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IMPACT OF BIODIESEL AGROINDUSTRY ON THE ACHIEVEMENT OF NATIONAL ENERGY SECURITY

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Abstract -- *The National Energy General Plan (RUEN) has set 11.6 million kiloliters of biodiesel production target in 2025. The determination of biodiesel production targets in RUEN is part of the objectives mandated in the National Energy Policy (KEN), which is to achieve energy security and independence. Therefore, this study aims to analyze the impact of biodiesel agroindustry on the achievement of national energy security in 2025. The simulation conducted in this study uses Long-range Energy Alternatives Planning (LEAP) software, which based on the accounting model. The model has run on Business as Usual (BAU) scenario, using four dimensions and 12 indicators of energy security in the context of biodiesel agroindustry. Model simulation results show a decreasing energy security trend in the period of 2022-2025, while the biodiesel production target, which was set at RUEN, cannot be achieved in 2025. This is mainly related to availability and affordability, which experienced a decline in the period. Further research needs to be done on the strategy of developing biodiesel agroindustry by considering scenarios of increasing production capacity and productivity as well as its impact on national energy security.*

Keywords: *Biodiesel; Agroindustry; Energy Security; LEAP; Simulation*

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INTRODUCTION

Indonesia is the largest palm oil-producing country in the world, with total Crude Palm Oil (CPO) production reaching 47 million tons in 2018 [1]. According to the Indonesian Palm Oil Association (GAPKI), export volume in 2018 reached 35 million tons or approximately 73% of total palm oil production, and the rest is intended for domestic consumption. Currently, the capacity for biodiesel production in Indonesia is 12 million kiloliters per year [2].

Although the trend of biodiesel production and consumption has increased over the last five years with a total national production of 6.2 million kiloliters in 2018, it is still far from the target which has been set in the RUEN. There is a difference of 5.4 million kiloliters that must be achieved by the biodiesel agroindustry within the next five years to meet the target.

Based on the situational analysis, it is deemed necessary to construct a biodiesel agroindustry model within the scope of the national energy sector. Cause the determination of biodiesel production targets is part of the objectives mandated in the national energy policy, which is to achieve energy security and independence. This study will project the development of biodiesel agroindustry and analyze its impact on the achievement of national energy security in 2025.

Research on the simulation of the biofuel agroindustry was conducted by [3], who recommends a Computable General Equilibrium (CGE) model to understand the maximum benefits of biofuel production. The CGE structural model is built based on microeconomic theory, where the behavior of economic agents is explicitly explained and in detail, in the form of an equation system [4]. The CGE approach was later adopted by [5] to analyze the potential impact of biofuel policy in Europe on the economy. Some past research also focuses on biofuel production modeling for long-term, recursive-dynamic projections within the CGE framework [6][7]. A study by [8] introduced the relationship between biofuels' mandatory and global agricultural markets through the Global Trade Analysis (GTAP) model.

Research conducted by [9] is one of the earliest studies utilizing the GTAP database to analyze the effects of substitution of crude oil into biomass on petroleum products in the US, using the CGE framework. The GTAP-Energy and Environmental model is extended by [10], while [11] uses it to analyze the impact of the European Union biofuel directive policy on the agricultural market. Completing previous studies, [12] uses the CGE framework to examine the economic and environmental impacts of bioenergy policies.

Based on the results of conducted studies using the CGE approach, it appears that the approach requires a large amount of data. However, there are often cases where not all the required data is available. Referring to the condition, [13] proposed an approach that considers data availability, namely the Partial Equilibrium (PE). A combined model of CGE and PE was then used by [14] to estimate the global impact of biofuel and detailed policies, as well as regional changes in land use.

