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Analysis of Factors Affecting Carbon Emissions in Indonesia

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Abstract: This research aims to examine the variables affecting Indonesia's carbon emissions between 2000 and 2022, with particular emphasis on the consumption of renewable energy sources, coal and oil. Indonesia is the object of this research, and data information is collected from official sources of the World Bank and Our World in Data. The amount of renewable energy, coal, and oil consumed is the independent variable, while carbon emissions are the dependent variable. The research method involves time-series multiple linear regression analysis with statistical testing steps to identify the causal relationship between variables. EViews software was used for statistical testing. Findings show a significant correlation between Indonesia's carbon emissions and the consumption of renewable energy, coal and oil. Strategies to expand the use of renewable energy to reduce carbon emissions are the main focus of the policy implications. This research provides a foundation for sustainable policy development to address Indonesia's carbon emission problem. Pro-renewable and anti-fossil policy recommendations need to be considered to achieve the sustainable goal of reducing carbon emissions and dealing with climate change in Indonesia.

Keyword: Carbon Emissions, Renewable Energy, Coal, Oil

1. Introduction

Development is a collection of actions that includes many things, such as changing social structures, people's lifestyles, and institutions. The success of a country's economic development can be evaluated based on a number of social and economic factors (Zheng et al., 2019). Economic growth means that the development of economic activities increases the distribution and production of goods and services in society, thereby increasing social welfare. Countries continue to get better at the production and distribution of goods and services. This improvement is due to the increase in the number and quality of logistics facilities and production factors. In the context of economic growth, the important role of industrialization lies in the fact that industrialization is the result or consequence of Production, distribution, and specialization have developed due to technological progress. Energy efficiency is one of the main issues in the energy sector today. This relates to rising energy costs, limited energy supplies, and initiatives to reduce greenhouse gas emissions. The environment is greatly affected by the increasing use of energy to industrialize and sustain human needs.

Carbon emissions are a component of overall greenhouse gas emissions produced over time by individuals or groups. Carbon emissions are expressed in tons of CO2 equivalent (tCO2e) or kilograms of CO2 equivalent (kgCO2e) (D Ratnawati, 2016). The United Nations Framework Convention on Climate Change (UNFCCC) defines carbon emissions as the release of greenhouse gases into the atmosphere that contribute to the greenhouse effect and global climate change. This definition of carbon emissions takes into account the fact that the main cause of climate change is human activity, particularly the burning of fossil fuels and unsustainable land use. Reducing carbon emissions is one of the main goals in efforts to mitigate climate change and achieve environmental sustainability.

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The use of renewable energy refers to the utilization of energy sources derived from renewable sources such as solar, wind, water, biomass, geothermal, and so on (Chandra Voumik et al., 2023). Energy is a crucial element in achieving lasting development (Khan et al, 2020). Global energy has undergone various transformations over time, initially dominated by the use of biomass, such as firewood, to meet energy needs. Subsequently, there has been a shift in focus towards energy sources, as fossil fuels such as coal, oil, and natural gas have received much attention since the industrial revolution of the 20th century (Setyono, A. E., & Kiono, B. F. T, 2021). Renewable energy is a non-fossil energy that is easy to renew and manage; therefore, renewable energy sources remain sustainable. Types of renewable energy include the utilization of resources such as geothermal energy, hydro power, solar power, wind power, biomass, ocean energy, fuel cells, and nuclear power.

Coal is a significant energy commodity in Indonesia, with a history of mining that dates back to the Dutch colonial era. The first coal exploitation was carried out by the Dutch on Kalimantan Island and Sumatra Island, and now these two islands are the leaders in the coal production sector in Indonesia. (Hartana H, 2017). While coal has been a major source of energy for decades, its use is increasingly criticized for its contribution to carbon emissions and its impact on climate change (Jiang et al., 2019).

Oil is a primary energy source that supports various economic activities of people, businesses, and industries. In particular, oil is essential for industrial production processes as it powers machinery, generates electricity and transports goods to customers (Rahmawati A, 2021). However, the use of oil as an energy source also contributes significantly to climate change by emitting greenhouse gases, especially carbon dioxide (CO2) (Alkhathlan & Javid, 2015). Therefore, various efforts have been made globally to move away from oil and towards sustainable energy sources such as renewable energy, with the aim of reducing its negative impact on the environment.

