Energy Security: A Case Study of Indonesia

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Abstract Indonesia as the largest country and the highest population in the Southeast Asia region results in the greatest value of energy consumption, therefore, being a huge energy-consuming country may represent the situation in that region. Various kinds of energy policies have been carried out by the Government of Indonesia, resulting in a situation, where energy production, energy exports, energy access, are increased, while energy imports, energy reserves, and emission intensities are decreased. However, these situations have never been well concluded. The energy security index provides information that can summarize all of the energy situations. The aim of this paper is to conduct an assessment of Indonesia's energy security index within the period of 2000–2018. The energy security index consists of dimensions, namely availability, affordability, accessibility, and acceptability. Each dimension consists of indicators, in which there are twelve indicators used in the assessment. All indicators and dimensions subject to the same weight, so that the selection of indicators is important to represent the energy situation in accordance with Indonesia's perspective on energy security. The indicator normalization uses the min–max method, in which the maximum indicator obtained based on the highest value owned by countries in the Southeast Asia Region, therefore the indicator value will be relative to it. The results show an increase for almost all dimensions except the affordability dimension. In general, Indonesia's energy security index has increased by 29.9%, which is 0.330 and 0.428 in the year of 2000 and 2018, respectively. The Indonesia's energy security index showing a value below 0.5 indicates that Indonesia is in an unfavorable situation of energy security. Furthermore, the improvement of energy security should be focused on the dimension that has the lowest value.

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Nomenclature

BFP	Biofuel Production
BIOPOP	Traditional biomass users, population
C_{exp}	Coal export
C_{imp}	Coal import
CP	Coal production
CPR	Coal proven reserves
$EMCO_2$	CO2 emissions
EPOP	Electricity users, population
GDPP	GDP per capita
G_{exp}	Gas export
G_{imp}	Gas import
GP	Gas production
GPR	Gas proven reserves
HH	Number of household
HH_g	Number of household using natural gas
OGC_{EXP}	Oil, gas, coal export
O_{imp}	Oil import
O_{imp}	Oil export
OP	Oil production
OPR	Oil proven reserves
POP	Population
PRd	Diesel price
PRe	Electricity price
PRg	Gasoline price
PRl	LPG price
RS	Renewable supply
TPEC	Total primary energy consumption
TPECP	TPEC per capita
TPEP	Total primary energy production
TPEPP	TPEP per capita

1 Introduction

Energy is a strategic commodity that it's availability is important to sustain economic activity. The high use of fossil fuels to meet the energy demands lead to the global decline of fossil energy availability, meanwhile, energy consumption continues to rise following the economic growth. This situation brings up the meaning of energy security.

The definition of energy security first appeared, since the oil crisis occurred in 1970. At that time, the concept of energy security is solely to avoid the occurrence of oil supply disruption. Changes in energy supply and demand led to growing the definition of energy security. The considerations of energy not just limited to the availability of oil, but other types of energy also being considered. Furthermore, other aspects are also being considered to describe the level of energy security [1].

All the situations regard to the high energy price, low accessibility of energy, inefficient energy use can be defined as a lack of energy security. Previous research has reported the measurement of energy security i.e. the measurement of the oil vulnerability index [2], the measurement of the gas supply resistance index [3], the measurement of energy security based on the level of diversity of energy sources [4]. However, these kinds of measurements describe energy security just focuses on the specific aspects, while there are still many other aspects that need to be considered, therefore multidimensional measurements are needed to describe all aspects of energy security. Meanwhile, a number of researchers and international organizations have developed various dimensions to measure energy security [5]. The previous study conducted by Erahman et al. has also reported an assessment of Indonesia's energy security using various dimensions [6], however, the assessment ranges in a narrow period from 2008 to 2013. Therefore, in this article, multidimensional measurements will be conducted to determine Indonesia's energy security with a broader period of assessment.

The definition of energy security itself is relative due to the perspective of each country to determine the level of success on its national energy policy. In Indonesia, the notion of energy security is not only a matter of energy availability but, affordability, accessibility, and acceptability are also being considered as stated in Energy Law 30/2007 [7]. Energy is a primary commodity for modern society to sustain daily activities however, its consumption will impact the environment, particularly the CO_2 emissions. Excessive CO_2 emissions from energy consumption can also be defined as poor energy security. The Indonesian Government has determined the greenhouse gas emissions reductions by 26%, which is based on the Copenhagen agreement, on January 2010 [8], Since then, the Government is committed to taking action to mitigate the CO_2 emissions. Implementation regards this target will certainly affect the level of energy security in the future.

Indonesia as an archipelagic country with the largest area and highest population may portray the energy situation in Southeast Asia. In addition, the best situation of the particular aspect of a country in Southeast Asia will be used as the highest parameter value in the process of measuring Indonesia's energy security.

2 Energy Security

2.1 Definition of Energy Security

Energy plays an important role in any economic activity, such as transportation, communications, security, health, education, services, etc. [9]. Based on Energy law 30/2007 the various definitions of energy are mentioned as follows [7]:

1. Energy is the ability to do work that can be heat, light, mechanical, chemical and electromagnetic;
2. The energy source is something that can generate energy, either directly or through conversion or transformation process;
3. Energy Resources is a natural resource that can be used both as a source of energy and as an energy.

The awareness of energy security began to recognize since the increase of crude oil prices occurred in 1970, in which the oil supply was controlled by oil producer. The impact of this crisis and the emergence of the OPEC cartel is a first milestone, which encouraged several countries to increase their energy security. For instance, Japan almost completely dependent on imported energy supplies, thus Japan continuously applies the principle of energy diversification through the development of natural gas infrastructure [10], nuclear power, renewable energy, and any type of energy. This situation brings the definition of energy security based on energy diversification. Below here are some definitions regards energy security according to several institutions:

1. APERC	the ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy [11];
2. European Commission	uninterrupted physical availability on the market of energy products at a price which is affordable for all consumers [12],
3. The International Energy Agency	the uninterrupted availability of energy sources at an affordable price [13];
4. World Bank	ensuring countries can sustainably produce and use energy at a reasonable cost in order to facilitate economic growth and, through this, poverty reduction, Directly improve the quality of peoples' lives by broadening access to modern energy services [14].

2.2 Energy Security Indicators

Indicator is a quantitative or a qualitative measure derived from a series of observed facts that can reveal relative positions [15]. The indicators are used to identify trends, predict problems, find out the various options, set targets and evaluate the decisions. The indicator determination should be selected in terms of highly useful information. In many cases a single indicator is not enough, therefore a set of several indicators that summarize a variety of information ought to be used. The indicator selection should meet the following criteria [15]:

1. Comprehensiveness	indicators must reflect on the targets measured
2. Quality	the data should be accurate and consistent
3. Comparable	the data should have clear definitions and comparable
4. Understandable	could be understood by decision-maker
5. Accessible and transparent	indicators and detailed explanation should be available to all stakeholders
6. Cost-effective	the data for Indicator should consider cost-effective
7. Net effects	indicator should indicate a change
8. Functional	the selected indicators are appropriate to explain the measurement.