Another approach in biofuel agroindustry modeling is the dynamic system models. Research conducted using a dynamic model of oil palm agroindustry, among others, was carried out by [15] compiled a dynamic model of the CPO supply chain industry and [16] conducted a study on the impact of biofuel development policies on the dynamics of national food and energy commodity prices. Whereas [17], through his research, has designed a policy model specifically on the biodiesel energy group in the context of achieving the biodiesel contribution target in the national energy mix of 2025. Several other studies conducted using the dynamic model of biodiesel agroindustry were conducted by [18] regarding the development of micro-scale biodiesel business models and macro-based dynamic systems, [19] focusing on technical aspects in the sustainability of biodiesel production, while [20] focusing on the CPO-based biodiesel production system model, and [21] focusing on the bioenergy development policy model with regard to food security.

The modeling of biofuel agroindustry models can also be done by accounting approaches or energy supply-demand balance. Software that is often used as a tool in this approach is LEAP (Long-range Energy Alternatives-Planning). There are many studies conducted using LEAP, including those conducted by [22] in China, [23] in Malaysia and [24] in Pakistan. LEAP model was used by [25] to described the impact of CPO utilization as biofuel in Indonesia's electricity generation sector. Previous studies related to biofuel agroindustry modeling can be grouped into five different approaches: CGE, PE, dynamic systems, accounting, and decision support systems. This study uses an accounting simulation approach, which based on LEAP software.

METHOD

This study was conducted in several stages, as presented in Figure 1.

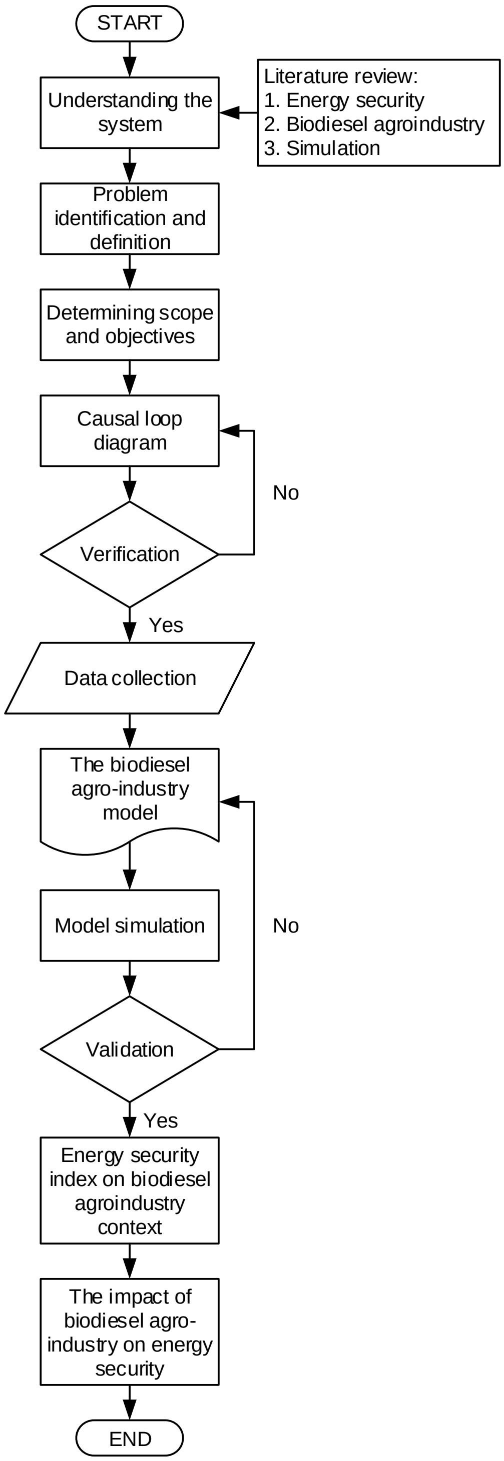

Figure 1. Research Flow Diagram

The scope of the model includes stakeholders in the biodiesel agroindustry, which consists of a series of sub-models (palm oil production, CPO production, biodiesel production, and biodiesel in the national energy sector). The scope of the model can be seen in Figure 2.

