Formulation of Indonesian palm oil biodiesel policy for energy security by using system dynamics model

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Abstract: This study was aimed at creating policy formulation in oil palm biodiesel to meet the mandatory biodiesel requirement in order to reach energy security in Indonesia. A system dynamics model was used to formulate policy recommendations. Identification of policies related to the existing biodiesel development was done. Current policies were analyzed to result in possible new policies to add in. The existing and new policies were then used as variables to develop a system dinamics model. The model was developed by taking into account the stakeholders involved in the supply chain system of biodiesel as a fuel mix. Existing policy formulation included CPO disincentive, interest rate relief for investment in biodiesel plant, tax exemption or reduction for import of technology or equipment for biodiesel plant, subsidy of Rp1 million per kl for mixed diesel-biodiesel products. These policies did not make biodiesel mandatory target achieved. Additional policies were needed in order to achieve biodiesel mandatory target. These included biodiesel production capacity increment, provision of incentives for biodiesel feedstock, plant productivity increment, provision of subsidy for biodiesel product to make it reach its economic price.

Keywords: biodiesel, bioenergy policy, oil palm, system dynamics, Indonesia

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1 Introduction

Energy security in this paper refers to the availability of biodiesel to meet the energy consumption in a certain period of time. Indonesia has not currently been able to significantly break away from the use of petroleum. National oil production tends to decline while its consumption rises so that Indonesia has to import petroleum. Petroleum is the largest energy source in Indonesia. About 42.3% of Indonesia's energy mixture in 2014 was derived from petroleum. In 2015, oil production was 248.8 million barrels and oil import was 175.4 million barrels (Ministry of Energy and Mineral Resources Republic of Indonesia, 2015).

Utilization of new and renewable energy which is believed to be the right solution to address energy supply, both for electricity and fuel oil, is still relatively low. The contribution of new and renewable energy (NRE) to total energy requirement in 2015 was 11% ((National Energy Council, 2016). Meanwhile, in order to ensure energy security in 2025, it is expected that NRE contributes by 17% (President of Republic Indonesia, 2006) and at least 23% (President of Republic Indonesia, 2014), to total energy requirement.

Biofuel is a liquid form of energy as an NRE source most able to replace the role of fossil energy for providing heat, electricity, and fuel for transportation (Thornley and Deborah, 2008). Some advantages of

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biofuel, among others, is that it is easy to be converted into electrical energy or fuel, easy and safe to be stored for long period of time, and easy to be transported and delivered (portable). It is also relatively easy to ignite but non-flammable (Soerawidjaja, 2014).

Biofuel can reduce poverty if the development of it involves small farmers (Thurlow, 2010). Biofuel can prevent the negative impact of fuel price increases, create new markets for downstream palm oil industry, improve the efficiency of utilization of domestic raw materials, improve socio-economic stability, and provide environmentally friendly energy sources to reduce greenhouse gas emissions (Zhou and Thomson, 2009). In addition, biofuel can improve infrastructure so that it can increase the supply of food crops (Lynd and Woods, 2011).

Development of biofuel requires policy support from the government. To increase the production and consumption of biofuels, policies including biofuel mandatory use, reduction or tax exemption, and subsidy (Sorda et al., 2010). Interference of the government biofuel policies will effectively control the price of biofuel so that biofuel will have competitiveness in the market (Jeffers et al., 2013). Biofuel policy is cross-sectoral involving agriculture, energy, environment, and trade sectors. Therefore, effective inter-sectoral policy process is needed (Panoutsou, 2008).

In order to support bioenergy development, the Government of Indonesia has issued some policies in the form of regulations. One of the latest regulations is the Regulation of Ministry of Energy and Mineral Resources of the Republic of Indonesia Number 12 Year 2015. This regulation specifies the minimum mandatory use of biodiesel as a fuel mixture to be applied gradually until 2025 in PSO (Public Service Obligation) and non-PSO transport, industrial, commercial, and power plant sectors (presented in Table 1). The stipulation of this target mandatory use of biodiesel is part of the government's efforts to ensure national energy safety until 2025.

This study was aimed at creating formulations of oil palm biodiesel development policies in order to meet the mandatory biodiesel target for energy security in Indonesia. This study started with identification of current policies on biodiesel development. These policies were analyzed to create new possibly added policies. The current and additional new policies were analyzed further by using system dynamic models to assess the achievement of mandatory biodiesel use. System dynamics model were developed by taking into account the stakeholders involved in the supply chain of biodiesel as a mixture material of fuel. The current and new additional policies were used as alternative scenarios for biodiesel development. Alternative scenarios were then simulated based on the developed system dynamic models. Scenario simulations which could reach mandatory biodiesel target were made as formulations of policies to be obtained in this study.

Table 1 Liabilities minimal utilization of biodiesel to the needs of the total (%)

Sector	January 2015	January 2016	January 2020	January 2025
PSO transportation, micro business, agriculture and fisheries	15	20	30	30
Non PSO transportation	15	20	30	30
Industrial and commercial	15	20	30	30
Power plants	25	30	30	30

2 Model Development

2.1 System dynamics development process

Stages of analysis of the built system dynamics included understand the system, define problems, develop system concept in a causal loop diagram, make model formulation (identification, relationship, formulation and assessment parameters), build a simulation and validation model on the computer, analyze results of model simulation, and implement the model (Sterman, 2000).

Biodiesel production system in the industry can be distinguished by the types of raw materials used. The raw material of oil palm biodiesel comes from the derivatives of Crude Palm Oil (CPO) processed by refinery industry. There are two alternative processes of CPO refinery, namely Refined Palm Oil (RPO) and RPO with fractionation. RPO is generated through degumming and distillation. RPO by fractionation is obtained through degumming, distillation, and bleaching processes and produces deodorized Refined Bleached and Deodorized Palm Olein (RBDPO) and Refined Bleached and Deodorized Palm Stearin (RBDPS).

Raw materials that can be used to produce biodiesel from oil palm refinery process are RPO, Palm Fatty Acid Distillate (PFAD), stearin, and olein. Glycerol is a by-product of RPO. Glycerol can be used to produce biodiesel after being coupled with PFAD through esterification process. PFAD is a by-product of oil palm refinery process, either through the RPO process or RPO with fractionation. Stearin is a derivative of RBDPS. Olein is a derivative of RBDPO. Alternative refinery process to obtain raw materials for biodiesel is depicted in Figure 1.

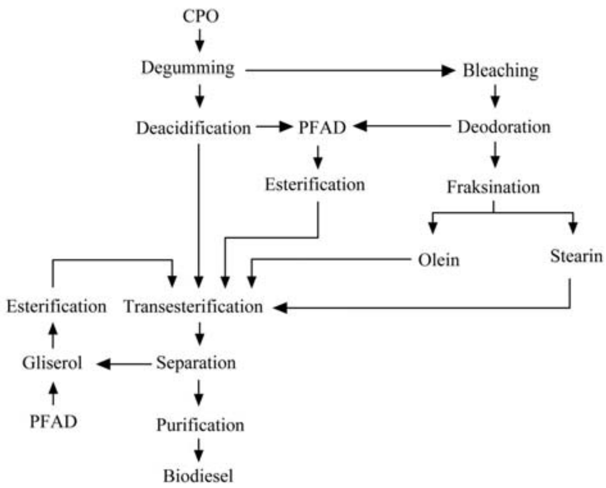

Figure 1 Alternative biodiesel feedstock from CPO

Development of biodiesel from CPO as an alternative energy source cannot be separated from the competition with the need for food. For raw materials which are also sources of food, priority of using them for food over other purposes should be given. This is because food is a basic need for humans (Popp et al., 2014; Ciaian and Kancs, 2011; Timilsina et al., 2011).

2.2 System dynamics modeling

Problem identification was done by taking into account the stakeholders involved in the implementation of biodiesel mandatory. They were policy makers including government (Ministry of EMR, Ministry of Finance, Ministry of Trade), CPO, palm, refining, biodiesel, and diesel-biodiesel mixing industries, and industries which were the users of diesel fuel and biodiesel mixture. Identified roles of each stakeholder involved and the constraints they faced are listed Table 2.

Results of problem identification showed that in practice, every stakeholder had constraints in implementing the Regulation of Ministry of EMR No. 12/2015. It was found that the main problem related to the achievement of mandatory biodiesel use was the economic price of biodiesel products.

Table 2 Identified roles of stakeholders and constraints they faced when producing biodiesel as a fuel mixture

Stakeholder	Role	Constraints
Government	- Biodiesel mandatory policy maker to ensure the availability of biodiesel market - Administrator for incentives and disincentives	- Policy alignment between government agencies
CPO and palm oil industry	- Supplier of feedstock for biodiesel	- Oil palm land limitation
Refinery industries	- Supplier of feedstock for biodiesel	- Competition with other CPO derivatives products
Biodiesel industries	- Biodiesel producer	- Low selling price of biodiesel
Diesel and biodiesel mixing industries	- Producer of diesel and biodiesel mixture fuel	- High purchase price of biodiesel
Industrial users (transportation sector)	- Manufacturers of vehicles that use mixed fuel	- No engine standardization for using biodiesel fuel mixture above 10% (above B10)

In a dynamic case, the amount of demand and supply may not be equal at a certain value and time, but it is the price which will make it so (Mantel, 1974; Debreu, 1974). Provision of biodiesel subsidy is one of the policies that the government should make in order to make the target contribution of biodiesel in Indonesia energy mix achieved by 2025 (Handoko et al., 2012). The interconnection between stakeholder and production activities in each stakeholder included in the production system of biodiesel as fuel mixture ingredient is depicted in a causal loop diagram (Figure 2).