Various indicators that will be used to measure energy security can be based on previous research. Specific indicators will be selected based on the definition of energy security. The various definition of energy security will result in different compositions of indicators, whereas each country has own definition of energy security. In general, energy security used to measure the level of success on the energy policy of a country. Since the definitions are country-based, therefore no exact definition of energy security.

Based on a review of previous studies concluded that energy security has at least four basic dimensions, namely availability, affordability, accessibility, and acceptability, or better known as 4A's, subsequently these four dimensions will be used in this paper. The four dimensions are in line with the provision of Energy Law 30/2007, where the objective of energy security by the Government are as follows [7]:

1. Achievement of energy independence (self-sufficiency);
2. Energy availability, both from domestic and foreign sources;
3. The management of energy resources in an optimal and sustainable manner;
4. The efficient use of energy;
5. Achieving energy access for society;
6. Affordable energy prices for the society;
7. The use of energy should environmental-friendly.

Furthermore, determining the definition of each dimension is translated based on the explanation above. Table 1 explains the definition of the energy security dimension.

Dimension consists of indicators, therefore the composition of indicators should be able to represent the closest meaning with its dimension. In this case, we only

Table 1 The definition of the energy security dimension

No.	Dimension	Definition
1	Availability	The availability of energy production, energy independence, and energy reserves for the future
2	Affordability	The affordable energy price which considers people's income
3	Accessibility	Commercial energy access for society
4	Acceptability	The energy consumption should environmental-friendly

need to use 3 indicators from each dimension that can represent the equal meaning of each dimension, therefore the total number of indicators is 12. Previous research has reported, that the effective use of energy security indicators is not more than 20 indicators [5]. Below are the explanation of indicators for each dimension.

1. Availability

The availability indicators consist of energy production, self-sufficiency, and available energy reserves. Energy production denotes domestic ability to produce energy. Self-sufficiency relates to the capabilities of domestic to supply energy, while the available energy reserves indicate the number of days of available energy reserves owned by a country.

2. Affordability

The final energy commodities that often be the main issue of energy prices in Indonesia are diesel, gasoline, and electricity. As a matter of fact, these final energies have always been subject to political discussion in Indonesia. Moreover, to bring a closer meaning to the definition of affordability dimension, the energy price should be divided by GDP per capita, since GDP per capita reflects the people's income. Therefore, the higher GDP per capita will have an impact on higher energy security.

3. Accessibility

The indicators for accessibility dimension consist of electrification ratio, percentage of households relying on traditional use of biomass, and the percentage of households using pipeline natural gas. The indicators are chosen based on the Government program implementation. The Government is working on to increase the electrification ratio throughout the region, that the most difficult task is to provide electricity to remote areas. Besides, a program of natural gas pipeline for households is being aggressively implemented by the Government. These two indicators are good enough to describe the energy access situation, however, the addition of the percentage of households relying on traditional use of biomass will provide a complete picture of the accessibility dimension.

4. Acceptability

The energy consumption should environmentally friendly means that the use of energy should efficient, less emission, and sustain. Therefore, indicators that can be chosen are energy intensity, emission intensity, and renewable energy utilization. The energy intensity describes how efficiently the use of energy in its contribution to the economy, while emission intensity shows how much emissions from the use of energy to boost the economy. These two indicators are complementary, therefore the renewable energy utilization in total energy consumption will describe the remaining definitions.

Based on the above explanation, it can be summarized, that the energy security indicators are as explained in Table 2.

Table 2 The energy security indicators

No.	Dimension	Code	Indicator	Equation	Increasing impact
1	Availability	Avail 1	Per capita energy production	$\frac{TPEP}{POP}$	+
2		Avail 2	Self-sufficiency	$\frac{(TPEP-OGC_{EXP})}{TPEC}$	+
3		Avail 3	Reserves (oil, gas, coal) to production ratio (RPR)	$\frac{OPR}{OP}+\frac{GPR}{GP}+\frac{CPR}{CP}$	+
4	Affordability	Afford 1	Diesel oil price to GDP per capita ratio	$\frac{(PR_d)}{GDPP}$	–
5		Afford 1	Gasoline price to GDP per capita ratio	$\frac{(PR_g)}{GDPP}$	–
6		Afford 2	Electricity price to GDP per capita ratio	$\frac{PR_e}{GDPP}$	–
7	Accessibility	Access 1	Electrification ratio	$\frac{EPOP}{POP}$	+
8		Access 2	% Household relying on traditional use of biomass	$\frac{BIOPOP}{POP}$	–
9		Access 3	% Household using pipeline natural gas	$\frac{HHg}{HH}$	+
10	Acceptability	Accept 1	Energy intensity	$\frac{TPEC}{GDP}$	–
11		Accept 2	Emissions intensity	$\frac{EMCO_2}{GDP}$	–
12		Accept 3	Renewable energy utilization to energy consumption	$\frac{RS}{TPEC}$	+

2.3 Methodology

Several steps to assess energy security are describes in Fig. 2, that the details explanation are as follows:

1. Data preparation according to the range of 2000–2018, followed by input data to the indicator equations as described in Table 2;
2. Indicators and dimensions calculation

   a. Indicator normalization into values in the range of 0 to 1, using the min-max method, below are the normalization equations.

$$I'_{it} = \frac{I_{it}}{\mathrm{Max}(I_i)} \quad (1)$$

$$\mathrm{Max}(I_i) = \mathrm{Max}\{I_1, I_2 \ldots I_i\}$$

   For indicators that have a negative impact should applied inverse indicator, as explained in the following equation.

$$I'_i = \frac{I_{INV,i}}{\mathrm{Max}_{INV}(I_i)} \quad (2)$$

$$I_{INV,i=\frac{1}{I_i}} \quad (3)$$

$$\mathrm{Max}_{INV}(I_i) = \mathrm{Max}\left\{\frac{1}{I_1}, \frac{1}{I_2} \cdots \frac{1}{I_i}\right\} \quad (4)$$

   The maximum value is based on the highest value achieved by countries in Southeast Asia, except for indicators that have been determined on other considerations and had a maximum value of 1 due to equations.

   b. The dimension value obtained by averaging all the indicators;

3. Averaging all dimensions will result in the energy security value (Fig. 1).

3 Indonesia's Energy Situation

3.1 Primary Energy Reserves

Fossil energy reserves in Indonesia, especially oil and gas tend to decrease until 2018. Indonesia and Malaysia have proven oil reserves that are nearly identical to around 4 billion barrels. Meanwhile, Indonesia's natural gas reserve is the largest reserves in Southeast Asia Region, which is reached 43% of the total gas reserves in Southeast Asia.

