1790	4426
Capital	VA1	115517	132122	151748	130017	156346	301277	77356	41140	45335	167057
Labor	VA2	28851	22484	18280	13596	59370	124115	37647	14815	20984	59955
Indirect tax	VA3	171	2477	2110	1401	3300	11474	2495	649	2652	2379
Subsidy	VA4	0	0	0	0	0	0	0	0	0	0
Adjustment	adj	0	0	0	0	0	0	0	0	0	0

Table C1. (Continued)

Sector	*Code*	*Chemical industry*	*fertilizer and pesticide*	*non-mental industry*	*Cement*	*Iron and steel*	*metal based industry*	*other industry*	*e_coal*	*e_oil*	*e_gas*	*e_r**	*e_b***
		21	*22*	*23*	*24*	*25*	*26*	*27*	*28a*	*28b*	*28c*	*28d*	*28e*
Paddy	01	1124	0	282	0	0	0	0	0	0	0	0	0
Corn	02	0	0	0	0	0	0	0	0	0	0	0	0
Cassava	03	0	0	0	0	0	0	0	0	0	0	0	0
other agriculture	04	565	0	113	64	0	1	81	0	0	0	0	0
Rubber	05	425	81	58348	0	0	26	250	0	0	0	0	0
Palm oil	06	6603	0	1209	0	0	0	0	0	0	0	0	0
Other Plantation	07	2236	37	334	0	0	14	269	0	0	0	0	0
Livestock	08	4	0	18	0	0	0	60	0	0	0	0	0
wood	09	112	0	470	0	0	7	498	0	0	0	0	0
other forest	10	597	24	289	0	0	7	279	0	0	0	0	0
Marine and fishery	11	34	0	17	0	0	0	111	0	0	0	0	0
Coal mining	12	37	7	10636	7321	680	3220	594	13262	0	0	0	0
Crude oil mining	13	27301	4153	7984	0	0	0	0	0	62	0	0	0
Natural gas mining	14	9170	0	3387	0	4928	9164	146	0	0	17066	0	0
Other mining	15	7394	1557	16426	7404	27387	45675	1186	0	0	0	0	0
Food, beverage and tobacco	16	3626	316	1640	76	172	266	953	47	13	38	18	0
Textile, foot and leather	17	512	15	1035	54	22	679	2878	61	17	49	24	0
Processed wood products	18	108	30	6231	15	3	157	9331	0	0	0	0	0
Pulp and Paper Products, and print	19	513	21	1020	201	112	184	3180	13	3	10	5	0
Petroleum refineries	20	4447	693	10264	1746	1996	3388	4785	0	34710	0	0	0
Chemical industry	21	54671	4279	34763	3794	7230	15268	10022	90	25	73	35	0
fertilizer and pesticide	22	261	67	95	10	0	6	20	0	0	0	0	0

Table C1. (Continued)