The objective of this model was to balance dynamic behavior of availability and need for biodiesel as a material in diesel fuel mixture. The need for biodiesel for this purpose is affected by the amount of solar consumption. The need for biodiesel increases as solar consumption increases.

The supply of biodiesel as a material in diesel fuel mixture is influenced by the level of biodiesel production and biodiesel export. Biodiesel production level will also affect the level of biodiesel exports. Higher production of biodiesel leads to higher supply of biodiesel for both diesel fuel mixture and export. On the other hand, higher biodiesel exports may lower biodiesel supply for diesel fuel mixture.

Biodiesel production level is influenced by the amount of biodiesel production capacity and availability of RPO, stearin, olein, and PFAD as biodiesel feedstock. Higher production of biodiesel will take place with higher production capacity and feedstock availability.

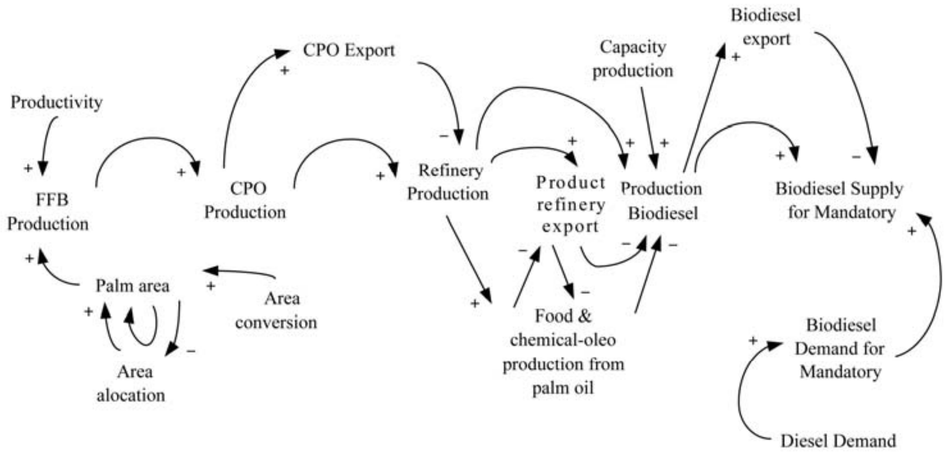

Figure 2 The basic framework of causal loop diagram achievement of mandatory biodiesel as a mixture material in diesel fuel

Feedstock availability for biodiesel production is influenced by CPO production, CPO export quantity and export of CPO refinery products. CPO supply for export is influenced by the level of CPO production. CPO refineries supply products for export is influenced by the level of CPO production and export.

Higher CPO production results in higher availability of biodiesel feedstock, higher CPO supply, and CPO refinery product export. Meanwhile, higher CPO export may lower supply of refinery products for export. Availability of biodiesel feedstock will get lower if the export level of CPO and CPO refinery products increases.

Besides being used as biodiesel feedstock, stearin and olein are also used as raw material for foods. Therefore, the availability of stearin and olein will be allocated first to meet the needs of the food industry. Consequently, higher need of stearin and olein for food industry will lower their availability for biodiesel feedstock.

CPO production level is linearly influenced by fresh fruit bunch (FFB) production level. FFB production is subject to the availability of and productivity oil palm land. Higher FFB production is expected to occur with higher land availability of and productivity. Meanwhile, land allocation and conversion positively affects land availability for oil palm.

Allocated land is oil palm land which is no longer productive as the oil plants are already more than 25 years old. This kind of land should be replanted with oil palm or other type of plants. Converted land is the one planted with non oil palm trees but then these trees are replaced by oil palm. Wider allocated and converted land increase oil palm availability and narrow down the size of land planted with other types of trees.

The system dynamics model which could be developed based on causal loop diagram consisted of 6 sub models including FFB, CPO, refinery, biodiesel, biodiesel need as a material for diesel fuel mixture, and economic price. The resulted causal loop diagram was developed into a stock flow diagram.

The sub model of FFB production was generated from the total quantity of oil palm plantation area ready for harvest and productivity of each producing oil palm plantation (Handoko et al., 2012). Producing oil palm trees can be grouped into three, namely young, mature, and old trees. They have productivity rates of 8, 26.167, and 21.10 ton ha^{-1}, respectively (Sunarko, 2007).

The FFB production equation was as follows:

$$FFB\_P_{ROD} = (A_{REA}\_M_{ATU}\_Y_{OUN}\ x\ Y_{OUN}\_P_{RDV}) + (A_{REA}\_M_{ATU}\_G_{ROU}\ x\ G_{ROU}\_P_{RDV}) + (A_{REA}\_M_{ATU}\_O_{LD}\ x\ O_{LD}\_P_{RDV}) \quad (1)$$

$$A_{REA}\_M_{ATU}\_Y_{OUN(t+1)} = (A_{REA}\_I_{NMA(t)}\ x\ Y_{OUN}\_G_{ROW}) + A_{REA}\_M_{ATU}\_Y_{OUN(t)} - (A_{REA}\_M_{ATU}\_Y_{OUN(t)}\ x\ G_{ROU}\_G_{ROW}) \quad (2)$$

$$A_{REA}\_M_{ATU}\_G_{ROU(t+1)} = (A_{REA}\_M_{ATU}\_Y_{OUN(t)} \times G_{ROU}\_G_{ROW}) + A_{REA}\_M_{ATU}\_G_{ROU(t)} - (A_{REA}\_M_{ATU}\_G_{ROU} \times O_{LD}\_G_{ROW}) \quad (3)$$

$$A_{REA}\_M_{ATU}\_O_{LD(t+1)} = (A_{REA}\_M_{ATU}\_G_{ROU} \times O_{LD}\_G_{ROW(t)}) + A_{REA}\_M_{ATU}\_O_{LD(t)} - (A_{REA}\_M_{ATU}\_O_{LD(t)} \times A_{LOC}\_G_{ROW}) \quad (4)$$

$$A_{REA}\_I_{NMA(t+1)} = (A_{REA}\_M_{ATU}\_O_{LD(t)} \times A_{LOC}\_G_{ROW}) + A_{REA}\_C_{ONV(t)} + A_{REA}\_I_{NMA(t)} - (A_{REA}\_I_{NMA(t)} \times Y_{OUN}\_G_{ROW}) \quad (5)$$

$$A_{REA}\_C_{ONV(t+1)} = A_{REA}\_C_{ONV(t)} + (A_{REA}\_C_{ONV(t)} \times A_{REA}\_C_{ONV}\_G_{ROW}) \quad (6)$$

where, FFB_P_{ROD}: FFB production (tonnes); $A_{REA}\_M_{ATU}\_Y_{OUN}$: area of young producing oil palm trees (ha); $A_{REA}\_M_{ATU}\_G_{ROU}$: area of mature producing oil palm trees (ha); $A_{REA}\_M_{ATU}\_O_{LD}$: area of old producing oil palm trees (ha); $Y_{OUN}\_P_{RDV}$: productivity of a young producing oil palm trees (tonnes ha^{-1}); $G_{ROU}\_P_{RDV}$: productivity of mature producing palm trees (tonnes ha^{-1}); $O_{LD}\_P_{RDV}$: productivity of old oil palm trees (tonnes ha^{-1}); $A_{REA}\_I_{NMA}$: area of unproducing oil palm trees (ha); $Y_{OUN}\_G_{ROW}$: growth of young oil palm trees area (%); $G_{ROU}\_G_{ROW}$: growth of mature oil palm trees area (%); $O_{LD}\_G_{ROW}$: growth of old oil palm trees area (%); $A_{LOC}\_G_{ROW}$: growth of land area allocated for replanting oil palm trees (%); $A_{REA}\_C_{ONV}$: area of non oil palm trees converted into oil palm plantation land (ha); $A_{REA}\_C_{ONV}\_G_{ROW}$: growth of non oil palm trees area converted into oil palm plantation land (%).

Sub CPO production model was a function of FFB production, fruit yield, and mesocarp yield. CPO fruit, fruit mesocarp, and mesocarp CPO yields were 64.5%, 81.5%, and 44%, respectively (Hambali et al., 2010).

