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Fuel oil supply demand projection and planning in Indonesia using system dynamics modeling

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Abstract

Oil is the most important source of energy and has had a critical impact on economic growth for many years. It has become a global commodity and supplies more than 40% of the total energy demand.
The research aims to assess the fuel oil supply and demand in Indonesia for gasoline and diesel oil, and projects the import parameter for both petroleum products using system dynamics modeling. There are 3 scenarios assessed by the simulation model: the first scenario is the base scenario in Indonesia, assuming there is no additional oil refinery capacity and supported by biodiesel production; the second scenario assumes the increasing refinery capacity planned by the government; and the third scenario is the ideal scenario that combines the increased national oil production and utilization of biofuel (both bioethanol and biodiesel).
The research shows that for the first scenario, import trend projections of gasoline will keep increasing whereas the diesel oil import will decrease and will be stopped in 2024, when B30 is pushed by the government. The second scenario projects the declining number of gasoline import in line with the increased production capacity, but the gasoline import still reaches 11.6–16.1 million kL. Meanwhile, diesel oil demand will be fully covered by national diesel oil production, and biodiesel, in 2018. The last scenario shows that gasoline import declines significantly because bioethanol is produced. However, this would necessitate least 11.21 million kL of new gasoline refinery production to meet the demand and eliminate the need for import. Either way, the bioethanol mandate should be accelerated and increased to E25–E30 in 2018.

Keywords: fuel oil supply and demand, system dynamics modeling, biodiesel production, bioethanol production, gasoline import, diesel oil import

1. Introduction

Energy has been the main vital of the economy and that within most sectors of a country. Energy demand has become a reference of country development. The more developed the country, the more energy is needed. Crude oil or petroleum is one of the most important energy resources in the world and supplied more than 40% of the total energy demand [1]. It is a liquid organic material found below the earth's surface, is highly flammable, and is non-renewable energy. It is composed of hydrogen and carbon atoms, also called hydrocarbons. The composition varies from 50% to 97%; the best quality of crude oil contains a higher percentage of hydrocarbons composition.

Petroleum is mostly used in transportation, as about 90% of all transportation fuels come from crude oil [2]. Indonesia has been producing crude oil for more than 100 years, but the production has decreased over the years. The country has proven oil reserves of 3.7 billion barrels and is ranked in the top 20 of oil producers in the world [3].

The decline in oil production, due to natural maturation of oil field production combined with a slower reserve replacement rate, and decreased exploration/investment [3], along with pipeline leakage,

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subsurface constraints, and non-technical issues such as land acquisition and permission, social and security issues, [4] and the increasing consumption of fuel oil has led Indonesia to be a net oil importer since 2004. If the trend continues, in the next decades, imported oil will contribute the highest portion of national oil supply, which will burden the country's budget and threaten the national energy security.

The research aims to evaluate the trends of fuel oil supply and demand in Indonesia and project its oil supply, either from domestic production or imported, in line with demand. The research also analyzes the scenarios of fuel oil supply and demand planning and projects the trends of those scenarios.

2. Literature Review

2.1. Petroleum products and utilization

Oil is the most important source of energy and has had a critical impact on economic growth for many years. It has become a global commodity; therefore its prices are determined by the factors of supply and demand in the world.

Petroleum is found in underground reservoirs and extracted by drilling and pumping. The process of finding oil fields and bringing oil up from the ground is called upstream sector. It consists of exploration, drilling, and production, while downstream sector includes the activities like purification of crude oil and refining it into different products, as well as transportation and marketing [2].

Different oil fields have different characteristics of oil combination and concentration, which depend on the density: there are light and heavy oils. Heavy oil contains high metal and sulfur content, thus it is known as low-grade oil, whereas light oil contains less of these. The API (American Petroleum Institute) gravity of particular oil is the measure of its specific gravity or density. The higher the API number, the less dense the oil, or the lighter the oil [3].

Refining, as the stage in the downstream sector, is a process in which the crude oil is purified and treated to remove unusable substances. The process consists of 3 steps: separation, conversion, and treatment.