Sector	*Code*	*Chemical industry*	*fertilizer and pesticide*	*non-mental industry*	*Cement*	*Iron and steel*	*metal based industry*	*other industry*	*e_coal*	*e_oil*	*e_gas*	*e_r**	*e_b***
		21	*22*	*23*	*24*	*25*	*26*	*27*	*28a*	*28b*	*28c*	*28d*	*28e*
Non-metal ind	23	4193	305	96329	4320	703	2798	30767	20	2	7	3	0
Cement	24	7	1	1555	1061	2	42	77	0	0	0	0	0
Iron and steel	25	93	81	4619	0	12925	42853	6449	0	0	0	0	0
metal based industry	26	63	13	5518	564	2127	17011	12361	70	19	56	27	0
other industry	27	2769	310	5183	1453	2722	10859	251074	1584	440	1281	620	2
Electricity (only commodity)	28	678	182	3556	763	745	2333	5773	56011	15547	45309	21932	78
Gas (Town gas)	29	661	237	3466	1075	947	2890	3905	0	0	4435	0	0
Water supply	30	157	4	597	191	2566	3358	485	61	17	49	24	0
Waste and recycling services	31	74	0	36	10	10	38	34	0	0	0	0	0
building and construction	32	855	96	3733	1956	1349	1564	2319	50	14	40	20	0
Transportation	33	2381	165	10145	2328	2247	5102	12821	1304	362	1055	511	2
Trade, hotel, restaurant	34	10500	978	21606	2824	1873	7686	81098	857	238	694	336	1
amusement and telecommunication	35	3774	265	3473	586	511	1393	9217	676	188	547	265	1
Financial Services	36	2436	265	5776	502	899	1988	7543	849	236	687	332	1
Public services-Gove	37a	456	72	1125	0	3	8	987	57	16	46	22	0
Public services-private	37b	368	20	2639	345	495	740	1475	283	79	229	111	0
Other Services	38	3366	247	3714	559	523	1473	8529	997	277	807	390	1
Capital	VA1	50517	5586	106865	12053	22860	58039	178896	18208	4332	8538	12864	34
Labor	VA2	25937	3442	58232	6256	5710	20878	94908	5816	1614	4705	2277	8
Indirect tax	VA3	4623	452	5482	644	1215	4542	17697	291	81	235	114	0
Subsidy	VA4	0	0	0	0	0	0	0	0	0	0	0	0
Adjustment	adj	0	0	0	0	0	0	0	14304	-26395	6998	5064	29

Table C1. (Continued)

Sector	*Code*	*Gas (Town gas)*	*Water supply*	*Waste and recycling services*	*building and construction*	*Transportation*	*Trade, hotel, restaurant*	*Amusement and telecommunication*	*Financial Services*
		29	*30*	*31*	*32*	*33*	*34*	*35*	*36*
Paddy	01	0	0	0	0	0	35	29	0
Corn	02	0	0	0	68	0	751	0	0
Cassava	03	0	0	0	21	0	3434	0	0
other agriculture	04	0	0	0	3690	443	22146	121	37
Rubber	05	0	0	0	0	0	0	0	0
Palm oil	06	0	0	0	0	0	0	0	0
Other Plantation	07	0	0	0	5	0	2054	12	0
Livestock	08	0	0	0	1124	0	9846	3	0
wood	09	0	0	0	23917	0	56	0	0
other forest	10	0	0	0	4183	0	64	0	0
Marine and fishery	11	0	0	0	941	0	19970	0	0
Coal mining	12	733	0	0	6	4	0	0	0
Crude oil mining	13	7	0	0	28	87	0	0	0
Natural gas mining	14	6607	0	0	0	0	0	0	0
Other mining	15	0	0	0	69206	0	110	3	0
Food, beverage and tobacco	16	77	46	0	10909	6266	104445	613	1086
Textile, foot and leather	17	4	2	0	3066	163	4204	85	83
Processed wood products	18	0	0	0	74735	13	2926	9	0
Pulp and Paper Products, and print	19	2	2	0	4385	144	23997	728	5255
Petroleum refineries	20	1768	56	1	79602	145943	79377	1065	227
Chemical industry	21	6	1096	48	29703	562	3901	138	660
fertilizer and pesticide	22	0	0	0	47	7	24	2	0

Table C1. (Continued))