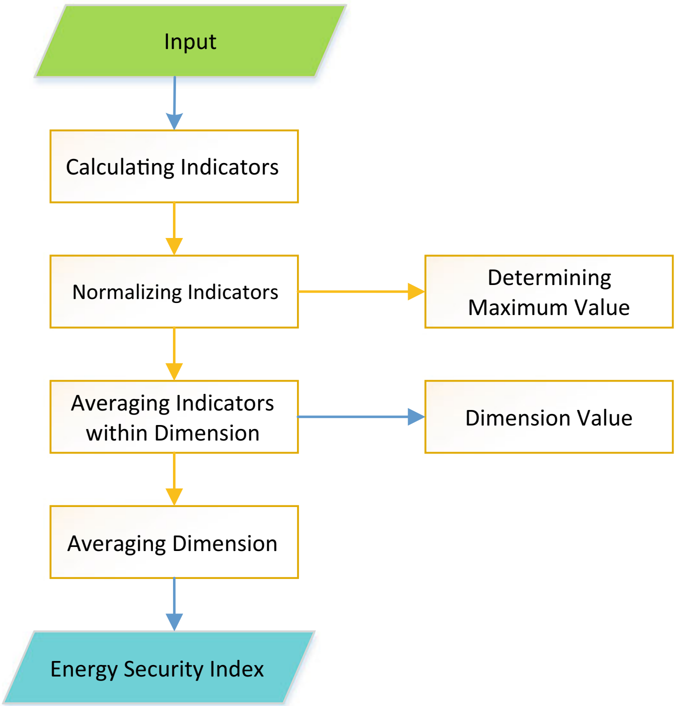

Fig. 1 Flowchart of energy security assessment

Figure 2 shows Indonesia's proven oil and gas reserves in 2000–2018.

Proven coal reserves have increased significantly started in 2006. This increase is the result of significant exploration and exploitation due to export demand. Indonesia's coal reserves reach 93% of all reserves in Southeast Asia. The rest are spread in Thailand, Laos, and Philippines. Figure 3 shows proven coal reserves in 2000–2018.

3.2 Primary Energy Production and Consumption

Primary energy production consists of production comes from fossil and renewable energy. Fossil energy production is the summation of petroleum, natural gas, and coal production. Indonesia's energy production is increasing with an increase of 3.84% per year. In 2018, the primary energy production was significantly increased that contributed by coal production. Primary energy production is larger than its consumption. Excess energy production was contributed largely by coal. Figure 4 shows the comparison of energy production and consumption in 2000–2018.

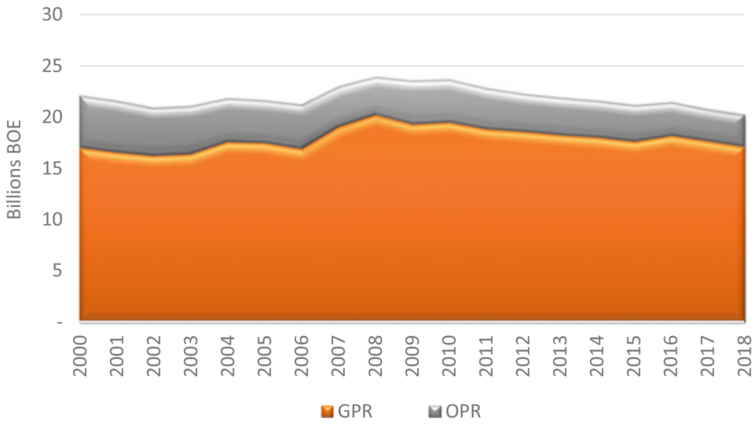

Fig. 2 Proven oil and gas reserves in 2000–2018

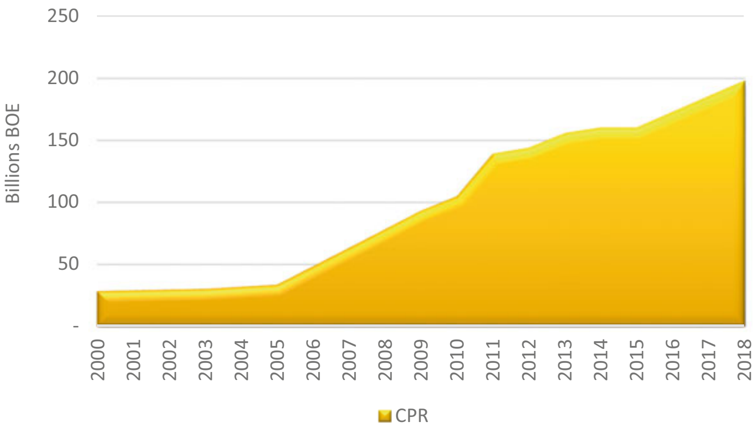

Fig. 3 Proven coal reserves in 2000–2013

Indonesia is the largest energy producer in Southeast Asia, with a share of 53% by total energy production in this region, followed by Malaysia with a share of 18% [16]. Indonesia's primary energy production was contributed largely by coal production. Figure 5 shows the production of primary energy by type of energy, namely oil production (OP), gas production (GP), coal production (CP) and renewable energy production (RP).

Coal production has increased significantly throughout the year. The high coal production caused Indonesia becomes the second-largest coal exporter globally and a significant supplier of coal to Asian countries. Meanwhile, crude oil production tends to decline from year to year, due to the numerous oil fields that experiencing a decline, while natural gas production was relatively stable throughout the year, especially in

