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Analysis of Indonesia's Electrical Energy Security Based on Aspects of Availability, Accessibility, Acceptability, and Affordability

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KEYWORDS
Coal Based Power Plants (PP); Availability; Accessibility; Acceptability; Affordability; Renewable Energy.

ABSTRACT
The increasing demand for electrical energy in Indonesia, driven by rapid economic growth, necessitates a comprehensive evaluation of the country's electrical energy security across four critical aspects: availability, accessibility, acceptability, and affordability. Despite significant expansion in power generation capacity, with coal-fired plants still dominating the energy mix, environmental concerns regarding emissions pose major challenges to sustainability. This study aims to analyze Indonesia's electrical energy security by quantitatively assessing 20 key indicators from 2008 to 2023 and projecting trends to 2030 and 2045. Employing data normalization and a rhombus area graphical model, the research integrates multi-dimensional data to provide a holistic security index. Results reveal improvements in availability, accessibility, and affordability over time, but acceptability declines due to rising greenhouse gas emissions, underscoring the environmental trade-offs of fossil fuel reliance. The findings highlight the urgent need for policy and technological interventions such as expanding renewable energy, implementing Carbon Capture and Storage (CCS) technologies, and promoting electrification of industrial and transport sectors. This study offers crucial insights for policymakers and stakeholders to balance energy growth with environmental sustainability, guiding Indonesia towards a secure and cleaner energy future.

INTRODUCTION

The availability of electrical energy is a very important aspect and even a parameter to support the success of the development of a region. The availability of adequate and targeted electrical energy will spur the development of regional development such as the industrial, commercial, public service sectors and even the quality of life of the community with an increasing number of residents enjoying electrical energy. Directly or indirectly, it will affect economic growth and the level of community welfare (PLN, 2021).

The electrical energy system in Indonesia continues to grow from year to year. Based on electrical energy data generated in 2023, coal-based power plants still supply more than 60% of the total electrical energy needs in Indonesia (Handbook of Energy and Economic Statistics of Indonesia, 2023). Oil and gas generation tends to decline, as total reserves are decreasing (Handbook of Energy and Economic Statistics of Indonesia, 2018, 2023). These fossil-based power plants continue to experience shocks, related to environmental issues and global warming, where the international community has highlighted this fossil-based energy to be immediately reduced and replaced with sustainable energy (Harjanto, 2008).

New and renewable power plants, although their share is still below 20% in 2023, continue to grow from year to year (Handbook of Energy and Economic Statistics of Indonesia, 2018, 2023).

According to the 2021 – 2030 Electricity Supply Business Plan (RUPTL), issued by the Directorate of Corporate Planning of PT PLN, there will be 63.3 GW of installed power generation capacity in 2020, with a composition of 50% coal-based coal-fired power plants (Steam Power Plants), 23.4% oil and gas power plants, the remaining 8% hydropower plants, 4% PLTPs and other NRE only 1%. The plan to add new power plants in the period 2020-2030 is 40.6 GW with a portion of NRE of 51.6%, so that the generation plan installed in 2030 will be 99.2 GW with a 45% coal-fired power plant mix (PLN, 2021, 2021). Figure 1 shows the details of the generation mix according to the 2021-2030 RUPTL (PLN, 2021).

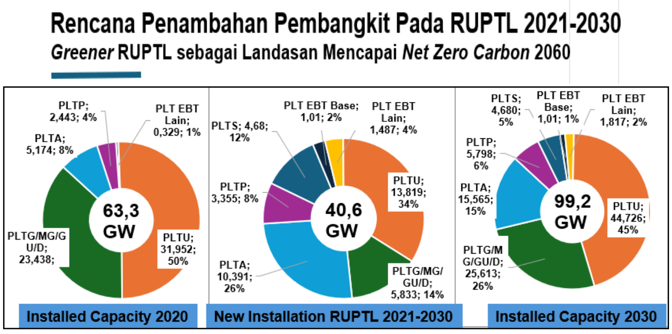

Figure 1. Mix and generation plan 2020-2030

The purpose of this discussion is to analyze the Electrical Energy Resilience Index in Indonesia in the future based on several indicators in four aspects, namely Availability, Accessibility, Acceptability, and Affordability.

The Indonesian electrical energy system faces significant challenges in ensuring a sustainable and secure electricity supply that balances availability, accessibility, acceptability, and affordability. Despite increases in installed capacity and energy production, reliance on fossil fuels—especially coal—raises serious environmental concerns due to emissions, threatening long-term sustainability. Additionally, disparities in access and economic conditions affect equitable electricity distribution and affordability for the population, complicating national energy security goals.

