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ANALISIS KEBERLANJUTAN ENERGI NASIONAL MENGGUNAKAN DATA ENERGI TAHUN 2013-2022

THE ANALYSIS OF NATIONAL ENERGY SUSTAINABILITY USING ENERGY DATA FROM THE YEARS OF 2013-2022

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ABSTRACT
The decision-making process to enhance energy sustainability requires scientifically-based information. In this study, various indicators are collected and quantitively analyzed to measure the national energy sustainability using sustainable energy development index derived from those indicators. Using this method of analysis, the most significant challenges related to energy sustainability can be analyzed. Additionally, this study aims to identify factors that hinder Indonesia to achieve energy sustainability during the period of 2013-2022.

Keywords*: Sustainable Energy, Renewable Energy, Indicators.*

ABSTRAK
Proses pengambilan keputusan untuk meningkatkan keberlanjutan energi memerlukan informasi yang berbasis ilmiah. Dalam penelitian ini, berbagai indikator dikumpulkan dan dianalisis secara kuantitatif untuk mengukur keberlanjutan energi nasional menggunakan indeks pembangunan energi berkelanjutan yang berasal dari indikator tersebut. Dengan menerapkan metode analisis ini, tantangan-tantangan terbesar yang terkait dengan keberlanjutan energi dapat diteliti. Selain itu, penelitian ini bertujuan untuk mengidentifikasi faktor-faktor yang menghambat Indonesia untuk mencapai keberlanjutan energi selama periode 2013-2022.

Kata Kunci: Energi Berkelanjutan, Energi Terbarukan, Indikator

INTRODUCTION

The increasing development in Indonesia in both domestic and industrial sectors brings logical consequences, such as the rise in the demand for electrical energy. Additionally, local government policies on beneficial investments draw the interest of investors to inject capital, contributing to the increased need for electrical energy. Currently, Indonesia's electrical system still relies heavily on fossil energy. Some reasons for emphasizing the importance of transitioning from fossil energy to new renewable energy include energy crisis and limited fossil resources, increased environmental awareness, development of renewable technology, energy storage technology, sustainability and energy independence, policy and regulatory influence, investment and financial support, and changes in energy market dynamics.

Despite some efforts to integrate clean energy sources, challenges continue to arise, including uneven growth among sectors and regions, energy supply uncertainties, and environmental impacts that need to be managed wisely. In this context, the analysis of energy data for the period of 2013-2022 serves as a robust foundation to detail developments, identify improvement potentials, and formulate policy strategies to enhance national energy resilience.

To achieve national energy sustainability, national energy policy is needed. National energy policy requires information that can be obtained from qualitative or quantitative analysis. This study utilizes quantitively analysis using some energy data reported in the last 10 years.

METODE

This study focuses on how the energy resilience conditions in Indonesia in the upcoming years in relation to sustainable development. This study involves in-depth analysis of energy policies, national energy infrastructure, and international collaboration opportunities. Primary data is obtained through scientific literature, government reports, and other verified sources.

Indonesia's national energy resilience refers to the country's ability to maintain a reliable, efficient, and sustainable energy supply to support economic growth, social needs, and environmental sustainability.

Indicators are powerful tools to assist policymakers and energy experts in measuring useful energy sustainability for policymakers, energy analysts, and statisticians. Additionally, indicators provide a deeper understanding of existing issues (Neves and Leal, 2010). Energy sustainability indicators are indeed chosen by policymakers or energy experts (Lee and Huang, 2007). They can show us what needs to be done to improve weaknesses in the energy resilience system in the future.

The determination of sustainable energy development index has several steps, which are:

1. Data collection and selection
   This study uses energy data taken from the government report in Handbook of Energy and Economic Statistics of Indonesia 2022 (ESDM, 2022). There are huge amount of energy and economic data in this report, and for this study, only some of them, strongly related to the energy sustainability, will be used for analysis, and will be discussed later.
2. Grouping of data into category and indicator
   In this step, all data were sorted to generate list of categories and indicators. The indicators are grouped into seven categories namely 1) environmental impact, 2) renewable energy, 3) transport, 4) use of energy, 5) resources access to energy, 6) resilience and safety, 7) policies (Razmojo, A. Armin, et al, 2019). All categories are related to the national energy sustainability.
3. Calculation of cross-correlation between indicators in a certain category
   A category may have some indicators, and they can be correlated or uncorrelated. There is no need to include all indicators having strong correlation, and one of them can be chosen as input for sustainable energy development index as the rest of them are just "duplicate". This can be done by simply calculating the cross-correlation coefficient between indicators. Therefore, the final indicators used for analysis should have low cross-correlation. The cross-correlation coefficient can be determined by using the formula below:

$$(X, Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

   x and y are indicators, and $\bar{x}$ and $\bar{y}$ are the average of the indicators.
4. Normalization of final indicators
   Different indicators have different range of values, i.e., they can be millions or tens or just fractions. Therefore, for visualization purpose, indicators are normalized to have similar range between 0 to 1. This is done by using the following formula:

$$X_m = \frac{X - X_{min}}{X_{max} - X_{min}}$$

5. Visualization
   The determined sustainable energy development index is then displayed in term of x-y curve or rose diagram to help the interpretation of the result

The selected data distribution of national energy from the period of 2013—2022, taken from ESDM (2022), is shown in Table 1 below.

Table 1. Selected data distribution of national energy from the period of 2013 – 2022 *).

Data	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
AE	244	249	253	256	260	263	266	264	250	254
AREE	8261	8418	8575	9065	9459	9805	10300	10507	11537	12603
TCO^2	489	488	539	540	557	594	651	606	616	729
EEX	3758	4566	3326	1800	2075	1971	2220	2863	1806	4039
EIM	4577	4654	3961	3290	3849	3952	3462	2790	3092	3901
ELC	187541	198602	202846	216004	223134	234618	245518	243583	257634	273761
GDP	955	1057	1153	1241	1359	1484	1583	1544	1698	1959
LA	1911	1911	1914	1914	1917	1917	1917	1917	1917	1917
LE	6668	7931	7782	7004	7674	7131	7993	7102	6951	7993
POP	253	256	259	262	265	267	270	272	274	276
RIFR	71	79	78	77	76	76	75	74	74	73
TEP	408725	380680	375272	385126	389296	447956	458282	424326	446660	458282
TEPR	11180	12885	13695	12868	13973	15918	19524	19749	20351	19524
TFC	118233	119777	118214	114515	118351	131391	141688	128312	129387	165977
TFCC	5493	5635	5500	5792	5933	6104	6376	5909	6153	6951
TFCET	11	13	18	19	20	24	26	25	27	27
TFCFFT	47786	47976	48355	47774	50908	55929	57823	50958	54351	59975
TFCI	39698	40770	40427	37251	38371	46163	54401	47840	44712	74865
TFCR	20890	21364	20873	20916	20738	21270	2151	22145	22634	22607
TFCT	47797	47989	48373	47774	50928	55952	57849	36416	38417	42860
TFFP	395238	365836	359509	369734	375322	3044940	3133991	2889834	3045069	3133991
TPES	184295	185920	181751	191379	27617	30113	31869	29653	30384	35899
TREP	11180	12885	13695	12868	13973	15918	19524	19749	20351	19524

* Source; Ministry of Energy and Mineral Resources Republic of Indonesia, "Handbook of Energy & Economic Statistics of Indonesia" 2022 (ESDM, 2022)

Table 2. Description Of Indicatory Energy Data

Data	Unit	Description
AE	Thousand of population	Acces to electricity
AREE	MW	Amount of RE in electricity production
TCO^2	MT of CO2	Total CO2 emission
EEX	Ktoe	Energy export
EIM	Ktoe	Energy import
ELC	MWh	Electricity consumption
GDP	Million Rupiahs	Gross domestic product
LA	Thousand Km2	Land area
LE	Ktoe	Loss of energy
POP	Million People	Population
RIFR	Km2	Renewable internal freshwater resources
TEP	Ktoe	Total energy production
TEPR	Ktoe	Total energy productionfrom RE
TFC	Ktoe	Total consumption
TFCC	Ktoe	Total consumption in commercial
TFCET	Ktoe	Total consumption of electricity in transport
TFCFFT	Ktoe	Total consumption of fossil fuel in transport
TFCI	Ktoe	Total consumption in industry
TFCR	Ktoe	Total consumption in residential
TFCT	Ktoe	Total consumption in transportation
TFFP	Ktoe	Total final fossil production
TPES	Ktoe	Total primary energy supply
TREP	Ktoe	Total RE production

