# Exploration of agent of change's role in biodiesel energy transition process using agent-based model

**A Hidayatno**[1,1]**, L R Vicky**[1,2] **and A R Destyanto**[1,3]

[1]System Engineering Modeling and Simulation Laboratory, Department of Industrial Engineering, Universitas Indonesia, Kampus UI Baru Depok, 16424, Indonesia

akhmad@eng.ui.ac.id[1], respativicky@gmail.com[2], arryrahmawan@ui.ac.id[3]

**Abstract**. As the world's largest Crude Palm Oil (CPO) producer, Indonesia uses CPO as raw material for biodiesel. A number of policies have been designed by the Indonesian government to support adoption of biodiesel. However, the role of energy alternatives faced complex problems. Agent-based modeling can be applied to predict the impact of policies on the actors in the business process to acquire a rich discernment of the behavior and decision making by the biodiesel industries. This study evaluates government policy by attending at the adoption of the biodiesel industry in the tender run by a government with the intervention of two policy options biodiesel energy utilization by developing an agent-based model. The simulation result show that the policy of adding the biodiesel plant installed capacity has a good impact in increasing the production capacity and vendor adoption in the tender. Even so, the government should consider the cost to be incurred and the profits for vendors, so the biodiesel production targets can be successfully fulfilled.

## 1. Introduction

Indonesia is the country that has the highest palm oil production in the world, Indonesia's palm oil production in 2015 reached 35,000,000 MT as the first in the world, followed by Malaysia, Thailand, Columbia, and Nigeria. Besides the highest production, the use of palm oil as a new material for biodiesel can produce many advantages for Indonesia, especially on environmental aspects. The emissions produced by CPO as biofuels can reduce 100% of Sulfur Dioxide (SO2), 48% Carbon Monoxide (CO), 47% Particulate Matter (PM), 67% of total burning hydrocarbons and mutagenesis up to 90% [1].

Biodiesel also can be utilized in several sectors: transportation, small medium enterprises, State Electricity Company, industrial and even commercial. In addition, the use of the CPO in Indonesia as a biodiesel feedstock has been supported by technology, infrastructure, and compliant policies.

Various policies have been planned by the Indonesian government to promote the usage of biodiesel energy alternatives. The first policy is the policy of mixing with oil fuel for reaching the target of biodiesel supply about 10.22 million KL in 2025. Another regulation targets of at least 15% of total biodiesel by 2015, 20% by 2016, and 30% by 2020 and 2025 for all sectors except power plant and household. The second policy is a biodiesel technical policy that appointed state owned enterprise (SoE/BUMN) as biodiesel buyer. In Indonesia, the use of biodiesel is arranged in two ways: direct election to purchase subsidized biodiesel and indirect election to purchase non-subsidized biodiesel that called tender.

However, the biodiesel production condition faces complex problems. More absorption is done by subsidizing biodiesel, while non-subsidized biodiesel has not been carried out optimally. There are

four major problems facing biodiesel production. First, the absorption of biodiesel production that is less than the target, which is in 2014 only reached 81% of the government's target of 2.91 million KL, in 2015 fell to 42% of the government's target of 3.91 million KL and by only 41% of the government's target of 6.31 million KL in 2016. Second, Indonesia's domestic biodiesel production conditions began to decline from 1.84 million KL in 2014 to 0.91 million KL in 2015 due to lower oil prices. Tertiary, the number of biodiesel industry that are relatively less to fit the target capacity of 10.22 million KL in 2025. And the last and foremost is the condition of CPO prices continue to increase causing Biodiesel Market Price Index to be less frugal. This issue becomes the consideration of biodiesel industries to continue to sell their biodiesel production in Indonesia [2].

Based on the condition and complexity stated above, this research tries to conduct simulation and evaluate alternative of several government policies to find which policy can help government reach its target for biodiesel adoption using agent – based modeling. Research on the implementation of biofuel with an agent-based approach has been practiced previously in various nations. One of them is to analyze how the German biodiesel industry can evolve in different institutional frameworks and to assess the alternative impact of biofuel policy on biodiesel production and production capacity [3], analysis of farmers' decision-making in the adoption of Bioenergy crops and predict the behavior of surrounding farmer groups [4] and research on investor behavior in dealing with the dynamics of asset prices on artificial financial markets [5].