Indonesia's rapid economic growth continues to drive rising electricity demand, making secure and sustainable energy supply essential to support industrial, commercial, and societal development. Without addressing these challenges, energy insecurity and environmental degradation could undermine economic progress and public welfare. Furthermore, global commitments to reduce greenhouse gas emissions put additional pressure on Indonesia to transition away from fossil fuels towards cleaner, renewable energy sources. Failure to adapt could result in environmental harm and increased economic vulnerability.

Moreover, the country's uneven distribution of electricity access and fluctuating affordability present social equity issues that need urgent attention. Ensuring that all Indonesians benefit from electrification and affordable energy prices is critical to improving living standards and achieving sustainable development goals. These intersecting economic, social, and environmental factors heighten the urgency to comprehensively analyze and improve Indonesia's electricity energy security.

Numerous studies have assessed Indonesia's energy sector, highlighting its heavy dependence on coal-fired power plants, which comprised approximately 50% of installed capacity as of 2020. Research by the Directorate of Corporate Planning of PT PLN outlined the 2021–2030 electricity supply plan, emphasizing the need to increase renewable energy capacity to 51.6% of new power plants by 2030. Other studies have explored Indonesia's electrification rates, indicating a steady increase in access but pointing to persistent gaps in rural and economically disadvantaged areas.

Environmental analyses have documented the rising CO2 and greenhouse gas emissions linked to fossil fuel use, raising concerns about Indonesia's contribution to global warming and its own air quality challenges. Research also suggests that technological innovations such as Carbon Capture and Storage (CCS) and Carbon Capture, Utilization, and Storage (CCUS) projects can mitigate emissions from existing fossil fuel infrastructure.

However, many existing studies focus on isolated aspects, such as capacity expansion or environmental impacts, without integrating multiple dimensions of energy security (availability, accessibility, acceptability, affordability) into a unified framework. This gap limits comprehensive policy formulation that balances growth, equity, and sustainability.

Despite extensive analyses on individual facets of Indonesia's energy landscape, there remains a lack of holistic assessment that quantitatively integrates availability, accessibility, acceptability, and affordability to project the future state of national electrical energy security. Moreover, existing research seldom provides forward-looking projections up to 2045 that can inform long-term strategic planning. The complex interactions among these four dimensions require comprehensive modeling to capture trade-offs and synergies for effective policy guidance.

This study innovatively employs a multi-indicator framework encompassing 20 distinct variables across four critical aspects of electrical energy security. It combines historical data with regression-based projections to assess Indonesia's electrical energy security trajectory through 2045. The use of a rhombus area graph to visually integrate and quantify the interplay between availability, accessibility, acceptability, and affordability provides a novel metric for holistic energy security evaluation in Indonesia. Additionally, the study highlights the environmental sustainability challenges posed by fossil fuel reliance and proposes policy and technological pathways for a cleaner energy transition.

The primary objective is to evaluate Indonesia's electrical energy security by analyzing and projecting key indicators of availability, accessibility, acceptability, and affordability from 2008 through 2045. The study aims to identify trends, challenges, and opportunities within these four pillars to inform strategic energy policy and sustainable development planning.

This research provides policymakers, energy planners, and stakeholders with a comprehensive, data-driven understanding of Indonesia's current and future electrical energy security. The findings can guide targeted investments in renewable energy, infrastructure expansion, emissions reduction technologies, and equitable access initiatives. By integrating environmental, economic, and social dimensions, the study supports balanced decision-making to achieve energy security while meeting national development and sustainability goals.

RESEARCH METHODS

This study was conducted by analyzing Indonesia's electrical energy data from 2008 to 2023, both from the generation system, production, consumption and also the environmental impact caused. Electrical energy and economic data are obtained from the Handbook of Energy and Economic Statistics of Indonesia (HEESI) for 2018 – 2023 (Handbook of Energy and Economic Statistics of Indonesia, 2018, 2023), as well as Electricity Statistics (2014) and (2018). The data analyzed is then used as indicators that will be placed based on their respective aspects.

The data that has been collected is then regressed to project the value in 2030 and 2045. The data collected has a range of different quantities and units, so in order to be compared with each other, the data needs to be normalized and given an index on a scale of 1-10 (Sahid et al,. 2019).