The model needs to be verified and validated before it runs the simulation. Model verification is related to the suitability of the conceptual model with the mathematical model, while the model validation is related to the suitability of the output between the mathematical model and the output of the actual system [26].

The simulation conducted in this study uses LEAP software, but the logical thinking in its scenario development has been checked by using a causal loop diagram. The causal loop describes the identification of a system that is built relationships between the processes involved in the system. Figure 3 presents a causal loop diagram on a biodiesel agroindustry model that was verified by a logical test using Vensim software.

The validation process on the model consists of the structural validity test and behavior test of the model against the real system. A structural validity test is done by testing the consistency of dimensions using LEAP software, while the behavior test is done by entering values based on past data to be simulated on the model, and the results are compared with real data. Model verification and validation in this study were also carried out by showing and simulating directly to experts. The experts are who were asked for their opinions about validity of the data, structure of the model, and results of the simulation.

Statistical data related to the research model includes regional data, demographic data, commercial sector data, transportation sector data, industrial sector data, and electrical system data. It is then processed for the purposes of developing the biodiesel agroindustry model and energy security index.

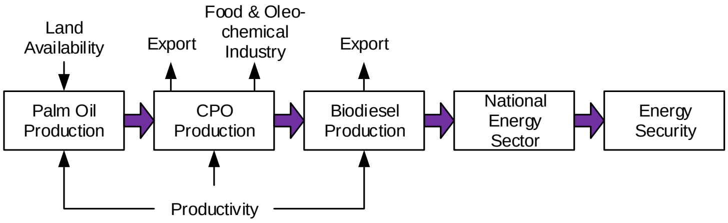

Figure 2. Scope of the Model

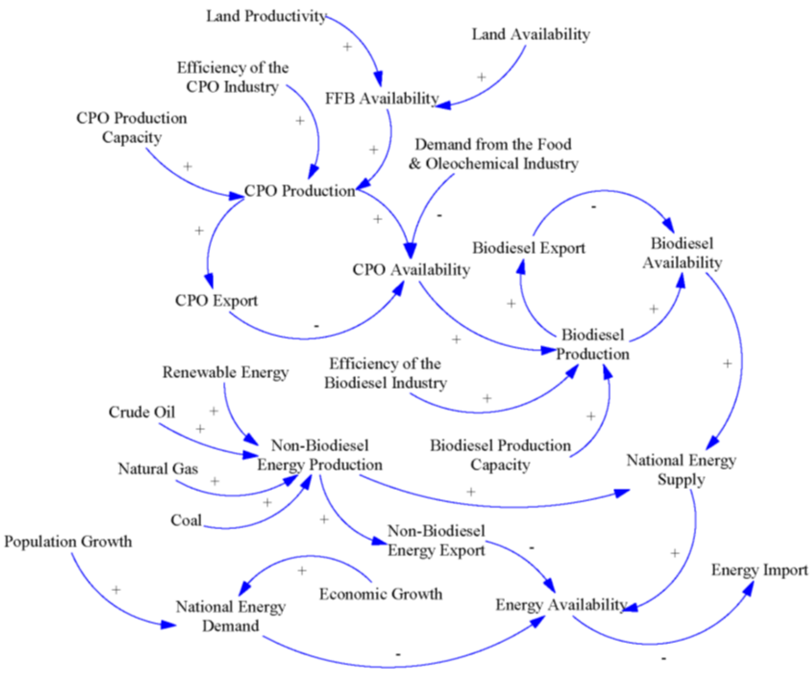

Figure 3. Causal Loop Diagram

The analysis stage was carried out based on the relationships between data, information, and assumptions. Based on these connections, we can determine the objectives of the system as well as factors that can accelerate or hinder the process of achieving system goals. Simulation results will show how the impact of biodiesel agroindustry on energy security.