RESULT AND DISCUSSION

The correlation and normalization methods are utilized to achieve the results based on the obtained figures. Since the main objective of this research is to achieve scientifically-based information on sustainability, it is necessary to measure different indicators based on relevant categories to obtain the main results. After that, with the normalization method of raw data and according to the situation of each of the seven main categories, corresponding indicators will be obtained.

The correlation coefficient takes a value between −1 and 1, with value of 1 indicating perfect correlation and value of -1 indicating perfect opposite correlation. The normalization value has a range between 0 and 1, where value of 1 indicating good and 0 indicating bad.

Table 1 shows the list of indicators and their original values from the year of 2013 to 2022. The values between indicators have a wide range and hence, they need to be normalized for visualization. Table 3 summarizes the categories and their related indicators. One category may have one or two or even more indicators.

Table 3. List Of Categories (Left) And Their Indicators (Right)

Category	Indicator
Environmental Impact	CO2/POP, CO/GDP, CO/TPES, TCO2
Renewable Energy	TEPR, AREE/TEPR, TREP/TEP, TEP
Transport	TFCFFT/TFCT, TFCET/TCT, TFCT
Use of Energy	TFC/GDP, LE/TPES, TFCI/POP, TFCR/POP, TFCC/POP, TPES/GDP, ELC/POP
Resource of Energy	TREP/TEP, TEP, TFFP/TEP
Resilliency	AR, RIFR, POP/LA
Policy	EEX/EIM, GDP/POP

Table 4. List Of Indicators And Their Values In The Years Of 2013 – 2022 (Before Normalization)

Indicator	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
$C0^2$/POP	1,93	1,90	2,08	2,06	2,11	2,22	2,41	2,23	2,25	2,64
$C0^2$/GDP	0,51	0,46	0,47	0,44	0,41	0,40	0,41	0,39	0,36	0,37
$C0^2$/TPES	0,0027	0,0026	0,0030	0,0028	0,0202	0,0197	0,0204	0,0204	0,0203	0,0203
$TC0^2$	489,06	487,89	539,13	540,09	556,94	594,10	650,91	605,98	615,92	728,88
TEPR	11180	12885	13695	12868	13973	15918	19524	19749	20351	19524
AREE/TEPR	0,74	0,65	0,63	0,70	0,68	0,62	0,53	0,53	0,57	0,65
TREP/TEP	0,03	0,03	0,04	0,03	0,04	0,04	0,04	0,05	0,05	0,04
TEP	408725	380680	375272	385126	389296	447956	458282	424326	446660	458282
TFCFFT/TFCT	0,9998	0,9997	0,9996	1,0000	0,9996	0,9996	0,9996	1,3993	1,4148	1,3993
TFCET/TFCT	0,0002	0,0003	0,0004	0,0004	0,0004	0,0004	0,0004	0,0007	0,0007	0,0006
TFCT	47797	47989	48373	47774	50928	55952	57849	36416	38417	42860
TFC/GDP	123,86	113,32	102,56	92,30	87,09	88,54	89,49	83,11	76,21	84,73
LE/TPES	0,036	0,043	0,043	0,037	0,278	0,237	0,251	0,239	0,229	0,223
TFCI/POP	156,74	159,11	156,03	142,26	145,07	172,85	201,80	175,97	163,33	271,48
TFCR/POP	82,48	83,38	80,56	79,88	78,40	79,64	7,98	81,46	82,68	81,98
TFCC/POP	21,69	21,99	21,23	22,12	22,43	22,86	23,65	21,73	22,48	25,21
TPES/GDP	193,06	175,89	157,69	154,25	20,32	20,29	20,13	19,21	17,90	18,33
ELC/POP	740,45	775,09	782,92	824,92	843,61	878,49	910,74	895,99	941,13	992,71
TFFP/TEP	0,967	0,961	0,958	0,960	0,964	6,797	6,839	6,810	6,817	6,839
TREP/TEP	0,027	0,034	0,036	0,033	0,036	0,036	0,043	0,047	0,046	0,043
AE	244,31	248,57	252,72	255,62	259,58	263,09	266,48	263,57	250,21	253,71
RIFR	70,90	78,79	77,91	77,09	76,32	75,59	74,88	74,26	73,65	73,06
POP/LA	0,133	0,134	0,135	0,137	0,138	0,139	0,141	0,142	0,143	0,144
EEX/EIM	0,82	0,98	0,84	0,55	0,54	0,50	0,64	1,03	0,58	1,04
GDP/POP	3,77	4,13	4,45	4,74	5,14	5,56	5,87	5,68	6,20	7,10

