THE INFLUENCE OF CLIMATE CHANGE AND ENERGY CONSUMPTION ON ECONOMIC GROWTH IN INDONESIA

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Abstract. Climate change and energy consumption are two important factors that can affect economic growth. This study aims to analyze the influence of climate change and energy consumption on Indonesia's economic growth. This study employs multiple linear regression on time-series data from 1992 to 2023 and finds that climate change and renewable energy consumption harm Indonesia's economic growth, whereas non-renewable energy consumption has a positive effect. The findings of this study confirm that the quality and resilience of electricity services can mediate the impact of climate change on the economy. When access is not accompanied by reliability, climate change can render such access fragile, thereby hampering economic growth. These findings imply the need for various efforts to reduce the vulnerability of the electricity system to climate shocks, the Government needs to encourage private capital participation and design incentives that focus on improving efficiency and innovation, combining energy transition policies with labor reskilling programs and technological incentives to maintain the long-term effects of renewable energy consumption to support growth sustainable economy, the need for a prudent energy transition strategy so that its short-term benefits can be transformed into the foundation of a sustainable energy transition, the Government can utilize the contribution of fossil energy to economic growth as capital to fund investments in renewable energy infrastructure so that it can reduce dependence on current non-renewable energy and strengthen renewable energy capacity in the future.

Keywords: climate change, renewable energy, non-renewable energy, economic growth

1. Introduction

Economic growth is one of the main indicators of a country's development, including Indonesia. However, in recent decades, economic growth has been inseparable from increasingly complex global challenges, including climate change and dynamics in energy consumption. Climate change, characterized by rising average temperatures, rainfall anomalies, and an increasing frequency of natural disasters, has placed significant pressure on productive sectors, including agriculture, industry, and energy infrastructure [1]. For developing countries such as Indonesia, the impacts of climate change may hinder the achievement of the Sustainable Development Goals (SDGs), particularly SDG 7 (Clean and Affordable Energy), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action).

On the other hand, energy consumption plays a dual role in economic development. Energy, both fossil and renewable, is an essential input for the production and distribution of goods and services. High energy consumption often correlates with higher economic output, particularly in countries with industrial structures that remain dependent on fossil fuels [2][3]. However, overreliance on nonrenewable energy poses a new dilemma, as it increases greenhouse gas emissions that exacerbate climate change [4]. Thus, there is a complex relationship among climate change, energy consumption, and economic growth that warrants a more in-depth empirical study in the Indonesian context.

Indonesia, as an archipelagic country with a large population and abundant natural resources, faces the unique challenge of balancing energy needs, economic growth, and environmental sustainability. Data from the Ministry of Energy and Mineral Resources [6] indicate that more than 85% of Indonesia's energy mix remains dominated by fossil fuels, despite increased investment in renewable energy. Meanwhile, Bappenas [7] noted that economic losses from climate-related disasters amount to trillions of rupiah annually, underscoring the urgency of research on this issue.

Based on this background, this study aims to analyze the influence of climate change and energy consumption on economic growth in Indonesia. Empirically, this research is expected to contribute to the literature on the relationships among climate, energy, and the economy, and to provide relevant policy inputs to support the energy transition and sustainable development in Indonesia.

Although the role of energy in supporting economic growth has been widely discussed in the literature, the relationship among energy consumption, climate change, and economic growth in Indonesia remains a broad area for study. First, most prior studies have focused primarily on the relationship between energy consumption and carbon emissions, without explicitly linking these to the impact of climate change on the economy. Second, Indonesia's continued dependence on fossil fuels creates a dilemma between short-term economic growth and long-term environmental sustainability. Third, although access to electricity continues to increase, the vulnerability of energy infrastructure to climate change could reduce productivity and economic performance.

Thus, there is a research gap in understanding how climate change and energy consumption simultaneously affect economic growth in Indonesia. This gap warrants research to inform policy recommendations that balance the interests of economic development and climate change mitigation.

Based on the formulation of the above problem, the research questions asked are as follows:

(1) How does climate change affect economic growth in Indonesia? (2) How does energy consumption, both renewable and non-renewable, affect economic growth in Indonesia? (3). What policy implications can the Indonesian Government take in order to maintain a balance between economic growth, energy security, and environmental sustainability?

This research aims to analyze the influence of climate change and energy consumption on economic growth in Indonesia, thereby providing an empirical basis for formulating sustainable development policies.

