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A System Dynamics Model for Biodiesel Industry in Indonesia

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Abstract. *The biggest demand for energy in Indonesia is oil fuels. To fulfill this demand, Indonesia has to import oil fuels. In order to decrease oil import, Government of Indonesia develop some policies to use biodiesel. Since 2009, biodiesel production in Indonesia has increased every year. To find out what factors and how these factors affect biodiesel industry's growth in Indonesia, this research was conducted using literature study and system dynamics modeling. In this research, the factors that were evaluated are feedstock, biodiesel price, and government mandatory and regulation. The evaluation was carried out through system dynamics modeling for the next thirty years. The results of the system dynamics modeling simulation show that the factor that most influence the profit and biodiesel capacity construction is the use of advanced technology that can produce biodiesel from low quality and low-cost feedstocks. The second factor is government incentives in the form of a carbon tax that can increase the profit. The next factor is the amount of mandatory mixing of biodiesel in diesel oil. While biodiesel price factor did not significantly affect the profit and biodiesel capacity construction.*

Keywords: *Biodiesel, causal loop diagram, industry, stock and flow diagram, system dynamics*

1. Introduction

Based on Indonesia Energy Outlook 2018 published by BPPT (*Badan Pengkajian dan Penerapan Teknologi*/Agency for the Assessment and Application of Technology), Indonesia's energy demand keeps increasing every year, along with economic growth, population growth, energy prices, government policies, and so on. Currently, the final energy growth rate is 5.3% per year, which is equal to the increase in energy demand from 795 million BOE (barrels of oil equivalent) in 2016 to 4,569 million BOE in 2050. In 2050, the biggest market share of energy is oil fuels, followed by electricity, gas, coal, LPG (Liquified Petroleum Gas), biofuel, and biomass (PPIPE BPPT, 2018).

The demand for oil fuels keeps increasing every year with an average growth of 4.7% per year. The demand reached 69.1 million kiloliters in 2016 and will increase in 2050 to 326.6 million kiloliters. To fulfill this demand, Indonesia has to import oil fuels. In 2016, oil fuels import was 22.9 million kiloliters and will increase per year by 6.3%. Currently, the largest share of fuel oil import is gasoline (68.6%), followed by diesel oil (25.3%), jet kerosene (4.4%), fuel oil (1.1%), and the rest is kerosene (PPIPE BPPT, 2018).

On the other hand, oil reserves, natural gas reserves, and coal production keep decreasing. In 2016, petroleum production was 338 million barrels and will decrease to 85 million barrels in 2050. In order to meet the demand of oil fuels that increase every year, Indonesia needs to import crude oil. Indonesia has been a net importer of crude oil since 2004 and it keeps increasing every year. In 2016, crude oil import was 148 million barrels and will increase to 953 million barrels in 2050 (PPIPE BPPT, 2018).

Oil fuel is consumed by six sectors i.e. transportation, industrial, power plant, households, commercial and others. In 2016, the highest oil fuel consumption was in the transportation sector (80.7%), followed by industrial sector (8.1%), power plant (5.5%),

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others (3.9%), households (1.0%) and commercial (0.8%). In 2050, transportation and the industrial sector still have the largest oil fuel consumption (PPIPE BPPT, 2018).

In order to decrease crude oil import, Government of Indonesia develops some policies to use new and renewable energy such as biofuels. It began with the issuance of Presidential Regulation No. 5 the Year 2006 concerning the National Energy Policy. This regulation is issued together with Presidential Instruction No. 1 of 2006 concerning the supply and utilization of biofuels as other fuels. Furthermore, in 2007, the Government of Indonesia published Law No. 30 of 2007 concerning Energy.

In 2014, the Government of Indonesia issued Government Regulation No. 79 of 2014 concerning the National Energy Policy, which replaces the Presidential Regulation No. 5 of 2006. This regulation states that in 2025 the role of new and renewable energy reaches at least 23% and by 2050 at least 31% as long as its economic value is fulfilled. To meet 23% new and renewable energy use by 2025, the government established blending target policy by issuing the Minister of Energy and Mineral Resources (MEMR) Regulation No. 12 Year 2015 concerning the mandatory for the use of biofuels as a mixture of fuel oil in the transportation, industrial, commercial and electricity generation sectors.

One of the biofuels that are currently used in Indonesia is biodiesel. Biodiesel can be produced from various feedstocks including vegetable oils (palm, soybean, canola, coconut, etc.), animal fats and waste oils (used cooking oil, etc.). In Indonesia, biodiesel is produced from Crude Palm Oil (CPO). Since 2009 biodiesel production in Indonesia has increased every year. The production growth of biodiesel is influenced by several factors. Hence, this research will evaluate biodiesel industry in Indonesia and determine the factors that influence biodiesel growth and develop system dynamics modeling to asses biodiesel growth in Indonesia for the next thirty years by only considering the government mandatory of biodiesel use.