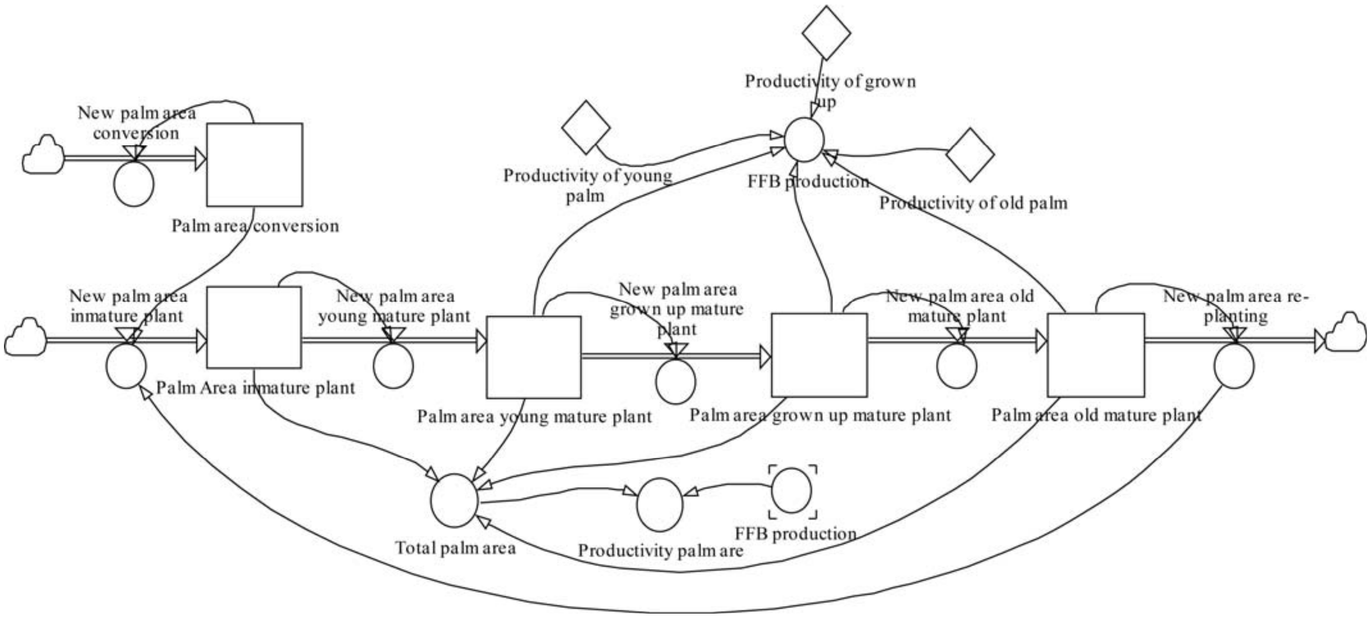

Figure 3 Stock flow diagram of FFB production sub model

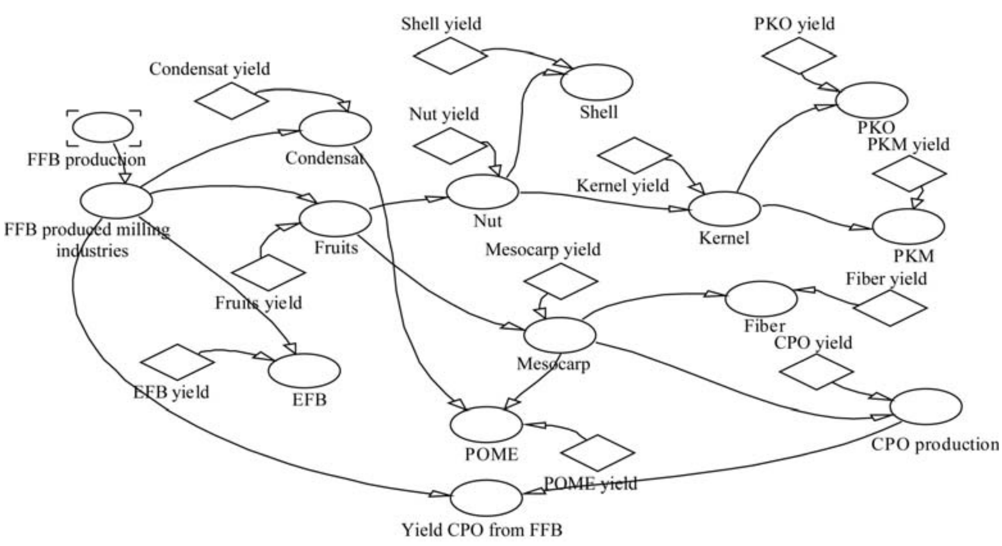

Figure 4 Stock flow diagram of CPO production sub model

CPO production equation was as follows:

$$CPO\_P_{ROD} = FFB\_P_{ROD}\ x\ F_{RUITS}\_Y_{IEL}\ x\ M_{SOC}\_Y_{IEL}\ x\ CPO\_Y_{IEL} \quad (7)$$

where, CPO_P_{ROD}: CPO production (tonnes); $F_{RUITS}\_Y_{IEL}$: palm fruit yield (%); $M_{SOC}\_Y_{IEL}$: fruit mesocarp yield (%); CPO_Y_{IEL}: mesocarp CPO yield.

Refinery sub model was developed to determine the amount of RPO, stearin, olein, PFAD, and glycerol which could potentially be used as feedstock for biodiesel. The initial input for the refinery model is the amount of CPO produced in CPO production sub model. RPO yield of CPO was 95% (Hambali et al., 2010). Proportion of CPO processed into RPO was assumed to be 15% of the total CPO production.

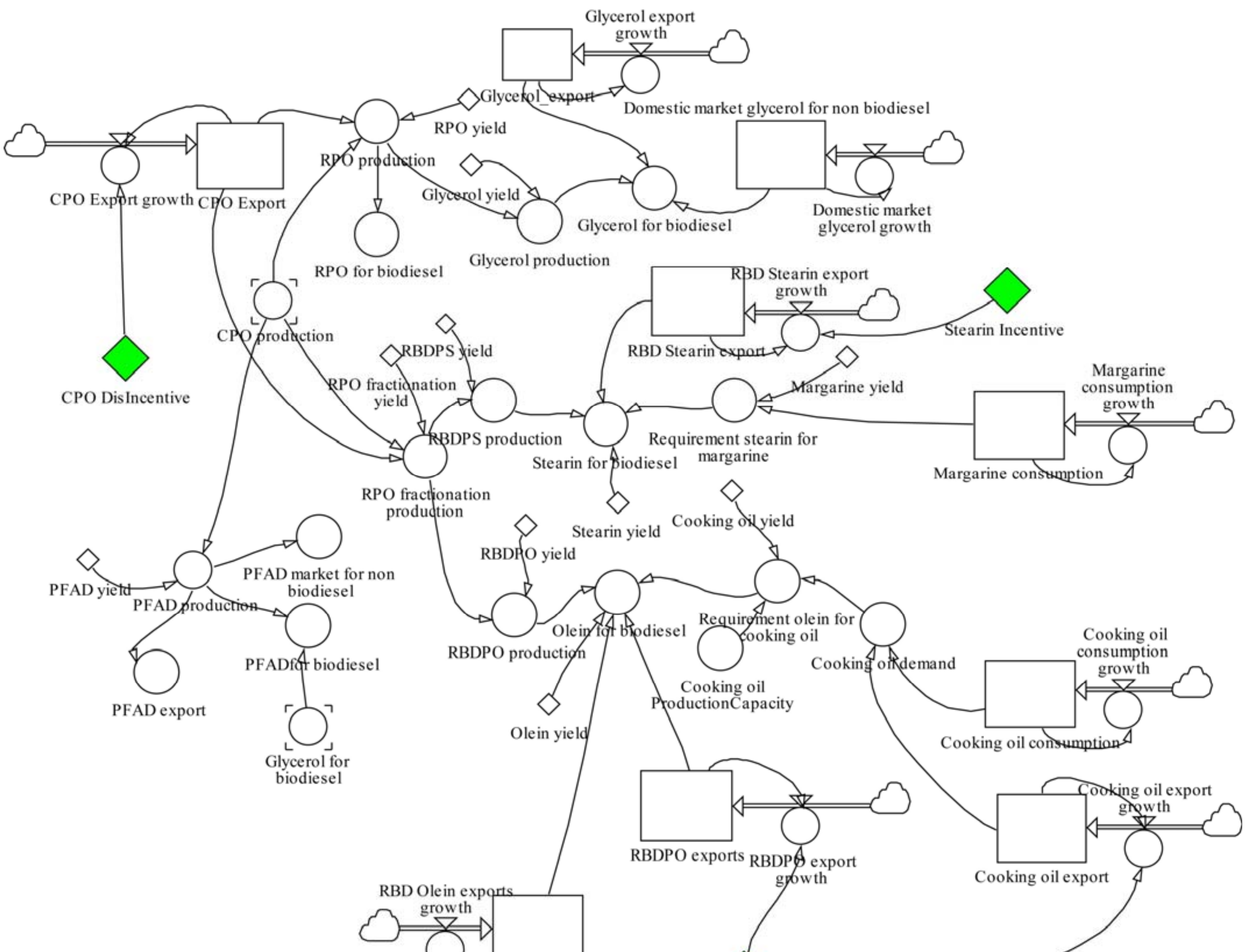

Figure 5 Stock flow diagram of refinery production sub model

Total RPO as feedstock for biodiesel was obtained by the following equation:

$$RPO\_B_{IOD} = (CPO\_P_{ROD} - CPO\_E_{xpo})\ x\ RPO\_Y_{IEL}\ x\ RPO\_P_{rop} \quad (8)$$

$$CPO\_E_{xpo(t+1)} = CPO\_E_{xpo(t)} + (CPO\_E_{xpo(t)}\ x\ CPO\_E_{xpo}\_G_{ROW}) \quad (9)$$

where, RPO_B_{IOD}: RPO used as feedstock for biodiesel (tonnes); CPO_E_{xpo}: exported CPO (tonnes); RPO_Y_{IEL}: RPO of CPO yield (%); RPO_P_{rop}: proportion of palm oil processed into RPO (%); $CPO\_E_{xpo}\_G_{ROW}$: annual CPO export growth (%).