The next step is to find the correlation coefficients between indicators for each category using the equation for cross-correlation previously given. The result for each category can be described as following:

a. Correlation between Data in Environmental Impact Category
In this factor, the emphasis is on the low emissions of fossil fuels. The population indicator has a strong linear influence on the fluctuations of the total CO2 emissions in Indonesia. However, it is evident that the GNP indicator shows an inverse relationship, with the negative correlation serving as an indication that Indonesia has successfully achieved economic growth with a relatively reduced carbon footprint.

Table 5. Correlation Data Of Environmental Impact

A =TCO2/TPES, B = TCO2/POP, C = TCO2/GDP, D = TCO2

A-B	A-C	A-D	B-C	B-D	C-D
0,74	-0,86	0,78	-0,76	1,00	-0,81

b. Correlation between Data in Renewable Energy Category
The high consumption of renewable energy has two benefits. Firstly, it reduces dependence on fossil fuels, and secondly, it lowers pollution. Therefore, the use of renewable energy should be a priority for every country in their energy sustainability plans. The total production of energy from Renewable Energy Sources (RES) in Indonesia significantly influences the overall energy production in the country. It can be observed that the correlation of RES usage has an inverse effect, in other words, the potential of RES sources in Indonesia until 2022 has not been fully maximized.

Table 6. Correlation data of Renewable Energy

A = TEPR, B = AREE/TEPR, C = TREP/TEP, D = TEP

A-B	A-C	A-D	B-C	B-D	C-D
-0,84	0,96	0,80	-0,87	-0,56	0,59

c. Correlation between Data in Transport Category
In this indicator, although fossil fuels are the main source of energy provision, it is advisable to prioritize the use of renewable energy over fossil fuels, and this transition can be gradually implemented over time. Greater access to electricity is recommended for this indicator because it leads to increased use of public transportation, resulting in lower CO2 emissions. There is a strong inverse relationship, meaning that as the use of fossil energy in transportation increases, the use of electric energy in transportation decreases, and vice versa.

Table 7. Correlation data of Transportation

A = TFCFFT/TFCT, B = TFCET/TFCT, C = TFCT

A-B	A-C	B-C
0,92	-0,83	-0,64

d. Correlation between Data in Use of Energy Category
During the period of 2013-2022, Indonesia should have been able to use more energy. However, the most important aspect in this regard is the balance of the types of energy used in a country. In the indicators TPES/GDP and ELC/POP, this implies that as the population increases, the consumption of electric energy in Indonesia also increases. There, we can see how strong the influence of population is on the occurrence of energy loss in household energy consumption. This is because with increasing population, there is usually an increase of energy consumption.

Table 8. Correlation data of Energy Usages

A = TFC/GDP, B = LE/TPES, C = TFCI/POP, D = TFCR/POP, E = TFCC/POP, F = TPES/GDP, G = ELC/POP

A-B	A-C	A-D	A-E	A-F	A-G	B-C
-0,79	-0,31	0,13	-0,44	0,87	-0,86	0,40
B-D	**B-E**	**B-F**	**B-G**	**C-D**	**C-E**	**C-F**
-0,32	0,53	-0,98	0,78	-0,23	0,89	-0,46
C-G	**D-E**	**D-F**	**D-G**	**E-F**	**E-G**	**F-G**
0,72	-0,34	0,28	-0,23	-0,58	0,78	-0,86

e. Correlation between Data in Resource of Energy Category

Based on the data, the indicator of total energy production in Indonesia from 2013-2023 is still heavily influenced by the fossil energy indicator. This indicates that until 2022, Indonesia is still dependent on fossil energy.