## 2. Literature Review

### 2.1. Biodiesel in Indonesia
Biodiesel or Fatty Acid Methyl Ester (FAME) is a type of biofuel produced as a substitution of diesel fuel. Biodiesel can be made from vegetable oils, animal oils, fats or used cooking oil with trans-esterification process. This procedure is widely selected for biodiesel processing due to cost considerations, low energy requirements, and high conversion rates obtained even in the process calling for high water to remove residue and salt. The source of the oil used to make various biodiesel. In Indonesia, palm oil is the greatest potential for making biodiesel.

Biodiesel has many benefits for the environment. The primary benefit of biodiesel is that it can be named "carbon neutral". This means that biodiesel fuel does not produce carbon dioxide ($CO_2$). This issue happens because when the oil plant grows, it absorbs $CO_2$ at the same amount as releasing fuel. In addition, biodiesel has biodegradable compounds that are fast and completely non-toxic, having in mind that biodiesel spills have less risk than diesel fuel. Biodiesel also has a higher flash point than diesel fuel, can be determined from its higher cetane number (> 57) than diesel fuel [6].

Biodiesel can be utilized in the form of pure biodiesel (B100) or as a mixture with diesel oil at a certain concentration level (Bxx). For example B20 means that the fuel contains 20% biodiesel mixed with 80% diesel oil. The utilization of biodiesel in Indonesia has been regulated by the government through various policies, including the Minister of Energy and Mineral Resources Regulation aimed at determining minimum utilities of biodiesel production in various sectors. In the Ministerial Regulation, public service obligation, non-public service obligation and industries as well as commercially in 2015, had minimum utilities reaches 15% of the total requirement, minimum 20% starting in 2016 and 30% in 2020 and 2025. In addition, the purchase of biodiesel in Indonesia has two mechanisms, namely direct election mechanisms and indirect or tender election mechanisms.

### 2.2. Agent-Based Modeling
In 1940, agent-based modeling was developed through cellular automata modeling, but this approach was entirely and used massively in 1990-2000 [7]. As a comparatively fresh approach, agent-based modeling is becoming so widespread because we live in an increasingly complex world in terms of their interdependencies that makes traditional modeling tools are no longer as applicable as they once were [8]. According to reference [9], an agent-based approach is a common and powerful shortcut because it can capture more complex and dynamic structures. Another significant advantage is that

ABM enables us who not actually realize how something will bear on a certain stage, only if we have some perception of how an actor behaves, we can create ABM and will gain global behavior.

According to Reference [8], there are five methodologies to build an agent-based model: (1) identify the agents and get a theory of agent behavior, (2) identify the agent's relationships and get theory of agent interaction, (3) get the requisite agent-related data, (4) validate the agent behavior models in addition to the model as a whole, and (5) run the model and analyze the output from the standpoint of linking the micro-behaviors of the agents to the macro behaviors of the system. The following is the general steps in building an agent model are as follows:

- *Agents*: Identify the agent types and other objects (classes) along with their attributes.
- *Environment*: Define the environment the agents will live in and interact with.
- *Agent Methods*: Specify the methods by which agent attributes are updated in response to either agent-to-agent interaction or agent interactions with the environment.
- *Agent Interactions*: Add the methods that control which agents interact, when they interact, and how they interact during the simulation.
- *Implementation*: Implement the agent model in computational software.

