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Article

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International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Firdaus, Alfa/Machfud, Machfud et. al. (2019). Measuring Indonesia's energy security level in the context of biodiesel agroindustry. In: International Journal of Energy Economics and Policy 9 (6), S. 154 - 164.
http://econjournals.com/index.php/ijeep/article/download/8255/4644.
doi:10.32479/ijeep.8255.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2019, 9(6), 154-164.

Measuring Indonesia's Energy Security Level in the Context of Biodiesel Agroindustry

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Received: 17 June 2019 **Accepted:** 10 September 2019 **DOI:** https://doi.org/10.32479/ijeep.8255

ABSTRACT

The development of biodiesel agroindustry in Indonesia is part of the Government's efforts to achieve national energy security. This study tries to form relevant dimensions and indicators of energy security, which can be used in the context of biodiesel agroindustry. It identified 4 dimensions and 12 indicators of energy security in the context of biodiesel agroindustry, which consisted of availability as measured by energy supply per capita, reserve to consumption ratio and energy diversity; accessibility as measured by feedstock absorption, consumption to production ratio and energy elasticity; affordability as measured by pricing, price volatility and cost of subsidy; efficiency and sustainability as measured by land utilization, CO_2 emissions reduction and energy intensity. Based on the energy security index, it is known that the level of national energy security in the context of biodiesel agroindustry over the past 4 years has experienced an increasing trend.

Keywords: Energy Security, Agroindustry, Biodiesel
JEL Classifications: Q41, Q42, Q43

1. INTRODUCTION

Indonesia has long been known as an agricultural country with various types of vegetable oil plants, of which, are very suitable to support the development of biofuel. The focus of biofuel development in Indonesia is mainly on palm oil-based biodiesel because of its abundant raw materials (Ministry of Energy and Mineral Resources, 2014). The utilization of biodiesel is a form of energy diversification to reduce dependence on fuel oil and to achieve national energy security, which is a vital component of economic development and national security. But in reality, there are no standard dimensions and indicators to measure the level of energy security because energy security is a concept that is very bound to context. These two contradictory facts certainly raise questions.

On the one hand, energy diversification through the development of biodiesel agroindustry is one of the efforts made by the Government to achieve national energy security. But on the other hand, there is no standard indicator to measure the level of national energy security in the context of biodiesel agroindustry. Based on the situational analysis, this study will identify relevant dimensions and indicators of energy security which can be used in the context of palm oil-based biodiesel agroindustry.

2. LITERATURE REVIEW

The Asia Pacific Research Center defines energy security as the ability of the economy to ensure the availability of supply of energy resources on a regular and sustainable basis, with energy prices at levels that do not adversely affect economic performance (Intharak et al., 2007). While (Badea et al., 2011) simplify the meaning of energy security by linking it to the context of energy supply security, namely the availability of regular energy supplies at affordable prices. In another context, as proposed by (Cherp and Jewell, 2014) energy security is defined as a low vulnerability of vital energy systems. The vital energy system in question includes energy resources, infrastructure and energy use, all of which are linked to the energy flow that sustains social functions.

The International Energy Agency (IEA) uses the reverse definition to interpret energy security as energy uncertainty, namely the loss of welfare caused by changes in energy prices or energy availability (IEA, 2007). In the short term, the IEA formulates that energy security can be assessed based on two aspects, namely risks and resilience. Risks represent the risk of disruption of energy supply. Whereas resilience is the ability of the national energy system to tackle disruption. Sovacool et al. (2011) define energy security in an international perspective, namely how to equitably provide available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to end-users.

In the Association of Southeast Asian Nations (ASEAN) region, Kanchana and Unesaki (2015) put the concept of resilience as a robust energy system with uninterrupted availability of resources and affordable prices, as well as access to modern energy services. Whereas, according to the Indonesian Government's definition, energy security is a condition of ensuring the availability of energy and public access to energy at affordable prices in the long term, while paying attention to environmental protection (Government of the Republic of Indonesia, 2014). From the definition of the Indonesian Government there are 4 aspects or dimensions that show the condition of energy security: availability (ability to guarantee energy supply); accessibility (ability to gain access to energy); purchase power (affordable energy prices) and environment protection.

Based on the research conducted by Ang et al. (2015), the main parameters of energy security consist of the availability of physical energy resources, diversification, infrastructure, energy prices, social impacts, environment, governance and energy efficiency. In management at the country level, the aspects of energy security are interrelated and support the aspects of economic competitiveness and environmental sustainability. Ang et al. (2015) separates these last two aspects from energy security and does not make it a direct dimension of energy security. However, between the three aspects, they have parametric indicators that intersect each other. Ang et al. (2015) stated that energy and infrastructure prices are not only dimensions of energy security, but also economic competitiveness. The same is true of efficiency and environment (clean energy) dimensions, which are also part of environmental sustainability.

Sovacool (2012) has detailed more on the dimensions of energy security, which consist of: availability, affordability, technological development and efficiency, environmental sustainability and regulation and governance. He also detailed these dimensions into specific components, such as the availability dimension, which is divided into supply security components, domestic energy production, energy supply dependence on other regions and energy diversification. The affordability dimension composed of components such as price stability, access to electricity, use of traditional fuels for cooking and fuel prices. In addition, he also pointed out dimensions of technological development, environmental sustainability and regulations that consist of components such as efficiency and reliability, water and land sustainability, anticipation of climate change and government policies and information dissemination regarding energy management.