Proportion of CPO processed into RPO fractionation was 85% of total CPO. RPO fractionation yield from CPO was 95%. RBDPS yield from RPO fractionation was 20% (Hambali et al., 2010). The yield of margarine was assumed to be 75% of RBDPS. The yield of stearin of RBDPS was assumed to be 99%. The amount of stearin used as feedstock for biodiesel was obtained through the calculation process based on the following equations:

$$RPO_{FRA}\_P_{ROD} = (CPO\_P_{ROD} - CPO\_E_{xpo}) x RPO_{FRA}\_Y_{IEL}\ x\ RPO_{FRA}\_P_{rop} \tag{10}$$

$$RBDPS\_P_{ROD} = RPO_{FRAC}\_P_{ROD\ X}\ RBDPS\_Y_{IEL} \tag{11}$$

$$M_{ARG}\_D_{EMA} = M_{ARG}\ \_C_{ONS} \tag{12}$$

$$M_{ARG}\ \_C_{ONS(t+1)} = M_{ARG}\ \_C_{ONS(t)} + (M_{ARG}\ \_C_{ONS(t)}\ x\ M_{ARG}\ \_C_{ONS}\_G_{ROW}) \tag{13}$$

$$S_{TEA}\_\ M_{ARG} = M_{ARG}\ \_D_{EMA} : M_{ARG}\_Y_{IEL} \tag{14}$$

$$S_{TEA}\_B_{IOD} = ((RBDPS\_P_{ROD} - RBD\_S_{TEA}\_E_{XPO})\ x\ S_{TEA}\_Y_{IEL}) - S_{TEA}\_M_{ARG} \tag{15}$$

$$RBD\_S_{TEA}\_E_{XPO(t+1)} = RBD\_S_{TEA}\_E_{XPO(t)} + (RBD\_S_{TEA}\_E_{XPO(t)}\ x\ RBD\_S_{TEA}\_E_{XPO}\_G_{ROW}) \tag{16}$$

where, $RPO_{FRA}\_P_{ROD}$: RPO fractionation production (tonnes); $RPO_{FRA}\_Y_{IEL}$: RPO fractionation yield from CPO (%); $RPO_{FRA}\_P_{rop}$: proportion of CPO processed into RPO fractionation (%); $RBDPS\_P_{ROD}$: RBDPS production (tonnes); $RBDPS\_Y_{IEL}$: RBDPS yield from RPO fractionation (%); $M_{ARG}\_D_{EMA}$: demand for margarine (tonnes); $M_{ARG}\_C_{ONS}$: domestic margarine consumption (tonnes); $M_{ARG}\_C_{ONS}\_G_{ROW}$: annual domestic margarine consumption growth (%); $S_{TEA}\_M_{ARG}$: stearin requirement for margarine production; $M_{ARG}\_Y_{IEL}$: margarine yield of stearin (%); $S_{TEA}\_B_{IOD}$: stearin used as feedstock for biodiesel (tonnes); $S_{TEA}\_Y_{IEL}$: stearin yield from RBDPS (%); $RBD\_S_{TEA}\_E_{XPO}$: RBD stearin export (tons); $RBD\_S_{TEA}\_E_{XPO}\_G_{ROW}$: annual RBD stearin export growth (%).

RBDPO yield from RPO fractionation was 80% (Hambali et al., 2010). Cooking oil yield from olein was assumed to be 94%. The yield of olein from RBDPO was assumed to be 99%. Total olein used as feedstock material for biodiesel was obtained through the calculation process based on the following Equations :

$$RBDPO\_P_{ROD} = RPO_{FRA}\_P_{ROD\ X}\ RBDPO\_Y_{IEL} \tag{17}$$

$$CO\_D_{EMA} = CO\_C_{ONS} + CO\_E_{xpo} \tag{18}$$

$$CO\_C_{ONS(t+1)} = CO\_C_{ONS(t)} + (CO\_C_{ONS(t)}\ x\ CO\_C_{ONS}\_G_{ROW}) \tag{19}$$

$$IF\ (CO\_C_{ONS} < CO\_C_{APC})\ THEN\ (CO\_C_{ONS})\ ELSE\ (CO\_C_{APC}) \tag{20}$$

$$CO\_E_{XPO(t+1)} = CO\_E_{XPO(t)} + (CO\_E_{XPO(t)}\ x\ CO\_E_{XPO}\_G_{ROW}) \tag{21}$$

$$O_{LEI}\_CO = CO\_D_{EMA} : CO\_Y_{IEL} \tag{22}$$

$$O_{LEI}\_B_{IOD} = ((RBDPO\_P_{ROD} - RBDPO\_E_{XPO} - RBD\_O_{LEI}\_E_{XPO})\ x\ O_{LEI}\_Y_{IEL}) - O_{LEI}\_CO \tag{23}$$

$$RBDPO\_E_{XPO(t+1)} = RBDPO\_E_{XPO(t)} + (RBDPO\ E_{XPO(t)}\ x\ RBDPO\_E_{XPO}\_\ G_{ROW}) \tag{24}$$

$$RBD\_O_{LEI}\_E_{XPO(t+1)} = RBD\_O_{LEI}\_E_{XPO(t)} + (RBD\_O_{LEI}\_E_{XPO(t)}\ x\ RBD\_O_{LEI}\_\ E_{XPO}\_G_{ROW}) \tag{25}$$

where, $RBDPO\_P_{ROD}$: RBDPO production (tonnes); $RBDPO\_Y_{IEL}$: RBDPO yield from RPO fractionation (%); CO_D_{EMA}: demand for palm oil (tonnes); CO_C_{ONS}: domestic cooking oil consumption (tonnes); CO_E_{xpo}: cooking oil export (tonnes); $CO\_C_{ONS}\_G_{ROW}$: annual domestic cooking oil consumption (%); CO_C_{APC}: cooking oil production capacity (tonnes); $CO\_E_{XPO}\_G_{ROW}$: annual cooking oil export growth (%); O_{LEI}_CO: olein requirement for cooking oil production; CO_Y_{IEL}: cooking oil yield from olein (%); $O_{LEI}\_B_{IOD}$: olein used as feedstock for biodiesel (tonnes); $O_{LEI}\_Y_{IEL}$: olein yield from RBDPO (%); $RBDPO\_E_{XPO}$: RBDPO export (tonnes); $RBDPO\_E_{XPO}\_G_{ROW}$: annual RBDPO export growth (%); *RBD_OLEI_EXPO RBD*: olein export (tonnes); $RBD\_O_{LEI}\_\ E_{XPO}\_G_{ROW}$: annual olein export growth (%).

PFAD yield from CPO was 4% (Hambali et al., 2010). Proportion of PFAD used as feedstock for biodiesel was assumed to be 20% of total PFAD production. The yield of glycerol from RPO was assumed to be 10%. The proportion of glycerol exported was assumed to be 50% of the total glycerol production. The amount of PFAD used as feedstock for biodiesel was obtained through the following Equations:

$$PFAD\_P_{ROD} = CPO\_P_{ROD\ X}\ PFAD\_Y_{IEL} \tag{26}$$

$$PFAD\_B_{IOD} = (PFAD\_P_{ROD\ X}\ \ PFAD\_B_{IOD}\_P_{rop}) + G_{LYC}\_B_{IOD} \tag{27}$$

$$G_{LYC}\_P_{ROD} = RPO\_P_{ROD}\ \ x\ \ G_{LYC}\_Y_{IEL} \tag{28}$$

$$G_{LYC}\_B_{IOD} = G_{LYC}\_P_{ROD} - G_{LYC}\_E_{XPO} - G_{LYC}\_C_{ONS} \tag{29}$$

$$G_{LYC}\_E_{XPO} = G_{LYC}\_P_{ROD}\ x\ G_{LYC}\_E_{XPO}\_P_{rop} \tag{30}$$

$$G_{LYC}\_C_{ONS(t+1)} = G_{LYC}\_C_{ONS(t)} + (G_{LYC}\_C_{ONS(t)}\ x\ G_{LYC}\_C_{ONS}\_G_{ROW}) \tag{31}$$

where, $PFAD\_P_{ROD}$: PFAD production (tonnes); $PFAD\_Y_{IEL}$: PFAD yield from CPO (%); $PFAD\_B_{IOD}$: PFAD used as feedstock for biodiesel (tonnes); $PFAD\_B_{IOD}\_P_{rop}$: proportion of PFAD used as feedstock for biodiesel (%); $G_{LYC}\_B_{IOD}$: glycerol used as feedstock biodiesel (tonnes); $G_{LYC}\_P_{ROD}$: glycerol production (tonnes); $G_{LYC}\_Y_{IEL}$: glycerol yield from RPO (%); $G_{LYC}\_E_{XPO}$: glycerol export (tonnes); $G_{LYC}\_C_{ONS}$: domestic glycerol consumption (tonnes); $G_{LYC}\_E_{XPO}\_P_{rop}$: proportion of exported glycerol (%); $G_{LYC}\_C_{ONS}\_G_{ROW}$: annual domestic glycerol consumption growth (%).

Sub model biodiesel production was structured to produce potential biodiesel that can be used as a mixture of diesel fuel. Inputs used in biodiesel production sub model consisted of amount of RPO, stearin, olein, PFAD, and glycerol produced in the refinery sub model.