## 3. Methodology

### 3.1. Concept and Model Formalization
In methodology, the research will go deeper into the main elements and properties of the system. All the different agents, attributes and global variables, and model narrative will be defined in this chapter. First of all, if we see in Figure 1, the global variables are defined. Global variables are exogenous variables that can affect the system. A global variable can be used as parameters that can be changed every a model starts.
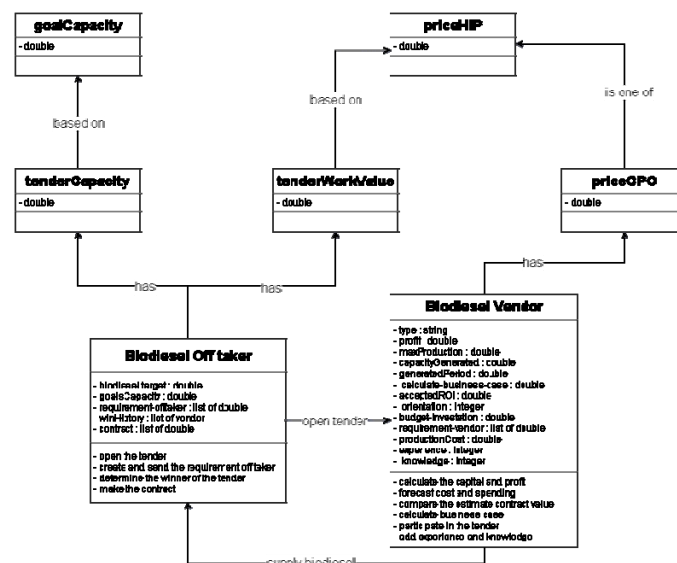


**Figure 1.** Schematic Model

*3.1.1. Agents.* Agent in this study is divided into two agents, there are biodiesel off taker and biodiesel vendor. *Biodiesel off taker* is an independent agent of biodiesel buyers appointed by the government to open tender to biodiesel industries aiming to meet National Biodiesel Production Targets. Each year, off taker undertakes its duty to open tender in an endeavor to sustain the success of the National Target of Biodiesel Production specified by the government. The tender is executed based on the biodiesel utilization mandate set forth by the Ministry of Energy and Mineral Resources Regulation. The decision off taker in selecting suitable vendors to extend the biodiesel production targeting program is founded by three things: (1) vendor experience, (2) installed capacity, and (3) price offer. The

behavior of biodiesel off taker is divided into three: (1) create and send the requirement off taker, (2) determine the winner of the tender, and (3) make the contract.

*Biodiesel vendors* or commonly called biodiesel suppliers are an agent of biodiesel industries who have the authority to participate in tender organized by off taker. According to the installed capacity, the vendor can be separated into three groups: large vendors, midsize vendor, and small vendors.

Installed capacity is not the only one thing to consider for defining vendor behavior, but also their own mindset and mentality in determining the alternative. This mentality is adopted from one literature in reference [5], this literature describes the case of investor decision-making, *loss-averse investor*, the mind-set of decision making is nailed on the environment of the system and fixated on the benefits to be derived.

For large vendors, there is a minimum of profits that have been determined because if you get a profit less than the standard, it will damage the finance of large vendors. Unlike the case with small and midsize vendors, in order to improve finances quickly and steadily, small and midsize vendors set a higher ROI than large vendors.

The behavior of biodiesel vendors, is divided into five: (1) calculate the capital and profit, (2) compare the estimated contract value with the investment budget, (3) calculates business case, (4) participate in the tender, and (5) add experience and knowledge.

### 3.2. Software Implementation

The next stage is to develop an agent-based model in software implementation, which researchers used AnyLogic to develop the model. The developed model is based on the gathered data which previously have been translated into model conceptualization and formalization.