2. Literature Review

2.1. Biodiesel Industry in Indonesia

Biodiesel began to be produced in Indonesia since 2009 with a total production of 190,000 kiloliters. Indonesia's biodiesel production continues to increase every year until 2017 Indonesia's biodiesel production reaches 3,416,000 kiloliters. Based on the Handbook of Energy and Economic Statistics of Indonesia, until 2017, the biodiesel industry in Indonesia is spread in 13 provinces with a total installed capacity of 12,059,372 kiloliters (Ministry of Energy and Mineral Resources, 2018).

The raw material for biodiesel production in Indonesia is the CPO (Crude Palm Oil) produced by the Palm Oil Mill with oil palm originating from the Large State Plantation, Large Private Plantation, and Community Plantation. Then the biodiesel is distributed for domestic consumption through oil fuel business entities such as PT Pertamina, PT AKR Corporindo Tbk, PT Shell Indonesia, etc. In addition, Indonesian biodiesel is also exported to several countries.

Besides being used as raw material for biodiesel, CPO is also used for raw materials for the production of cooking oil, margarine, and others. Rahman et al. (2017) investigated the availability of Indonesian CPO to support food and energy security using system dynamic approach. They concluded that the availability of CPO is sufficient for food and energy if there was an increase in productivity, diversification of raw materials and reduction of palm oil exports.

Currently, the biodiesel market index price is determined by the Ministry of Energy and Mineral Resources every month. This price depends on the average CPO KPB price and the freight charges that are stipulated in the Minister of Energy and Mineral Resources

Decree. If the price is higher than the diesel price, then the incentives will be given by the Palm Oil Plantation Fund Management Agency to cover the price gap. The incentives provided by the Palm Oil Plantation Fund Management Agency come from export levies of CPO and its derivative products.

2.2. Review on the Existing Studies of Biofuel Policy

In 2015, Solomon et al. reviewed policies for biofuels sustainable development in the United States, Brazil, Argentina, Canada, and Mexico. The U.S. government developed a tax credit policy for biodiesel producer. Brazil has biodiesel policy called National Program for the Production and use of Biodiesel. It mandated the use of B5 (biodiesel 5%) in 2010. The Brazilian government also provided tax exemption for biodiesel depends on the type of feedstock, production region, and size of feedstock farms. The government of Argentina mandated to use B10 in 2014. They also determined the biodiesel export tax rate of 32%. The Canadian government mandated the blending of 2% biofuel with diesel fuel in 2011. Canada also has a biofuel subsidy program which began in 2008. Unlike the other countries, Mexico did not have a policy that mandates the mixing of ethanol and biodiesel with their fossil fuel equivalents.

Also, in 2015, Mofijur et al. evaluated energy scenario and biofuel policies and targets in ASEAN countries. The government of Indonesia mandated the use of 15% bioethanol and 20% biodiesel by 2025 while the Government of Philippine mandated the use of 10% bioethanol and 2% of biodiesel by 2010. Malaysia started B7 (biodiesel 7%) in 2015 and planned to revise the B10 Malaysian standard. Cambodia created a master plan on renewable energy, Laos established an Ad Hoc Committee for Formulation of National Strategy on Biofuel Energy and Myanmar created indicative national biofuel program framework. Thailand and Vietnam published National Alternative Energy Plan and Renewable Energy Action Plan respectively.

Biofuel policy in India is reviewed by Saravanan et al. (2018). Government of India proposed mandate of 20% biodiesel and bioethanol by 2017. Besides, there were state-specific biofuel policies in India on the sales tax rate of diesel and ethanol.

2.3. Review on the Existing Studies of Biodiesel System Dynamics

Research on biofuel-related system dynamic models have been carried out in the past few years. Jeffers et al. (2013) created a model of United States bioenergy feedstock commodity market, investigated the dynamic analysis of policy drivers for bioenergy commodity markets and found that with current policy incentives and ignoring exports, biofuels dominate the market. In 2014, Pereira et al. evaluated the impact of the Swedish biofuel system on the achievement of 10% of renewable fuels by 2020 and identified development patterns in order to establish a vehicle fleet independent of fossil fuels by 2030.

Eker and van Daalen (2015) developed a system dynamics model of the biomethane production in the Netherlands and evaluated the effectiveness of subsidization policy under uncertainty. Also, in 2015, Shafiei et al. used an integrated system dynamics model of the energy system to simulate the transition path towards alternative fuel market during 2015-2050 in Iceland. Shafiei et al. (2016) also proposed a study of the capacity expansion strategies of biofuels supply and examined the potential for the market development of biofuel vehicles using an integrated system dynamics model of energy and transport systems for Iceland.