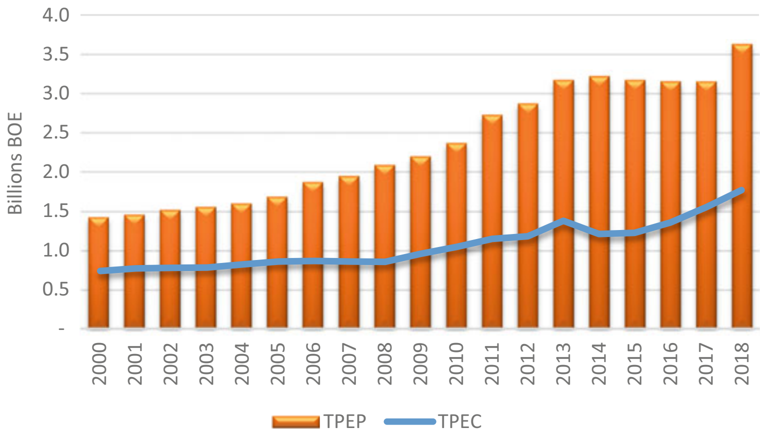

Fig. 4 Primary energy production and consumption in 2000–2018

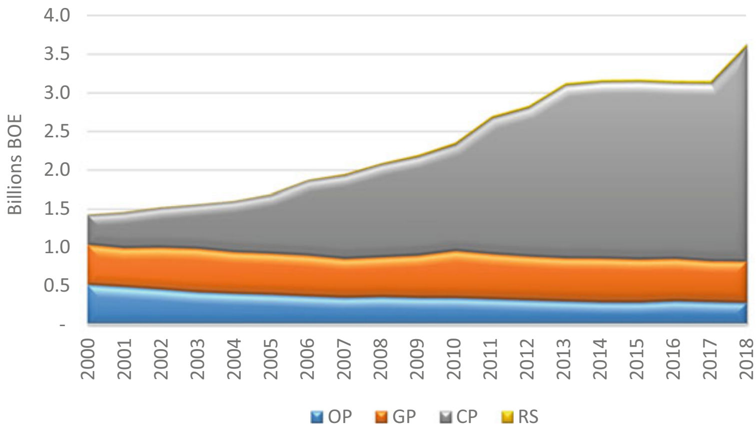

Fig. 5 Primary energy production by type in 2000–2018

the last few years. Production of renewable energy has increased throughout the years due to the increase of biofuels and geothermal energy. However, the renewable production share is still very small compared to the fossil.

3.3 Export—Import of Primary Energy

The exports of crude oil and natural gas simultaneously decreased, due to Government policies that increase the utilization of domestic energy to meet national needs. Figure 6 shows the export of oil and gas in 2000–2018.

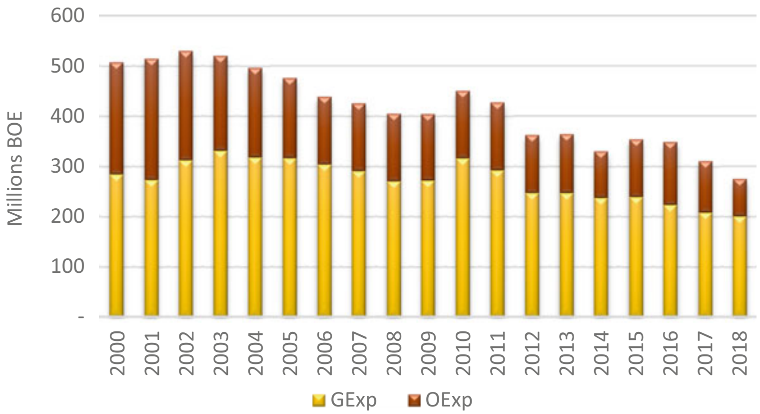

Fig. 6 Export of oil and gas in 2000–2018

On the contrary, coal export has increased significantly in 2010 with an average of increase by 26% per year. Figure 7 shows the export of coal in 2000–2018.

The energy imports contributed by crude oil and a small amount of coal. In recent years, crude oil and coal imports reached 150–175 million and 3–27 million BOE per year, respectively. Meanwhile, there is no import in natural gas. Figure 8 shows the import of fossil energy in 2000–2018.

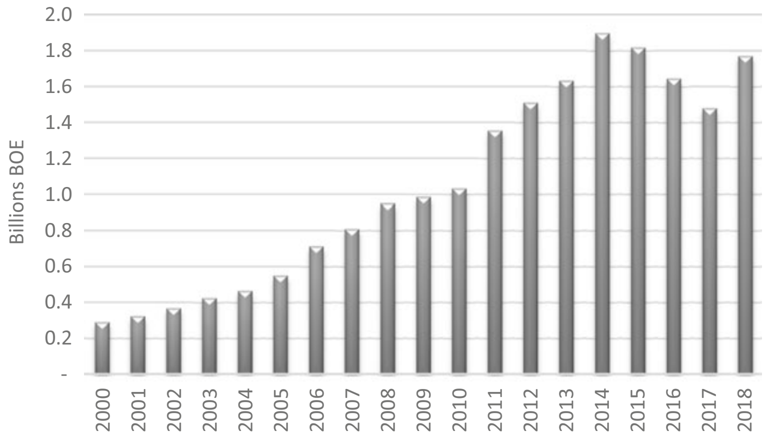

Fig. 7 Export of coal in 2000–2013

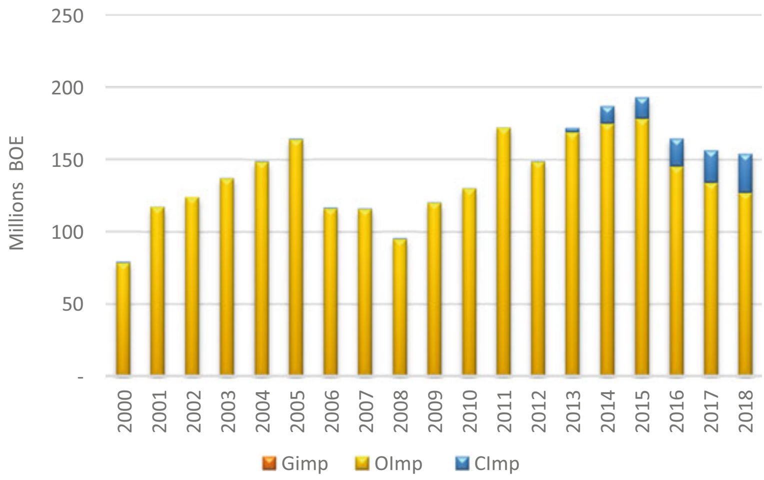

Fig. 8 Imports of fossil energy in 2000–2013

3.4 *Primary Energy Supply*

The energy supply is known through calculation, which can be obtained from total energy production minus total energy exports plus total energy imports. The primary energy supply continues to increase throughout the year. Figure 9 shows the primary energy supply by type in 2000–2018.