This research focuses on renewable energy, coal and oil consumption as the main independent variables affecting Indonesia's carbon emissions. This research can provide new insights and a deeper understanding of the relationship between energy consumption and carbon emissions. Indonesia, a developing country with rapid economic growth, faces serious challenges related to carbon emissions. In recent years, Indonesia has seen a significant increase in energy consumption, including renewable energy, coal and oil. Therefore, it is crucial to analyze the factors that influence Indonesia's carbon emissions. The aim is to identify appropriate policies and initiatives to lower carbon emissions.

Against this background, this research focuses on providing a knowledge base for developing effective policies to reduce carbon emissions and promote sustainable development in Indonesia. This research is expected to contribute to the establishment of sustainable environmental policies. It can also be used as a basis for the government, non-governmental organizations and the private sector to develop effective carbon reduction strategies in Indonesia. As a result, this research can help Indonesia achieve its carbon emission reduction targets while supporting global initiatives to combat climate change.

2. Research Method

A quantitative analysis approach was used in this research. To calculate changes in carbon emission levels, researchers used a formula based on the consumption of renewable

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energy sources, coal and oil, while causality analysis involves determining the extent to which changes in one variable can influence changes in another. This method helps to understand how the consumption of renewable energy, coal, and oil contributes to the increase or decrease of carbon emissions in Indonesia. The object of this research includes data on carbon dioxide (CO2) emissions, renewable energy consumption, coal consumption, and oil consumption in Indonesia during the period 2000-2022. The reason for the selection of the year period is on the basis of complete available data and support related to similar research to support research at the national level. Furthermore, Indonesia was used as a research location because it is among the top ten highest CO2 emitters in the world, mainly because most of the country's energy comes from fossil fuels. According to data from the European Commission, Indonesia will be the 7th largest emitter in the world by 2022. In addition, Indonesia is part of the 2016 Paris agreement. Thus, in order for Indonesia to achieve the goals of sustainable economic development and environmental protection, this research is needed to monitor Indonesia's obligations under this agreement and understand the impact of renewable and non-renewable energy consumption on carbon emissions.

This research uses secondary data. Information on carbon emissions, coal, and oil was taken from the Our World in Data website. After that, data on renewable energy use was taken from the World Bank website. In addition, time series data from 2000 to 2022 is also used in this research.

Table 1. Variable Operationalization

Name Variable	Symbol	Data Objects	Data Sources
Carbon Emissions (Y)	CO_2	Total annual emissions (Million tons)	Our World in Data
Renewable Energy Comsumption (X_1)	REC	Amount of energy consumed from renewable energy sources (% of total consumption)	The World Bank
Coal Comsumption (X_2)	CC	Total coal consumed (TWh)	Our World in Data
Oil Comsumption (X_3)	OC	Total oil consumed (TWh)	Our World in Data

Sources: processed by the author, 2023

To get a clear picture of the relationship between the research variables, through the use of the E-Views application, the author applies multiple linear regression techniques and quantitative analysis using econometric models. The following is the multiple linear regression model equation:

$$CO_2 = \beta_0 + \beta_1 REC + \beta_2 CC + \beta_3 OC + e$$

Notes:
Y : Carbon Emissions (CO_2)
β_0 : Constant/Intersep
$\beta_1, \beta_2, \beta_3$: Regression Coefficient
REC : Renewable Energy Comsumption

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CC : Coal Comsumption
OC : Oil Comsumption
e : Error

Testing for classical assumption deviations is necessary to produce a model that is BLUE (Best Linear Unbiased Estimator) or provides unbiased results. If a research model passes the standard regression assumption test (autocorrelation, heteroscedasticity, multicollinearity, and normality), it will theoretically produce appropriate parameter estimates.