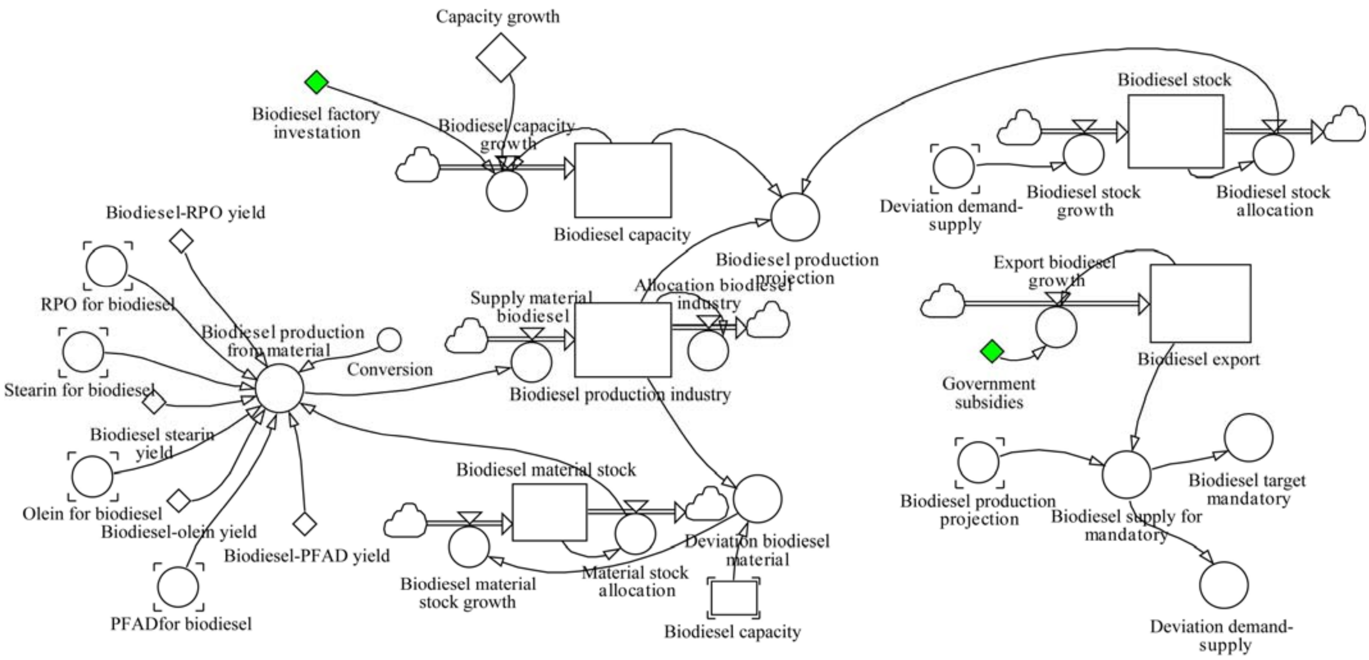

Figure 6 Stock flow diagram of biodiesel production sub model

The yield of biodiesel from feedstock of CPO derivatives (RPO, olein, stearin, PFAD) was assumed to be 97% (Crabbe et al., 2001). Biodiesel conversion from tonnes kl was obtained by using the following formula: 1 ton of biodiesel was equal to 1,176 kl (density of biodiesel: 0.85 g mL^{-1} according to the limits of SNI 04-7182-2006). The amount feedstock that can be used to produce biodiesel was obtained through the following equation:

$$BIOD\_MATE = (RPO\_B_{IOD} \; x \; RPO\_B_{IOD}\_Y_{IEL} + O_{LEI}\_B_{IOD} \; x \; O_{LEI}\_B_{IOD}\_Y_{IEL} + S_{TEA}\_B_{IOD} \; x \; S_{TEA}\_B_{IOD}\_Y_{IEL} + PFAD\_B_{IOD} \; x \; PFAD\_B_{IOD}\_Y_{IEL}) \; x \; B_{IOD}\_C_{ONV} \quad (32)$$

where, $B_{IOD}\_M_{ATE}$: biodiesel production based on feedstock availability (kl); $RPO\_B_{IOD}\_Y_{IEL}$: biodiesel yield from RPO (%); $O_{LEI}\_B_{IOD}\_Y_{IEL}$: biodiesel yield from olein (%); $S_{TEA}\_B_{IOD}\_Y_{IEL}$: biodiesel yield from stearin (%); $PFAD\_B_{IOD}\_Y_{IEL}$: biodiesel yield from PFAD (%); $B_{IOD}\_C_{ONV}$: biodiesel conversion from tonnes into kl.

Biodiesel production in industry in 2014 was 3.65 million kl and biodiesel production capacity was 5.65 million kl (Ministry of Energy and Mineral Resources Republic of Indonesia, 2015). Total biodiesel sales were assumed to be equal to its production. Biodiesel production in industry was calculated by using the following Equations:

$$B_{IOD}\_P_{ROD(t+1)} = B_{IOD}\_M_{ATE(t)} + B_{IOD}\_P_{ROD(t)} - B_{IOD}\_D_{EMA(t)} + B_{IOD}\_M_{ATE}\_S_{TOC(t)} \quad (33)$$

$$IF \; (B_{IOD}\_P_{ROD} < B_{IOD}\_C_{APC}) \; THEN \; (B_{IOD}\_P_{ROD}) \; ELSE \; (B_{IOD}\_C_{APC}) \quad (34)$$

$$B_{IOD}\_C_{APC(t+1)} = B_{IOD}\_C_{APC(t)} + (B_{IOD}\_C_{APC(t)} \; x \; B_{IOD}\_C_{APC}\_G_{ROW}) \quad (35)$$

$$B_{IOD}\_M_{ATE}\_S_{TOC} = B_{IOD}\_P_{ROD} - B_{IOD}\_C_{APC} \quad (36)$$

where, $B_{IOD}\_P_{ROD}$: biodiesel produced in industry (kl); $B_{IOD}\_D_{EMA}$: biodiesel sales (kl); $B_{IOD}\_C_{APC}$: biodiesel production capacity in industry (kl); $B_{IOD}\_C_{APC}\_G_{ROW}$: annual biodiesel production capacity growth in (%); $B_{IOD}\_M_{ATE}\_S_{TOC}$: potential amount of biodiesel not yet processed due to limited production capacity (kl).

Sub model of biodiesel demand as a mixture material of diesel fuel was arranged to determine the need for biodiesel to be mixed in diesel fuel. Diesel users included in this model consisted of transportation, industry, and power plants sectors.

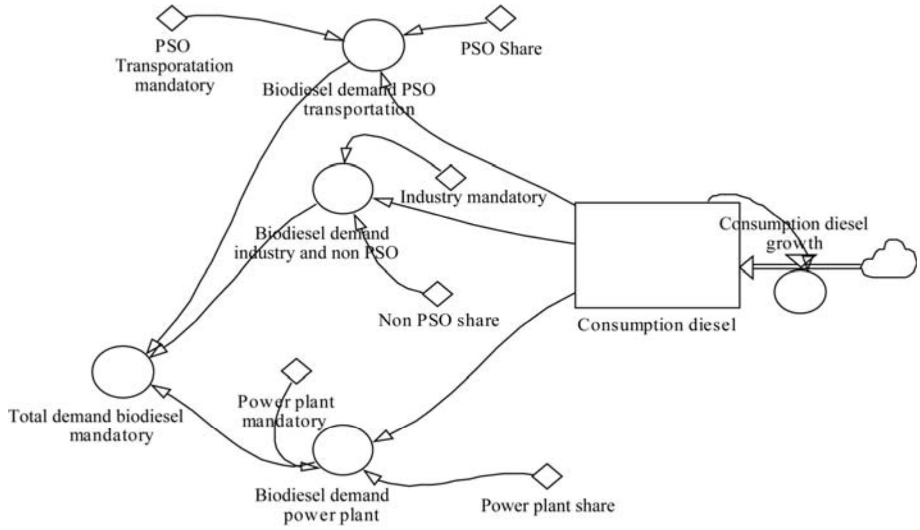

Figure 7 Stock flow diagram of diesel need sub model

Demand for diesel fuel was calculated by using the following equations:

$$D_{IES}\_C_{ONS(t+1)} = D_{IES}\_C_{ONS(t)} + D_{IES}\_C_{ONS(t)} \times D_{IES}\_C_{ONS}\_G_{ROW} \quad (37)$$

$$B_{IOD}\_D_{EMA}\_M_{AND} = (D_{IES}\_C_{ONS}\_T_{RAN} \times B_{IOD}\_T_{RAN}\_M_{AND}) + (D_{IES}\_C_{ONS}\_I_{NDU} \times B_{IOD}\_I_{NDU}\_M_{AND}) + (D_{IES}\_C_{ONS}\_P_{OWE} \times B_{IOD}\_P_{OWE}\_M_{AND}) \quad (38)$$

where, $D_{IES}\_C_{ONS}$: diesel consumption (kl); $D_{IES}\_C_{ONS}\_G_{ROW}$: annual diesel consumption growth (%); $B_{IOD}\_D_{EMA}\_M_{AND}$: biodiesel requirements for diesel mixture (kl); $D_{IES}\_C_{ONS}\_T_{RAN}$: diesel consumption in transportation sector (kl); $D_{IES}\_C_{ONS}\_I_{NDU}$: diesel consumption in industrial sector (kl); $D_{IES}\_C_{ONS}\_P_{OWE}$: diesel consumption in power plant sector (kl); $B_{IOD}\_T_{RAN}\_M_{AND}$: percentage of biodiesel mandatory use for transportation sector (%); $B_{IOD}\_I_{NDU}\_M_{AND}$: percentage of biodiesel mandatory use for industrial sector (%); $B_{IOD}\_P_{OWE}\_M_{AND}$: percentage of biodiesel mandatory use for power plant sector (%).