The primary energy supply for crude oil fell slightly throughout the year, from 350 thousand BOE in 2000 to 334 thousand BOE in 2018, due to the decline of crude oil supply to domestic refineries. Oil refineries are not having significant additional

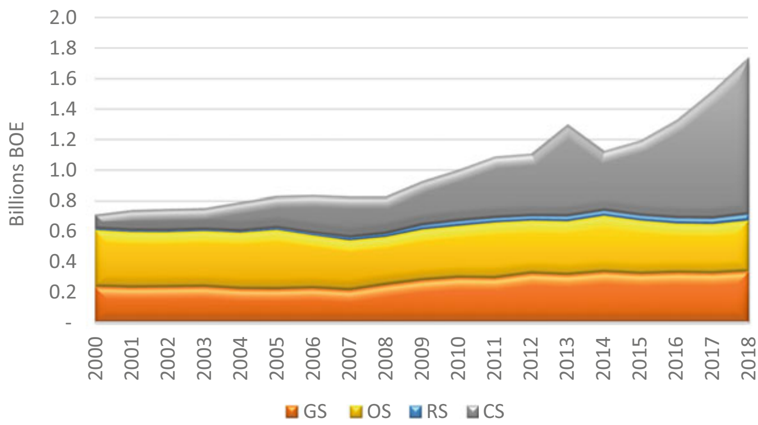

Fig. 9 Primary energy supply by type in 2000–2018

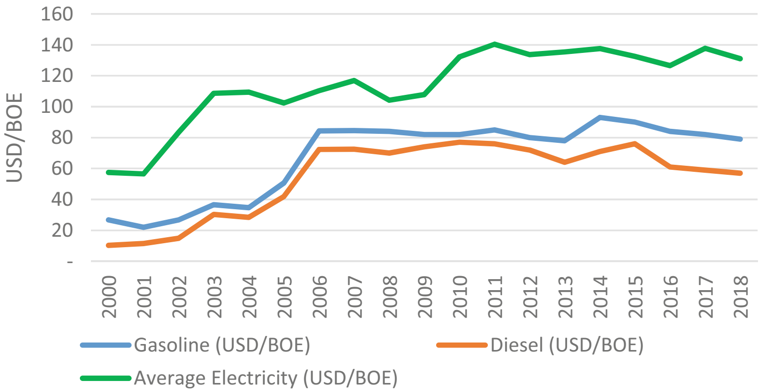

Fig. 10 Price of gasoline and diesel fuel in 2000–2018

production capacity throughout the year, instead of having a slight decrease in oil refining activity. In contrast, natural gas supply continues to increase throughout the year with the percentage of increase is equal to 2.24% per year. The increase of natural gas supply is as a result of Government domestic market obligation of natural gas. Meanwhile, the supply energy derived from coal shows a significant increase which is occurred after 2010 due to the supply of coal for domestic power generation.

3.5 Energy Price

Energy price plays an important role in stimulating the national economy. The lower the energy price, the better the energy security. Indonesia still applies subsidized prices, especially diesel fuel for certain users. The diesel fuel price refers to diesel fuel with cetane number 48, while gasoline refers to gasoline with octane number 88 [17]. The following Fig. 10 shows the fuel prices of diesel fuel and gasoline in 2000–2018. Furthermore, electricity prices determined by Government pricing regulations, which is differ for each electricity consumer, therefore the presented price in the Fig. 10 is the average price of electricity to all types of consumers.

3.6 Energy Access

The electrification ratio continues to increase throughout the year, due to the implementation of the rural electrification development program by the Government. This program has instructed the local Government to implement the accelerated development of rural electricity in each province.

Indonesia's population which has not been connected to electricity remained 6.6 million inhabitants in 2018. Besides, some households still depend on the use of traditional biomass, mostly it occurs in remote areas or away from commercial energy infrastructure.

Figure 11 shows the electrification ratio in 2000–2018 and Fig. 12 shows the percentage of households relying on traditional use of biomass in 2008–2013.

The Indonesian Government nowadays is implementing the natural gas distribution networks for domestic customers. The availability of natural gas resources, provide benefits in the development of distribution networks. The program is implemented gradually each year and giving more access to commercial energy. Figure 13 shows the number of households that connected to natural gas pipeline in 2000–2018 (Fig. 13).

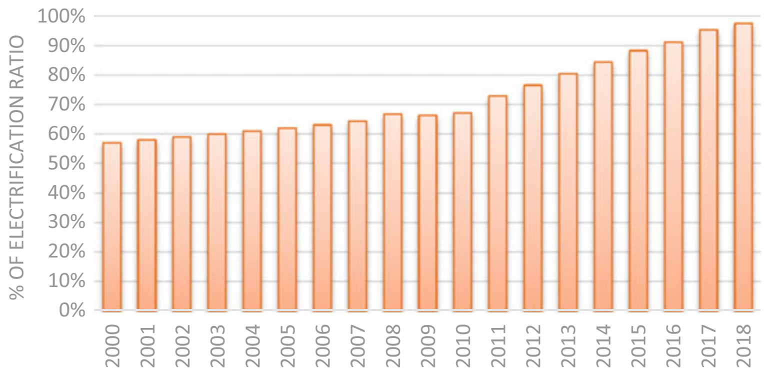

Fig. 11 Electrification ratio in 2000–2018

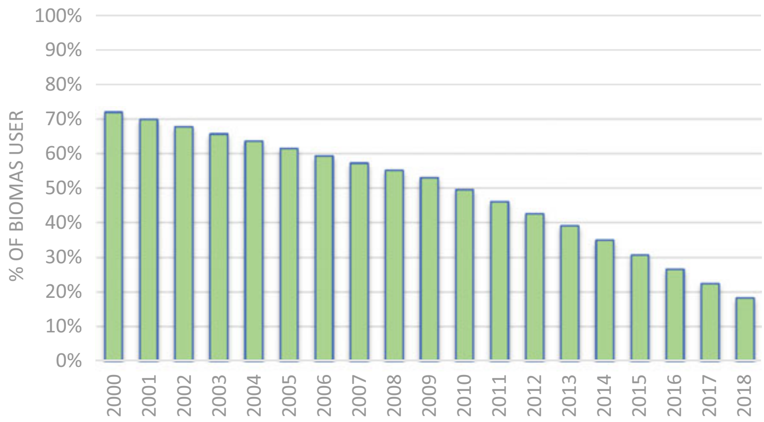

Fig. 12 Percentage of households relying on traditional use of biomass in 2000–2018

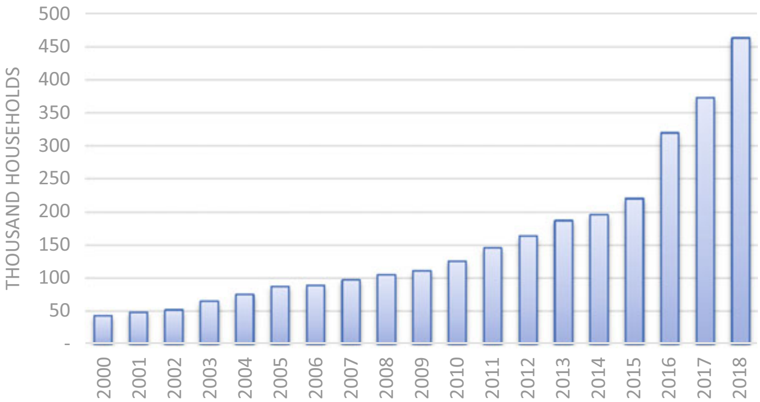

Fig. 13 Number of household connected to natural gas pipeline in 2000–2018

4 Energy Security Assesment

4.1 Data and Indicators

The data should be collected, before performing the calculations. Table 3 shows the data for indicator calculation.