Around 84% volume of hydrocarbons is converted to rich energy fuel, such as gasoline, diesel, jet fuel, heating, Liquid Petroleum Gases, and other fuel oil, while the remaining is used as pharmaceuticals, solvents, fertilizers, pesticides, and plastics [1]. The most common utilizations of petroleum products are: gasoline, used as fuel intended for combustion engines; diesel, for diesel engines; jet fuels, a type of aviation fuel designed for aircrafts powered by gas turbine engines; and Liquid Petroleum Gases, a fuel used in heating appliance and vehicles.

2.2. Indonesia production of petroleum and its product

Indonesia has been producing oil for more than 130 years after the first oil discovery in North Sumatera in 1885. The peak oil production in Indonesia was in 1977 and 1995, with production averages of 1.68 million barrel per day (bpd) and 1.62 million bpd, respectively. After 1995, the production declined at a natural decline rate of 12%, but in 2004, the decline rate was stabilized at 3% per year.

Meanwhile, the oil consumption has increased sharply as the production was declining in numbers. The result of these conditions is that Indonesia has become an importer of oil since 2004 [3].

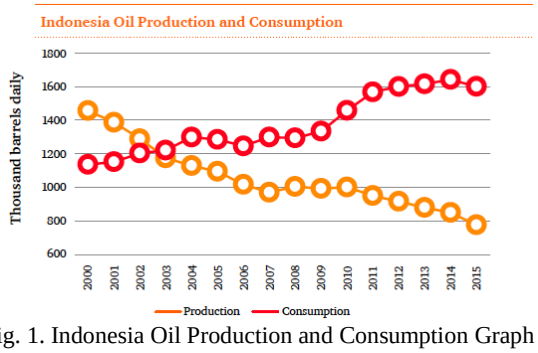


Fig. 1. Indonesia Oil Production and Consumption Graph [5]

Fig. 1 illustrates Indonesia's production and consumption of fuel oil from 2000 to 2015. The production declined throughout the years, due to natural maturation of oil field production, slower reserve replacement rate, and decreased exploration/investment.

Total domestic refinery capacity in 2014 was 1.167 million bpd from 7 state-owned refineries and 3 private-owned refineries. From the installed capacity of 1.167 mbpd in 2014, the refineries could only produce 0.65 mbpd. However, fuel oil (petroleum products) demand in 2013 was 1.3 million bpd. Therefore the government needed to import oil in order to fulfill the demand. Around 0.6 mbpd of oil import was needed, the value amounting to more than 1 billion USD per day [6].

Besides importing the fuel oil, Indonesia also imports the petroleum (crude oil) as the input for domestic refineries. Of all of Indonesia's crude oil production, 40% is being exported due to unmatched domestic refinery specification therefore, it cannot be refined [6].

During the period 2013–2050, petroleum demand will increase more than 3 times, with an average growth of 3.3% per year. Thus from 297 million barrels in 2013, the demand will grow to 980 million barrels in 2050. Meanwhile the national production declines up to 5.8% per year. This is an indication that the import of oil will increase and reach 953 million barrels in 2050 if the country cannot find new oil reserves [7].

2.3. Indonesia policies on fuel oil supply–demand

The Indonesian government has issued the National Energy Policy (KEN) on Government Regulation No. 79/2014. KEN mandates the shared percentages of the primary energy resource in Indonesia, with less fossil fuel and more renewable energy. In 2025, fossil fuel for oil, gas, and coal will be 25%, 22% and 30% respectively, while renewable energy will account for 23%. KEN expects a greater contribution of renewable energy in 2050, from 23% in 2025 to 31% in 2050, meanwhile the contribution of oil and coal will be reduced to 20% and 25%, respectively.

In order to enhance biofuel utilization, the Indonesian government set the regulation of Ministry Energy and Mineral Resources No.20/2014 which states that biodiesel will be blended with diesel oil with 30% biodiesel and 70% diesel oil (also called B30), in 2020 and 2025. The regulation also set the blending target for bioethanol as 10% in 2020 and 20% in 2025. This biodiesel mandate's target is currently being met, because Indonesia has plenty of CPO as the feedstock, therefore it is an optimistic target. Conversely, bioethanol utilization was stopped in 2010 due to several issues, such as the limited feedstock, the high production cost, the declining of fossil oil and yet, the government could not solve those problems.