Winzer (2012) emphasizes energy security as energy supply security and divides dimensions based on risk source categories such as technical risk sources, human risk sources and natural risk sources. He narrows down the concept of energy security with the concept of continuity of energy supply to reduce the overlap between policy objectives for energy security, sustainability and economic efficiency. He also proposed energy security indicators that can be quantified directly, namely the Average Interruption Duration Index (SAIDI), the System Average Interruption Frequency Index, SAIDI for the city heating system (Heat SAIDI), CO_2 per capita, electricity price trends and electricity price volatility.

Prambudia and Nakano (2012) conducted an integrated research of interactions between various components to assess energy security performance from an economic perspective by using simulation models and dynamic systems in Indonesia. There are three dynamic scenarios used, namely business as usual, increasing production and reducing subsidies. Dimensions are measured by group availability, affordability, efficiency and acceptability, with indicators of adequacy, imports, costs, subsidies and emissions. The results of his research concluded that in order to improve energy security in Indonesia, the establishment of policies to reduce subsidies would be more profitable than policies to increase energy production. The policy of reducing subsidies for energy will improve the dimensions of performance, availability, efficiency and acceptability, while increasing production meets the dimensions of availability, affordability and efficiency it does not meet acceptance. This research has identified the actors involved in implementing policy, but has not specifically linked it to the biodiesel sector.

The difference in the use of methods and indicators in quantification, results in a different model framework for assessing and analyzing energy security. Based on several aspects of energy security that have been described, it can be seen that energy security is a concept that is very bound to the specific context. For example, researchers can focus on discussing energy security on the supply side, such as energy availability and prices. On the other hand, the topic of energy security can also be drawn to the end-user side, such as the economic impact and social welfare. Not limited to this, the focus of the study can also be directed at the context of the type of energy, such as electricity and biodiesel.

In the context of biodiesel energy management, the aspects of energy security - dimensions, as well as indicators - that have been discussed above are not all relevant for use. Therefore it is necessary to formulate related aspects and indicators that can be used to measure the level of energy security in the context of biodiesel. There are at least four aspects that can be used as a basis for measuring energy security, these aspects are availability, ease of access, affordability and efficiency and sustainability. Table 1 summarizes some studies that involve the composing of energy security index.

3. RESEARCH METHOD

The method that is often used as a basis for measuring a country's level of energy security is the energy security index. This index is a set of indicators and metrics that represent various aspects or dimensions that are processed based on a particular framework. Indicators and dimensions of energy security were selected based on the assessment of five experts who screened energy security indicators from previous studies. Experts were selected due to their expertise in energy security with minimum 10 years of experience and they all have written scientific papers regarding energy security. Appraisal from experts was not limited to existing indicators, but also included other indicators which related to the biodiesel agroindustry context. This screening process was carried out using in-depth interviews, which was done repeatedly to get indicators and dimensions that can represent the energy security index in the context of biodiesel agroindustry. Figure 1 shows a flow diagram of the research stages carried out in this study.

There are three processes that must be carried out in quantifying the energy security index; namely weighting, normalization and aggregation. Weighting is a process that emphasizes the contribution of several aspects of a data set to the final result, thus sustaining a stronger weight on the final results of the calculation and analysis process. The purpose of weighting is to give a stronger weight to indicators that are considered more important than other indicators. Weighting can be done by various methods, one method is the pairwise comparison method, which is part of the analytical hierarchical process (AHP) model. AHP is widely used in the energy field because it is simple and easy to use (Hughes, 2009). AHP synergizes expert judgment, in this study we used assessments from several experts in the field of energy security.

The next process is normalization, which is the adjustment of measurement values on various scales to more general parameters. Each energy security indicator has different units and at different scales. For this reason, normalization is needed to ignore the units in the data and facilitate analysis. In principle, normalization converts basic data linearly onto a simpler scale. There are various methods for normalizing indicators, one of which is the composite performance index (CPI) method. The procedures for completing the CPI method are as follows (Rangkuti, 2011):

1. Identify indicators with a positive trend or negative trend.
2. Indicators with a positive trend (+) indicate the higher the value the better and conversely the negative trend (−) indicates the lower the value the better.
3. For the positive trend criteria, the minimum value for each criterion is transformed to one hundred, while the other values are transformed proportionally higher.
4. For the negative trend criteria, the minimum value for each criterion is transformed to one hundred, while the other values are transformed proportionally lower.

The CPI calculation for positive trend criteria is as follow:

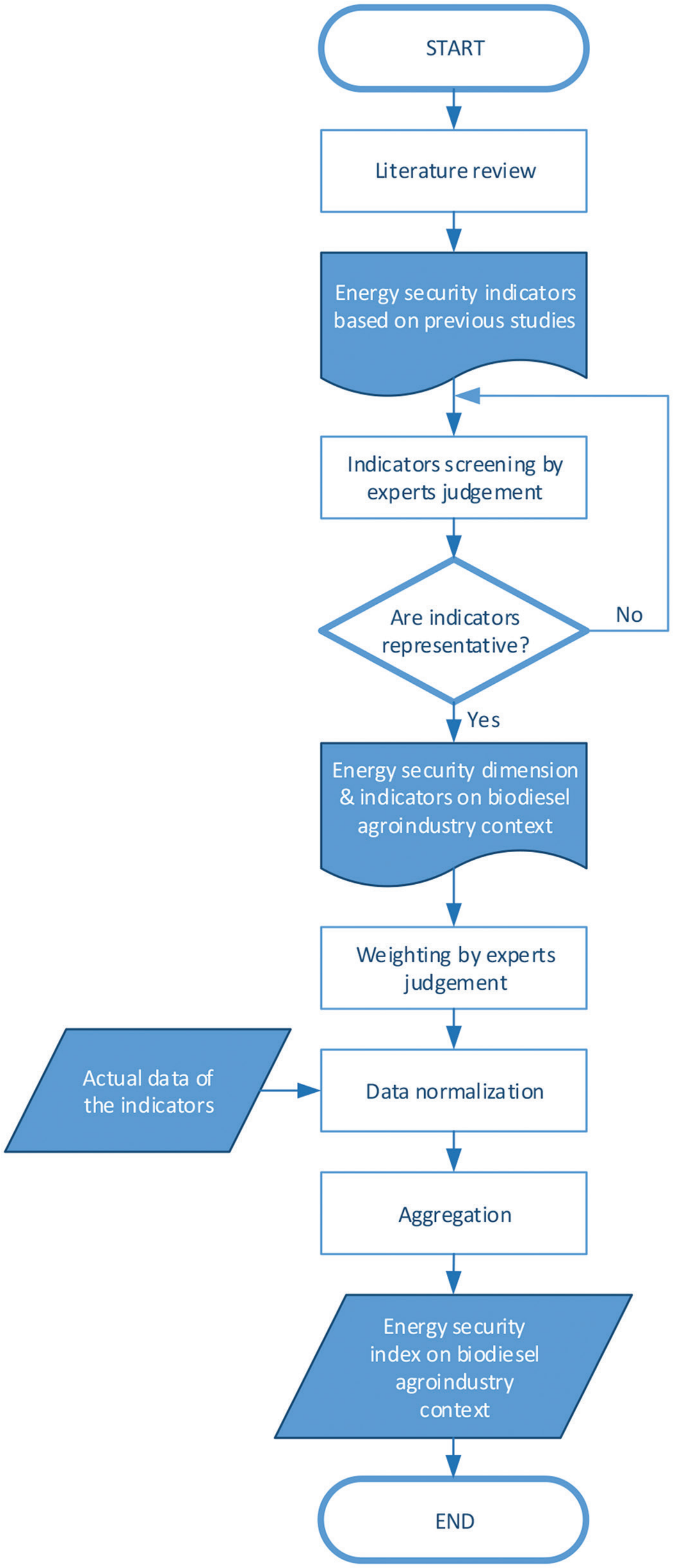
$$e_i = \frac{x_i \times 100}{\min x_{i,n}} \quad (1)$$

Table 1: Various studies on energy security

Author (s)	Model	Energy security dimensions	∑ of indicators
(Sovacool and Brown, 2007)	Energy sustainability index	Oil security; electricity reliability; energy efficiency; environmental quality	10
(IAEA, 2007)	Energy indicators for sustainable development	Equity; health; energy use and production patterns; security	31
(IEA, 2007)	Energy security index	Energy price; physical availability	2
(Gnansounou, 2008)	Composite index of vulnerability	Energy intensity; energy dependence; Sensitivity to volatility of energy prices; vulnerability from consumer and supplier perspective	5
(Jansen, 2009)	Energy services security indicators	Reliability; energy costs; policy framework; public acceptance	38
(Jewell, 2011)	IEA model of short- term energy security	Crude oil; oil products; natural gas; coal; biomass and waste; biofuels; hydropower; nuclear power	35
(Sovacool et al., 2011)	Energy security performance	Availability; affordability; technology development and efficiency; environmental sustainability; regulation and governance	20
(ERIA, 2012)	Energy security index	Development of domestic resources; acquisition of overseas resources; transportation risk management; securing a reliable domestic supply chain; management of demand; preparedness for supply disruptions; environmental sustainability	16
(Winzer, 2012)	Energy security levels	Sources of risk; scope of the impact measure; severity filter	8
(World Energy Council, 2012)	Energy sustainability index	Energy security; social equity; environment impact mitigation; political strength; societal strength; economic strength	21
(National Energy Council, 2017)	Energy security levels	Availability; accessibility; affordability; acceptability	20
(Erahman et al., 2016)	Energy security index	Availability; accessibility; affordability; acceptability; efficiency	14
(Hamdani and Sepriana, 2014)	Energy security index	Availability; accessibility; affordability; acceptability	7
(Prambudia and Nakano, 2012)	Energy security performance	Availability; affordability; acceptability; efficiency	12

Source: Adopted from Ang et al., 2015

Figure 1: Flowchart of research stages



While the CPI calculation for negative trend criteria is as follow:

$$e_i = \frac{\min x_{i,n} \times 100}{x_i} \quad (2)$$

Where e_i is the normalized data of indicator i; x_i is the actual data of indicator i and min x_i,n is the minimum value of indicator i in n years.

The final stage of the index composing method is aggregation, which is a combination of related categories, usually in a general branch of the hierarchy, to provide information at a broader level in detailed observations (United Nations Statistics Division, 2016). In this study, the purpose of aggregation is to combine all processing indicators into one index value. Aggregation is done by multiplying the normalized values by weight of each dimension and indicator, as can be seen in the following aggregation formula (Lindiasari, 2017):

$$WII_{i,j}=w_{i,j}e_{i,j}$$

$$IAV_j=\sum WII_{i,j}$$

$$WDI_j=w_jIAV_j$$

$$ESI=\sum WDI_j \quad (3)$$

Where $WII_{i,j}$ is weighted index of indicator i in dimension j; $w_{i,j}$ is the weight of indicator i in dimension j; $e_{i,j}$ is the normalized value of indicator i in dimension j; IAV_j is the indicators aggregate value of dimension j; WDI_j is the weighted index of dimension j; w_j is the weight of dimension j and ESI is the energy security index.