The information and assumptions used in the model are as follows:

1. Energy consumption for the base year of 2015 is obtained from the Handbook of Energy and Economic Statistics of Indonesia [27].
2. Population and economic growth for the 2015-2030 period follow the long-term projection of Statistics Indonesia [28] and RPJMN IV [29].
3. The price of crude oil and CPO in 2020-2030 follows the World Bank's projections [30].
4. Mandatory biofuels are considered and included in several sectors that utilize biofuels (industry, transportation, and power generation), assuming the B-30 program starts in 2020.
5. The moratorium on the expansion of palm oil plantation area was carried out for three years, namely the period 2019-2021, in accordance with Presidential Instruction No. 8 of 2018 concerning the Postponement and Evaluation of Palm Oil Plantation Licensing.

The next step after data collection and model verification is the model simulation using LEAP software. There are four main modules in the LEAP, namely Driver, Demand, Transformation, and Resources. The energy supply projection process is carried out in the Transformation and Resources Module, while the energy demand projection process is carried out in the Demand Module, which is controlled by the Driver Module. From these four main modules, it can be further developed into a structural model that will be used in analyzing energy supply and demand [31]. The modeling structure used in LEAP can be seen in Figure 4.

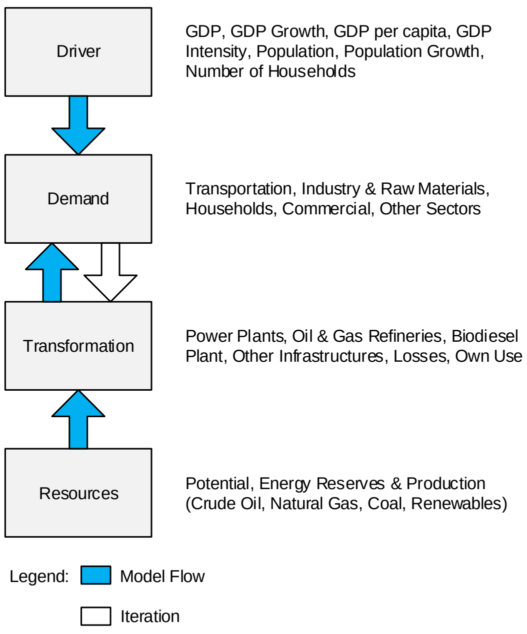

Figure 4. LEAP Model Structure Source

The following is the structure of the LEAP model used in this study:

1. Driver
   The driving variables used in the model include Gross Domestic Product (GDP), population, industrial GDP elasticity, commercial GDP elasticity, CPO prices, palm oil plantations area, CPO productivity, biodiesel productivity, and petroleum prices.
2. Demand
   The energy demand in this model consists of fluctuating needs in the transportation, industrial, commercial, and household sectors.
3. Resources and Transformation (R&T)
   The relationship between resources and energy transformation in this study can be seen in Figure 5. It shows the Sankey diagram or process flow from primary energy to final energy.

The model which developed in this study aims to analyze the impact of biodiesel agroindustry on national energy security based on current conditions or the BAU scenario. The energy security indicator uses the results of the previous study, namely four dimensions covering 12 energy security indicators in the context of biodiesel agroindustry [30].

The following is an explanation of each dimension and indicator of energy security:

1. The dimension of availability (ability to guarantee energy supply), which consist of following indicators:

I_{11}: Energy supply per capita
Amount of biodiesel supply per Indonesian population. This indicator is measured in Barrel Oil Equivalent (BOE) / Capita.

I_{12}: Reserve to consumption ratio
Comparison between ending stock biodiesel with the amount of consumption in the same period. This indicator is measured in percent.

I_{13}: Energy diversity
Comparison between biodiesel supply and total energy supply. This indicator is measured in percent.

2. The dimension of accessibility (ability to gain access to energy), which consist of following indicators:

I_{21}: Feedstock absorption
Comparison between Crude Palm Oil (CPO) used for biodiesel and total national CPO production. This indicator is measured in percent.