Total supply of biodiesel used as a mixture of diesel fuel was calculated by using the following Equations:

$$B_{IOD}\_S_{UPP}\_M_{AND} = B_{IOD}\_P_{ROD} - B_{IOD}\_E_{XPO} + B_{IOD}\_S_{TOC} \quad (39)$$

$$B_{IOD}\_E_{XPO(t+1)} = B_{IOD}\_E_{XPO(t)} + (B_{IOD}\_E_{XPO(t)} \times B_{IOD}\_E_{XPO}\_G_{ROW}) \quad (40)$$

$$B_{IOD}\_S_{TOC} = B_{IOD}\_S_{UPP}\_M_{AND} - B_{IOD}\_D_{EMA}\_M_{AND} \quad (41)$$

where, $B_{IOD}\_S_{UPP}\_M_{AND}$: supply of biodiesel used as a mixture material of diesel (kl); $B_{IOD}\_E_{XPO}$: biodiesel export (kl); $B_{IOD}\_S_{TOC}$: stock of biodiesel as a mixture of diesel fuel (kl); $B_{IOD}\_E_{XPO}\_G_{ROW}$: annual biodiesel exports growth (%).

Biodiesel economic model was constructed to calculate the cost of feedstock and transportation. In addition to feedstock cost, transportation cost was also calculated as in biodiesel HIP and HPE cost determination, transportation costs were excluded.

Total cost of biodiesel feedstock supply was calculated by using the following equations:

$$R_{AWM}\_C_{OST} = \{([RPO\_B_{IOD} \times CPO\_P_{RIC}] / RPO\_Y_{IEL}) + (S_{TEA}\_B_{IOD} \times S_{TEA}\_P_{RIC}) + (O_{LEI}\_B_{IOD} \times O_{LEI}\_P_{RIC}) + (PFAD\_B_{IOD} \times PFAD\_P_{RIC})\} / ([RPO\_B_{IOD}/RPO\_Y_{IEL}] + S_{TEA}\_B_{IOD} + O_{LEI}\_B_{IOD} + PFAD\_B_{IOD}) \quad (42)$$

$$TC\_R_{AWM}\_C_{OST} = (B_{IOD}\_P_{ROD} / [B_{IOD}\_C_{ONV} \times B_{IOD}\_Y_{IEL}]) \times R_{AWM}\_C_{OST} \quad (43)$$

where, $R_{AWM}\_C_{OST}$: cost of biodiesel feedstock (Rp ton^{-1}); CPO_P_{RIC}: CPO price (Rp ton^{-1}); $S_{TEA}\_P_{RIC}$: stearin price (Rp ton^{-1}); $O_{LEI}\_P_{RIC}$: olein price (Rp ton^{-1}); $PFAD\_P_{RIC}$: PFAD price (Rp ton^{-1}); $TC\_R_{AWM}\_C_{OST}$: total cost feedstock for biodiesel production (Rp); $B_{IOD}\_Y_{IEL}$: biodiesel yield from feedstock (%).

Total biodiesel transportation cost was calculated by using the following Equation:

$$TC\_T_{RAN}\_C_{OST} = B_{IOD}\_P_{ROD} \times T_{RAN}\_C_{OST} \quad (44)$$

where, $TC\_T_{RAN}\_C_{OST}$: total biodiesel transportation cost (Rp); $T_{RAN}\_C_{OST}$: biodiesel transportation cost (Rp kl^{-1}).

Financial feasibility parameter used to measure the economic price of biodiesel was Net Present Value (NPV) and Net Benefit Cost Ratio (Net B/C). NPV and Net B/C were calculated by using the Equations as follows Gray et al. (1997).

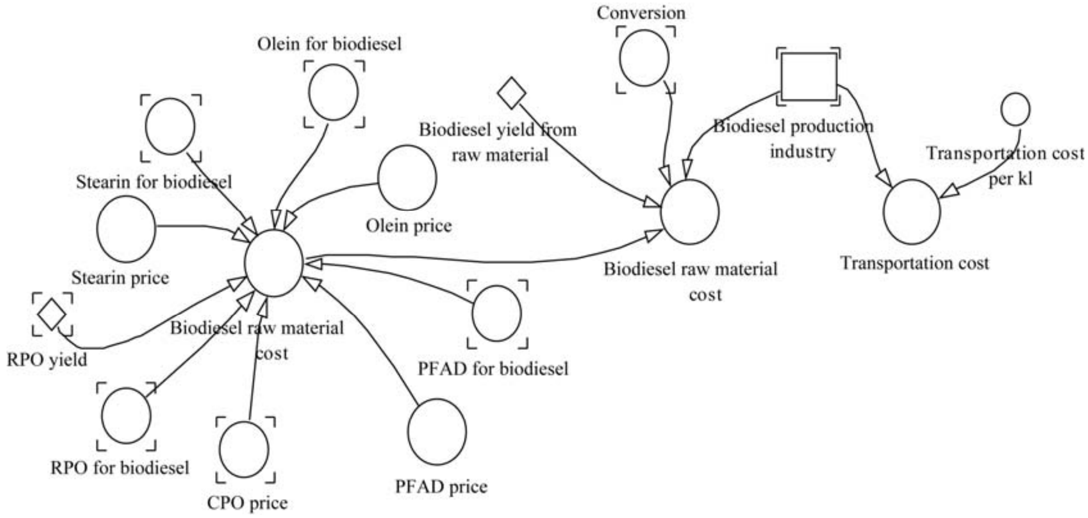

Figure 8 Stock flow diagram of economy sub model (feedstock and transportation cost)

Validation conducted on system dynamics model consisted of structure and behavior validity tests of the model to the real system (quantitative behavior pattern comparison). Validity test of the structure was done by testing the consistency of dimensions directly by the software. Quantitative behavior pattern comparison test was performed by using the precision measurement of Mean Absolute Percentage Error (MAPE). MAPE was calculated by using the formula as follows Makridakis et al. (1995).

Model validation was tested on two key variables, namely CPO production and diesel consumption. MAPE value of CPO production obtained from model simulation results, which was compared with actual data of CPO production in 1991-2014 was at 7.24%. MAPE value of diesel consumption obtained from model simulation results, which was compared with the actual data in 2000-2013 was 4.91%. Based on MAPE values of two key variables, it could be concluded that the constructed dynamic model had high accuracy. Therefore, the constructed model could be further used to predict system behavior of biodiesel mandatory use as material of diesel mixture.

3 Results and Discussion

Simulation of dynamics model results was performed to compare the amount of biodiesel supply and the economics of alternative simulation scenarios. Comparison of the alternatives was done with and without changing the existing conditions. Current policies in biodiesel production supply chain to support the implementation of biodiesel mandatory use are:

1) Regulation of Ministry of EMR No. 12/2015 on mandatory use of biodiesel for transportation, industry, and power plant sectors is needed to ensure the availability of domestic biodiesel market.

2) Law No. 30 Year 2007 is to prioritize the provision and utilization of renewable energy as a form of diversification of energy resources to ensure national energy security. Provision of renewable energy sources can obtain facilities and/or incentives for a certain period of time until they reach economic value.

3) Disincentives CPO, in the form of government policy to set tax and export prices. Regulation of Ministry of Finance No. 128/PMK.011/2013 on progressive export duty tax on oil palm, CPO, and its derivative products.

4) Market index prices of biodiesel mixed into diesel fuel is determined based on the published price of Mean of Platss Singapore (MOPS) diesel in the previous month period plus 3.48% MOPS according to the Decree of Ministry of EMR No. 2185 K/12/ MEM /2014.

5) Incentives for diesel fuel mixture product and biodiesel in the form of product subsidy of Rp 1 million per kl.

These policies were found to be effective for the end actor in supply chain, namely the diesel-biodiesel mixing industry. Other actors before this diesel-biodiesel mixing industry including farmers, CPO industries, and biodiesel producers were not affected. If this condition continued, the government mandatory use of biodiesel target would not be achieved. This was due to the fact that other actors except diesel-biodiesel mixing industry would not get any economic benefits. Therefore, other policies that reached farmers, CPO industries, and biodiesel producers needed to be made. This could encourage producers to produce biodiesel as they would get some economic benefits.

Basically, there were four main policies that could make other actors in supply chain, in addition to those in diesel-biodiesel mixing industry, get economic benefits. These included 1) improvement of production capacity (for biodiesel industry), 2) provision of incentives for biodiesel feedstock (CPO and refinery industry), 3) improvement of plant productivity (for farmers), and 4) provision of subsidy (biodiesel industry).

In this study, simulation by using a system dynamics was done to assess the effect of these four policies on Indonesia's biodiesel production in order to reach the stipulated mandatory use target. To implement these four policies, the following scenarios were made.

Compiled simulation scenarios included:

1) The existing condition was the one describing the effects of existing policies on supporting the achievement of minimum use of biodiesel as a mixture of diesel fuel. The model covered the notions that there were an increment of palm plantation area at the rate of increment similar to the average oil palm land area increment within the last 25 years (1990-2014), a CPO disincentive, an increment of biodiesel plant capacity at the rate similar to the growth rate of biodiesel production capacity obtained based on 2008-2014 data, and an incentive for diesel-biodiesel mix products.