3. Method and Research Design

3.1. System dynamics modeling on energy planning

System dynamics approach and computer simulation has become one of the common methods applied in many fields, such as energy system planning, economy and management policy, health and biology, science development and social aspect. This method has the ability to define the system behavior through its structure and interactions between variables. The purpose of system dynamics is to understand the resulting behavior, and to predict the interpretation of the time-based policy modification of the system.

System dynamics modeling has been used by many researchers recently, from electricity demand projection in Indonesia by Sulistio, et.al. (2017), increasing bioethanol feedstock production by Ariadi, et.al. (2016), developing a comprehensive sustainability model of biodiesel industry by Hidayatno, et.al. (2011) and Pan, et.al. (2017), who established a system dynamic model for oil supply chain analysis in China, emphasizing on over-capacity and energy security issues [8-11].

Musango, et. al. (2012) had used system dynamics approaches to assess the technology sustainability through renewable energy policy interference in South Africa. They made Bioenergy Technology Sustainability Assessment (BIOTSA) models with system dynamics to demonstrate and analyze the output of biofuel production based on sustainability indicators [12]. Escalara, et.al. (2008) analyzed the biofuel production and determined the feasibility of production planning using system dynamics modeling. They also simulated and analyzed the feedstock, from cultivation to refinement process [13].

Mayasari & Dalimi made biodiesel production models from CPO as the feedstock, using system dynamics, meanwhile Bantz & Deaton (2006) were focusing on profitability of biodiesel industry using system dynamics [14,15].

3.2. System dynamics model on fuel oil supply–demand in Indonesia

This research began with identifying of the variable influencing fuel oil production of either the crude oil or the petroleum products, such as gasoline and diesel oil. The variables are shown in Fig. 2 as the causal loop diagram of fuel oil supply demand. A causal loop diagram is a simple tool to give a general picture of system variables and its interaction, and also explain the causal-effect relationships among the elements.

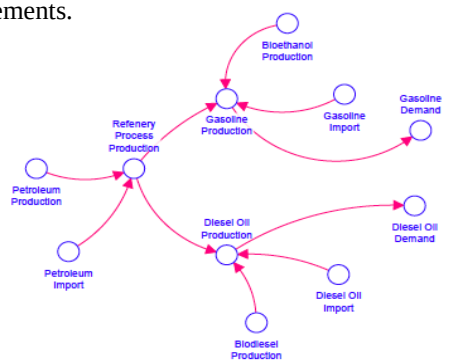


Fig. 2. Causal Loop Diagram of Fuel Oil Supply and Demand

Gasoline production is the total of national gasoline production from refinery production, gasoline import, and bioethanol production. The same applies to diesel oil production. The supply variable is compared with the demand variable, to analyze the increase in the value of national production or how much import is needed in order to fulfill the demand. Biofuel is an alternative way to reduce the amount of imported oil, therefore there is a dynamic loop between the import variable and biofuel production.

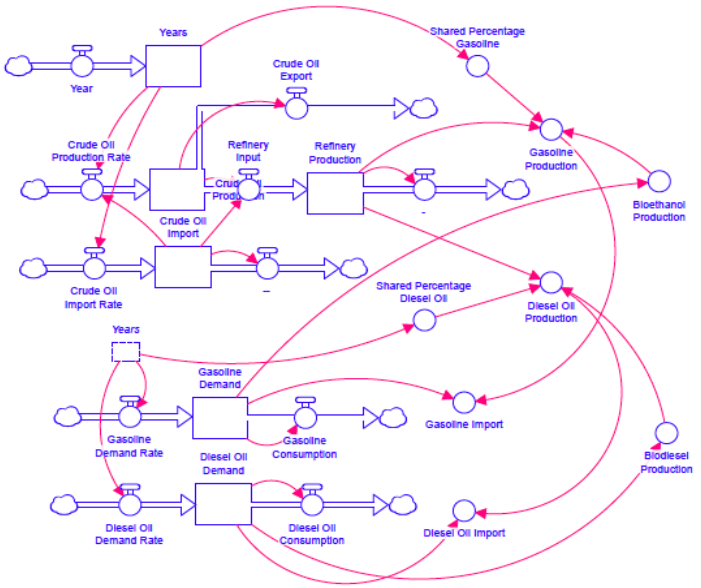


Fig. 3. Stock flow diagram of fuel oil supply and demand

The next step after identifying the variables was creating the list of stocks, flows, and converters. Fig. 3 shows the stock flow diagram of fuel oil supply and demand. The model has 4 stocks, which are petroleum production, refinery process production, gasoline demand, and diesel oil demand. Assigning

the initial value of the stocks according to the data of the base year is the stage of the research. Then, change in stocks (Δstock) was calculated, as well as new values for the stocks (stock t) per dt (delta time), as shown in the following equations.