In 2017, Guevara et al. evaluated the sustainability of Brazilian ethanol production using a system dynamics model. Muthingi et al. (2017) proposed system dynamics archetypes that are useful in energy policy modeling and simulation in uncertain environments. System dynamics modeling also used by Andre Demczuk and Antonio Domingos Padula (2017) and Ximei Liu and

Ming Zeng (2017) to evaluate the feasibility of ethanol supply chain in Brazil and renewable energy investment risk, respectively. Kuo et al. (2018) used system dynamics modeling to evaluate government subsidy policies for biofuel in Taiwan.

Research on system dynamic modeling of biodiesel has also been carried out in the past decades. Bantz et al. (2006) identified the factors that affect biodiesel industry growth in the United States and formulated a system dynamics model of the biodiesel marketplace in the United States. Later in 2011, Hidayanto et al. used system dynamics to investigate the sustainability of palm-oil based biodiesel production chain in Indonesia. They found that the accomplishment of a sustainable biodiesel production within the target and the timeframe is impossible without a subsidized price and further policy from the government.

Musango et al. (2011) introduced a system dynamics model named Bioenergy Technology Sustainability Assessment (BIOTSA). They demonstrated and evaluated the effects of biodiesel development on selected sustainability indicators for the Eastern Cape Province in South Africa. Further, in 2012, they investigated policy interventions on biodiesel development in Eastern Cape Province, South Africa. Barisa et al. (2014) developed a system dynamic model to capture the Latvian biodiesel industry in the transport sector and evaluated the effect of different policy strategies for achieving the national transport policy target.

Bautista et al. (2016) developed a system dynamics model to analyze the Colombian biodiesel market and governmental biodiesel policy for creating and managing the biodiesel market. Further, in 2018, they evaluated the sustainability of biodiesel production in Colombia in the baseline scenario using a system dynamics model. They concluded that strong support from government policies is required to increase biodiesel production and production capacity.

3. Methodology

A simulation is the imitation of the operation of a real-world process or system overtime. (Banks, 2014). Simulation is the process of model "execution" that takes the model through (discrete or continuous) state changes over time. In general, for complex problems where time dynamics is important, simulation modeling is a better answer (Borshchev et al., 2004).

According to Borshchev et al. (2014), the major approaches in simulation modeling are System Dynamics (SD), "Discrete Event" (DE) and Agent Based (AB). System dynamics is used because of its ability to capture the whole system which may be used to explore how the system structures impacts the system behavior (Morgan et al., 2016).

Several studies on simulation modeling have been carried out, i.e. Wasesa et al. (2012) analyzed and proposed measures to improve the pre-notification protocol of the containers pick-up procedure with an Agent Based approach. Lidia et al. (2012) applied System Dynamics approach to propose a decision support system for an apparel company in Indonesia. In 2016, Inayati et al. developed System Dynamics model on international movements of Indonesian scientists and engineers.

3.1. System Dynamics

System dynamics is a powerful method to gain useful insight into situations of dynamic complexity and policy resistance. System dynamics can be applied to any dynamic system, with any time and spatial scale. In the world of business and public policy, system dynamics has been applied to industries from aircraft to zinc and issues from AIDS to welfare reform (Sterman, 2000). There are five iterative steps of modeling in system dynamics according to Sterman (2000).

1. Problem Articulation (Boundary Selection)
   The first step of modeling in system dynamics is problem articulation. In

this step, the issue of concern, time frame, level of analysis, the boundary of the study and scope of factor involved are identified.

2. Formulating a Dynamic Hypothesis
   The next step is formulating a dynamic hypothesis. The dynamic hypothesis provides an explanation of the dynamics characterizing the problem in terms of the underlying feedback and stock and flow structure of the system.
3. Formulating a Simulation Model
   After developing a model boundary and dynamic hypothesis the next step is formulating a simulation model. In this step, the conceptual realm of the diagram is transformed into a fully specified formal model, complete with equations, parameters, and initial conditions.
4. Testing
   In this step, the simulated behavior is compared to the actual behavior of the system. Every variable has to resemble a meaningful concept in the real world and every equation has to be checked for dimensional consistency.
5. Policy Design Formulation and Evaluation
   The last step is developing policy design and evaluate the policies with the model that have developed before. Their performance has to be assessed under a wide range of alternative scenarios.