I_{22}: Consumption to production ratio
Comparison between domestic consumption of biodiesel with the amount of production. This indicator is measured in percent

I_{23}: Energy elasticity
The ratio of changes in energy consumption to economic growth. This indicator has no units (unit-less).

3. The dimension of affordability (affordable energy prices), which consist of the following indicators:

I_{31}: Pricing
Determination of the average selling price of biodiesel within a year period. This indicator is measured in Rupiah / Liter.

I_{32}: Price volatility
The level of CPO price volatility as biodiesel raw material. This indicator has no units.

I_{33}: Cost of subsidy
Biodiesel subsidy costs per year. This indicator is measured in billions of Rupiahs.

4. The dimension of efficiency and sustainability (from energy and environment perspective), which consist of the following indicators:

I_{41}: Land utilization
Comparison between the utilization of oil palm cultivation land and biodiesel production. This indicator is measured in Ha / BOE.

I_{42}: CO_2 emissions reduction
Difference between CO_2 emissions resulting from the use of diesel fuel and CO_2 emissions resulting from the use of biodiesel. This indicator is measured in a million tons of CO_2e.

I_{43}: Energy intensity
Total supply of biodiesel needed to obtain one unit of GDP. This indicator is measured in BOE / Billion Rupiah.

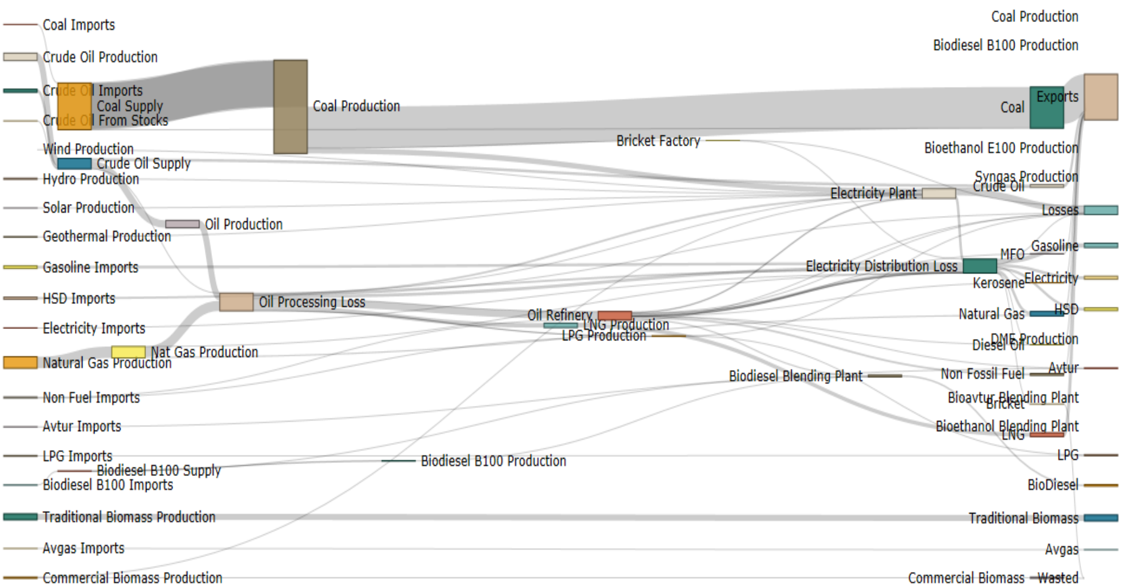

Figure 5. Sankey Diagram of R&T Module

RESULTS AND DISCUSSION

The driving variables used in the model can be seen in Table 1, while the results of the model simulation to measure the level of energy security can be seen in Table 2. The values shown in Table 2 are the results of simulations using the BAU scenario with the year 2015 set as the base year.