All data is inputted into the energy security indicator equation as described in Table 2. Furthermore, the normalization process is conducted by specifying the maximum value of each indicator. The maximum value of each indicator is described in Table 4. Most of the data are sourced from U.S energy information administration [18].

The normalization results of the indicators will provide a value between 0–1. Furthermore, this value is used until the energy security index is obtained.

4.2 Dimension Results

4.2.1 Availability

The availability dimension consists of the national per capita energy production, self-sufficiency, reserves to production ratio. Based on the Fig. 14, the availability dimension has increased by 3.24% between years 2000–2018. The increase in availability dimension is largely due to the contribution of self-sufficiency indicators. The self-sufficiency was quite good, although crude oil production continues to decline.

The second contribution comes from energy production per capita indicator. The per capita energy production is largely due to an increase in coal production. Finally, the smallest contribution comes from reserves to production ratio indicator due to

Table 3 The data input for indicator calculation [17]

NO	DATA	UNITS	2000	2005	2010	2015	2018
1	TPEC	BOE	736,999,657	857,360,844	1,054,376,994	1,238,180,042	1,787,659,021
2	TPEP	BOE	1,456,364,696	1,719,907,387	2,408,984,865	3,217,990,119	3,680,592,533
3	OPR	BOE	5,120,000,000	4,190,000,000	4,230,000,000	3,600,000,000	3,150,000,000
4	OP	BOE	517,489,000	386,483,000	344,888,000	286,814,000	281,826,000
5	OExp	BOE	223,500,000	159,703,000	134,473,000	115,017,000	74,449,000
6	OImp	BOE	78,615,000	164,007,000	130,060,000	178,313,000	126,904,000
7	GPR	BOE	17,017,100,000	17,467,896,000	19,468,640,000	17,599,004,000	17,095,509,229
8	GP	BOE	521,073,839	536,167,244	612,003,523	559,659,103	538,225,639
9	GExp	BOE	284,551,954	316,569,785	316,439,036	239,311,253	200,830,183
10	Gimp	BOE	0	0	0	0	0
11	CPR	BOE	28,462,086,194	33,600,519,570	105,052,716,192	160,392,432,384	198,309,879,735
12	CP	BOE	382,989,872	759,229,056	1,367,923,768	2,294,583,454	2,772,856,617
13	CExp	BOE	290,624,644	550,768,836	1,034,030,400	1,818,748,166	1,771,744,907
14	CImp	BOE	696,559	488,077	274,565	14,953,342	27,186,578
15	BFP	BOE	0	0	28,503,000	19,075,000	18,991,683
16	RS	BOE	34,811,985	38,028,087	56,956,785	59,946,858	97,134,099
17	DPR	USD/BOE	10	42	77	76	57
18	GPR	USD/BOE	17,017,100,000	17,467,896,000	19,468,640,000	17,599,004,000	17,095,509,229
19	EPR	USD/BOE	57	102	132	133	131
20	LPGPR	USD/BOE	246,300	498,600	833,533	966,533	1,006,867
21	EPOP	%	57%	62%	67%	88%	98%

(continued)

Table 3 (continued)

NO	DATA	UNITS	2000	2005	2010	2015	2018
22	EMCO2	Million ton	257	295	386	392	486
23	BIOPOP	%	72%	61%	50%	31%	18%
24	Population	Jiwa	208,726,109	223,183,718	238,518,800	255,461,700	264,824,520
25	GDPPPP	USD	347,930,725,256	434,129,181,596	709,190,823,320	971,494,144,095	1,151,397,753,124
26	GDP Perkapita USD	USD/Person	1,667	1,945	2,973	3,803	4,348
28	GHH	%	0.08%	0.16%	0.20%	0.33%	0.66%

Table 4 The maximum data for indicator calculation

Indicator	Parameter	Maximum value	Units	Annotation
AVAIL 1	Per capita energy production	364.65	BOE/person	Refers to Brunei Darussalam energy production per capita in 2013
AVAIL 2	Self-sufficiency	1.00	Unitless	No import at all (highest value)
AVAIL 3	Reserves (oil, gas, coal) to Production ratio (RPR)	573	Year	Refers to Laos reserves to production ratio in 2013
AFFORD 1	Diesel Oil Price to GDP per capita ratio	0.0019	Person/BOE	Refers to Brunei Darussalam affordability diesel oil price in 2013
AFFORD 2	Gasoline Oil Price to GDP per capita Ratio	0.0019	Person/boe	Refers to Brunei Darussalam affordability of gasoline price in 2013
AFFORD 3	Electricity Price to GDP per capita ratio	0.0280	Person/boe	Refers to Brunei Darussalam affordability of electricity price in 2013
ACCESS 1	Electrification ratio	1.00	%	Maximum achievable electrification ratio
ACCESS 2	% Population relying on traditional use of biomass	1.00	%	Maximum possibilities of % population relying on traditional use of biomass
ACCESS 3	Number of household gas pipeline connections	0.50	%	Maximum achievable pipeline household gas connections
ACCEPT 1	Energy intensity	0.46	BOE/thousand USD	Refers to Burma energy intensity in 2013
ACCEPT 2	Emissions intensity	0.1092	Tonnes CO_2/USD	Refers to Burma energy intensity in 2013
ACCEPT 3	Renewable energy share	12	%	Refers to Laos renewable energy share in 2013

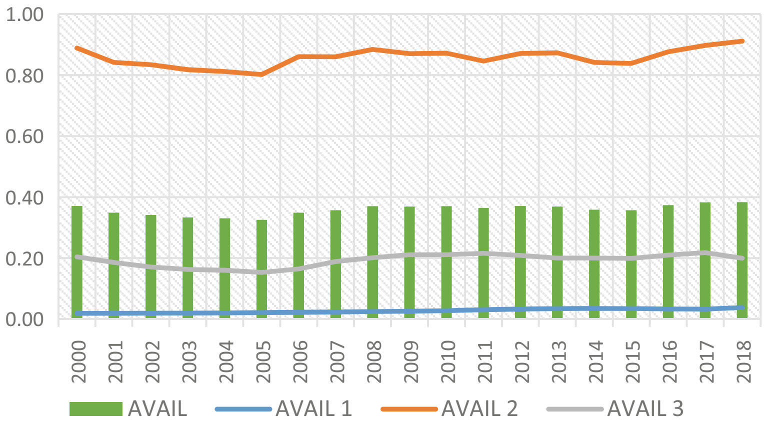

Fig. 14 The results of availability dimension in 2000–2018

a very high maximum reference in the Southeast Asia Region. Laos has 573 days of reserves to production ratio compared to Indonesia which is only one-fifth from Laos.