Data Normalization

For indicators that have a positive trend, it means that the greater the value of the indicator, the better the performance of the electricity resistance, then normalize the data using the following formula 10 (Sahid et al,. 2019):

On the other hand, for indicators that have a negative trend, the data normalization uses the following formula:

Where:

X' : Index Normalization of data based on a scale of 1-10.
X : The value of the indicator used.
Xmin : The smallest data from the data range from 2008 to 2045.
Xmax : The largest data from the data range from 2008 to 2045.

In the final analysis, only 2008, 2014, 2019, 2023, 2030 and 2045 will be analyzed in the form of a radar curve / rhombus graph to show how the index shifts from each aspect in the specified years.

Rhombus Area

The rhombus area is an area of parallelogram that indicates the security of electrical energy in a certain year and has a square unit. In the 4-aspect Rhombus Graph, the rhombus area is calculated by multiplying the length of the horizontal diagonal by the length of the vertical diagonal divided by half (https://byjus.com/maths/area-of-rhombus/). In the calculation at this writing, the horizontal diagonal length is the sum of the final value of the Accessibility aspect with the Affordability value and the vertical diagonal length is the sum of the final value of the Availaility aspect with the final value of the Acceptability aspect.

RESULTS AND DISCUSSION

ANALYSIS AND CALCULATION

There are 20 indicators used, and they are grouped into 4 main indicator aspects. Indicators for each aspect are grouped based on data match and availability.

a. Availability

The Availability aspect is an important aspect to evaluate energy security, in this case the security of electricity supply at a certain time. In this analysis, there are 4 (four) indicators that will be included in the availability aspect. The following is a table of availability indicators and also the data sources.

Table 1. List of Availability Indicator

Code	Indicator	Data Source
AV1	Power Plant Installed Capacity (MW)	HEESI Item 6.4.1 Page 88 (2018 & 2023)
AV2	Import Electricity (GWh)	HEESI Item 6.4.3 Page 96 (2018 & 2023)
AV3	Total Electricity Generation (GWh)	HEESI Item 6.4.2 Page 92 (2018 & 2023
AV4	PP Installed per Capita (W/Capita)	HEESI Item 1.1 page 2 dan item, 6.4.1 page 88 (2018 & 2023

Power Plant Installed Capacity is the main indicator of the physical form of infrastructure that shows the availability of domestic electricity supply, as the basis for electrical energy security. It has a positive trend because the higher the value, the better the availability. Import Electricity shows how much electricity supply availability from other countries can be obtained from year to year. Which can be used as an additional supply in meeting domestic needs. It has a positive trend because the higher the value, the better the availability. Total Electricity Generation shows how much annual electrical energy can be produced in a country. It has a positive trend because the higher the value, the better the availability. Power Plant Installed Capacity per Capita shows the comparison of installed power plant capacity with the number of people each year. It has a positive trend because the higher the value, the better the availability.

Data for the Availability aspect from 2008 to 2023 and also data predictions for 2030 and 2045, are in the following table:

Table 2. Data and predictions of data from the Availability aspect indicator

Year	AV1 (MW)	AV2 (GWh)	AV3 (GWh)	AV4 (W/Capita)
2008	31.463	0,00	149.437	136
2009	31.959	1,26	156.797	136
2010	33.980	2,22	169.786	142
2011	39.916	2,54	183.419	165
2012	45.246	2,99	200.318	184
2013	50.988	3,03	216.189	205
2014	53.064	8,99	228.555	210
2015	54.688	12,75	233.982	214
2016	58.416	692,70	247.918	226
2017	62.233	1.119,47	254.660	238
2018	64.955	1.495,89	283.775	245
2019	69.679	1.683,12	295.449	260
2020	72.751	1.553,00	291.831	268
2021	74.533	972,73	309.076	273
2022	83.813	797,38	333.537	304
2023	91.166	892,91	350.609	327
2030	112.514	2.104,52	434.272	397
2045	169.500	3.684,15	631.019	579

Data for Availability aspects in 2008, 2014, 2019, 2023, and data predictions in 2030 and 2045, after data normalization are in Table 3 below.

Table 3. Index of Availability Indicator

Year	AV1'	AV2'	AV3'	AV4'	Average
2008	1,00	1,00	1,00	1,00	**1,00**
2014	2,41	1,02	2,48	2,52	**2,11**
2019	3,49	5,11	3,73	3,52	**3,96**
2023	4,89	3,18	4,76	4,89	**4,43**
2030	6,28	6,14	6,32	6,30	**6,26**
2045	10,00	10,00	10,00	10,00	**10,00**

b. Accessibility

The Accessibility aspect shows how much energy, in this analysis electrical energy, can be accessed and used by a single country. This aspect also indicates the resilience of the energy supply and efficiency in a few years. In this analysis, there are 6 factors that are categorized as indicators in Accessibility.