Table 9. Correlation Data Of Resource Access To Energy

A = TREP/TEP, B = TEP, C = TFFP/TEP

A-B	A-C	B-C
0,59	0,79	0,93

Correlation between Data in Resilient and Safety Category

More resources for each country are a value, but proper utilization will be more valuable. A country with proper planning and effective policies can use energy resources wisely for energy sustainability. Based on the data, the use of electric energy for the population in Indonesia is very high, correlating with the increase in population with the area's extent.

Table 10. Correlation Data Of Resilient & Safety

A=AE,B=RIFR,C=ELC/POP,D=POP/LA

A-B	A-C	A-D	B-C	B-D	C-D
0,16	0,46	0,51	-0,31	-0,29	0,98

f. Correlation between Data in Policy Category

Correct policies are one of the most crucial factors for advancing and sustaining existing resources; the right policies can also lead to achieving energy sustainability. However, in Indonesia, the correlation appears to be very low, possibly due to a highly diversified economy and significant contributions from other sectors in the economy, such as the service or manufacturing sectors. Additionally, external factors, such as fluctuations in global energy prices during the period 2013-2022, political uncertainty, and economic upheavals (pandemics), may play a role.

Table 11. Correlation Data Of Policy

A = EEX/EIM, B = GDP/POP

A-B
0,02

To determine the resulting figures, data uniformity is needed, hence the process of data indicator normalization is carried out. Normalization is one of the pre-processing methods that transforms the initial data into another form with the aim of obtaining more suitable data for analysis and modelling. The normalization process focuses on scaling the data. Normalizing the data can help prevent large initial data ranges from overshadowing data with smaller initial ranges by giving all data the same weight. In this writing, for ease of calculation, the min-max normalization method is used. This method is carried out by projecting the initial data range onto the new data range. The resulting new data range is generally [0, 1] with the following formula;

$$v' = \frac{v - Nmin_{(x)}}{Nmaks_{(x)} - Nmin_{(x)}}$$

where:

- v' is the new normalized value.
- v is the value before normalization.
- N min (x) is the minimum value of attribute x
- N max (x)) is the maximum value of attribute x

Table 12. List Of Indicators And Their Values In The Years Of 2013 – 2022 (After Normalization)

Indicator	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
$C0^2$/POP	0,96	1,00	0,76	0,79	0,73	0,57	0,31	0,56	0,53	0,00
$C0^2$/GDP	0,00	0,94	1,00	0,69	0,45	0,36	0,46	0,28	0,00	0,09
$C0^2$/TPES	1,00	1,00	0,98	0,99	0,01	0,03	-0,01	-0,01	0,00	0,00
$TC0^2$	0,00	0,00	0,21	0,22	0,29	0,44	0,68	0,49	0,53	1,00
TEPR	0,00	0,19	0,27	0,18	0,30	0,52	0,91	0,93	1,00	0,91
AREE/TEPR	1,00	0,60	0,47	0,84	0,71	0,42	0,00	0,02	0,19	0,56
TREP/TEP	-0,51	0,00	0,21	-0,03	0,16	0,13	0,69	1,00	0,92	0,69
TEP	0,40	0,07	0,00	0,12	0,17	0,88	1,00	0,59	0,86	1,00
TFCFFT/TFCT	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,96	1,00	0,96
TFCET/TFCT	1,00	0,90	0,71	0,63	0,64	0,59	0,53	0,00	-0,04	0,12
TFCT	0,53	0,54	0,56	0,53	0,68	0,91	1,00	0,00	0,09	0,30
TFC/GDP	1,00	0,78	0,55	0,34	0,23	0,26	0,28	0,14	0,00	0,18
LE/TPES	0,00	0,03	0,03	0,00	1,00	0,83	0,89	0,84	0,80	0,77
TFCI/POP	0,11	0,13	0,11	0,00	0,02	0,24	0,46	0,26	0,16	1,00
TFCR/POP	0,99	1,00	0,96	0,95	0,93	0,95	0,00	0,97	0,99	0,98
TFCC/POP	-0,14	-0,04	-0,29	0,00	0,10	0,24	0,50	-0,12	0,12	1,00
TPES/GDP	1,00	0,90	0,80	0,78	0,01	0,01	0,01	0,01	0,00	0,00
ELC/POP	0,00	0,14	0,17	0,33	0,41	0,55	0,68	0,62	0,80	1,00
TFFP/TEP	0,00	0,00	0,00	0,00	0,00	0,99	1,00	1,00	1,00	1,00
TREP/TEP	0,00	0,34	0,48	0,32	0,45	0,43	0,79	1,00	0,95	0,79
AE	0,00	0,19	0,38	0,51	0,69	0,85	1,00	0,87	0,27	0,42
RIFR	0,00	1,00	0,89	0,78	0,69	0,59	0,50	0,43	0,35	0,27
POP/LA	0,00	0,14	0,25	0,38	0,48	0,60	0,71	0,82	0,91	1,00
EEX/EIM	0,60	0,90	0,63	0,09	0,08	0,00	0,27	0,98	0,16	1,00
GDP/POP	0,00	0,11	0,20	0,29	0,41	0,54	0,63	0,57	0,73	1,00