2) Scenario 1 was the one describing the existing condition by taking into account the notion that there was an increment in biodiesel plant capacity in such a rate that the potential availability of biodiesel feedstock from 2015 to 2025 could be processed.

3) Scenario 2 illustrated changes that might occur to the condition set in scenario 1 if biodiesel feedstock incentives were given.

4) Scenario 3 illustrated changes that might occur to the condition set in scenario 2 if there was an increment in oil palm plant productivity to increase feedstock availability.

5) Scenario 4 illustrated changes that might occur to the condition set in scenario 3 if the productivity of palm oil plant was higher so that the mandatory biodiesel use target could be achieved.

Results of the simulation of the existing (baseline) conditions showed that biodiesel availability was below its mandatory requirement with greater failure difference over the period of time (Figure 9). The finding that the existing conditions did not meet the mandatory targets, might be caused by the fact that a) an increased biodiesel production capacity was below the mandatory biodiesel requirement which kept increasing over time; b) there was a competition with exports of upstream refinery processed products (RBDPO, RBD olein); and c) biodiesel feedstock (CPO) availability was limited. Priority was given to the use of these materials to meet the needs for food products so that their availability for biodiesel production was inadequate.

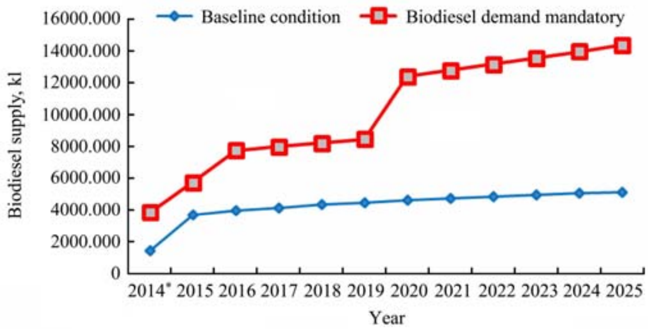

Figure 9 Comparison of the availability and the mandatory requirement of biodiesel based on baseline conditions

In the model developed for all scenarios, it was found that the priority use of raw materials was to meet the national food requirements and only the remains were used as biodiesel feedstock. Biodiesel feedstock, especially olein and stearin are also the raw materials of food products such as cooking oil and margarine. Cooking oil and margarine production was found to increase over time making the availability of olein and stearin as biodiesel feedstock reduced. Export of processed products in the form of upstream refinery products was still relatively high. Government through the Regulation of Minister of Finance No. 128/PMK.011/2013 aimed to push the growth of palm oil downstream product industry and ensure the fulfillment of domestic product requirement.

Results of scenario 1 simulation showed that the availability of biodiesel could meet the mandatory biodiesel requirement in 2015 to 2019 but not in 2020 to 2025 (Figure 10). It was also shown that the increment of biodiesel production capacity significantly increased the supply of biodiesel for mandatory requirement. Failure to meet the target of mandatory biodiesel use following an increase in biodiesel production capacity might be caused by the fact that there was a competition in the use refinery processed products for biodiesel production and for export in the form of upstream refinery processes. Limited availability of biodiesel feedstock (CPO) might also be the cause of this failure.

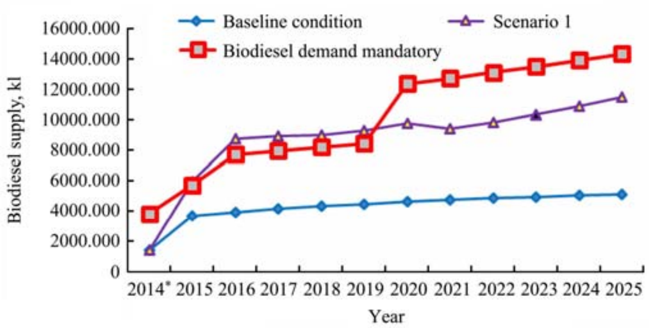

Figure 10 Comparison of the availability and the mandatory requirement of biodiesel based on baseline conditions and scenario 1

Results of scenario 2 simulation showed that biodiesel availability could meet the mandatory biodiesel requirement in 2015 to 2019, but not in 2020 to 2025 (Figure 11). Results of scenario 2 simulation were the same as those of scenario 1. However, biodiesel availability was found to be higher in scenario 2 than that in scenario 1. Results of scenario 2 simulation also showed that supply of feedstock for biodiesel would not be sufficient to meet mandatory biodiesel requirement although additional incentive for biodiesel feedstock was given. It was indicated from these results that feedstock availability (CPO) was so limited that efforts to increase the availability biodiesel feedstock (CPO) were needed. Increased availability of biodiesel feedstock in this study would be achieved through increased productivity of palm oil land as described in scenario 3 and 4.

Simulation of scenarios 3 and 4 showed that the availability of biodiesel could meet the mandatory use requirement in 2015 to 2025 if there was an increase in palm oil plant productivity by 12% (scenario 4). If oil palm plant productivity increased by less than 12% (e.g. 11%) by 11% (scenario 3), the availability of biodiesel would not meet the mandatory requirement (Figure 12). Results of scenario 3 simulation showed that if there was an increase of palm oil plant productivity by 11%, biodiesel availability would not meet biodiesel mandatory needs by 2025.

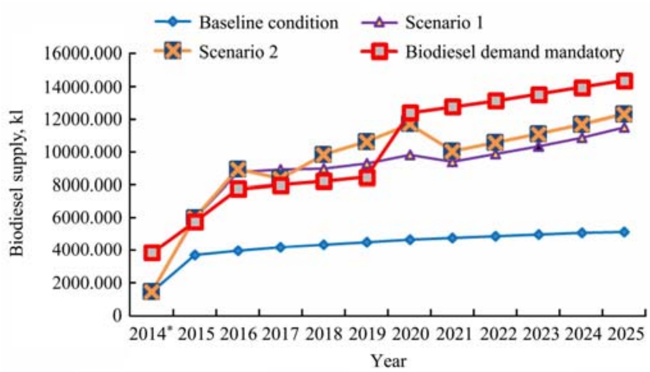

Figure 11 Comparison of availability and the mandatory requirement of biodiesel based on baseline conditions, scenario 1 and 2

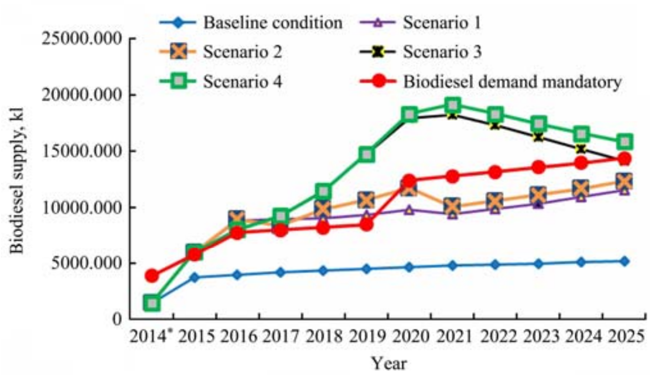

Figure 12 Comparison of mandatory biodiesel supply and demand based on baseline conditions, scenario 1, 2, 3 and 4

Results of scenario 3 and 4 illustrated that increasing productivity of palm oil plant would increase the availability of biodiesel. Scenario 4 gave better results than the baseline conditions, scenario 1, 2, and 3. Achievement of biodiesel availability compared to its mandatory requirements is listed in Table 3.

It was also shown from the simulation that the implication of additional policies in the forms of the increment of average biodiesel production capacity, provision of incentive for biodiesel feedstock, increment of plant productivity, and provision of subsidy for biodiesel product which could achieve its economic price would clearly increase Indonesia's biodiesel production to meet the expected mandatory target.

Table 3 Attainment status of biodiesel availability with biodiesel mandatory needs

Scenario	Year										
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Base condition	no	no	no	no	no	no	no	no	no	no	no
1	yes	yes	yes	yes	yes	no	no	no	no	no	no
2	yes	yes	yes	yes	yes	no	no	no	no	no	no
3	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
4	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

In order to assess the amount of subsidy to be provided by the government, an economic calculation on the results of scenario 4 (the best scenario) was conducted. Simulation of the scenario 4 was done by inserting a condition in the form of a subsidy of Rp1 million per kl of biodiesel sold and used as a mixture material of diesel fuel. This subsidy was then increased to a level at which financial feasibility was achieved. Simulation calculation with NPV and net B/C as parameters was done from the period of 2015 to 2025.

The basic assumptions used in the financial analysis were a) the financial analysis conducted in the period of 2015-2025; b) the cost of the investment was assumed to be Rp5,149,321 per tonne of biodiesel (Hambali et al., 2010); c) initial working capital was set for 1 month of total operating costs in 2015; d) sources and capital structure were derived from the financial institution loans and equity in the ratio of 55: 45; d) interest rate was assumed to be 7%-9% as there was an interest rate relief from the government in accordance with Law No. 30 Year 2007; e) cost of depreciation was calculated by using a straight line method; f) maintenance fee was 2.5% of the investment value; and g) insurance costs of machinery and equipment was 5‰ of the initial investment value.