A significance level of 5% (0.05) is applied to statistical tests to determine the effect of the independent variable on the dependent variable. The statistical techniques used in this research are simultaneous test (F-test) and partial test (t-test). The partial test (t-test) is used to verify the partial significance between the independent variable and the dependent variable, assuming that the other independent variables remain fixed. Meanwhile, the simultaneous test (F-test) is used to determine the effect together (simultaneously) of each independent variable in the model on the dependent variable. If the significance of t is smaller than 0.05, then the independent variable partially affects the dependent variable, and vice versa. This condition also applies to the simultaneous test: if the F significance value is smaller than 0.05, then all independent variables together have an effect on the dependent variable (Nafiudin et al., 2021).

The value outside the coefficient of determination can be explained by variables that are not included in the model, while the coefficient of determination according to Sari et al. (2019) shows how well the independent variable can explain the dependent variable.

3. Results and Discussion

A. Results

Multiple Linear Regression Model Test

Table 2. Multiple Linear Regression Test Results

Variable	Coefficient	t-Statistic	Prob.
C	3.532548	4.985202	0.0001
Renewable Energy	-0.017437	-8.896382	0.0000
LogCoal	0.203789	6.365220	0.0000
LogOil	0.289486	2.848797	0.0103
Adjusted R-squared	0.989743	Durbin-Watson stat	1.452404
F-statistic	708.6004		
Prob (F-statistic)	0.000000		

Sources: processed by the author, 2023

The research model was estimated from the data using the EViews application program, and the estimate can be seen in the regression equation as follows:

$$CO_2 = 3.532548 - 0.017437\ REC + 0.203789\ LogCC + 0.289486\ LogOC + e$$

The coefficient value of 3.532548 in the regression equation above indicates that the level of carbon emissions (CO2) will be 3.532548 if the variables of renewable energy

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consumption (REC), coal consumption (CC), and oil consumption (OC) are held constant. Then, the coefficient for renewable energy consumption is - 0.017437. Assuming all other independent variables remain constant, this means that if renewable energy consumption increases by 1%, carbon dioxide (CO2) emissions will decrease by 0.017437. Furthermore, the coefficient of coal consumption is 0.203789. This means that carbon emissions (CO2) will increase by 0.203789 if coal consumption increases by 1% and all other independent variables remain the same. Furthermore, 0.289486 is the coefficient for oil consumption. Therefore, carbon emissions (CO2) will increase by 0.289486 if oil consumption increases by 1% and all other independent variables remain constant.

Classical Assumption Test

a) Normality Test

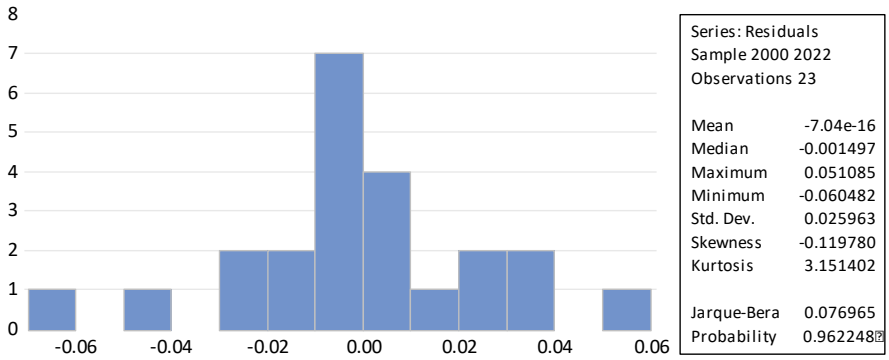

Figure 1. Normality test results (processed by EViews, 2023)

As shown in Figure 1, the output results of the normality test with a probability value of 0.962228, show that the probability value exceeds the significance value (0.05). It can be concluded that this research data is normally distributed.

b) Multicollinearity Test

Table 3. Multicollinearity Test Results

Variable	Centered VIF
C	NA
Renewable Energy	8.123899
LogCoal	7.391452
LogOil	3.081363

Sources: processed by the author, 2023

The results of the multicollinearity test using the Variance Inflation Factor (VIF) value are shown in Table 3. Variables related to petroleum, coal, and renewable energy consumption have VIF values of 8.123899, 7.391452, and 3.081363, respectively. Since the VIF value between dependent variables is less than 10, it can be concluded that there is no multicollinearity.