Sector	*Code*	*Gas (Town gas)*	*Water supply*	*Waste and recycling services*	*building and construction*	*Transportation*	*Trade, hotel, restaurant*	*Amusement and telecommunication*	*Financial Services*
		29	*30*	*31*	*32*	*33*	*34*	*35*	*36*
non-metal ind	23	2	10	0	184109	8542	20203	191	2252
Cement	24	0	0	0	54285	0	0	0	0
Iron and steel	25	0	0	0	81454	0	0	0	0
metal based industry	26	0	16	0	181626	829	9669	467	2734
other industry	27	283	450	7	47752	32214	22365	14900	3229
Electricity (only commodity)	28	19	514	7	2923	1724	15952	2375	1657
Gas (Town gas)	29	83	2	0	1461	722	148	124	16
Water supply	30	1	760	28	510	277	1884	89	33
Waste and recycling services	31	0	0	0	3	2	58	1	0
building and construction	32	433	50	42	34784	9678	50937	10453	4834
Transportation	33	262	335	2	58151	36731	37959	6231	1633
Trade, hotel, restaurant	34	107	64	4	148241	17407	70173	3998	4356
amusement and telecommunication	35	29	38	1	16228	8626	28464	61900	15364
Financial Services	36	250	86	1	22200	9337	54365	6753	26783
Public services-Gove	37a	2	213	0	8409	2271	1042	9562	2889
Public services-private	37b	116	15	1	23798	2821	16407	6227	7379
Other Services	38	168	175	3	11033	25489	28892	11814	10514
Capital	VA1	9588	17211	0	559756	151052	687963	177565	165968
Labor	VA2	3912	2333	80	257144	83705	295431	66793	73711
Indirect tax	VA3	120	109	2	27086	-7420	1665	2770	2355
Subsidy	VA4	0	0	0	0	0	0	0	0
Adjustment	adj	0	0	0	0	0	0	0	0

Table C1. (Continued)

Sector	Code	Public services-Gove *37a*	Public services-private *37b*	Other Services *38*	Final consumption *FD1*	Government consumption *FD2*	Private fixed capital formation *FD3*	Public fixed capital formation *FD4*	Export *FD5*
Paddy	01	4	0	8	0	0	0	0	0
Corn	02	124	59	6	14741	0	0	0	86
Cassava	03	63	18	0	11809	0	0	0	223
other agriculture	04	5502	2665	0	82158	0	19800	0	771
Rubber	05	0	0	0	0	0	8824	0	262
Palm oil	06	0	0	0	0	0	34418	0	0
Other Plantation	07	45	147	0	6010	0	23237	0	20214
Livestock	08	634	699	52	85591	0	20091	0	1749
wood	09	0	2	21	1638	0	0	0	5
other forest	10	0	0	9	84	0	0	0	782
Marine and fishery	11	463	360	20	95740	0	980	0	7809
Coal mining	12	0	189	1	0	0	0	0	177130
Crude oil mining	13	0	112	38	0	0	0	0	101181
Natural gas mining	14	0	0	0	0	0	0	0	26074
Other mining	15	0	1159	3	0	0	8245	0	74818
Food, beverage and tobacco	16	12696	6451	1138	784242	13342	0	0	163585
Textile, foot and leather	17	2925	524	1982	112028	0	1444	0	117244
Processed wood products	18	245	50	361	5017	0	0	0	20406
Pulp and Paper Products, and print	19	37399	6591	17039	6419	0	1	0	41434
Petroleum refineries	20	9569	1508	10734	110828	0	0	0	124152
Chemical industry	21	15695	12408	6497	57801	0	0	0	51695
fertilizer and pesticide	22	267	25	211	634	0	0	0	5445
non-mental ind	23	5911	3994	4093	58862	0	1298	0	109846
Cement	24	0	0	0	607	0	0	0	702

Table C1. (Continued)