3.1.1. Causal Loop Diagram

Causal loop diagrams are flexible and useful tools for diagramming the feedback structure of systems in any domain. Causal diagrams are simply maps showing the causal links among variables with arrows from a cause to an effect (Sterman, 2000). Causal loop diagrams also capture hypotheses about dynamic behavior (Morecroft, 2015). The causal link in the causal loop diagram is assigned a polarity, positive (+) or negative (-) to indicate how the dependent variable changes when the independent variable changes. The important loops are highlighted by a loop identifier which shows whether a loop is a positive (reinforcing) or negative (balancing) (Sterman, 2000).

3.1.2. Stock and Flow Diagram

Causal loop diagrams emphasize the feedback structure of a system. Stock and flow diagrams emphasize their underlying physical structure (Sterman, 2000). Flows are the increase or decrease rates in stock. Stocks are accumulation that characterizes the state of the system. In the stock and flow diagram, stocks are symbolized by rectangles, inflows and outflows are symbolized by a pipe arrow pointing into the stocks and out of the stock respectively. There is a valve symbol in the pipe arrow of inflows and outflows that represent the control of the flows. At the end of the pipe arrow, there is a cloud symbol that represents the sources and sinks for the flows.

3.1.3. Scenario Development

According to Sterman (2000), the key to effective scenario modelling is to unfold several alternative futures (each an internally consistent story, but with a different plot and a different ending) in order to challenge conventional wisdom and to encourage users to think how they would act if this future were to unfold.

3.1.4 Verification and Validation

According to Banks (2014), the purpose of model verification is to assure that the conceptual model is reflected accurately in the operational model. Validation attempts to confirm that a model is an accurate representation of the real system (Banks, 2014). According to Sterman (1988), validation is a continuous process of testing and building confidence in the model. There is no model that can be validated by a single test or the ability to fit the historical data. According to Barlas (1996), it is not generally possible to classify the model as correct or incorrect, but the model can be of good quality or poor quality.

4. Analysis

4.1. Causal Loop Diagram

The causal loop diagram for this research is based on the previous studies which are carried out by Bantz (2006), Musango (2011), Pereira (2014), and Barisa (2014) with several modifications and improvements to adjust with the condition in Indonesia. The modifications and improvements are as follows:

- Feedstock price that directly affects biodiesel price.
- Incentives from the Palm Oil Plantation Fund Management Agency that are affected by biodiesel price and diesel price.
- The capital cost will affect the desired capacity.

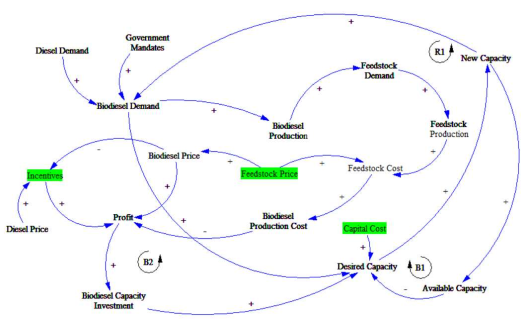

Figure 1.
Causal loop diagram

The causal loop diagram of the biodiesel industry in Indonesia is shown in Figure 1. The green highlight color in the figure shows the modification/improvement for this research. Diesel demand has a positive correlation with biodiesel demand. If biodiesel demand increase, the feedstock demand, and production will increase. Feedstock production has a positive correlation with feedstock cost. Feedstock price has a positive correlation to both feedstock cost and biodiesel price. When the feedstock price is increasing, the biodiesel price will be increased too. Biodiesel price has a positive correlation with biodiesel company profitability. If the biodiesel company's profit increase, the biodiesel capacity investment will increase, so as the new capacity.

4.2. Stock and Flow Diagram

The stock and flow diagram of the biodiesel industry in Indonesia is shown in Figure 2.

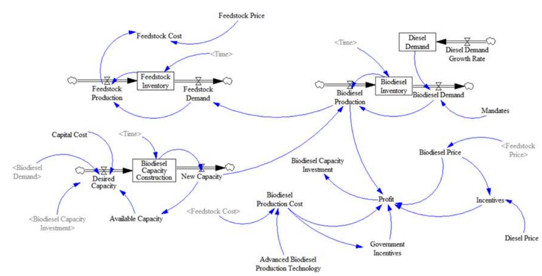

Figure 2.
Stock and flow diagram

4.3. Scenario Development

Government mandates

One of the factors that greatly affect the production and consumption of biodiesel in Indonesia is the existence of a government mandate to use biodiesel as a mixture of fuel oil. At present, the Government of Indonesia has determined the use of B30 starting in 2020 until 2025.

- Scenario A1: Mandatory mixing of biodiesel in diesel oil to 35% from 2030 to 2050.
- Scenario A2: Mandatory mixing of biodiesel in diesel fuels to 40% from 2030 to 2050.
- Scenario A3: Mandatory mixing of biodiesel in diesel oil to 50% from 2030 to 2050.