Table 1. Driving variables for the BAU scenario

Year	Population	Palm Area	CPO Production	GDP	CPO Price	Petroleum Price
	Million People	Thousand Ha	Thousand Ton	Trillion IDR	USD/ Ton	USD/ Barrel
2019	267.95	14,327	49,242	10,967	600	66.0
2020	271.07	14,327	51,116	11,549	623	65.0
2021	273.82	14,327	53,062	12,223	646	65.5
2022	276.57	15,178	53,784	13,003	670	66.0
2023	279.32	16,080	60,980	13,903	696	66.5
2024	282.08	17,036	69,140	14,940	723	67.0
2025	284.83	18,048	78,390	16,135	749	67.5
2026	287.14	19,120	88,879	17,410	779	68.0
2027	279.32	16,080	60,980	13,903	696	66.5
2028	282.08	17,036	69,140	14,940	723	67.0
2029	284.83	18,048	78,390	16,135	749	67.5
2030	287.14	19,120	88,879	17,410	779	68.0

Table 2. Simulation results for the BAU scenario

Year	Energy Supply	Biodiesel Production		Biodiesel Consumption		Biodiesel Stock	Palm Area Allocation	CPO Allocation	Biodiesel Subsidy	Biodiesel Price
	Million BOE	Million BOE	000 KL	Million BOE	000 KL	000 KL	Thousand Ha	Thousand Ton	Trillion IDR	IDR/Liter
2019	1,958	34.23	6,599	22.55	4,346	1,150	2,008	6,902	11.07	7,004
2020	2,011	39.63	7,639	30.90	5,956	1,301	2,240	7,991	15.26	7,234
2021	2,064	42.04	8,103	33.65	6,485	1,212	2,288	8,476	17.07	7,464
2022	2,244	44.59	8,594	36.55	7,045	1,119	2,537	8,990	18.99	7,704
2023	2,338	47.29	9,116	39.66	7,644	1,016	2,514	9,535	21.05	7,967
2024	2,495	50.16	9,669	43.03	8,294	891	2,492	10,114	23.23	8,231
2025	2,641	53.42	10,296	46.73	9,007	774	2,480	10,770	25.54	8,494
2026	2,681	56.69	10,926	49.33	9,508	872	2,459	11,429	27.50	8,796
2027	2,674	60.16	11,595	52.03	10,029	987	2,438	12,128	29.51	9,099
2028	2,659	63.84	12,305	54.80	10,563	1,126	2,417	12,871	31.54	9,401
2029	2,632	67.74	13,058	57.65	11,111	1,294	2,397	13,658	33.60	9,703
2030	2,601	72.98	14,068	60.55	11,672	1,693	2,413	14,715	35.69	10,005

The driving variables and the model simulation results are then used to calculate ESI by the index construction method. However, the model validation step must first be done with a statistical test. The statistical method used in this study is MAPE (Mean Absolute Percentage Error):

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{|X_t - F_t|}{X_t} \times 100\%$$

Where X_t is actual data, Ft is simulation result data, and n is the amount of data [32]. The validation results indicate that the model has fulfilled the element of conformity between the simulation results with the real conditions, where the MAPE value for primary energy supply is 3.62%, and for biodiesel production is 18.06%.

Forecasting result for energy supply is included in the category of highly accurate forecasting because it has a MAPE value below 10%, while forecasting results for biodiesel production is included in the category of good forecasting because it has a MAPE value between 10-20%. The validation process is also carried out by showing and simulating the model directly to stakeholders. They were being asked to argue for validity of the data, structure of the model, and results of the model simulation.

Parameters used in the index construction method are four dimensions and 12 indicators, as discussed earlier in the research method. Energy security indicators can be seen in Table 3.