The following is the Accessibility indicator table and also the source of the data.

Table 4. List of Accessibility Indicator

Code	Indicator	Data Source
AC1	*Total Electricity Sales (GWh)*	HESSI Item 6.4.4 Page 98 (2018 & 2023)
AC2	*Electricity Consumption Industrial Sector (GWh)*	HESSI Item 6.4.4 Page 97 (*2018* & 2023)
AC3	*Electricity Consumption Household Sector (GWh)*	HESSI Item 6.4.4 Page 97 (2018 & 2023)
AC4	*Electricity Consumption Commercial Sector (GWh)*	HESSI Item 6.4.4 Page 97 (2018 & 2023)
AC5	*Electricity Consumption Transportation Sector (GWh)*	HESI Item 6.4.4 Page 98 (2018 & 2023)
AC6	*Ratio of Electrification* (%) It is a comparison of the number of electrified households with the total number of households.	STATISTIK KETENAGALISTRI-KAN 2014, Table 26 Page 25, 2018, Table 17 Page 61. HEESI 2018&2023, Page VIII

Total sales are used to show how much energy is absorbed overall. Consumption analysis from each consumer sector is used to show and ensure an increase in electrical energy consumption from year to year because in the future electrical energy is the main energy that drives various sectors to create a cleaner and healthier environment and society. Both the absorption as a whole and each sector have a positive trend because the higher the value, the better the accessibility.

The ratio of electrification shows how much people have access to electrical energy. Having a positive trend because the higher the value, the better the accessibility.

Data for the Accessibility aspect from 2008 to 2023 and also data predictions for 2030 and 2045, are in the following table.

Table 5. Data and data prediction from the Accessibility aspect indicator

Year	AC1 (GWh)	AC2 (GWh)	AC3 (GWh)	AC4 (GWh)	AC5 (GWh)	AC6 (%)
2008	129.019	47.969	50.184	22.845	81	66,71
2009	134.582	46.204	54.945	24.715	111	66,28
2010	147.297	50.985	59.825	27.069	89	67,15
2011	159.867	54.725	65.112	30.093	88	72,95
2012	173.991	60.176	72.133	30.880	108	76,56
2013	187.541	64.381	77.211	34.369	129	80,51
2014	198.602	65.909	84.086	36.128	155	84,35
2015	202.846	64.079	88.682	36.773	205	88,30
2016	216.004	68.145	93.635	39.852	223	91,16
2017	223.134	72.238	94.457	41.459	236	95,35
2018	234.618	76.947	97.832	43.753	274	98,30
2019	245.518	77.879	103.733	46.600	301	98,89
2020	243.583	72.240	112.156	42.527	292	99,20
2021	257.634	80.904	115.370	44.124	317	99,45

2022	273.761	88.483	116.095	50.188	344	99,63
2023	288.436	88.588	122.340	56.728	384	99,79
2030	356.340	107.056	157.759	66.046	513	100
2045	510.544	147.985	229.937	95.051	827	100

Data for the Accessibility aspects in 2008, 2014, 2019, 2023, and data prediction in 2030 and 2045, after data normalization, are in the following Table 6.

Table 6. Index of Accesibility Indicator

Year	AC1'	AC2'	AC3'	AC4'	AC5'	AC6'	Average
2008	1,00	1,16	1,00	1,00	1,00	1,11	**1,05**
2014	2,64	2,74	2,70	2,66	1,89	5,82	**3,08**
2019	3,75	3,80	3,68	3,96	3,65	9,70	**4,76**
2023	4,76	4,75	4,61	5,22	4,66	9,94	**5,66**
2030	6,36	6,38	6,39	6,38	6,21	10,00	**6,95**
2045	10,00	10,00	10,00	10,00	10,00	10,00	**10,00**

c. Acceptability

This aspect shows the environmental and social acceptance of the consequences of generating electrical energy, namely related to the adverse effects caused such as CO2 emissions or greenhouse gases, as well as factors that can reduce these emissions. In this analysis, there are 5 factors that indicate Acceptability.