Government incentives

In addition to government mandates, which affect the growth of the biodiesel industry in Indonesia, there is a government incentive. These incentives are different from the incentives currently in Indonesia, namely in the form of the carbon tax which can increase profit.

- Scenario B1: Determination of carbon tax that can increase the profit by 5% of the production cost. The determination of carbon tax will begin in 2030.
- Scenario B2: Determination of

carbon tax that can increase the profit by 10% of the production cost. The determination of carbon tax will begin in 2030.

- Scenario B3: Determination of carbon tax which can increase the profit by 20% of the production cost. The determination of carbon tax will begin in 2030.

Feedstock price

Feedstock prices are also one of the factors that can influence the growth of the biodiesel industry in Indonesia. The more advanced technology can produce biodiesel not only from CPO but also from palm oil industry waste such as PAO (Palm Acid Oil), PFAD (Palm Fatty Acid Distillate) and used cooking oil which is cheaper than CPO.

- Scenario C1: Use of advanced technology starting in 2025 which can reduce feedstock prices by 10%.
- Scenario C2: Use of advanced technology starting in 2025 which can reduce feedstock prices by 20%.
- Scenario C3: Use of advanced technology starting in 2025 which can reduce feedstock prices by 30%.

Biodiesel price

In addition to the feedstock price, price biodiesel can also affect the growth of the biodiesel industry in Indonesia. At present, the price of biodiesel depends on fluctuating CPO prices.

- Scenario D1: The price of biodiesel is 105% of the feedstock price.
- Scenario D2: The price of biodiesel is 110% of the feedstock price.
- Scenario D3: The price of biodiesel is 120% of the feedstock price.

Scenario Configuration

From the four factors described above, there are 3 scenarios for each factor. In addition, there are also 3 scenarios that combine these four factors. All scenarios can be seen in Table 1. The scenarios are then simulated on the system dynamics model that has been developed previously.

Table 1.
Scenario configuration

Scenario	Gov. Mandates	Gov. Incentives	Feedstock Price	Biodiesel Price
S1	A1			
S2	A2			
S3	A3			
S4		B1		
S5		B2		
S6		B3		
S7			C1	
S8			C2	
S9			C3	
S10				D1
S11				D2
S12				D3
S13	A1	B1	C1	D1
S14	A2	B2	C2	D2
S15	A3	B3	C3	D3

4.4. Model Verification and Validation

4.4.1 Model Verification

The verification method for this research is by asking the experts whether the model in this study is in accordance with the real conditions in Indonesia.

Expert opinion

In this research, the causal loop diagram for biodiesel industry in Indonesia has been confirmed to the stakeholders i.e. Directorate of Upstream Business Development - Directorate General of Oil and Gas (MEMR), Directorate of Bioenergy - Directorate General of New Renewable Energy and Energy Conservation (MEMR), and PT BDZ.

4.4.2 Model Validation

The validation test for the model in this research is described in the following passage.

Dimensional consistency test

Dimensional consistency is one of the most basic tests and should be among the very first be done (Sterman, 2000). In Vensim software, there is a feature to check the consistency of the unit. Modeling in this research has gone through the unit checking stage in Vensim software. The result is "Units are OK" which means the units in this modeling are consistent.

Extreme condition test

According to Sterman (2000), models should be robust in extreme conditions. Robustness under extreme conditions means the model should behave in a realistic fashion no matter how extreme the inputs or policies imposed on it may be. In this research, there are three extreme condition scenarios, i.e. extreme diesel demand growth (EC1), no incentives from Management Board of Oil Palm Plantation Funds (EC2) and no biodiesel capacity investment (EC3). The results of the extreme condition test indicate that the system dynamic model in this research generates the right results for extreme conditions.

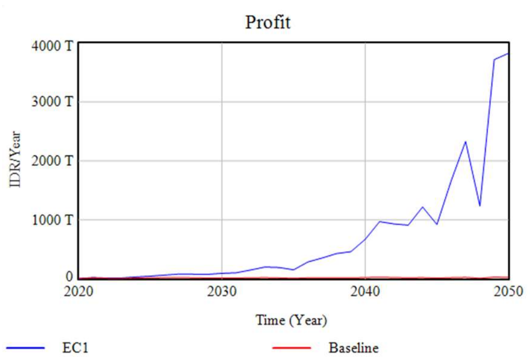

Figure 3.
EC1 results – profit

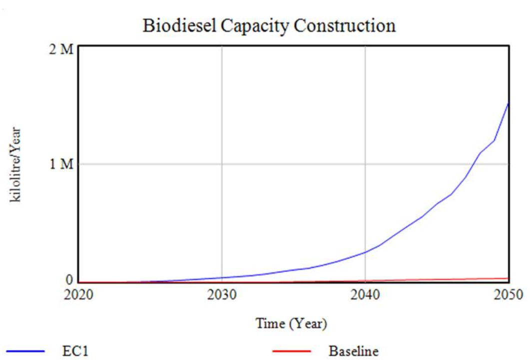

Figure 4.
EC1 result – biodiesel capacity construction

Figure 3 and Figure 4 shows the simulation results in the EC1 scenario. In this scenario, diesel demand growth increases from 2% per year to 20% per year. This condition makes the profit generated increases very sharply, so does the biodiesel capacity construction.