$$\Delta\text{stock} = \text{dt} \times \text{flow} \tag{1}$$

$$\text{stock}t = \text{stock}t - \text{dt} + \Delta\text{stock} \tag{2}$$

3.3. Data of Indonesia oil production

Indonesia has plenty of crude oil and gas potential with 60 sedimentary basins including 36 in Western Indonesia that have already been thoroughly explored, 14 of these produce oil and gas. About 75% of oil exploration regions are in Sumatra, The Java Sea, East Kalimantan, and Natuna Island [5].

Table 1 shows Indonesia Petroleum Data, 50.7% of oil reserves in Indonesia have proved to be oil resources, with an efficiency of 8.3%. This indicates that, of 4,230 million barrels or 672.6 million kL proven oil reserves in 2010, it could only produce 945 million barrels or 54.84 million kL crude oil or petroleum, and only 60% of this production is converted to petroleum products by refinery processes, while the remaining is being exported. Meanwhile, the production of crude oil declined at an average rate of –2.6% per year. The oil reserve predicted by the scientists will have vanished in the next 13–26 years [12].

Table 1. Indonesia petroleum data [5,16]

Years	Reserves (Million kL)	Proven (Million kL)	Potential (Million kL)	Crude Oil Production (Million kL)
2010	1233.8	672.6	561.2	54.84
2011	1229.1	642.4	586.7	52.35
2012	1178.2	594.7	583.5	50.03
2013	1200.5	586.7	613.8	47.83
2014	1171.8	575.6	596.2	45.78
2015	1171.8	575.6	596.2	45.60
2016	1171.8	575.6	596.2	42.75
2017*	1171.8	575.6	596.2	39.10

*Prediction Data

Table 2 gives the refinery data in Indonesia, and from it we can be seen that the refining process of crude oil is around 72% of the input capacity. The refining products data or petroleum products, such as gasoline and diesel oil are given in Table 3. The table indicates that gasoline and diesel oil production account for 64% of total refinery production.

Table 2. Indonesia refinery data

years	refinery capacity[a]		refinery throughput[b]	
	thousand bpd	million kl	thousand bpd	million kl
2010	1,157	67.15	853	49.50
2011	1,167	67.73	880	51.07
2012	1,167	67.73	820	47.59
2013	1,167	67.73	822	47.70
2014	1,167	67.73	848	49.21
2015	1,167	67.73	836	48.52
2016	1,167	67.73	885	51.36
2017*	1,167	67.73	865	50.22

[a][6]; [b][17]; *Prediction Data

Table 3. Production of petroleum products in Indonesia [16]

Years	Gasoline		Diesel Oil		Total
	Million Barrels	Million kL	Million Barrels	Million kL	Million kL
2010	70.79	11.26	108.74	17.29	28.55
2011	67.64	10.76	117.77	18.73	29.48
2012	70.69	11.24	124.74	19.83	31.07
2013	71.39	11.35	125.17	19.90	31.25
2014	75.00	11.93	130.99	20.83	32.75
2015	81.09	12.89	130.52	20.75	33.65
2016	93.61	14.88	125.29	19.92	34.80
2017*	94.15	14.97	139.49	22.18	37.15

*Prediction Data

3.4. Data of Indonesia oil consumption

Total crude oil demand for domestic refinery was 300.5 million barrels in 2011. It was obtained from 201.1 million barrels of domestic production and 99.4 million barrels from crude oil import [18].

Oil consumption (included aviation, bunkers, refinery loss and consumption of biofuel) has an average growth percentage of 1.4% per year, while oil production has an average declining percentage of 2.3%. To solve the disparity between demand and supply, the government had imported oil, both crude oil and petroleum products. Data is given in Table 4.