The following is a table of Acceptability indicators and also the data sources

Table 7. List of Acceptability Indicator

Code	Indicator	Data Source
AP1	*Total CO2 Emmision (Million Ton)*	https://ourworldindata.org/co2-and-greenhouse-gas-emissions
AP2	*CO2 Emmision/ Capita (T)*	https://ourworldindata.org/co2-and-greenhouse-gas-emissions
AP3	*GHG (Million Ton)*	https://ourworldindata.org/co2-and-greenhouse-gas-emissions
AP4	*GHG/Capita (T)*	https://ourworldindata.org/co2-and-greenhouse-gas-emissions
AP5	*Share of NRE Generation (GWh)*	Hand Book of Energy Item 6.4.2 Page 88 (year 2018 & 2023)

Data for the Acceptability aspect from 2008 to 2023 and also data predictions for 2030 and 2045, are in the following table.

Table 8. Data and data prediction from the Acceptability aspect indicator

Year	AP1 (MT)	AP2 (T)	AP3 (MT)	AP4 (T)	AP5 (%)
2008	366	1,50	1.322	5,50	13
2009	399	1,60	1.705	7,00	13
2010	446	1,80	1.562	6,30	16
2011	501	2,00	1.772	7,10	12
2012	516	2,00	1.848	7,30	11
2013	489	1,90	1.803	7,00	12
2014	488	1,90	2.083	8,00	11

2015	539	2,10	2.500	9,50	10
2016	540	2,00	1.735	6,60	12
2017	557	2,10	1.714	6,40	13
2018	594	2,20	1.783	6,60	17
2019	654	2,40	2.104	7,70	16
2020	608	2,20	1.682	6,10	18
2021	620	2,20	1.649	6,00	18
2022	737	2,60	1.817	6,50	20
2023	733	2,60	1.922	6,80	19
2030	858	2,93	2.034	6,77	21
2045	1.178	3,83	2.264	6,63	28

Data for the Acceptability aspects of 2008, 2014, 2019, 2023, and data predictions in 2030 and 2045, after data normalization, are in the following Table 6.

Table 9. Index of Acceptability Indicator

Year	AP1'	AP2'	AP3'	AP4'	AP5'	Average
2008	10,00	10,00	10,00	10,00	2,51	**8,50**
2014	8,65	8,45	4,19	4,38	1,39	**5,41**
2019	6,81	6,52	4,02	5,05	4,03	**5,29**
2023	5,93	5,74	5,42	7,08	5,23	**5,88**
2030	4,54	4,46	4,56	7,15	6,50	**5,44**
2045	1,00	1,00	2,80	7,46	10,00	**4,45**

d. Affordability

This pillar indicates the affordability of the community to energy prices. This is related to the economic condition of the community as measured from per capita income, energy consumption per capita, energy consumption per income of the community and electricity prices in the community. There are 5 factors used in the Affordability analysis.

The following is a table of Affrodability indicators and also the source of the data.

Table 10. List of Affordability IndicatoKode

Code	**Indicator**	**Data Source**
AF1	*Electrical Consumption Per Capita (BOE/Capita)*	HESI Item 1.1 Page 3 HESI Item 6.4.4 Page 9 (2018 & 2023)
AF2	*Electricity Consumption per GDP (kWH/Milion of IDR)*	HESI Item 1.1 Page 3 HESI Item 6.4.4 Page 9 (2018 & 2023)
AF3	*Household Electricity Price (IDR/BOE)*	HESI Item 4.4 Page 37 (2018 & 2023)
AF4	*GDP/Capita (Thousand IDR)*	HESI Item 1.1 Page 3 (2018 & 2023)
AF5	*Un-employment Percentage (toward labor force)*	HESI Item table 1.4 Page 7 (2018 & 2023)

Electricity Consumption Per Capita indicates the amount of electrical energy consumption per population. It has a positive trend because the greater the value, the better the Affordability.

Electricity Consumption per GDP indicates the amount of electrical energy consumption per gross domestic product, in this analysis it is calculated that electricity consumption per Rp 1000,000,- meaning how much energy is needed to produce Rp 1000,000,- . It has a negative trend because the greater the value, the worse the Affordability.

Household Electricity Price shows the price of electricity for the household sector. Indicates the affordability of the community. Having a negative trend because the greater the value, the worse the affordability.

GDP/Capita shows the development of the community's economy as measured by income per population. Have a positive trend because the greater the value, the better the affordability

Un-employment Percentage shows the equal distribution of income in society. The negative trend is because the greater the value, the worse the affordability.

Data for the Affordability aspect from 2008 to 2023 and also data predictions for 2030 and 2045, are in the following table.