4. RESULTS

4.1. Identify the Dimensions and Indicators

As explained in research method, the first stage of this study was to conduct a literature review to develop energy security indicators based on previous studies. The indicators of energy security can be seen in Table 2. The next step we took was to screen the energy security indicators that are in accordance with the biodiesel agroindustry context. As shown in Table 2, there were 54 indicators of energy security which were divided into 11 aspects. Indicators included in the aspect of the electricity system were not selected as indicators in the context of biodiesel agroindustry, with consideration that the biodiesel portion is below 1% of the fuel consumption in power plants (Ministry of Energy and Mineral Resources, 2018). The trend of using biodiesel in power plants continues to decline along with the increase in the portion of coal that is more economical as fuel for electricity generation. While the focus of renewable energy utilization in the electricity generation sector comes from geothermal and hydro power.

Other aspects, namely, research and development, were not chosen because of constraints in measuring the indicators such as technological maturity and innovation. While the aspects of oil and gas system were not chosen, considering that six indicators in this aspect did not have direct impact to biodiesel agroindustry. Furthermore, indicators in the aspects of National and International governance were also not selected as indicators in the context of biodiesel agroindustry. There were several considerations in conducting screening, among others, due to the fact that the indicators did not have relevance to the biodiesel agroindustry. Such constraints as in measuring qualitative indicators, the unavailability of intended policy indicators and indicators can be substituted by other indicators. Regarding the self-sufficiency aspect, given the fact that biodiesel used in

Indonesia entirely comes from domestic production, the indicator of import energy per capita and import cost becomes irrelevant in the context of biodiesel agroindustry. The result of energy security indicators in the context of biodiesel agroindustry can be seen in Table 3.

Referring to the results of expert judgement's, 12 indicators were used to measure the level of national energy security. Of the 12 indicators, 10 indicators were the results of screening from energy security indicators in Table 2, while the other two indicators were new indicators that are specifically used in the

Table 2: Energy security indicators based on previous studies

Energy security indicators			
Electricity system		**Energy mix**	
1	Increased electricity supply	29	Shannon-Wiener Index for energy diversification
2	GDP loss due to electricity interruptions	30	Renewable energy utilization
3	Electrification ratio	**Research and development**	
4	Reserve margin of generation capacity	31	Technological maturity
5	Power outage frequency/duration	32	Innovation
6	Diversity of electricity generation	**Oil and gas system**	
7	Number of power plants	33	Oil and Gas reserves per consumption ratio
8	Average age of power plants	34	Daily send-out oil and gas capacity
9	Fraction of the total energy generated by distributed generation and smaller-scale energy systems in the total production	35	Number of refineries
		36	Proportion of offshore/underground production
Pricing issues		37	Flexibility of refining infrastructure
10	Energy price volatility	38	Wholesale margin on gasoline
11	Energy price to GDP per capita ratio	**Demand side management**	
12	Market liquidity	39	Energy efficiency
13	Affordability of fossil fuel price	40	Energy intensity
14	Cost of subsidy	**National and International governance**	
Negative impacts on the environment caused by the use of energy		41	International politics and international relations that influence energy trade
15	CO_2 emissions per capita	42	Vehicle ownership
16	Emission intensity	43	Provision of natural gas
17	Greenhouse gas emission reduction	44	Compliance of DMO for gas and coal
Supply reliability		45	Transparency of energy information
18	Resilience of energy system to risks, terrorism and natural disasters	46	Public attitudes and perceptions of energy systems
19	Percentage of households relying on traditional use of biomass	47	Public acceptance of energy infrastructure development
20	Energy supply per capita	48	Investment and employment
21	Increased fossil fuel supply and utilization	49	Military power
22	Volatility of domestic production	50	Political stability
23	Volatility of agricultural output	**Energy elasticity**	
24	Entry points (ports, rivers and pipelines)	51	Five years energy consumption growth
25	Ratio of energy production to consumption	52	Energy consumption to GDP per capita ratio
26	Commercial energy access ratio	**Self-sufficiency**	
27	Diversity of import source	53	Energy import per capita
28	Reserve to production ratio	54	Oil import cost

Table 3: Energy security indicator in the context of biodiesel agroindustry

Dimensions	#	Indicators	Metric	Unit	Trend
Availability	1	Energy supply per capita	Ratio between biodiesel supply and population	BOE/Capita	+
	2	Reserve to consumption ratio	Ratio between stock and biodiesel consumption	%	+
	3	Energy diversity	Ratio between biodiesel supply and total energy supply	%	+
Accessibility	4	Feedstock absorption	Ratio between FFB used for biodiesel and total FFB production	%	+
	5	Consumption to production ratio	Ratio between consumption and biodiesel production	%	+
	6	Energy elasticity	Ratio between biodiesel demand growth and GDP growth	Unit-less	−
Affordability	7	Pricing	Market index price per liter of biodiesel	IDR/Liter	−
	8	Price volatility	CPO price fluctuations which measured by the relative volatility index	Unit-less	−
	9	Cost of subsidy	Government subsidy costs for biodiesel	Trillion IDR	−
Efficiency and Sustainability	10	Land utilization	Ratio between oil palm cultivation land and biodiesel production	Ha/BOE	−
	11	CO_2 emissions reduction	CO_2 emissions reduction due to the substitution of fuel oil to biodiesel	Million Ton CO_2e	+
	12	Energy intensity	The biodiesel supply needed to produce one unit of GDP	BOE/Billion IDR	−

context of biodiesel agroindustry, namely feedstock absorption and land utilization. These two indicators were specifically used in this study and have never been found in previous studies of energy security indicators.

In general, energy security indicators in the biodiesel agroindustry context consist of availability dimension as measured by energy supply per capita indicator, reserve to consumption ratio and energy diversity, accessibility dimension as measured by feedstock absorption indicators, consumption to production ratio and energy elasticity; affordability dimension as measured by indicators of pricing, price volatility and cost of subsidy; and the dimension of efficiency and sustainability as measured by land utilization, CO_2 emissions reduction and energy intensity. The following is an explanation of each of these indicators.