Table 4. Oil import data in Indonesia [16, 19]

Years	Crude Oil Import		Petroleum Products Import	
	Million Barrels	Million kL	Million Barrels	Million kL
2010	101.09	16.07	163.6	26.01
2011	96.86	15.40	195.9	31.15
2012	95.97	15.26	201.1	31.97
2013	118.33	18.82	205.6	32.69
2014	121.99	19.40	209.0	33.23
2015	136.67	21.73	175.4	27.89
2016	148.36	23.59	143.1	22.75
2017*	152.39	24.23	147.8	23.50

*Prediction Data

In 2015, transportation accounted for the biggest share of total oil consumption in Indonesia, followed by industry, electricity and other sectors with 23%, 3%, and 4%, respectively. Table 5 gives the total consumption of gasoline and diesel oil in all sectors.

Table 5. Consumption of petroleum products in Indonesia [16]

Years	Gasoline		Diesel Oil		Total
	Million Barrels	Million kL	Million Barrels	Million kL	Million kL
2010	152.01	24.17	132.12	21.01	45.18
2011	161.54	25.69	162.36	25.82	51.50
2012	178.81	28.43	202.75	32.24	60.67
2013	186.35	29.63	201.74	32.08	61.71
2014	188.87	30.03	191.67	30.48	60.51
2015	193.02	30.69	155.33	24.70	55.39
2016	201.26	32.00	165.24	26.27	58.27
2017*	211.82	33.68	188.49	29.97	63.65

*Prediction Data

3.5. Design of scenarios

The research results will be given in 3 different scenarios, thus the model will be simulated in 3 different conditions. The first condition is the base scenario, which is the real condition in Indonesia currently, with assumption there are no additional refinery or renewal of existing refineries, and it also takes into account the biodiesel mandate that has been implemented for the last 10 years, and is added as one of the influenced variables as biodiesel production. The second condition is the planned scenario of the government regarding the improvement of several refineries in order to increase the oil production and still counts on biodiesel production. The third scenario includes adding bioethanol production as

much as the bioethanol mandate is stated. This would also be the ideal scenario, where all the planned targets of the government are achieved such as improvement of refineries and all the biofuel mandates.

All the scenarios will project the main variables of the model, such as refinery production, demand of gasoline and diesel oil, import of crude oil and the gasoline and diesel oil import up to 2025.

4. Result and Analysis

4.1. Base scenario

According to the data, crude oil or petroleum production in Indonesia has the following trend:

$$Y = –1.9293\ x + 56.171 \text{ million kL} \quad (3)$$

37%–40% of produced crude oil is being exported due to unsuitable characteristics within national refineries, therefore some crude oil is being imported to fulfill the demand of refinery input. The refinery output, also known as petroleum product oil, such as gasoline and diesel oil have their own trends, Eq (4) and (5) show the trends of gasoline and diesel oil shared percentage productions respectively.

$$Y_{\text{Gasoline}} = 0.0108\ x + 0.2009 \quad (4)$$
$$Y_{\text{Diesel Oil}} = 0.0087\ x + 0.3635 \quad (5)$$

The projections of crude oil production, import and refinery production as well as gasoline and diesel oil production, are given in Table 6 and Table 7.

Table 6. The projections of crude oil production and import and production of refinery products

Years	Crude Oil Production (Million kL)	Crude Oil Import (Million kL)	Refinery Production (Million kL)	Gasoline Production (Million kL)	Diesel Oil Production (Million kL)
2018	37.24	25.63	50.43	15.58	22.72
2019	35.39	27.04	50.59	16.17	23.23
2020	33.35	28.45	50.75	16.77	23.75
2021	31.68	29.85	50.91	17.38	24.26
2022	29.82	31.26	51.07	17.98	24.79
2023	27.97	32.66	51.24	18.59	25.31
2024	26.11	34.07	51.40	19.21	25.84
2025	24.26	35.47	51.56	19.83	26.37

Table 7. Total diesel oil production in Indonesia

Years	Diesel Oil Production (Million kL)	Biodiesel Production (Million kL)	Total Diesel Oil Production (Million kL)
2018-B20	22.72	3.04	25.76
2019	23.23	3.07	26.30
2020-B30	23.75	6.21	29.96
2021	24.26	6.27	30.53
2022	24.79	6.33	31.12
2023	25.31	6.38	31.69
2024	25.84	6.43	32.27
2025	26.37	6.47	32.84

Total Diesel Oil Production is production of diesel oil as a part of the petroleum products production and biodiesel production according to the biodiesel mandate in Indonesia. Table 7 gives the projection of total diesel oil production in Indonesia. The biodiesel mandate is regulated by the ministry of energy and mineral resources regulation No. 20/2014, and states that from 2016–2019, B20 should be applied, which means biodiesel will be blended with diesel oil by 20% and 80%, respectively and B30 mandate will be started in 2020.