Table 11. Data and data prediction from the Affordability aspect indicator

Year	AF1 (MT)	AF2 (T)	AF3 (MT)	AF4 (T)	AF5 (%)
2008	557,00	26,07	959	21.365	8,39
2009	573,28	24,01	961	26.485	7,87
2010	617,55	21,46	1.005	27.029	7,14
2011	660,63	20,41	1.008	33.461	6,56
2012	708,94	20,19	1.030	33.582	6,14
2013	753,73	19,65	1.129	38.366	6,30
2014	787,59	18,79	1.237	41.916	5,90
2015	794,04	17,60	1.365	45.120	6,60
2016	834,94	17,41	1.376	47.957	5,90
2017	852,01	16,42	1.723	51.891	5,80
2018	885,30	15,81	1.798	55.992	5,60
2019	915,86	15,51	1.793	59.060	5,50
2020	898,61	15,78	1.618	56.953	7,60
2021	944,81	15,18	1.670	62.258	6,90
2022	992,70	13,98	1.841	71.030	6,20
2023	1.034,95	13,81	1.886	74.965	5,60
2030	1.242	8	2.430	95.359	5,10
2045	1.699	-	3.496	145.681	3,64

Data for Affordability aspects in 2008, 2014, 2019, 2023, and predicted data in 2030 and 2045, after data normalization are in Table 6 below.

Table 12. Index of Affordability Indicator

Year	AF1'	AF2'	AF3'	AF4'	AF5'	Average
2008	1,00	1,00	10,00	1,00	1,00	**2,80**
2014	2,82	3,51	9,01	2,49	5,72	**4,71**
2019	3,83	4,65	7,04	3,73	6,48	**5,15**
2023	4,77	5,23	6,71	4,88	6,29	**5,58**
2030	6,40	7,26	4,78	6,36	7,25	**6,41**
2045	10,00	10,00	1,00	10,00	10,00	**8,20**

Results of calculation and discussion

The average calculation results of each pillar for the years 2008, 2014, 2019, 2023, 2030 and 2045 can be tabulated as shown in the following Table 13, which indicates the overall electrical energy security.

Table 13. Ovearall Indonesi Eletricity Scurity Indicator

Year	Availability	Accessibility	Acceptability	Affordability
2008	1,00	1,05	8,50	2,80
2014	2,11	3,08	5,41	4,71
2019	3,96	4,76	5,29	5,15
2023	4,43	5,66	5,88	5,58
2030	6,26	6,95	5,44	6,41
2045	10,00	10,00	4,45	8,20

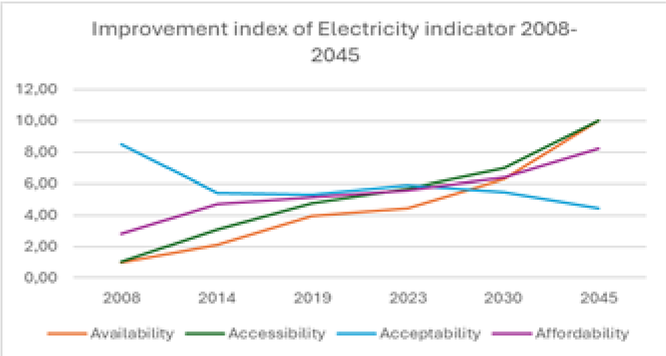

Figure 2. Movement curve of the electrical energy security index 2008-2045

Figure 2 shows the movement trend of the average index of electrical energy security indicators from 2008 to 2045 based on the values in Table 13. Only the Acceptability aspect shows a negative trend or decline, while the other 3 (three) aspects, namely Availability, Accessibility and Affordability, have a positive trend.

The shift in Indonesia's overall electricity security index from 2008 to 2045 can be illustrated in the rhombus graph as shown in Figure 3 below.

Figure 3. The status of Indonesia's electrical energy security from 2008 to 2045

Figure 3 above shows that in 2045 only the availability and accessibility side will occupy the ideal point (index 10), affordability will only occupy an index of 8.2, and acceptability will only occupy 4.45.

Ideally, the rhombus area has a perfect box, but in practice it is quite difficult. The area rhombus area is calculated by square units.

The area of Rhombus area each year can be calculated by:

RA = (Diagonal horizontal x Diagonal Vertical)/2

Or in this case

RA = ((Accesibility point + Affordability point) x (Availability point + Acceptability point))/2 overall electrical energy security from year to year in Indonesia.