From the normalized indicators in Table 4, we can summarize for the final calculation by computing the average values based on the grouping of indicators according to the predefined categories shown in Table 5 as follows:

Table 13. Final Sustainable Energy Development Index

Indicator	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Enviromental Impact	0,49	0,74	0,74	0,67	0,37	0,35	0,36	0,33	0,27	0,27
Renewable Energy	0,22	0,21	0,24	0,28	0,34	0,49	0,65	0,64	0,74	0,79
Transportation	0,51	0,48	0,42	0,39	0,44	0,50	0,51	0,32	0,35	0,46
Use of Energy	0,42	0,42	0,33	0,34	0,39	0,44	0,40	0,39	0,41	0,70
Resource access to Energy	0,13	0,13	0,16	0,14	0,21	0,76	0,93	0,86	0,94	0,93
Resilient & Safety	0,00	0,37	0,42	0,50	0,57	0,65	0,72	0,68	0,58	0,67
Policy	0,30	0,50	0,42	0,19	0,24	0,27	0,45	0,78	0,44	1,00

The result in Table 5 can now be visualized using x-y curve (Figure 1) or rose diagram (Figure 2).

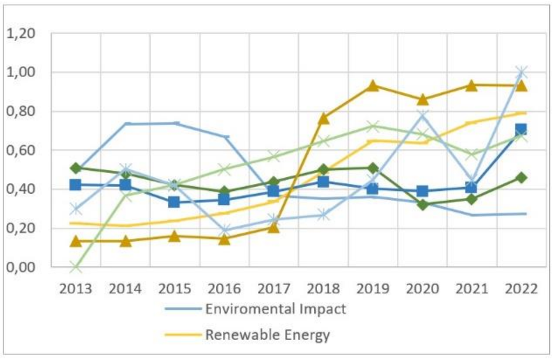

Figure 1. Sustainable Energy Development Index Displayed As x-y Curve

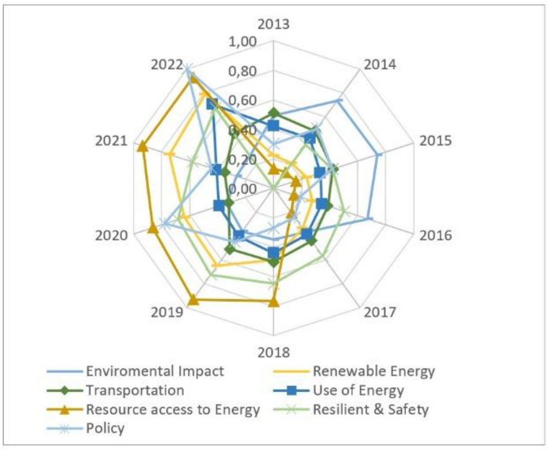

Figure 2. Sustainable Energy Development Index Displayed As Rose Diagram

CO2 emissions in Indonesia from 2013 to 2022 tend to increase, indicating an escalating environmental degradation in Indonesia. Based on the correlation data above, the influence of the rise in CO2 emissions in Indonesia is due to the significant increase in the population. The increase in CO2 emissions needs to be mitigated to achieve the sustainability aspect of the energy utilization system in Indonesia.