4.1.1. Energy supply per capita
Energy supply per capita is an indicator that describes the amount of biodiesel supply per Indonesian population. The higher the value of this indicator, the better because it means that biodiesel is increasingly being used nationally. The unit used to compare between energy supply and population is barrel oil equivalent (BOE) per capita. Annual biodiesel energy supply data is obtained from the Handbook of Energy and Economic Statistics of Indonesia (HEESI) issued by the Ministry of Energy and Mineral Resources (MEMR), while data on population numbers are obtained from BPS (Central Bureau of Statistics).

4.1.2. Reserve to consumption ratio
The reserve to consumption ratio is an indicator that measures the ratio between ending biodiesel stocks and the amount of consumption in the same period. The greater the value shows, the greater the national biodiesel stock reserves. A high ratio of total reserves indicates availability and will support energy security in the context of biodiesel agro-industry. The units used to compare between stocks and biodiesel consumption are in percent, while annual stock and biodiesel consumption data is obtained from Association of Indonesian Biofuel Producers (APROBI).

4.1.3. Energy diversity
The concept to calculate the level of diversification comprehensively was stated by Stirling (1998). According to him, diversification consists of three important components, namely, variety, balance and disparity. Stirling uses the Shannon-Wiener Index, which is commonly used to measure bio-diversification. But in the context of biodiesel agroindustry, energy diversification is the ratio between biodiesel supply and total energy supply to measure the portion of biodiesel in the national energy mix. The higher the value of energy diversification means the more positive national energy security will be due to the increasing role of biodiesel energy. Energy diversification indicator is measured in percent units, while the primary energy supply data per year is obtained from HEESI.

4.1.4. Feedstock absorption
Feedstock absorption is an indicator that measures the ratio between fresh fruit bunches (FFB) of oil palm used for biodiesel and the total national FFB production. The higher the value, the greater absorption of biodiesel agroindustry to FFB production. The basis for calculating the conversion of FFB to biodiesel is based on the result of (Rosmeika, 2014) study that 1 kg of biodiesel is produced from 1.05 kg of crude palm oil (CPO) or approximately 4.76 kg of FFB. The unit used for the raw material absorption indicator is in percent, while the FFB production data is obtained from BPS and annual biodiesel production data is obtained from APROBI.

4.1.5. Consumption to production ratio
The consumption to production ratio is an indicator that measures the ratio between domestic consumption of biodiesel and the amount of production in the same period. The higher the value, the greater absorption of the consumer towards biodiesel production. High consumption ratios can also be interpreted as having accessibility and it supporting energy security in the context of biodiesel agroindustry. The unit used to compare between biodiesel consumption and production is in percent, while annual consumption and biodiesel production data is obtained from APROBI.

4.1.6. Energy elasticity
Energy elasticity is defined as the ratio of energy consumption growth to economic growth. Based on this definition, low energy elasticity represents high economic growth as a result from insignificant increase in energy consumption. In general, the value of energy elasticity can help to analyze changes in energy demand along with the growth of gross domestic product (GDP). Energy elasticity indicators do not have units (unit-less), while annual biodiesel consumption growth data is obtained from APROBI and GDP growth data is obtained from BPS.

4.1.7. Pricing
Pricing is an indicator of the biodiesel average selling price in a year period. Affordable selling prices will have a positive impact on the increasing use of biodiesel. The unit used for the selling price indicator is in Indonesian Rupiah (IDR) per liter, while the market index price (HIP) data for biodiesel was obtained from the Directorate General of Renewable Energy and Energy Conservation of the MEMR.

4.1.8. Price volatility
Price volatility is an indicator that measures the volatility of CPO prices as a biodiesel feedstock. The higher the level of volatility, the more CPO prices will be harder to predict. Therefore, a low level of price volatility is needed to ensure the stability of CPO prices. This study used the relative volatility index (RVI) indicator to measure the CPO prices volatility. The RVI indicator does not have a unit (unit-less), while the RVI value is calculated based on CPO prices per month which obtained from BPDPKS (Palm Oil Plantation Fund Management Agency). The following is the RVI formula that was first developed by (Dorsey, 1993).

$$
\begin{aligned}
&\textit{If } price > price_{[-1]} \textit{ then}\\
&\quad up = StdDev^{i}_{i-9}(price)\\
&\quad dn = 0\\
&\quad else\\
&\quad up = 0\\
&\quad dn = StdDev^{i}_{i-9}(price)\\
&\quad upavg = \frac{upavg \times (n-1) + up}{n}\\
&\quad dnavg = \frac{dnavg \times (n-1) + dn}{n}\\
&\quad RVIoring = 100 \times \frac{upavg}{upavg + dnavg}\\
&\quad RVI = \frac{RVIoring(high) + RVIoring(low)}{2}
\end{aligned} \tag{4}
$$

Where *price* is the commodity prices; *up* is the rising price movements; *dn* is the fall price movements; *StdDev* is the standard deviation; *upavg* is the average on rising price movements; *dnavg* is the average on fall price movement; *n* is period of calculation and *RVI* is RVI.