Table 3. Energy security indicators

Indica-tors	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
I_{11}	0.13	0.15	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.25
I_{12}	26.46	21.84	18.69	15.89	13.29	10.75	8.59	9.17	9.84	10.66	11.64	14.50
I_{13}	1.75	1.97	2.04	1.99	2.02	2.01	2.02	2.11	2.25	2.40	2.57	2.81
I_{21}	14.02	15.63	15.97	16.71	15.64	14.63	13.74	12.86	12.04	11.27	10.54	10.02
I_{22}	65.86	77.97	80.04	81.97	83.86	85.78	87.48	87.02	86.49	85.85	85.09	82.97
I_{23}	3.05	6.99	1.52	1.35	1.23	1.14	1.07	0.70	0.70	0.69	0.68	0.67
I_{31}	7,004	7,234	7,464	7,704	7,967	8,231	8,494	8,796	9,099	9,401	9,703	10,005
I_{32}	64.41	17.65	19.08	20.96	15.63	72.75	23.24	90.32	15.84	78.01	15.05	77.92
I_{33}	11,071	15,258	17,073	18,986	21,051	23,227	25,541	27,501	29,505	31,539	33,602	35,693
I_{41}	0.06	0.06	0.05	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03
I_{42}	9.74	13.34	14.53	15.78	17.13	18.58	20.18	21.30	22.47	23.67	24.89	26.15
I_{43}	2.06	2.68	2.75	2.81	2.85	2.88	2.90	2.83	2.77	2.71	2.65	2.59

Three processes must be carried out in quantifying the energy security index, namely weighting, normalization, and aggregation. This study uses a pairwise comparison method for weighting. Weight of each indicator and dimensions are using the results of the previous study, while the normalization process is using the composite performance index (CPI) method. The final stage of the index composing method is aggregation, which is done by multiplying the normalized values by weight of each dimension and indicator. The calculation results of the energy security index for the period 2019-2030 can be seen in Table 4 and Figure 6.

Table 4. Energy security index (ESI)

Dimension	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Availability	54.71	53.16	50.99	48.69	47.08	45.37	44.36	46.77	49.54	52.65	56.11	62.51
Accessibility	30.94	34.44	37.90	39.50	39.28	39.09	38.90	40.45	39.54	38.74	37.97	37.07
Affordability	15.30	15.47	14.51	13.60	13.86	10.65	11.71	9.59	11.97	8.94	11.46	8.32
Sustainability	11.48	11.89	12.36	12.61	13.30	14.06	14.91	15.69	16.51	17.36	18.26	19.19
ESI	112	115	116	114	114	109	110	112	118	118	124	127

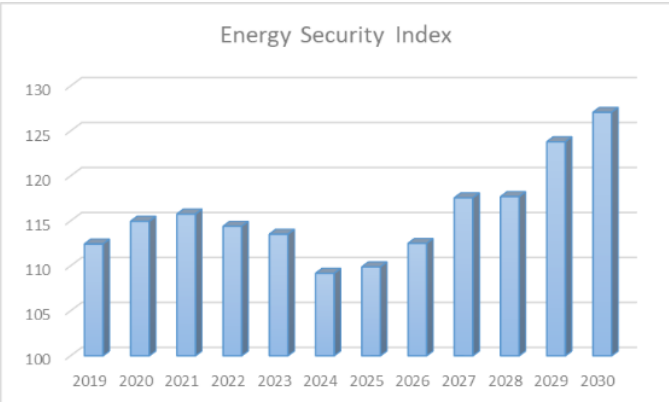

Figure 6. Energy security index 2019-2030

Model simulation results show a decreasing energy security trend in the period of 2022-2025. The condition is mainly related to the availability and affordability dimensions that experienced a decline in the period. In terms of availability, an indicator that has experienced a significant decline is the reserve to consumption ratio. The greater the value indicates the greater national biodiesel stockpile. The high reserve ratio shows the level of availability that will support energy security in the context of biodiesel agroindustry. The simulation results show that biodiesel stock has decreased from 2022 to 2025 because the consumption growth rate is higher than the rate of production growth, assuming the export portion does not change, which is approximately 5% of the total production. By increasing the value of the reserve to consumption ratio in this period, it is necessary to increase the productivity of biodiesel agroindustry so that the production growth rate can exceed or be at least equal to the growth rate of biodiesel consumption.