4.2.2 Affordability

Based on the Fig. 15, the affordability dimension resulting in fluctuates value. The affordability of the electricity contributed largely to the dimension. Whereas,

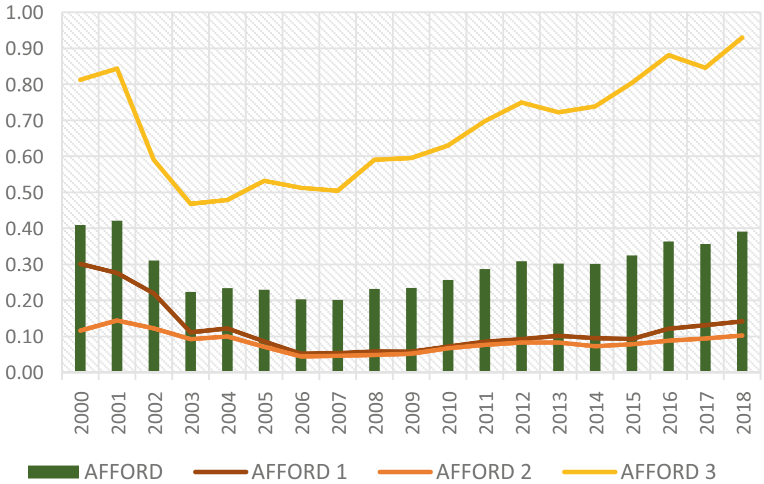

Fig. 15 The results of affordability dimension in 2000–2018

since 2015 the electricity subsidy policy as regulated in Ministry Energy Regulation 31/2014 [19] has been changed to no more electricity subsidies given to all types of users such as household, business, industrial, office government, public street lighting, and specialized services. The electricity subsidy removal increased the prices of electricity, however, the situation is still showing good to the affordability due to the increase of GDP per capita.

Moreover, gasoline subsidy was also removed, due to the decline of the oil price since 2015. However, subsidies for diesel fuel still exist and reduced to only Rp. 2000 per liter. Subsidy reductions have an impact on the price hike of diesel fuel and gasoline, however, it can be offset by the GDP per capita, so the value of affordability unchanged. The small affordability value of diesel fuel and gasoline caused by the high disparity from the maximum reference in Southeast Asia. Brunei Darussalam has the highest affordability energy in Southeast Asia. Figure 15 shows the results of the affordability dimension in 2000–2018.

4.2.3 Accessibility

The accessibility dimension consists of electrification ratio, percentage of households relying on traditional use of biomass, and the percentage of households using pipeline natural gas. The accessibility dimensions increased by 111.98% between 2000 and 2018. Contributions largely contributed by the electrification ratio. The increase of accessibility dimension occurs gradually and consistently, which describes better energy commercial access for society. Indonesia continues to improve the electrification ratio that the highest challenge is to build electricity connections in remote areas. This challenge has to deal with a difficult location, a small number of customers, but the investment required is huge. The percentage of households relying on traditional use of biomass throughout the years continued to decrease. This occurred due to household commercial energy access developed by the Government, particularly the household LPG conversion program. The maximum target is no longer households still relying on the use of traditional biomass.

The last indicator is the percentage of households using pipeline natural gas, which describes the development of natural gas users, particularly household. The achievement of the indicator is supported by the acceleration of natural gas distribution network development program. The development priorities are carried out in areas that already have natural gas transmission pipelines or natural gas sources. The development program serves to replace LPG for households, which is mostly domestic LPG consumption derived from imports. The amount of natural gas pipeline connections for households is still very low compared to the total number of households. For instance, in 2018, the number of household connections just reached only 460 thousand connections, while total Indonesia's registered household reaches 70 million households. The program currently relies on the Government budget, while high capital is required, therefore the role of the private sector is needed to succeed in this program. Figure 16 shows the results of the accessibility dimension in 2000–2018.

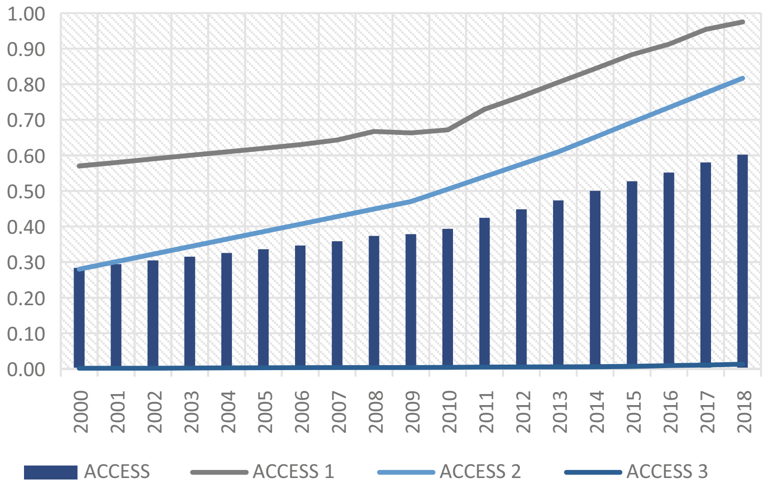

Fig. 16 The results of accessibility dimension in 2000–2018

4.2.4 Acceptability

The acceptability dimension is related to the environment, especially CO_2 emissions as a result of energy consumption. As stated in Law 30/2007, energy management in the context of promoting national energy security should pay attention to the environment. Indonesia, in the UNFCCC declaration and Pittsburg's agreement, stated its commitment to reduce GHG emissions by 26% with own effort and 41% with international assistance from Business as usual (BAU) conditions. Following up on the commitment, the Government of Indonesia issued the Presidential Regulation 61/2011 [20] on national plan to reduce greenhouse gas emissions. Moreover, The Presidential Regulation 22/2017 [21] was issued to support previous regulation, particularly the implementation of emission reductions in the energy sector. These regulations are the legal basis for regional Governments, which is mandated to reduce greenhouse gas emissions on activities that occurs in their respective regions. The activities are divided into agriculture, forestry and peatland, energy and transportation, industry, waste management, and other supporting activities. In terms of energy security, emission reduction is related to energy and transportation activity. Based on the Presidential Regulation 22/17, the target of 26% greenhouse gas emission reductions from Business As Usual (BAU) should contribute to a reduction of 356 million tons, while 41% should contribute to a reduction of 562 million tons in 2025, with a BAU situation estimated to 1,370 million tons of CO_2 emissions.