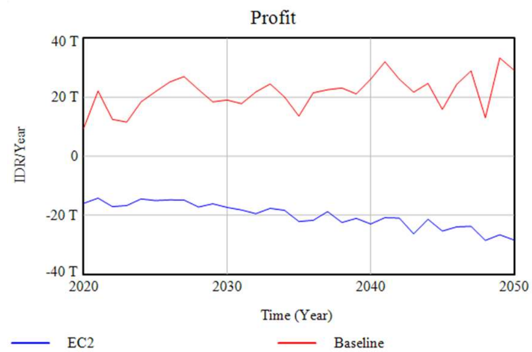

Figure 5.
EC2 results – profit

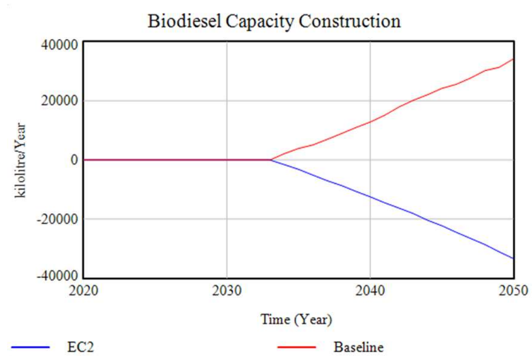

Figure 6.
EC2 result – biodiesel capacity construction

The EC2 scenario simulation results are shown in Figure 5 and Figure 6. In the EC2 scenario, there is no incentive to cover the difference in biodiesel prices with diesel prices. So, the results obtained are that is no profit generated even negative so there is no addition to biodiesel capacity construction.

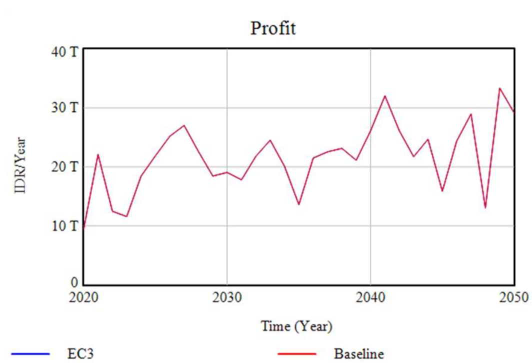

Figure 7.
EC3 results – profit

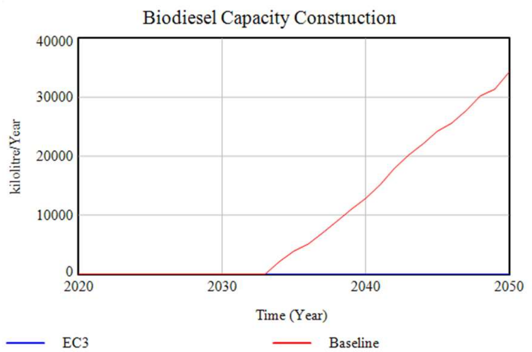

Figure 8.
EC3 result – biodiesel capacity construction

In Figure 7 and Figure 8, you can see the simulation results from EC3. In this scenario, biodiesel capacity investment is set to zero. This has no effect on the profits obtained but has an effect on the construction of new biodiesel capacity. Because biodiesel capacity investment is set to zero, there is no biodiesel capacity construction.