In terms of affordability, indicators that have significantly decreased are pricing and cost of the subsidy. Both of these indicators are related to CPO prices, which refer to forecasts from the World Bank. CPO price hike will have an impact on determining the selling price of biodiesel at the domestic level, which using the Market Index Price formula = (CPO price + 100 USD/ton) x 870 kg/m^3. The selling price that is affordable by the public will have a positive impact on the increasing use of biodiesel, but on the other hand, it will have an impact on the larger number of subsidies. By increasing the value of affordability dimensions in this period, a strong Rupiah exchange rate against the USD is needed, which will have an impact on determining the selling price of biodiesel and the amount of subsidy needed. Subsidies will also ensure the stability of biodiesel selling prices to reduce high price volatility in 2024.

In addition to the energy security index, the model simulation results also show that the 11.6 million kiloliters biodiesel production target in 2025, as stated in the RUEN, will not be achieved. Yet, it will be achieved in 2027, with the portion of 2.25% from the national energy mix. Several factors cause this production target is two years late to be achieved, namely as follows:

1. The basic assumptions of the RUEN is a very optimistic 8% economic growth in the period 2020-2025, while the model used in this study uses the RPJMN IV reference with a projected economic growth of 4.9% in the 2020- 2025. The assumption of economic growth will affect the projected energy consumption, including biodiesel.
2. RUEN uses 2.3 million kiloliters of biodiesel production in 2015 as its base-year projection. Nevertheless, biodiesel production in 2015 was only 1.6 million kiloliters. As a result, the gap between the projections of biodiesel production in RUEN with the actual conditions is getting bigger because in the RUEN projections there is no decrease in production during the 2015-2018 period, whereas in reality there was a fluctuation in biodiesel production during that period with a decrease in production in 2017.
3. The model in this study considers a moratorium on the expansion of the oil palm area, which carried out during the 2019-2021 period. Although with the moratorium, it is hoped that the productivity of oil palm plantations will increase, but this will still affect the national CPO supply and slightly hamper the rate of biodiesel production in the period of the moratorium.

Referring to points 1 and 2, the non-achievement of production targets set at RUEN is more due to the influence of external factors. Whereas for point 3 is an internal factor, namely the need to increase land productivity and increase the productivity of biodiesel agroindustry.

CONCLUSION

The focus of biofuel development in Indonesia is mainly on palm oil-based biodiesel due to its abundant raw materials. Based on the projections from the model, biofuel development in Indonesia will not affect food security because it will only reach a maximum of 17% from the national CPO production. The simulation also shows that the biodiesel production target, which was set at RUEN, cannot be achieved in 2025. For this reason, an increase in productivity for biodiesel agroindustry is needed so that the target can be achieved. The basis for calculating the conversion of Fresh Fruit Bunch (FFB) to biodiesel is based on the result of a study [33] that 1 kg of biodiesel is produced from 1.05 kg of crude palm oil (CPO) or approximately 4.76 kg of FFB.

In addition to increasing productivity, production capacity must also be considered. The current condition of the national biodiesel production capacity is about 12 million kiloliters, so it is necessary to increase production capacity to anticipate the increased productivity. On the other hand, the addition of production capacity must consider the growth of biodiesel market share. As is known, the sectors that utilize biodiesel as an energy source are power generation, transportation, and industry. Based on the projections from the model, the consumption of biodiesel in the power generation sector in 2019 will be around 400 thousand kiloliters or 9% of the total biodiesel consumption at the national level and this number will continue to decline as the portion of the Diesel Power Plant will decrease in the future come. Whereas in the transportation sector, the inclusion of an electric car development scheme in the Electricity Supply Business Plan (RUPTL) 2019-2028 has the potential to erode the biodiesel market share. Therefore, further research needs to be done on the strategy of developing biodiesel agroindustry by considering scenarios of increasing production capacity and productivity, as well as its impact on national energy security.

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