4.1.9. Cost of subsidy

Cost of subsidy is an indicator that measures the cost of biodiesel subsidies per year. The subsidy is paid to fill the gap between biodiesel selling price and production cost. Since the issuance of Presidential Regulation No. 61 of 2015 concerning the Collection and Use of Palm Oil Plantation Funds, biodiesel subsidies are not paid from the State Budget (APBN), but rather from BPDPKS, which was established to manage oil palm plantation funds so that the national palm oil industry can be managed sustainably through the policy of Indonesia sustainable palm oil. Companies that export CPO must deposit levies to the Government. The funds obtained from this levy amount to USD 50 per ton of CPO. The higher the value of subsidies, the more affordable price of biodiesel. However, subsidies will also threaten the sustainability of the biodiesel agroindustry itself because the funds raised in addition to biodiesel subsidies are also allocated for human resource development, research and development of oil palm plantations, promotion of oil palm plantations, rejuvenation of plantation crops and facilities and infrastructure for oil palm plantations. Therefore, in the perspective of energy security, the ideal value of subsidies is in minimum conditions. The unit is used for indicators in Trillion Rupiah, while annual biodiesel subsidy data is obtained from BPDPKS.

4.1.10. Land utilization

Land utilization is an indicator that measures the ratio between the utilization of oil palm cultivation land and biodiesel production in the same period. The lower value of land utilization indicates the more efficient the use of land resources to produce the same amount of energy, this will support energy security in the context of biodiesel agroindustry. The unit used for land utilization indicators is in Hectare (Ha) per BOE, with data on land area used for oil palm cultivation obtained from the BPS (Badan Pusat Statistik (Central Bureau of Statistics)) and biodiesel supply data, which is obtained from the HEESI (Handbook of Energy Economics and Statistics Indonesia).

4.1.11. CO_2 emissions reduction

CO_2 emissions reduction is an indicator that measures the difference between CO_2 emissions generated from the use of diesel fuel and CO_2 emissions generated from the use of biodiesel. Based on research from the Agency for the Assessment and Application of Technology (BPPT), CO_2 emissions of palm oil biodiesel are lower than diesel, with a difference of 1.87 kg CO_2e/kg of fuel (Suwedi, 2017). The higher the level of utilization of biodiesel, the greater the CO_2 emissions that can be reduced from the use of diesel fuel. The unit used for the indicator of CO_2 emission reduction is in units of million tons of CO_2e, while the annual consumption of biodiesel is obtained from APROBI.

4.1.12. Energy intensity

Energy intensity is an indicator of the biodiesel supply needed to obtain one unit of GDP. Low energy intensity values indicate more efficient use of energy to produce GDP. The unit used for energy intensity indicator is the BOE per Billion IDR. Annual biodiesel supply data is obtained from the HEESI, while GDP data is obtained from the BPS.

4.2. Composing the Energy Security Index

4.2.1. Weighting

After obtaining dimensions and indicators that can represent energy security in the context of biodiesel, the next step was to weight the dimensions and indicators. Figure 2 is the AHP model used in this study along with the weights of each dimension and indicator.

4.2.2. Data normalization

Benchmarking is needed to find out trends in national energy security conditions. In this study, the benchmark was annual data with a period of 2015-2018. The data are then normalized to resolve various scales into more general parameters, the results of data collection and normalization can be seen in Table 4.

4.2.3. Aggregation

The results of the aggregation process can be seen in the following Tables 5 and 6, where in Table 5 the result of indicators aggregate value is shown and in Table 6 the result of dimensions aggregate value with the Energy Security Index (ESI) highlighted at the bottom of Table 6 can be found.

5. DISCUSSION

Based on the assessment results for dimensions index, it is known that the availability and accessibility dimension have an increasing trend each year. From the results it can be said that in 2015-2018 period there was an increase in availability and access to biodiesel energy in Indonesia. This is a good news for the development of biodiesel agroindustry. However, there are still price constraints for consumers, where affordability index experienced fluctuations