Meanwhile, demand variables of gasoline and diesel oil follow the following trends:

$$Y_{gasoline\_demand} = 1.2532\ x + 23.65 \text{ million kL} \quad (6)$$

$$Y_{diesel\_oil\_demand} = 23.777\ x^{0.1113} \text{ million kL} \quad (7)$$

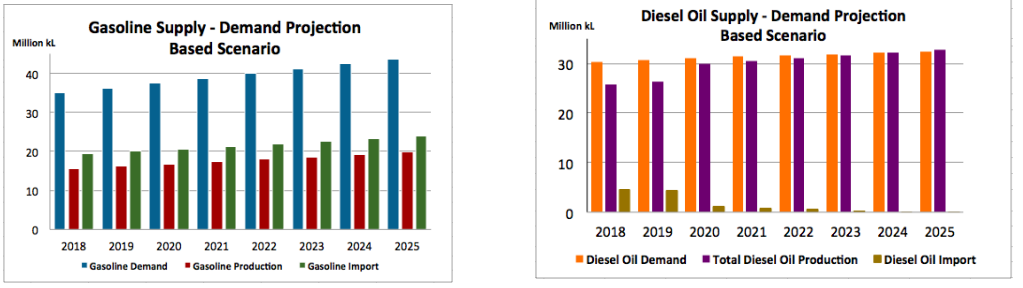
The demand and import projections of gasoline and diesel oil are shown in Table 8. The import variable is the deduction of total production and demand.

Table 8. Demand and import projections of gasoline and diesel oil in Indonesia

Years	Gasoline Demand (Million kL)	Diesel Oil Demand (Million kL)	Gasoline Import (Million kL)	Diesel Oil Import (Million kL)
2018	34.93	30.36	19.35	4.61
2019	36.18	30.72	20.01	4.42
2020	37.44	31.05	20.66	1.09
2021	38.69	31.35	21.31	0.82
2022	39.94	31.63	21.96	0.52
2023	41.19	31.89	22.60	0.2
2024	42.45	32.14	23.24	–0.13
2025	43.70	32.37	23.88	–0.47

Table 8 shows that the import trend for gasoline will keep increasing as the demand increases, because the supply tends to decline and bioethanol is not being produced. Unlike diesel oil trends, the import of diesel oil will decrease as the biodiesel mandate B30 is pushed in 2020. Furthermore, there will be surplus production in 2024, where the production is able to reach the demand and the import is stopped. This means the biodiesel utilization will have succeeded in decreasing and stopped import.

Fig. 4 gives the projection graph for gasoline and diesel oil supply and demand in Indonesia for the base scenario.



(a) (b)

Fig. 4. Projection of Supply and Demand in Indonesia: (a) Gasoline; (b) Diesel Oil

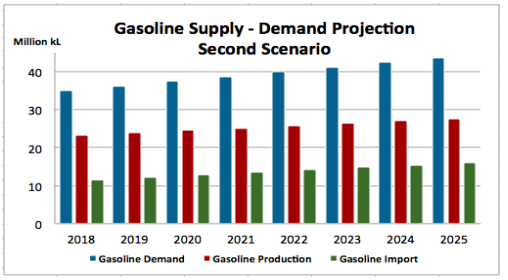
4.2. The second scenario, the increasing of national oil production

The Indonesian government has planned to develop 2 new refineries that will be operational in 2018. They will produce 7.79 million kL of gasoline and 7.23 million kL of diesel oil [18]. As a consequence of this, additional production will reduce the need for import, as illustrated in Table 9.