*3.2.1. Agent States.* Biodiesel off taker has one type of state that is modeled by using statechart on Anylogic. The Statechart illustrates the tender carried out by off taker as shown in Figure 2. This statechart describes four states of decision making (yellow box) and three transitions (arrows). At the beginning of the simulation, the agent will be at pretender state and the agent is deemed to have completed the bidding process if it has been in completed state. In contrast to biodiesel vendors who have three states in decision making and three transitions to following the tender or not. At the beginning of the simulation, biodiesel vendor will wait for the requirement issued from biodiesel off taker, ending with the decision to participate in the tender (describe by state decision) or not following the tender (back to potential).
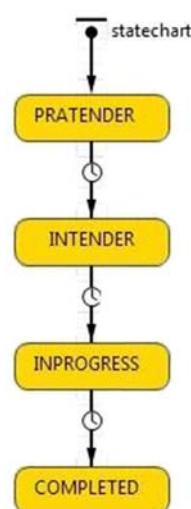
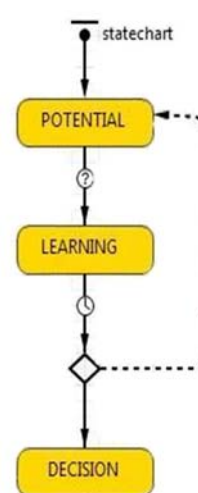

**Figure 2.** Biodiesel Off taker Statechart          **Figure 3.** Biodiesel Vendor Statechart

### 3.3. Policy Intervention

Policy alternatives are the policies given by the government in achieving certain goals. Intervention options can be seen in Table 1. There are two policy alternatives given by the government for the fulfillment of the national target of Biodiesel production.

**Table 1.** Policy intervention options and its parameter which would be evaluated in agent – based model

|  | Business as Usual | Pricing Policy | Installed Capacity Enhancement |
|---|---|---|---|
| Biodiesel Market Index | Average CPO + 188USD | Average CPO + 100USD | Average CPO + 188USD |
| Number of Vendors | 17 vendors | 17 vendors | Based on Installed Capacity Projection |

*3.3.1. Pricing Policy.* The biodiesel selling price is set in the Biodiesel Market Index parameter. Since 2015, the calculation of prices is change depending on the conditions at the time. By 2015, Biodiesel Market Index is the average of CPO plus 188USD. In 2016, Biodiesel Market Index is an average of CPO plus 125USD until now and the government plans to reduce XUSD from Biodiesel Market Index is due to the increasingly expensive price of CPO.

*3.3.2. Installed Capacity Enhancement.* Regulation of Installed Capacity is a regulation aimed at creating biodiesel plant market potential, increasing competition in the distribution of biodiesel and new investment. Table 2 is the projection of installed capacity that provided by the government.

**Table 2.** Installed Capacity Projection

| Year | Capacity (Million KL) |
|---|---|
| 2015 | 2.08 |
| 2016 | 7.80 |
| 2017 | 7,56 |
| 2018 | 7.83 |
| 2019 | 8.65 |

## 4. Model Result

### 4.1. Policy Intervention Analysis

Policy intervention is conducted to see what policy alternatives can increase production capacity, vendor adoption and vendor profitability. The analysis of the results is described in Table 3.

**Table 3.** Result of Simulation

|  |  | Business as Usual | Price Regulation | Installed Capacity Regulation |
|---|---|---|---|---|
| Production Capacity | First Year (2015) | Completed (1.5 Million KL) | Completed (1.5 Million KL) | Completed (1.5 Million KL) |
|  | Second Year | Increase 1,8% | Decrease 56,6% | Increase 1,8% |
|  | Lowest Capacity (Year) | 2021 (0 Capacity) | 2020 (0 Capacity) | 2025 (558,000 KL) |
| Adoption of The Tender | Highest | 2015 (13 vendors) | 2015 (9 vendors) | 2015 (13 vendors) |
|  | Second Most | 2016 – 2018 (8 vendors) | 2016 (4 vendors) | 2016 – 2018 (8 vendors) |

|                   | Lowest        | 2021 – 2025<br>(0 vendors)          | 2020 – 2025<br>(0 vendors)   | 2024 – 2025<br>(2 vendors)          |
|-------------------|---------------|-------------------------------------|------------------------------|-------------------------------------|
|                   | Highest       | 2015<br>(3.7% - 5.2%)               | 2015<br>(1.1% - 2.6%)        | 2015<br>(3.7% - 5.2%)               |
| Vendor's Profit   | Start Losses  | 2019<br>(by big and<br>medium vendors) | 2016<br>(by all vendors)  | 2017<br>(by big and<br>medium vendors) |
|                   | Mass Losses   | 2020 – 2025                         | 2016 – 2025                  | 2019 - 2025                         |

*4.2. Model Analysis*

In the model analysis, the result of each policy alternative will be analyzed to study the impact of each policy when implementing to the main output indicator, which are production capacity, adoption of the tender, and vendor's profit. The analysis is divided into three sections based on how policy intervention cause changes in output indicator: (1) analysis of production capacity, (2) analysis of vendor adoption behavior, and (3) analysis of vendor's profitability.