Based on this situation, the emissions from the energy sector in 2000, 2005, 2010, 2015, and 2018 are 257, 295, 386, 392, and 486 million tons of emissions, respectively. The results show that Indonesia's emission intensity is slightly decreased throughout the year, from 0.739 ton/thousand USD in 2000 to become 0.422 ton/thousand USD in 2018. The reduction in emission intensity is caused by the GDP growth which higher than the emission rate. The lowest emission intensity achieved by Burma, that in 2013 the emission intensity reaches 0.109 ton/thousand USD.

Meanwhile, Indonesia's energy intensity reaches 1.5 BOE/thousand USD. For this situation, Indonesia still uses energy quite efficiently compared to countries in the Southeast Asia region, such as Brunei Darussalam which the energy intensity reaches 4.54 BOE/thousand USD. The lowest energy intensity achieved by Burma reaches 0.46 BOE/thousand.

The renewable energy utilization indicator shows an increase throughout the years. The value of renewable energy utilization is still relatively small with a percentage of 4–6% by total energy consumption. These contributions were obtained from the utilization of biofuel, hydro and geothermal. Laos has the highest value for the percentage of renewable energy utilization to total energy consumption, which amounted to 10%, therefore it is used as a maximum reference. The increases in renewable energy utilization due to the higher renewable utilization growth than total energy consumption.

The acceptability dimensions increased by 32.86% between 2000 and 2018. The dimension largely contributed by the renewable energy share indicator. The increase in acceptability dimension occurred gradually and consistently. Figure 17 the results of the acceptability dimension in 2000–2018.

All dimension values result in the energy security index, where the index values are in the range of 0–1. The results of the energy security index are shown in Fig. 18. Based on the figure, Indonesia's energy security index has increased from 0.330 becomes 0.428 in 2000 and 2018, respectively, which shows a 29.9% increase. Despite the increase, Indonesia's energy security index still relatively low due to

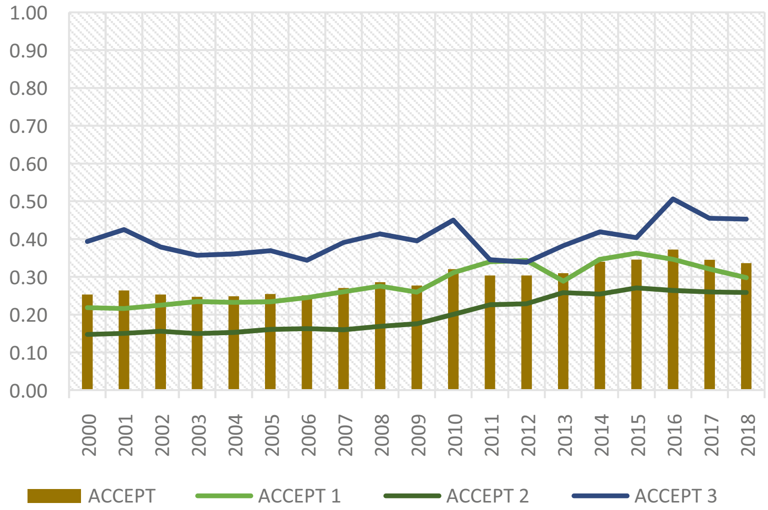

Fig. 17 The results of acceptability dimension in 2000–2018

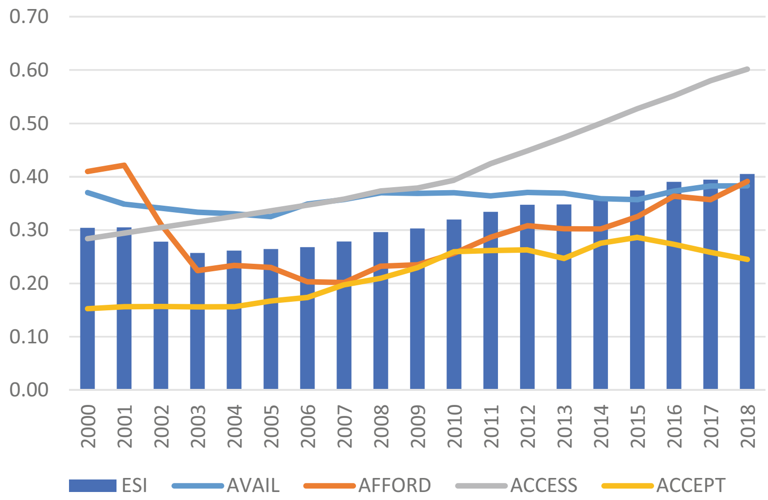

Fig. 18 the results of energy security assessment in 2000–2018

the lower value than 0.5. Therefore, improvement of all aspects needs to be done immediately by evaluating policies that are not supportive to increase the energy security index. Priority improvements can be made on the dimension that has the lowest value.

5 Conclusion

The assessment summarizes that Indonesia's energy security index is still relatively low due to the lower index value than 0.5. The energy security index has increased from 0.330 becomes 0.428 in 2000 and 2018, respectively, which shows a 29.9% increase. Several improvements need to be done to improve energy security, especially acceptability dimension which has the lowest value. Increasing the acceptability can be conducted through policies which stimulating the higher economic activity, but consume less energy. Moreover, it is necessary to transform the use of fossil energy towards renewable energy for all sectors, especially for industrial and transport sectors.

The availability dimension is necessary to focus on self-sufficiency. Indonesia needs to set a strategy that the exploitation is conducted at an optimum amount, especially coal. High coal production should be directed to higher domestic purposes than export. Energy exploration should continuously be improved in order to increase the number of primary energy reserves.

Regarding the affordability dimension, the Government should begin to involve more private sector's role in the final energy business, thus providing competitive energy prices. Furthermore, the Government should create regulations to business entities that energy providers which in a good market, have an obligation to serve areas with a less attractive market, therefore the affordable prices apply throughout the region.

Finally, for the accessibility dimension, the Government needs to focus on providing access to commercial energy in all regions of Indonesia, particularly in the remote areas. Providing access to natural gas across the region for domestic use, as well as to take the advantage of large Indonesia's natural gas reserves. For regions that are still using biomass, at the early stage can be supplied through the use of LPG, therefore the access to commercial energy occurs in all regions.

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