Figure 2: Analytical hierarchical process model and weighting results

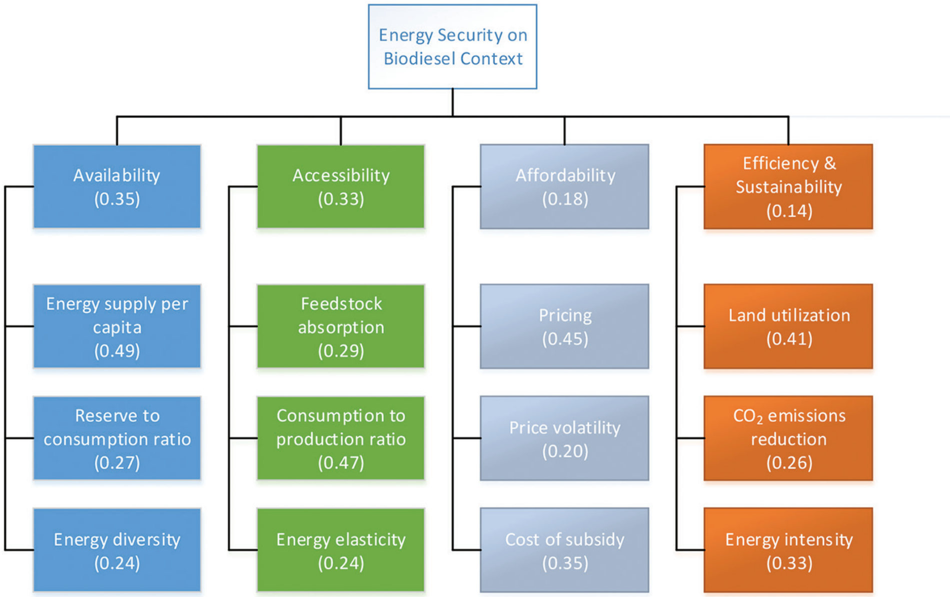


Table 4: Data collection and normalization result

#	Indicators	Unit	Actual data				Normalization result			
			2015	2016	2017	2018	2015	2016	2017	2018
1	Energy supply per capita	BOE/Capita	0.02	0.08	0.06	0.09	100	325	274	395
2	Reserve to consumption ratio	%	32.15	7.28	25.57	16.86	442	100	351	232
3	Energy diversity	%	0.37	1.23	1.01	1.44	100	332	273	389
4	Feedstock absorption	%	21.52	46.62	36.56	61.24	100	217	170	285
5	Consumption to production ratio	%	55.00	82.00	75.00	61.00	100	149	136	111
6	Energy elasticity	Unit-less	10.33	45.43	2.87	8.90	28	6	100	32
7	Pricing	IDR/Liter	7185	8183	9002	7607	100	88	80	94
8	Price volatility	Unit-less	14.00	16.00	8.00	12.00	57	50	100	67
9	Cost of subsidy	Trillion IDR	4.50	11.17	10.30	9.80	100	40	44	46
10	Land utilization	Ha/BOE	0.41	0.27	0.31	0.38	66	100	87	71
11	CO_2 emissions reduction	Million Ton CO_2e	2.05	6.74	5.76	8.40	100	329	281	410
12	Energy intensity	BOE/Billion IDR	0.66	2.07	1.68	2.34	100	32	39	28

Table 5: Indicators aggregate value

#	Indicators	Weight	Weighted indicators index				Indicators aggregate value			
			2015	2016	2017	2018	2015	2016	2017	2018
1	Energy supply per capita	0.49	49.24	159.77	134.91	194.65	192.56	265.55	294.69	349.52
2	Reserve to consumption ratio	0.27	119.66	27.10	95.17	62.75				
3	Energy diversity	0.24	23.67	78.69	64.61	92.12				
4	Feedstock absorption	0.29	29.48	63.87	50.08	83.89	83.31	136.02	137.84	143.93
5	Consumption to production ratio	0.47	47.42	70.70	64.66	52.59				
6	Energy elasticity	0.23	6.41	1.46	23.10	7.44				
7	Pricing	0.45	44.83	39.37	35.79	42.34	91.61	63.49	70.92	71.74
8	Price volatility	0.20	11.19	9.79	19.58	13.06				
9	Cost of subsidy	0.36	35.58	14.34	15.55	16.34				
10	Land utilization	0.41	27.05	41.26	35.91	29.32	85.79	137.14	121.79	145.06
11	CO_2 emissions reduction	0.26	25.99	85.42	73.01	106.47				
12	Energy intensity	0.33	32.75	10.47	12.87	9.27				

following the Government's biodiesel selling price policy. The efficiency and sustainability index has also fluctuated. It is strongly influenced by the land utilization indicator, which should improve every year, but in reality what has happened is the opposite trend. Figure 3 describe fluctuations in energy security dimensions index during the 2015-2018 period.

The aggregation results show that the level of national energy security in the context of biodiesel agroindustry over the past 4 years has had an increasing trend, with the energy security index values from 2015 to 2018 respectively 123, 168, 178 and 203. This can be interpreted that the development of biodiesel agroindustry in Indonesia is in line with the Indonesian Government's efforts

Figure 3: Energy security dimensions index

Table 6: Dimensions aggregate value and energy security index

Dimensions	Weight	Weighted dimensions index			
		2015	2016	2017	2018
Availability	0.35	67.40	92.94	103.14	122.33
Accessibility	0.33	27.49	44.89	45.49	47.50
Affordability	0.18	16.49	11.43	12.76	12.91
Efficiency and sustainability	0.14	12.01	19.20	17.05	20.31
Energy security index		123	168	178	203

to diversify energy to achieve national energy security. Based on expert judgment, it is known that the availability dimension is more important than other dimensions with the highest weight, followed by accessibility, affordability and finally the dimension of efficiency and sustainability.

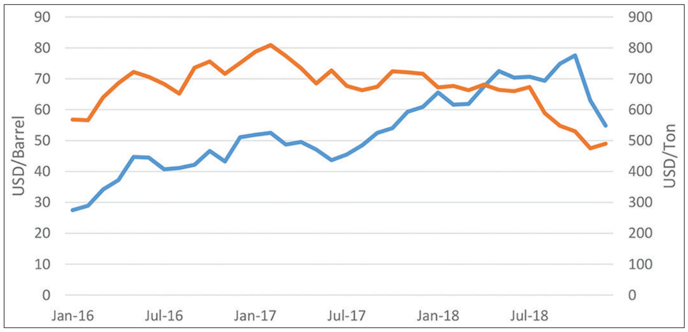
The preference for availability as the biggest weighting dimension is based on the fact that in the last 4 years the portion of biodiesel was only 1% of the national energy mix (Ministry of Energy and Mineral Resources, 2018), with biodiesel supply in 2018 approximately 3.7 million kiloliters. Therefore it is necessary to increase the portion of biodiesel in the national energy mix considering the consumption target of biodiesel set out in the National Energy Plan (President of the Republic of Indonesia, 2017) is 30% of diesel consumption or 11.6 million kiloliters in 2025. There is a gap of 7.9 million kiloliters which must be achieved within 6 years to meet the targets set in the National Energy Plan.

The indicator value for energy supply per capita in 2018 is the highest for the last 4 years with a value of 0.09 BOE per capita. While the lowest occurred in 2015, which is approximately 0.02 BOE per capita. The low energy supply per capita in 2015 occurred because in mid-2015 the source of biodiesel subsidy budget began to switch from the State Budget to BPDPKS, so that biodiesel producers preferred a wait and see attitude. In 2016 the value of the energy supply per capita indicator had surged to 0.08 BOE per capita, but again declined in 2017 to only 0.06 BOE per capita. This phenomenon can be explained if it is linked with pricing indicators, where the price of the market index per liter of biodiesel had increased in 2017 with an average price in that year of IDR 9,002 per liter. The price of biodiesel is the highest in the last 4 years, where the average price of biodiesel in 2015, 2016 and 2018 are in the range of IDR 7,185; IDR 8,183 and IDR 7,607 per liter respectively.