The following is an analysis of the movement of electrical energy security in Indonesia in 2008, 2014, 2019, 2023, 2030 and 2045.

Table 14 Luasan Rhombus Area (Square Unit)

Year	2008	2014	2019	2023	2030	2045
Rhombus Area	18,27	29,26	45,80	57,91	78,20	131,51
Increase		10,99	16,54	12,11	20,29	53,31

Electricity resilience movement in 2008-2014

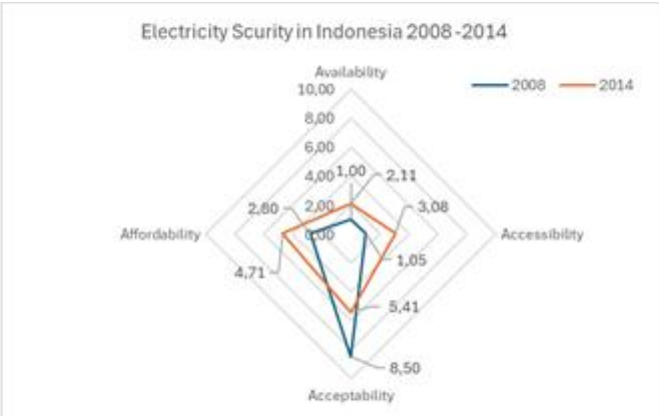

Figure 4 shows the shift in the electrical energy security index from 2008 to 2014, which is the leadership of President SBY, there was an increase in rhombus area of 10.99 square units in 6 years. The increase occurred due to the addition of power plants that were almost 70%. The total energy generated also increased by more than 50%. However, the addition and generation are mostly coal-based power plants, causing Acceptability to decrease, due to the emissions it causes. Accessibility is increasing due to the increase in consumption of all consumer sectors, as well as the increase in the electrification ratio.

Electricity resilience movement in 2014-2019

Figure 5. The status of Indonesia's electrical energy security from 2014 to 2019

Figure 5 shows the shift in the electrical energy security index from 2014 to 2019, which is the first period of President Jokowi's leadership, there was an increase in rhombus area of 16.54 square units for 5 years. Significant improvements occurred on the Availability and Accessibility side. The Acceptability side tends to be stable, there is no significant decline. The increase occurred due to an increase in the electrification ratio, the addition of power plants by around 30%, an increase in the amount of electricity consumption of around 23% but electricity production from the renewable energy sector increased by around 90% and also the number of electrical energy imports (from Malaysia) increased so as to reduce the adverse impact on the Acceptability aspect.

Electricity security movement in 2019-2023

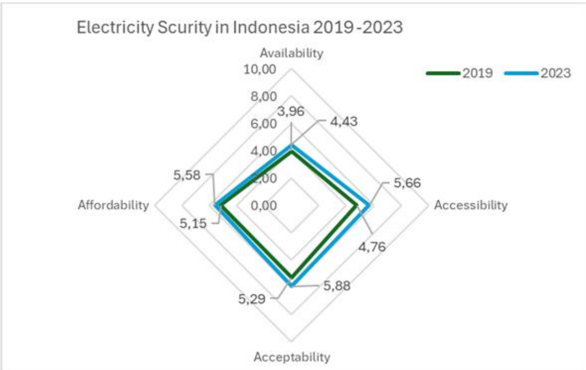

Figure 6. The status of Indonesia's electrical energy security from 2019 to 2023

Figure 6 shows the shift in the electrical energy security index from 2019 to 2023, which is the second period of President Jokowi Perode's leadership, there was an increase of 12.11 square units over 4 years. There has been an improvement/improvement of all aspects in all aspects, be it Availability, Accessibility, Acceptability and Affordability. The increase tends to be more, in terms of accessibility because electricity consumption is increasing for all sectors, indicating an improving economy. The Acceptability side also shows improvement because the government has innovated in increasing renewable energy, energy efficiency from domestic generation. Electricity imports are reduced during this period.