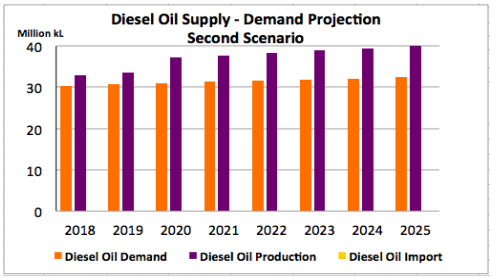
The increase in production of petroleum products will directly lead to a decline in imported oil. With this scenario, Indonesia will stop importing diesel oil in 2018 and will have plenty of supplies to fulfill the demand. Meanwhile, gasoline still has import values since the bioethanol production cannot support the demand. Fig. 5 shows the projection of supply and demand of gasoline and diesel oil in Indonesia from 2018 to 2025.

Table 9. Gasoline and diesel oil production and import projection

Years	Gasoline Production (Million kL)	Diesel Oil Production (Million kL)	Gasoline Import (Million kL)	Diesel Oil Import (Million kL)
2018	23.37	32.98	11.56	–2.62
2019	23.96	33.53	12.12	–2.81
2020	24.56	37.19	12.87	–6.14
2021	25.17	37.77	13.52	–6.41
2022	25.77	38.34	14.17	–6.71
2023	26.38	38.92	14.81	–7.03
2024	27.00	39.50	15.45	–7.36
2025	27.62	40.07	16.09	–7.70



(a)



(b)

Fig. 5. Indonesia supply–demand projection of: a) gasoline; b) diesel oil

4.3. The third scenario, bioethanol utilization

This scenario will add bioethanol production to the second scenario. Indonesia will be assumed to produce bioethanol starting from 2018, with the production amount equal to that required in the bioethanol mandate. The simulation results are given in Table 10.

Table 10. Projection of total production and import of gasoline in Indonesia

Years	Gasoline Production (Million kL)	Bioethanol Production (Million kL)	Total Gasoline Production (Million kL)	Gasoline Import (Million kL)
2018–E5	23.37	1.75	25.11	9.82
2019	23.96	1.81	25.77	10.41
2020–E10	24.56	3.74	28.31	9.13
2021	25.17	3.87	29.04	9.65
2022	25.77	3.99	29.77	10.17
2023	26.38	4.12	30.50	10.69
2024	27.00	4.24	31.24	11.21
2025–E20	27.62	8.74	36.36	7.35

Table 10 illustrates how the bioethanol production will impact the gasoline import. It will sharply decrease the import to 30% in 2020 when E10 is enacted and 55% in 2025 for E20. This is also shown in Fig. 6. The graph shows that bioethanol will significantly contribute to the total production in 2025 when E20 is applied.

For both scenarios 2 and 3, diesel oil import will have stopped and the demand will be fully supplied by national production of diesel oil and biodiesel. To stop gasoline import however, Indonesia needs to increase its refinery production of gasoline by at least 10 million kL in 2018 with support from additional bioethanol production.

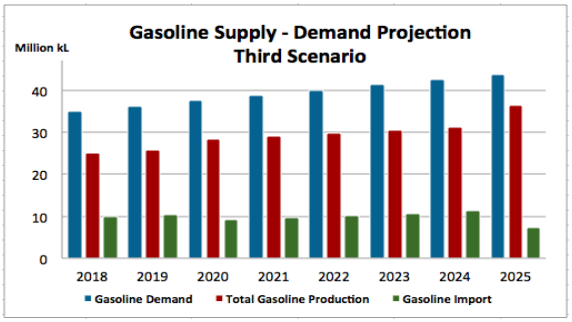


Fig. 6. Graph of Gasoline Supply and Demand Projection in Indonesia

5. Conclusion

This research has been conducted to project petroleum products supply and demand in Indonesia, such as gasoline and diesel oil, using system dynamics modeling. Then three different scenarios were analyzed to assess which plan is the most suitable to stop the import of oil.

The result shows that the first scenario or the base scenario, which is the real condition in Indonesia, projects that import trends for gasoline will keep growing as the demand increases, because the supply tends to decline, and there is no support from bioethanol. Meanwhile, import of diesel oil will decrease as the biodiesel mandate B30 is pushed in 2020. The diesel oil supply will be sufficient in 2024, thus, the import will stop. The second scenario, the increase of national oil production plan forecasts the declining number of gasoline import in line with the increasing capacity, but it still requires 11.6–16.1 million kL of gasoline to be imported, whereas diesel oil demand will be completely fulfilled by national diesel oil and biodiesel production in 2018, or in other words diesel oil import will stop in 2018.