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c) Heteroscedasticity Test

Table 4. Heteroscedasticity Test Results

Variable	Prob.
C	0.7486
Renewable Energy	0.4837
LogCoal	0.5280
LogOil	0.8992

Sources: processed by the author, 2023

The probability value is higher than the α = 0.05 level for the renewable energy consumption variable (X1), coal consumption variable (X2), and petroleum consumption variable (X3), in accordance with the results of the Glejser test used to test heteroscedasticity. The values of each variable are 0.4837, 0.5280, and 0.8992. Therefore, it can be concluded that the data does not experience heteroscedasticity.

d) Autocorrelation Test

Table 5. Autocorrelation Test Results

Breusch-Godfrey Serial Correlation LM Test:			
Obs*R-squared	4.385913	Prob. Chi-Square	0.1116

Sources: processed by the author, 2023

The results of the LM test, which is used to measure autocorrelation, show that the Chi-Square probability value is 0.1116. Since this value is higher than the alpha threshold of 0.05, there is no autocorrelation symptom.

Statistical Test

a) Partial Test (t Test)

Table 6. Partial Test Results

Variable	t-Statistic	Prob.
C	4.985202	0.0000
Renewable Energy	-8.896382	0.0000
LogCoal	6.365220	0.0000
LogOil	2.848797	0.0103

Sources: processed by the author, 2023

Table 6 shows that although the variables in this research have relationships with different directions, both the amount of renewable energy consumed, the amount of coal consumed and the amount of oil consumed have a significant impact (0.0000) on Indonesia's carbon emissions. The renewable energy consumption variable has a negative relationship of -

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8.896382, so any increase in this variable will result in a significant decrease in carbon emissions. In contrast, there is a positive correlation of 6.365220 between the coal consumption variable and carbon emissions, indicating that an increase in coal consumption will lead to an increase in carbon emissions. Furthermore, it was found that the relationship for the oil consumption variable is positive 2.848797, meaning that any increase in oil consumption will increase carbon emissions in Indonesia during the period under research.

b) Simultaneous Test (Test f)

Table 7. Result Simultaneous Test

F-statistic	708.6004
Prob (F-statistic)	0.000000

Sources: processed by the author, 2023

The regression results of the variables related to coal, oil, and renewable energy consumption on carbon emissions (CO2) are shown in Table 7. The F-count value obtained is 708.6004 and the probability is smaller than α (0.000000 < 0.05). When comparing the F-count and F-table values, the F-count value (708.6004 > 3.13) is higher than the F-table. So, it can be concluded that, from 2000 to 2022, the variables of renewable energy consumption, coal, and petroleum jointly affect carbon dioxide (CO2) emissions in Indonesia because the F-count value is greater than the F-table and the significance value is smaller than 0.05.

Test Coefficient of Determination (Adjusted R2)

Table 8. Determination Coefficient Test Results

Adjusted R-squared	0.989743

Sources: processed by the author, 2023

The Adjusted R-squared value in Table 8 of 0.989743 indicates that the independent variables can explain 98% of the variation in the dependent variable. Therefore, it can be concluded that the relationship between the independent variables of renewable energy consumption, coal, and oil can be used to predict the amount of carbon emissions (CO2) in Indonesia. The remaining 2% (100% - 98%) is influenced by additional variables that are not included in this research model.

B. Discussion

Effect of Renewable Energy Consumption on Carbon Emissions (CO2)

The research found that from 2000 to 2022, Indonesia's carbon (CO2) emissions were significantly affected by the use of renewable energy sources in the direction of a negative relationship. This means that if the consumption of renewable energy increases, the level of carbon emissions over the same period will decrease. The results of this research support the research of Xiao Liu, Qianniu b, Shuli Dong, and Shuiying Zhong (2023), which shows that renewable energy consumption significantly reduces carbon intensity and carbon emissions per capita in China. The results of this research are also in line with the expectations of the Energy

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Transition Theory, a concept that has evolved over time and involves contributions from various researchers, scientists, activists, and experts in various fields. According to S&P Global (2020), this theory states that by switching from fossil fuels to renewable energy sources such as solar, wind and water energy, we can significantly reduce carbon emissions.