The first analysis is about production capacity, where the fulfillment of production capacity at the beginning of the year in each experiment has similarities. In contrast to production capacity indicator in 2015, is a decrease in production capacity by 2016. This suggests that the impact of supplier-focused policies on the behavior of each new agent can be seen after four to five years of policy being implemented. If determined in the real world, governments are better at making policies that focus also on suppliers, not only focusing on buyers. Our suggestion for a policy that focused on suppliers, governments are urged not to act quickly to modify the policy.

Second, the vendor adoption behavior in both policy alternatives shows that the installed capacity policy results in a higher vendor adoption than the price policy. This because when price policy implemented and cause fewer vendor adoptions, it indicates that the price scenario determined by the government is unitary of the obstacles to the successful fulfillment of current biodiesel production targets. Alterations in the calculation of monetary value will improve vendor adoption behavior.

Third, the vendor profit analysis is grounded on the investment and sales costs incurred by vendors. When compared to policy alternatives, the installed capacity policy produces a more volatile trend. While price regulation has a form similar pattern to the Business as Usual, it's mere that the profit gained in price policy is lower than the Business as Usual.

## 5. Discussion and Conclusion

Every modeling process starts with a problem that needs to be solved [14]. In this paper, the researcher tried to provide insight into the real world problem of fulfilling the national target of Biodiesel production in Indonesia. Due to the assumptions and limitations of the model, the agent-based model development in this research has been able to illustrate the predicted end picture of biodiesel production conditions in 2025 based on agent behavior that is influenced by two alternative government policies.

The overall simulation results that have been done, there is government interventions or regulation that can speed up and hinder the fulfillment of the national target of biodiesel production. This condition is common appear when a policy focuses on solving problem on one side only without balance on the other side. The speed up and hinders of fulfilling national target of biodiesel production can be caused in some cases, in the previously described schematic model, we can see various attachments between attributes in interconnected agents.

Established along the simulation results, of each policy option, the biodiesel plant's installed capacity building regulation is a regulation that delivers appoint production capacity and vendor adoption. Consequently, this regulation is good to keep. Even so, the government should reconsider the costs incurred for these alternatives and the profits for vendors, so the biodiesel production targets can be successfully fulfilled. This better result is caused by the emergence of new vendors built by the government, which increases the competition that occurs in the tender and the involvement of medium

vendors in the tender of the previous year, resulting in the knowledge possessed by the vendor and can be used to reduce the production cost of the vendor. However, in this regulation, the profit received by the vendor is smaller than the business as usual, as more vendors participate in the tender, with different variations of estimating value, the smallest estimate will be selected by biodiesel off taker to make the expense of biodiesel off taker not getting bigger.

Different with the other price policy intervention, as we know before, the price regulation is focused only on biodiesel buyers, this intervention may inhibit the fulfillment of national biodiesel production targets. This condition is visualized in the simulation result of agent-based model that have been developed. Based on indicator output, this intervention has the lowest level of production capacity, vendor adoption and the smallest vendor profitability. The result of pricing policies indicates high CPO prices strongly influence by the decision of the vendor to invest. If the price of CPO is greater without the CPO price determination (minimum and maximum), that will cause on the absorption of biodiesel.

The quote from LeBaron (2000), "The field is only in its infancy, and much remains to be done". In future research, combine other types of investor decision-making, such as herding and anchoring [5] on a tender that has a larger number of industry hopefully given better understanding and knowledge about the interaction between agents.

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