Electricity security movement in 2008-2045

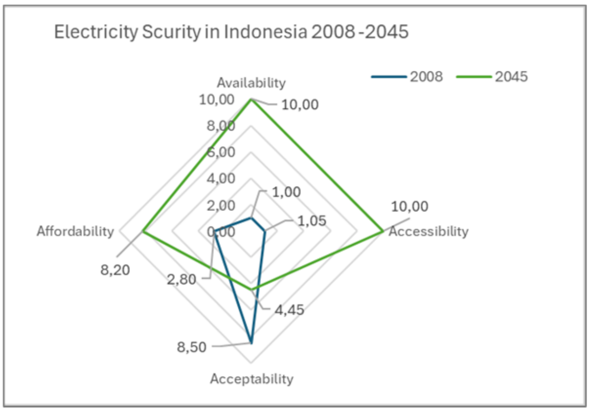

Figure 7. The status of Indonesia's electrical energy security from 2008 to 2045

Figure 7 shows the shift in the level of electrical energy security in Indonesia from 2008 to 2045 based on the trend expected to increase by 113.24 square units. The increase occurred due to the increase in generation capacity, power generation, and electricity consumption in all sectors which indicated an improvement in the community's economy in general.

The affordability index does not reach the index value of 10, due to the increase in electricity tariffs from year to year until 2045 the price of electricity is quite expensive, even though it is accompanied by the value of Gross Domestic Product (GDP) per capita which is also increasing, but the unemployment rate (un-emplyment rate) still exists, so that people's purchasing power is uneven. The decline in the index of Acceptability is due to the continuous increase in CO2 and other Green House Gases emissions which have adverse effects on the environment and society.

CONCLUSION

The analysis of electrical energy security in Indonesia above is carried out based on 20 indicators to measure the aspects of Availability, Accessibility, Acceptability and Affordability. Based on the analysis, there has been an increase in electrical energy security from 2008 to 2045 for all aspects, except for the Acceptability aspect. The total increase occurred around 113.24 square units in the Rhombus area. There has been a decrease in the Acceptability aspect related to the impact on the environment due to emissions caused by the use of fossil fuels which is no less important to be immediately corrected. Emissions caused by energy use have become a concern for all parties related to global warming that must be addressed immediately. The energy transition to renewable energy and clean energy is urgently needed to reduce the use of fossil energy. The electrification of the industrial and transportation sectors is also worth considering, so that industrial equipment and vehicles are driven by electrical energy instead of fossil energy, to concentrate emissions only in the generation area, thus making it easier to control their emissions. The implementation of the Carbon Capture Storage development programs that have been launched by the government (15 CCS/CCUS projects) [6] which are targeted to operate in 2030 can help reduce emissions and also the development of CCS/CCUS for the power generation sector is also worth considering. In terms of policy, the government should encourage the public to participate in renewable energy programs, for example by subsidizing rooftop solar PV. Implementing a carbon tax and recommending the entire industry including power generation to implement CCS technology is also worth considering.

REFERENCES

Handbook of Energy and Economic Statistics of Indonesia 2018
Handbook of Energy and Economic Statistics of Indonesia 2023
STATISTIK KETENAGALISTRIKAN 2014
STATISTIK KETENAGALISTRIKAN 2018
Ritchie, H,. Rosado, P., & Roser, M. CO2 and greenhouse gas emissions. https://ourworldindata.org/co2-and-greenhouse-gas-emissions
Sidemen, I. G. S. (2023) Indonesia Tabled CCS and CCUS in Net Zero Emission Road Map: Opening Possibilities for Cross-Border Carbon Trading/Storage. https://www.asiaccusnetwork-eria.org/article/indonesia-tabled-ccs-and-ccus-in-net-zero-emission-road-map-opening-possibilities-for-cross-border-carbon-tradingstorage
Sahid, E. J. M., Zahid Imran, S. H., & Mohamed Yusop, N. Y. (2019). Renewable energy and energy security in Malaysia. International Journal of Recent Technology and Engineering (IJRTE), 8(4), 2277-3878. https://doi.org/10.1109/ijrte.2019.0001
PT PLN (PERSERO). (2021). Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) 2021-2030. Mentri Energi dan Sumber Daya Mineral Republik Indonesia.
PT PLN (PERSERO). (2021). Diseminasi RUPTL 2021-2030. Directorat Perencanaan Korporat.
Wibowo, A. C., Hermawan, & Karnoto. (n.d.). Analisis proyeksi kebutuhan energi listrik dengan menggunakan metode simple econometric.
Harjanto, N. T. (2008). Dampak lingkungan pusat listrik tenaga fosil dan prospek PLTN sebagai sumber energi listrik nasional. Pusat Teknologi Bahan Bakar Nuklir, BATAN, 1. https://doi.org/10.1109/PTBN-PLTN.2008
BYJU'S. (n.d.). Area of rhombus. Retrieved from https://byjus.com/maths/area-of-rhombus/
Resources for the Future. (n.d.). Electrification 101. Retrieved from http://www.rff.org/publications/explainers/ecltrification-101/