Sector	*Code*	*Public services-Gove* 37a	*Public services-private* 37b	*Other Services* 38	*Final consumption* FD1	*Government consumption* FD2	*Private fixed capital formation* FD3	*Public fixed capital formation* FD4	*Export* FD5
Iron and steel	25	0	0	0	0	0	0	0	13294
metal based industry	26	902	488	2456	1846	0	4024	0	77835
other industry	27	8018	18254	16971	312096	0	273545	0	185604
Electricity (only commodity)	28	3186	1699	4512	86517	0	0	0	0
Gas (Town gas)	29	56	16	62	194	0	0	0	0
Water supply	30	126	923	686	7893	228	0	0	592
Waste and recycling services	31	0	6	9	5973	0	0	0	0
building and construction	32	23436	7313	4734	247483	0	1553787	0	25879
Transportation	33	31463	5537	7893	251614	123	4498	0	40740
Trade, hotel, restaurant	34	45367	10686	10008	748237	1690	78731	0	200926
amusement and telecommunication	35	9620	10075	8891	176592	221	8970	0	22969
Financial Services	36	19103	7163	8792	111861	6859	0	0	1027
Public services-Gove	37a	3749	1503	47	18221	595716	252	0	6135
Public services-private	37b	3956	22851	3658	202317	0	29431	0	23760
Other Services	38	16723	12136	43580	172777	0	241	0	14650
Capital	VA1	35742	105179	154971	0	0	0	0	0
Labor	VA2	358698	83412	102314	0	0	0	0	0
Indirect tax	VA3	2897	3756	2085	80993	0	56025	0	8896
Subsidy	VA4	0	0	0	0	0	0	0	0
Adjustment	adj	0	0	0					

Table C1. (Continued)

Sector	*Code*	*Import (excluding tax)* FD6	*Import tax* FD7	*Stock change* FD8
Paddy	01	-135	0	9337
Corn	02	-3368	0	770
Cassava	03	0	0	312
other agriculture	04	-34761	0	-570
Rubber	05	-322	0	630
Palm oil	06	-30	0	2546
Other Plantation	07	-12867	0	247
Livestock	08	-4623	0	9155
wood	09	-212	0	1592
other forest	10	-87	0	29
Marine and fishery	11	-88	0	3877
Coal mining	12	-128	0	309
Crude oil mining	13	-77823	0	3734
Natural gas mining	14	0	0	0
Other mining	15	-9442	0	194
Food, beverage and tobacco	16	-83568	0	5785
Textile, foot and leather	17	-58028	0	9789
Processed wood products	18	-2883	0	823
Pulp and Paper Products, and print	19	-24693	0	846
Petroleum refineries	20	-182502	0	2013
Chemical industry	21	-123620	0	4626
fertilizer and pesticide	22	-10678	0	111
non-mental ind	23	-73992	0	8574
Cement	24	-757	0	565

Table C1. (Continued)

Sector	Code	Import (excluding tax)	Import tax	Stock change
		FD6	FD7	FD8
Iron and steel	25	-64900	0	6006
metal based industry	26	-69512	0	6521
other industry	27	-510824	0	15367
Electricity (only commodity)	28	0	0	0
Gas (Town gas)	29	0	0	0
Water supply	30	0	0	55
Waste and recycling services	31	-6116	0	0
building and construction	32	-33764	0	19775
Transportation	33	-30554	0	806
Trade, hotel, restaurant	34	-19996	0	11471
amusement and telecommunication	35	-27376	0	454
Financial Services	36	-10823	0	0
Public services-Gove	37a	-6067	0	0
Public services-private	37b	-42467	0	0
Other Services	38	-10713	0	4
Capital	VA1	0	0	0
Labour	VA2	0	0	0
Indirect tax	VA3	0	0	3340
Subsidy	VA4	0	0	0
Adjustment	adj			

Notes:

*) e_r : Electricity from renewable energy sources (excluding biomass and waste)

**) e_b : Electricity from biomass and waste sources

Table C2. Further aggregation for Sectoral GDP and Employment

No.	Classification	Sector
1.	Agriculture	Paddy, corn, cassava, other agriculture, rubber, palm oil, other plantation, livestock, wood, other forest, marine and fisheries.
2.	Energy	Coal mining, crude oil mining, natural gas mining. Petroleum refineries, electricity, gas (town gas)
3.	Industry	Chemical industry, fertilizer and pesticide, non-metal industries, cement, iron and steel, metal-based industries, other industries
4.	Waste	Waste and recycling services, water supply
5	Trade	Trade, hotel, and restaurant
6.	Other	Building and construction, transportation, amusement, telecommunication, financial services, services for public, other services.