4.5. Simulation Results

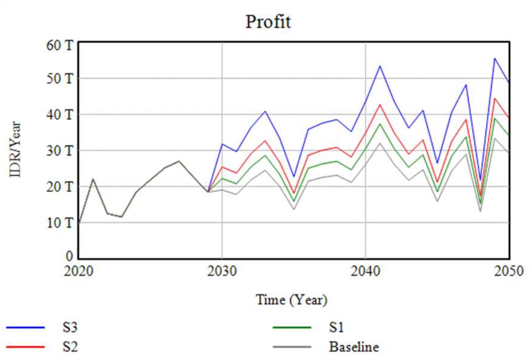

Figure 9.
Government mandates results – profit

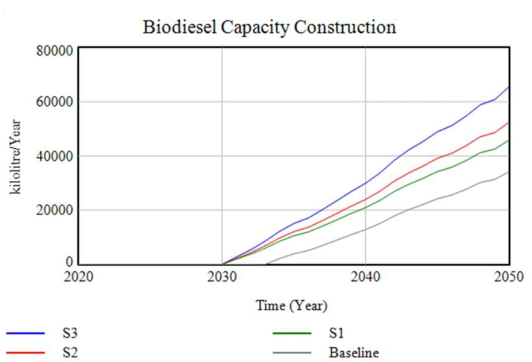

Figure 10.
Government mandates result – biodiesel capacity construction

Figure 9 and 10 shows the results of simulating scenarios on the government's mandate on profit and construction capacity of biodiesel. As seen in the graph, the resulting profit fluctuates every year. The higher the mandatory mixing of biodiesel in oil fuel, the higher the profit generated. Meanwhile, biodiesel capacity construction will always increase since the new mandatory enactment in 2030. The higher the mandatory mixing of biodiesel in oil fuel, the higher the biodiesel capacity that must be built to meet biodiesel demand until 2050.

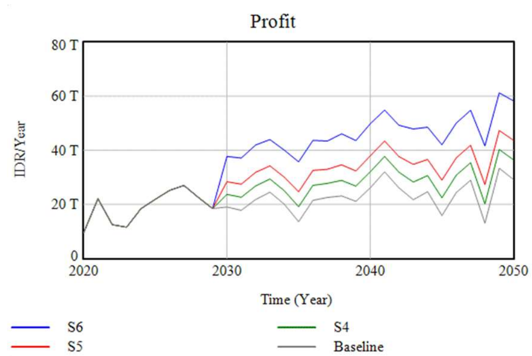

Figure 11.
Government incentives results – profit

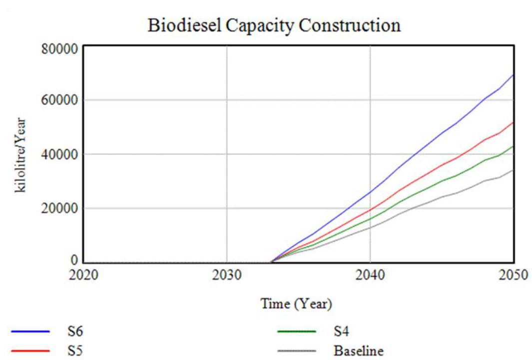

Figure 12.
Government incentives result – biodiesel capacity construction

Government incentives scenario simulation results can be seen in Figure 10 and 11. The higher the incentives provided by the government, the higher the profit generated, even though the profit fluctuates every year. With increasing profits, investment to build new biodiesel capacity is also increasing. The new capacity building began in 2034.

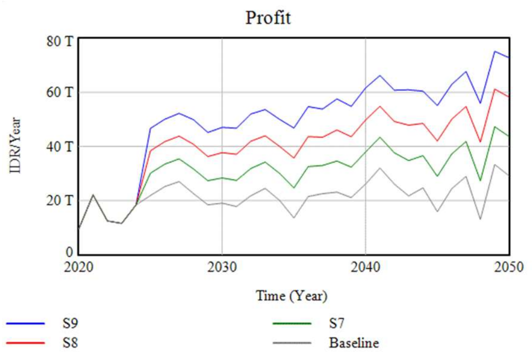

Figure 13.
Feedstock price results – profit

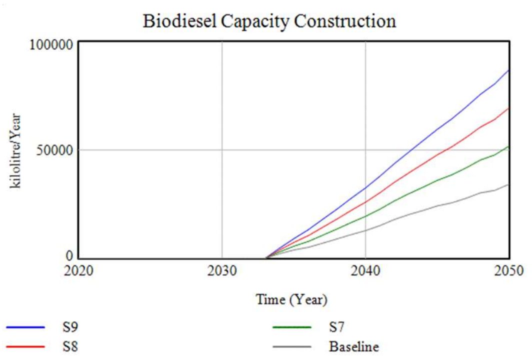

Figure 14.
Feedstock price result – biodiesel capacity construction

Figure 13 and 14 shows the simulation results on the feedstock price using advanced technology that can reduce feedstock costs. With the reduction in feedstock prices, the profits will increase. The resulting profit fluctuates every year but tends to increase until 2050. Similar to the results of the simulation on government incentives, the higher the profit, the higher the capacity of biodiesel to be built. Biodiesel capacity construction began in 2034.