Renewable energy sources such as solar, wind and water energy produce no carbon emissions when generating electricity or heat energy (Chandra Voumik et al., 2023). Solar panels convert sunlight into electricity, while wind and water turbines generate electricity through the movement of wind and water. There is no fuel combustion that emits carbon dioxide in this process, which is a major cause of carbon emissions such as from burning coal or oil. Given that the main source of CO2 emissions is the energy sector, the consumption of renewable energy has a significant impact on reducing CO2 emissions. Using renewable energy to generate electricity and meet other energy needs can significantly reduce emissions in this sector.

One of the main sources of carbon emissions is Indonesia's dependence on fossil fuels such as coal and oil to meet its energy needs. As a result, Indonesia's dependence on fossil fuels such as coal and oil will decrease as the use of renewable energy increases. Carbon emissions from burning fossil fuels can be greatly reduced if renewable energy sources are used instead of fossil energy sources (Chandra Voumik et al., 2023). However, like many other countries, renewable energy consumption in Indonesia is increasing and, if implemented correctly and in large quantities, has the potential to reduce CO2 emissions. The increase in renewable energy consumption must be accompanied by a decrease in coal consumption in the energy sector. In addition, we also need to use renewable energy significantly to replace fossil fuels (Zheng et al., 2019). The impact on CO2 emissions will be limited if renewable energy is only used to complement an energy mix that is still dominated by fossil fuels.

By 2030, Indonesia wants to reduce carbon emissions by 29%, and with help from abroad, that number could increase to 41% (Suzzane, The Guardian 2015). Consuming renewable energy is one of the key elements needed to achieve this goal. Given that Indonesia has one of the highest levels of carbon emissions due to its reliance on fossil fuels, especially coal, increasing renewable energy consumption in Indonesia is crucial to lowering carbon emissions, especially since this research also found a highly significant correlation between carbon emissions and renewable energy consumption. With an abundance of renewable energy sources-solar, wind, water, and biomass-Indonesia has a lot of potential to increase renewable energy consumption (EBTKE PR, 2022). With year-round tropical weather, Indonesia has enormous solar energy potential. Indonesia also has a lot of potential for wind power and hydropower. Therefore, Indonesia should be able to maximize its renewable energy potential.

Effect of Coal Consumption on Carbon Emissions (CO2)

According to the findings of this research, Indonesia's carbon (CO2) emissions from 2000 to 2022 are significantly influenced by coal consumption with a positive slope. This implies that as coal consumption increases, the amount of carbon emissions will also increase in the same time period. The findings of this result are consistent with the research of Jalu Aldho Fajar Prasetyo (2023), which showed a positive correlation and significant effect of coal consumption on carbon emissions. The results of this research have also been in accordance with the expectations of Svante Arrhenius' theory of "Climate Change Theory". Miguel Barral (2019), argues that Arrhenius was one of the first scientists to link the consumption of fossil fuels including coal with the increase in CO2 concentration in the atmosphere.

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Increased coal consumption can result in increased carbon (CO2) emissions because one of the fossil energy sources with the highest carbon intensity is coal. This is especially true if coal is used for power generation, industry, and transportation (Ronald Sofyan G.S. Sipayung, 2023). Indonesia itself still relies heavily on coal-fired power plants to meet its needs, especially since Indonesia is listed as one of the countries with sizable coal reserves and coal is still a relatively cheap energy source, so Indonesia's coal consumption is still quite high, even though Indonesia has also committed to reducing carbon emissions within the framework of the Paris agreement, which requires countries to reduce their emissions. Coal consumption in Indonesia has a significant impact on the country's carbon emissions. Moreover, Indonesia is one of the largest coal users in the world. In fact, according to Happy Fajrian, quoted from data from the Ministry of Energy and Mineral Resources, Indonesia's coal consumption will increase by 33% by 2022, setting a record for the highest emissions from coal.