The last scenario, as the ideal scenario that combines the increase in national oil production and utilization of both biodiesel and bioethanol, shows a significant decline in the amount of gasoline import because bioethanol production is being utilized and supports the demand. This will need at least 11.21 million kL of new gasoline refinery production to meet the demand and stop gasoline import, and either way the bioethanol mandate should be accelerated and increased to E25–E30 in 2018.

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References

[1] Demirel Y. Chapter 2: Energy and energy type. in *Energy, Green Energy and Technology*, London : Spinger-Verlag: 2012
[2] OPEC, *I Need to Know: An Introduction to The Oil Industry and OPEC*, OPEC Secretariat, Public Relation and Information Department, Korneuburg: 2013
[3] Devold H, *Oil and Gas Production Handbook: An Introduction to Oil and Gas Production, Transport, Refining and Petrochemical Industry*, ABB Oil and Gas, 2013
[4] Ministry of Energy and Mineral Resources, *Strategic Plans of Ministry of Ministry Energy and Mineral Resources Indonesia 2015* – 2019 (Renstra KESDM 2015-2019), Jakarta: 2015
[5] PwC Indonesia, *Oil and Gas in Indonesia: Investment and Taxation Guide*, Jakarta: 2016
[6] Rochman NN. *Oil and Gas Strategic Plans 2015–2019* (Renstra Migas 2015–2019, Directorate General of Oil and Gas, Ministry of Energy and Mineral Resources, Jakarta: 2015
[7] Sugiyono A, Anindhita, L.M.A. Wahid, Adiarso, *Indonesia Energy Outlook 2016: Energy Development in Supporting Green Industry*, Center for Technology of Energy Resources and Chemical Industry, Agency for The Assessment and Application of Technology (BPPT), Jakarta: 2016
[8] Sulistio J, Wirabhuana A, and Wiratama MG, *Indonesia's Electricity Demand Dynamic Modeling*, IOP Conf. Series: Materials Science & Engineering, 2017, 215.
[9] Ariadi BY, Karmana MH, Rochdiani D., Rasmikayati E. *Using system dynamic approach in modeling the integrated farming*

scenario to increase cassava production in Indonesia, *Int. Journal of Comp. App*., 2016; 142;34-40
[10] Hidayatno A, Sutrisno A, Zagloel YM, and Purwanto WW. System dynamics sustainability model of palm oil based biodiesel production chain in Indonesia. *International Journal of Engineering and Technology*, 2011;11.
[11] Pan L, Lui P, Li Z. A system dynamic analysis of China's oil supply chain: Over-capacity and energy security issues. *Elsavier, Applied Energy*, 2017;188:508–520.
[12] Musango JK, Brent AC, Amigun B, Pretorius L, Müller H. A system dynamics approach to technology sustainability assessment: The case of biodiesel developments in South Africa. *Journal of Technovation*, 2012;32:639–651.
[13] Escalera E, Lee J, Parsons J, Rusangiza I. *Biofuel Production System Analysis, Systems and Information Engineering Design Symposium*, 2008.
[14] Mayasari F. and Dalimi R. Dynamic modeling of CPO supply to fulfill biodiesel demand in Indonesia. In *Proc. of IEEE International Conference on Quality in Research (QiR),* Bali, 2017
[15] Bantz SG and Deaton ML. Understanding U.S. biodiesel industry growth using system dynamics modeling. In: *Proc. of* 2006 *IEEE Systems and Information Engineering Design Symposium*, 2006, pp. 156-161.
[16] Ministry of Energy and Mineral Resources, *2017 Handbook of Energy and Economic Statistics of Indonesia,* Jakarta: 2017
[17] BP Global, *BP Statistical Review of World Energy June 2017*, 66th Edition, 2017
[18] Data Center and Information of Energy and Mineral Resources, *Analysis of Supply Demand Energy* (Kajian Supply Demand Energi), Ministry of Energy and Mineral Resources, Jakarta: 2012
[19] Abdurrahman S. *Indonesia Energy Outlook 2016*, Secretary General of Indonesia Energy Council (DEN), Jakarta: 2016