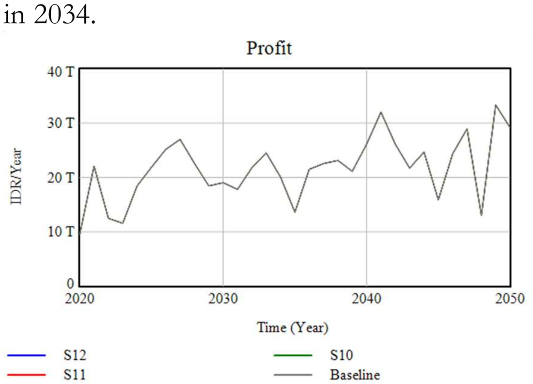

Figure 15.
Biodiesel price results – profit

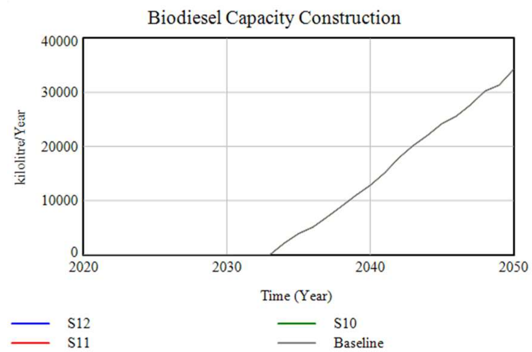

Figure 16.
Biodiesel price – biodiesel capacity construction

The simulation results on the biodiesel price are shown in Figure 15 and 16. Changes to the biodiesel price did not significantly affect the profit generated so the biodiesel capacity construction was the same for the three scenarios on the biodiesel price.

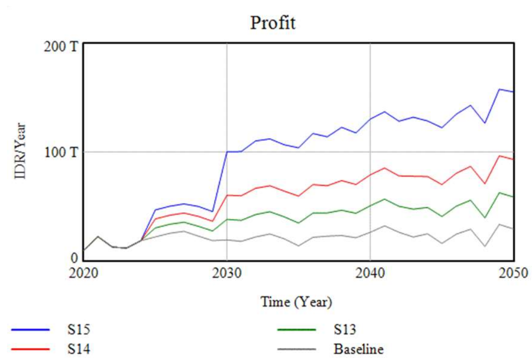

Figure 17.
Mix scenario results – profit

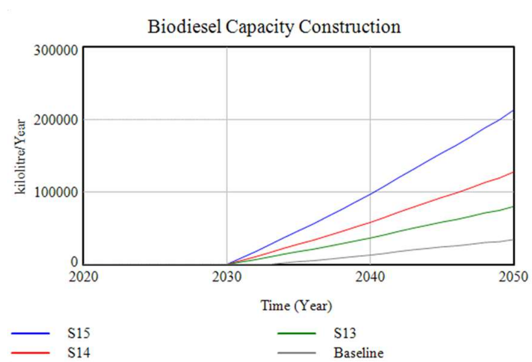

Figure 18.
Mix scenario result – biodiesel capacity construction

The simulation results for the mix scenario can be seen in Figure 17 and 18. The highest profit is generated from the S15 scenario, as well as biodiesel capacity construction. Because in the S15 scenario, government mandates are inputted for mixing biodiesel on fuel by 50%, government incentives in the form of 20% carbon tax which can reduce biodiesel production costs, advanced technologies implementation that can reduce feedstock prices by 30% and biodiesel prices are 120% from the feedstock price. In the S15 scenario, the profit reached around 150 trillion IDR in 2050 and the biodiesel capacity construction is 200,000 kiloliters/year in 2050.

5. Conclusion

The biodiesel industry in Indonesia has started to develop since 2009. Until now, biodiesel needs in Indonesia have continued to grow due to government support through mandatory and regulation. In addition to the mandatory and regulation of the government, there are several other factors that can influence the growth of the biodiesel industry. Based on the literature study that has been done, these factors are feedstocks, biodiesel price, advanced technology, and the environment. In this research, evaluation of factors from the feedstock, biodiesel sales, and government mandates and regulations were carried out through system dynamic modeling.

From the results of the system dynamics modeling simulation, it can be concluded that the factor that most influences the biodiesel industry in terms of profit are the use of advanced technology that can process biodiesel from raw materials at a cheaper price than CPO. Followed by government incentives in the form of a carbon tax that can reduce production costs. The next factor is the amount of mandatory mixing of biodiesel in fuel. With the greater profit generated, investment in building new biodiesel capacity is also increasing. A factor that does not significantly affect profit and biodiesel capacity construction is the price of biodiesel.

From these conclusions, so that the biodiesel industry has good growth, the biodiesel industry can use advanced technology that can process biodiesel using cheaper raw materials than CPO, such as waste from oil palm plantations and CPO processing wastes. In addition, to support the growth of the biodiesel industry, the government can implement carbon tax regulations that can reduce production costs from the biodiesel industry.

For future research, this study can be developed by considering future technology or government regulations that can affect biodiesel demand such as the use of electric cars and so on.

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