Due to its abundant coal resources, especially on the islands of Kalimantan and Sumatra, Indonesia is the highest producer and consumer of coal (MEMR, 2021). Coal is a widely used fossil fuel in Indonesia, especially for steam power plants. The process of burning coal produces significant carbon dioxide (CO2) emissions, as coal contains the element carbon. When coal is burned, the carbon reacts with oxygen from the air, producing CO2. These CO2 emissions are released into the atmosphere as greenhouse gases. The higher the coal consumption, the more CO2 is produced from the combustion process (Jiang et al., 2019). Therefore, because Indonesia still relies heavily on coal power plants, its coal consumption is still high and that is followed by the high carbon emissions it produces. On the other hand, Indonesia has actually realized that the influence of coal consumption reflects the complexity of the challenges of climate change and clean energy transition. The Indonesian government has launched a program to increase renewable energy capacity, namely the construction of solar and wind power plants in various regions. One such project is the largest solar power plant, with a capacity of 5 MWp, located in Kupang, East Nusa Tenggara. This is because increased coal consumption directly contributes to increased carbon emissions. (D. Y. Manurung et al., 2022).

Effect of Oil Consumption on Carbon Emissions (CO2)

According to the findings of this research, Indonesia's carbon (CO2) emissions from 2000 to 2022 will be significantly affected by oil consumption in the direction of a positive relationship. This implies that as oil consumption increases, the amount of carbon emissions will also increase in the same time period. Research by Pradipta Galih Sekar Palupi, Masruri Muchtar, and Pardomuan Robinson Sihombing (2023) confirmed that there is a partially significant and positive relationship between oil consumption and carbon emissions, which is consistent with the findings of this research. In addition, the findings of this research support the theory. "the relationship between oil consumption and carbon emissions" as well as the theory of "Climate Change Theory". These theories explain that when oil consumption increases, carbon emissions will also increase significantly.

Oil is a carbon-containing fossil energy source. When oil is burned to produce energy, CO2 and other gases are produced as by-products. Therefore, the more oil consumed by society, industry and the transportation sector, the greater the increase in carbon emissions. This relationship is the basis of much research and analysis on the impact of oil consumption on climate change and global warming. Transportation is one of the most oil-intensive industries (Alkhathlan & Javid, 2015). Due to its large population and rapid economic growth, it drives a high demand for motorized vehicles in Indonesia. Fossil fuels such as gasoline and

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diesel are still widely used in cars in Indonesia, and when burned, they release carbon dioxide (Li et al., 2021). In addition, the industry is one of the main sources of carbon emissions. Many industries rely on energy from crude oil and natural gas to operate. Increased industrial activity and the expansion of these sectors also means increased oil consumption, which impacts CO2 emissions. Burning fossil fuels, such as oil, releases carbon dioxide into the atmosphere as a by-product. Since carbon emissions are directly correlated with oil consumption, higher oil consumption will result in higher carbon emissions as well. In addition, the use of oil in electricity production can increase carbon emissions, especially if conventional fossil fuels or less efficient power generation technologies are used.

It is important to emphasize that higher carbon emissions are generated not only when burning oil but also throughout its entire life cycle, from extraction and production to distribution and end-use. These operations can also result in the release of other greenhouse gases, such as methane, during the oil extraction process. Therefore, efforts need to be made to reduce dependence on oil as the main source of energy and a number of factors related to the overall environmental impact of increased oil consumption must be taken into account. Indonesia needs to create an energy policy that emphasizes improving energy efficiency, promoting renewable energy, and diversifying energy sources to reduce the adverse environmental impact of increased oil consumption. These actions are in line with international efforts to combat climate change and lower carbon emissions and promote environmental sustainability.

4. Conclusion

The conclusion of this research supports the notion that there is a significant inverse relationship between carbon emissions and renewable energy use. This implies that carbon emissions will decrease as more renewable energy is used. This is because renewable energy sources do not produce carbon emissions when generating electricity or heat energy. On the other hand, it has been shown that coal consumption positively and significantly affects carbon emissions. In other words, carbon emissions increase proportionally with coal consumption. This is due to coal's characteristics as a highly carbon-intensive fossil energy source. On the other hand, oil consumption also proved to have a significant influence on carbon emissions. The significance is because when oil is burned to produce energy, CO2 and other gases are produced as by-products. These conclusions provide a foundation for formulating more effective policies to address Indonesia's carbon emission problem. Pro-renewable and anti-fossil policy recommendations need to be considered to achieve the sustainable goal of reducing carbon emissions and dealing with climate change in Indonesia.

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