The increase in the consumption of renewable energy during the period 2013-2022 in Indonesia has a positive impact on national energy resilience, although there are some values that still fall below the trend. The rise in renewable energy consumption helps Indonesia in reducing greenhouse gas emissions, aligning with Indonesia's commitment to mitigating the impact of global climate change to achieve sustainability goals.

In 2020, during the COVID-19 pandemic, mobility and economic activities were restricted, resulting in a negative impact on the transportation sector, manifested in a decrease in demand for fossil fuels. This had a positive effect on reducing carbon emissions and created opportunities for transitioning to clean, renewable energy. This transition was marked by a significant increase in the indicators of energy availability and accessibility, which could benefit reducing import dependence, thus alleviating budget deficits, and potentially reducing energy intensity and elasticity, ultimately meeting energy sustainability goals. However, the economic crisis during the pandemic hindered efforts towards energy transition. Government policy priorities and funding were more focused on controlling the COVID-19 pandemic and economic recovery efforts rather than energy transition, reflected in the stagnant trend of renewable energy in 2020

CONCLUSION

The proper utilization of resources, improvement of infrastructure, and energy resilience for both urban and rural populations, providing energy access across all regions, utilizing new technologies to optimize energy consumption, and maintaining energy sustainability are essential. Additionally, the numerical results from the examined data over the period 2013-2022 presented indicate which indicators need improvement and which ones need revision. Effective actions should be implemented for sustainable energy.

Determining appropriate energy indicators is also effective and necessary to enhance and improve energy sustainability infrastructure. In this study, viable indicators were developed based on the previously presented method called the Sustainable Energy Development Index. The results of conceptual analysis indicate that achieving energy sustainability requires policymakers and government roles with systematic planning to implement applied policies. Policies such as gradually reducing the use of fossil fuels and replacing them with renewable energy sources are crucial.

REFERENCES

A. Armin Razmjoo, Andreas Sumper, Afshin Davarpanah, “Development of sustainable energy indexes by the utilization of new indicators: A comparative study”, Elsevier Energy Report, 2019

Badan Pusat Statistik Republik Indonesia, “ Neraca Energi Indonesia 2017 – 2021”, Catalog: 6204001, 2022

Bhattacharyya, S.C., “Energy access programmes and sustainable development: a critical review and analysis. Energy Sustainable” 2012. Dev. 16 (3), 260–271.

Djoni Hartono, Arief Anshory Yusuf, Sasmita Hastri Hastuti, Novani Karina Saputri, Noor Syaifudin, “Effect of COVID-19 on energy consumption and carbon dioxide emissions in Indonesia”, Elsevier Energy Report, 2021

Electricity consumption Indonesia, https:/www.ceicdata.com/en/Indonesia

Indonesia Energy Transition Outlook 2023: Tracking Progress of Energy Transition in Indonesia: Pursuing Energy Security in the Time of Transition, Institute for Essential Services Reform (IESR) (2022)

International Atomic Energy Agency, United Nation Department of Economic and Social Affairs, “Energy Indicators for Sustainable Development”

Ministry of Energy and Mineral Resources Republic of Indonesia, “Handbook of Energy & Economic Statistics of Indonesia”, 2022

Nugroho Agung Pambudi, Ridho Alfan Firdaus, Reza Rizkiana, Desita Kamila Ulfa, Muntasy Syahrul Salsabila, Suharno and Sukatiman, “Renewable Energy in Indonesia: Current Status, Potential, and Future Development”, https://www.mdpi.com/journal/sustainability

R Edi Sewandono and Adis Imam Munandar, “Covid-19 and its effect on the supply and demand of fossil fuel energy: Indonesian context.”, IOP Conference Series: Earth and Environmental Science 2023

W. Fu, S. Gudmundsson, K. Wichuk, S. Palsson, B. O. Palsson, and K. Salehi-ashtiani, “Sustainable Energy

Development: History Of The Concept And Emerging Themes," *energy Technol.*, pp. 275–283, 2021