Financial analysis of biodiesel at an interest rate of 7% is as follows. A biodiesel subsidy of Rp1 million per kl will result in an NPV of Rp16.70 trillion with a Net B/C ratio of 0.76. A biodiesel subsidy of Rp1.25 million per kl will result in an NPV of Rp2.29 trillion with a Net B/C ratio of 1.04.

Financial analysis of biodiesel at an interest rate of 9% is as follows. A biodiesel subsidy of Rp1 million per kl will result in an NPV of Rp23.14 trillion with a Net B/C ratio of 0.65. A biodiesel subsidy of Rp1.35 million per kl will result in an NPV of Rp 0.62 trillion with a Net B/C ratio of 1.01. The results of financial analysis are listed in Table 4.

Table 4 NPV and B/C financial eligibility criteria for scenario 4

Subsidy (Rp million/kl)	Interest Rate 7%		Interest Rate 9%	
	NPV (Rp)	Net B/C	NPV (Rp)	Net B/C
1	-16 705 076 491 196	0.76	-23 137 879 724 600	0.65
1.2	-1 502 396 628 786	0.98	-9 564 136 744 862	0.85
1.25	2 298 273 336 817	1.04	-6 170 700 999 927	0.90
1.35	9 889 613 268 022	1.16	616 170 489 942	1.01

It was shown that with a subsidy of Rp1 million per kl, the NPV and Net B/C feasibility would not be reached. With the interest rate of 7%, NPV and Net B/C feasibility would be achieved if the subsidy was Rp1.25 million per kl. Providing subsidy at above Rp1.35 million per kl would make the limit of NPV and Net B/C feasibility for 9% interest rate be reached.

Results of the economic simulation showed that biodiesel industry was not yet financially feasible, if the subsidy given was Rp1 million per kl. This indicated that all scenarios, including scenario 4, could not be implemented if the subsidy provided by the government was Rp 1 million per kl. Scenario 4 could be implemented if the subsidy was at minimum Rp1.25 million and Rp1.35 million per kl at the interest rates of 7 and 9%, respectively.

4 Conclusions and Policy Implications

The simulation results in this study could be used to describe the effects of policies on supporting the achievement of mandatory use of oil palm biodiesel as a mixture material in diesel fuel as stipulated in the Regulation of Ministry of EMR No.12/2015. Current government policies included CPO disincentive, interest rate relief for investment in biodiesel plant, tax exemption or reduction for import of technology or equipment for biodiesel plant, subsidy of Rp1 million per kl for mixed diesel-biodiesel products. However, these current government policies on support to the achievement of mandatory use of biodiesel as a mixture material in diesel fuel would not make it realize (Figure 3).

In order to achieve the target mandatory use of palm oil biodiesel as a mixture material in diesel fuel, supports in the forms of additional policies or conditions including biodiesel production capacity increment, provision of incentives for biodiesel feedstock, plant productivity increment, provision of subsidy of at minimum Rp1.25 million and Rp1.35 million per kl at the interest rates of 7 and 9%, respectively, were needed. Mandatory use of biodiesel as a mixture material in diesel fuel needed policy packages which protected all business people of upstream and downstream industries.

The increment of average biodiesel production capacity was achieved by increasing the installed capacity and number of biodiesel plants. Incentives for biodiesel feedstock supply industry should be given to CPO or refinery industries. The incentives could be in the forms of reduction in value added tax, tax allowance, and tax holiday. Plant productivity increment was done by the use of superior seeds, appropriate fertilizing, improvement of human resources skill, implementation of good plantation practice. Plant productivity increment needed research supports. Subsidy provision was aimed at the achievement of economic prices so that biodiesel plants could run their production. Provision of subsidy should be at minimum Rp1.25 million and Rp1.35 million per kl at the interest rates of 7%and 9%, respectively.

The policy on the improvement of production capacity brought an implication that the number and capacity of biodiesel plants should be increased so that investment from government and private sector was required. Improvement of biodiesel plant capacity required land availability and Indonesia had plenty of it. Improved capacity also required labor support so that it could create new employments which directly or indirectly would help increase local people and national economy. In a certain period of time, the return of the investment capital would be economically gained.

Incentive provision would bring an implication of lower government income as a result of tax reduction. However, feedstock suppliers, both CPO and refinery industries would be interested in providing biodiesel feedstock supply in addition to exporting or selling it to other industrial sector such as oleo chemical industry. Adequate feedstock supply would make biodiesel industry able to have continuous production which eventually would lead to the fulfillment of biodiesel mandatory use target over time. Lower state income as caused by reduced tax would then be compensated as income would be regained through employment in biodiesel plants, reduction in government subsidy or reduction in fossil fuel import budget as a result of fossil fuel replacement by biodiesel.

Plant productivity improvement would bring another implication. The government should provide extra budget for this. This policy required support from research activities to produce superior seeds, improve human resources skill, implement good plantation practice, etc. Although required extra budget, this policy in turn would bring more substantial benefits. Higher plant production would ensure the fulfillment of future requirement. Compared to land size increase, plant productivity improvement was a sustainable policy choice. Through this policy, productivity was increased in a more environmentally friendly way by preserving ecology and biodiversity and avoiding greenhouse gasses emission and land conversion.

The policy of provision of subsidy for biodiesel product to make it reach its economic price required the government to increase the expenditure budget. However, this increased expenditure would be compensated with the removal of subsidy or fossil fuel purchase as a result of fossil fuel substitution by biodiesel. The use of biodiesel was also more environmentally friendly as it produced 36% less greenhouse gasses emission (Machmud, 2009).

References

Ciaian, P., and A. Kancs. 2011. Food, energy and environment: is bioenergy the missing link? *Food Policy*, 36(5): 571–580.

Crabbe, E., N. H. Cirilo, K. Genta, S. Kenji, and I. Ayaaki. 2001. Biodiesel production form crude palm oil and evaluation of butanol extraction and fuel propesrties. *Process Biochemistry*, 37(1): 65–71.

Debreu, G. 1974. Excess demand functions. *Journal of Mathematical Economics*, 1(1): 15–21.

Gray, C., S. Payaman, K. S. Lien, P. F. L. Maspaitella, and R. C. G. Varley. 1997. *Pengantar Evaluasi Proyek*. Jakarta: PT Gramedia Pustaka Utama

Hambali, E., A. Thahar, and K. Aan. 2010. *The Feasibility Study of Biodiesel Industry Development.* Bogor: Surfactant and Bioenergy Research Center (SBRC).

Handoko, H., E. G. Sa'id, and S. Yusman. 2012. System dynamic model biodiesel to meet biodiesel contribution in Indonesia's energy mixture by 2025. *Journal of Technology Management*, 11(1): 15–27.

Jeffers, R. F., J. J. Jacob, and M. S. Erin. 2013. Dynamic analysis of policy drivers for bioenergy markets. *Energy Policy*, 52: 249–263.

Lynd, L., and J. Woods. 2011. Perspective: new hope for Africa. *Nature*, 474(7352): 20–21.

Makridakis, S., S. T. Wheelwrigth, and V. E. McGee. 1995. *Forecasting Method and Application: Translation of Forecasting*, 2nd Edition. Interpreter: S. A. Untung, A. Basith. Jakarta: Erlangga

Mantel, R. 1974. On the characterization of excess demand. *Journal of Economic Theory*, 7: 348–353.

Ministry of Energy and Mineral Resources. 2015. *Hand book energy and economic statistic of Indonesia 2016*. Republic of Indonesia: Jakarta.

National Energy Council. 2016. *Indonesia energy outlook 2016*. National Energy Council: Jakarta

Panoutsou, C. 2008. Bioenergy in Greece: policies, diffusion framework and stakeholder interactions. *Energy Policy*, 36(10): 3674–3685.

Popp, J., Z. Lakner, M. H. Rákos, and M. Fári. 2014. The effect of bioenergy expansion: food, energy, and environment. *Renewable and Sustainable Energy Reviews*, 32(32): 559–578.

President of Republic Indonesia. 2006. Regulation of President of Republic Indonesia number 5/2006 concerning National energy policy. vol. 25. Jakarta, Indonesia, National Academy Press.

President of Republic Indonesia. 2014. Regulation of President of Republic Indonesia number 79/2014 concerning National Energy Policy. vol. 17. Jakarta, Indonesia, National Academy Press.

Soerawidjaja, T. H. 2014. Hurdles to bioenergy implementation programs in Indonesia. Seminar of Indonesia Chamber of Commerce and Industry: entering the era of new and renewable energy for the national energy souvereignty, Jakarta.

Sorda, G., B. Martin, and K. Claudia. 2010. An overview of biofuel policies across the world. *Energy Policy*, 6977–6988.

Sterman, J. D. 2002. Business dynamics: system thinking and modelling for a complex world. *Journal of the Operational Research Society*, 53(4): 472–473.

Thornley, P., and C. Deborah. 2008. The effectiveness of policy instruments in promoting bioenergy. *Biomass and Bioenergy*, 32: 903–913.

Thurlow, J. 2010. Economy wide effects of bioenergy development in bioenergy and food security: the BEFS analysis for Tanzania. Environment and Natural Resources Management Working Paper, 35, FAO, Rome, Italy.

Timilsina, G. F., S. Mevel, and A. Shrestha. 2011. Oil price, biofuels and food supply. *Energy Policy*, 8098–8105.

Zhou, A., and E. Thomson. 2009. The development of biofuels in Asia. *Applied Energy*, 86(11): S11–S20.