The average surge in the price of the biodiesel market index in 2017 also affects the indicator of reserve to consumption ratio. In 2017, the condition of biodiesel stock had increased by 25% compared to its consumption. That is, approximately 25% of biodiesel production in 2017 that was not absorbed by the domestic and export markets. The increase of biodiesel stock had a positive contribution to the increase of availability dimension index in 2017. This condition was not caused by a decline in national energy consumption, because almost all types of primary energy h increased the consumption in 2017, including petroleum whose consumption had risen to 6%, even though crude oil price h increased from USD 40.16 per barrel in 2016 to USD 51.17 per barrel in the year 2017. Consumption of diesel fuel (ADO - Automotive Diesel Oil) as a biodiesel substitution product also increased by around 13% in 2017 compared to its consumption in 2016.

Another indicator in the availability dimension is energy diversity. Increasing energy supply per capita has also been in-line with the value of energy diversity, where from the results of energy diversity indicator it is known that the best energy diversity condition for the past 4 years was achieved in 2018 with the composition of biodiesel reaching 1.44% from the national energy mix. In the same year, CPO prices decreased from USD 724 per Ton in 2017 to USD 610 in 2018, while oil prices actually increased from USD 51.17 per barrel in 2017 to USD 67.47 per barrel in 2018. It can be said that national biodiesel consumption was influenced by CPO prices and oil prices. If CPO prices and oil prices both rise, then diesel fuel will be chosen to meet national energy needs. Under these conditions, consumption of biodiesel is limited to mandatory fulfilment. But if the CPO price falls while the price of petroleum rises, then biodiesel should be used to meet national energy needs with a threshold of 20% of total diesel consumption (B-20). Based on this premise, the ideal

Figure 4: Fluctuation of crude palm oil and crude oil price



Source: BPDPKS and MEMR 2019

condition to develop biodiesel agroindustry is the time when CPO prices fall and oil prices rise.

As is known, CPO prices are independent factors that cannot be controlled by the Indonesian Government. The measurement results of the price volatility indicator for CPO prices with RVI metrics in the last 4 years are below the value of 20, ranging from 8 to 16 and can be categorized as steady. This can be interpreted that even though CPO prices have fluctuated, but because the conditions are relatively stable, so the amount of subsidies can be planned to obtain an optimal selling price, which in turn will have an impact on the increasing value of affordability. The cost of subsidy during the period of 2015 to 2018 were 4.5, 11.17, 10.30 and 9.8 Trillion Rupiah, respectively. It can be s seen that the trend of subsidy costs follows the trend of energy supply per capita, where the greater the energy supply per capita, the higher the indicator value of cost of subsidy. However, in 2018 when the energy supply per capita peaked, cost of subsidy decreased, compared to 2016 and 2017. This is again related to the decline in CPO prices in 2018. Figure 4 describes fluctuations in CPO and petroleum prices during the 2016-2018 period.

The decline in CPO prices in 2018 also had a positive impact on feedstock absorption indicators, where the ratio between FFB used for biodiesel and the total FFB production reached 61% in this year. However, it should be noted that with the feedstock absorption condition, the biodiesel supply in 2018 was only 3.7 million kiloliters. With a target of 11.6 million kiloliters of biodiesel supply in 2025, of course, a significant reduction in land utilization is needed so that FFB production is available enough for the development of biodiesel agroindustry. However, land utilization over the past 3 years has actually increased with the value of indicators in the period of 2016-2018, respectively, 0.27, 0.31 and 0.38 Ha per BOE. The condition describes how the utilization of oil palm cultivation land for biodiesel agroindustry for the past 3 years has worsened. In 2018, an area of 0.38 ha was needed to produce approximately 1 BOE of biodiesel.

Land utilization indicators are included in the dimension of efficiency and sustainability. According to expert judgment, the dimension of efficiency and sustainability are considered to have no significant impact on energy security in the context of biodiesel agroindustry. Even though there are CO_2 emissions reduction, which measured by the gap between CO_2 emissions generated from the use of diesel fuel and biodiesel, but with the current B-20 portion. The CO_2 emissions reduction indicator has a small impact on environmental sustainability.

Another indicator on the dimensions of efficiency and sustainability is energy intensity. The interpretation for the value of energy intensity must be accompanied by energy elasticity indicator (Sepriana, 2016). During the period of 2015-2018, the trend in the value of biodiesel energy intensity was in line with the trend of energy elasticity, which indicated an expansion of energy access so that the existing energy supply and consumption system was not efficient.

6. CONCLUSION

Based on the measurement results using the index composing method, it is known that the level of national energy security in the biodiesel agroindustry context has experienced an upward trend in the last 4 years, with the energy security index values from 2015 to 2018 ranging respectively from 123, 168, 178 and 203. If we refer to the findings of a study from the National Energy Council, it turns out that the level of energy security at the national level in the period of 2015-2017, also experienced an upward trend, namely 6.16, 6.38 and 6.41. Although the rate of increase at the national level is not as drastic as what happened in the context of biodiesel, the tendency of the sharp slope in 2015-2016 period and a slight increase in 2016-2017 period indicates that the direction of biodiesel agroindustry development in Indonesia has been on-track with efforts to strengthen the level of national energy security.

Future work needs to encompass simulations with models that can accommodate the dimensions and indicators of energy security, so that the formulation of government policies in the development of biodiesel agroindustry can contribute maximally to the achievement of national energy security, which has been identified in this study.

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