The benefits of academic research are (1) making an empirical contribution to the literature on the relationship between climate change, energy consumption, and economic growth in developing countries, especially Indonesia; (2) to be a reference for further research in examining the issues of energy transition and sustainable development with quantitative and policy perspectives. Meanwhile, the practical benefits expected from this study are: (1) providing input for the Indonesian Government in formulating economic development strategies that are adaptive to the impacts of climate change; (2) provide empirical evidence to support energy policy formulation, particularly in managing the transition from fossil energy to renewable energy without compromising the stability of economic growth; (3) to be a basis for consideration for stakeholders, such as energy industry players, research institutions, and civil society organizations, in supporting the sustainable development agenda and achievement of SDGs targets.

2. Methods

This research is quantitative. The data used in this study pertains to economic growth, climate change, renewable energy, and non-renewable energy for the period 1992-2023. The data for this research are sourced from the World Bank and the World Energy database. The analysis technique used is multiple linear regression. Specifically, the formula in this study is

$$PE = PI_t + EBT_t + ETBT_t + e \text{...} (1)$$

Information:
PE: Economic Growth (%)
PI: Climate Change (%)
NRE: Renewable Energy (%)
ETBT: Non-Renewable Energy (Terawatt-Hours)
The indicators used in this study are as follows:

Variable	Indicator
Economic growth	Economic growth of Indonesia (%)
Climate change	Population that accesses electricity (%)
Renewable energy	Hydropower electricity consumption (%)
Non-renewable energy	Primary energy consumption consisting of coal, uranium, and petroleum (terawatt-hours)

To obtain the best estimates from variables with different units, data transformation is performed. In this study, the non-renewable energy variable was transformed in the form of Natural Logarithm (Ln) because the initial unit of the variable is not in the form of percentages. In detail, the data transformation formula in this study is as follows:

$$\boldsymbol{PE = PI_t + EBT_t + LnETBT_t + e} \text{...} (2)$$

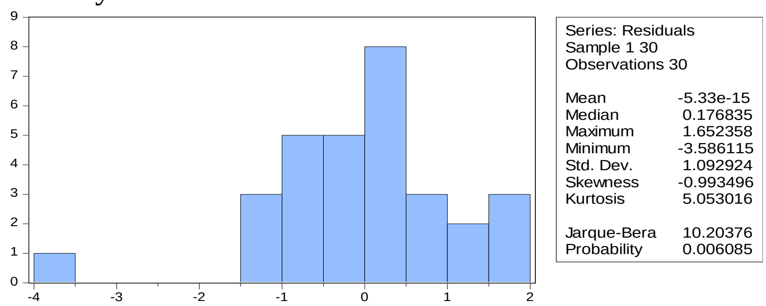
3. Results And Discussion

3.1. Data Analysis Results

To obtain a valid model that meets the characteristics of the Best Linear Unbiased Estimator, a classic assumption test is first performed.

1) Classic Assumption Test

a. Normality Test



Source: Data Processed, 2025

Figure 1. Normality Test

Figure 1 shows a *p-value of 0.006 < 0.05, indicating* that the data in this study did not pass the normality test. Although it did not pass, the data in this study can be considered *random* because the number of research objects is ≥30 (Sahab, 2019).

b. Multicollinearity Test

To identify the presence or absence of multicollinearity, use the VIF values shown in Table 1.

Table 1. Multicollinearity Test

Variable	VIF
PI	9,143
EBT	1,507
ETBT	8,085

Source: Data Processed, 2025

Table 1 shows that all VIF values for the independent variables are < 10, indicating that the data in this study are free of multicollinearity [8].

c. Heteroscedasticity Test

To identify the presence or absence of symptoms of heteroscedasticity, use *the Heteroskedasticity Test: Harvey* as seen in Table 2.

Table 2. Heteroscedasticity Test

Heteroskedasticity Test: Harvey			
Scaled explained SS	6,007	*Prob. Chi-Square*	0,111

Source: Data Processed, 2025

Table 2 shows a chi-square probability of 0.111 for the Scaled explained SS, which is > 0.05, indicating that the research model passed the heteroscedasticity test. [8].

d. Autocorrelation Test

To identify the presence or absence of symptoms of multicollinearity, using *the Breusch-Godfrey Serial Correlation LM Test value*, as seen in Table 3.

Table 3. Autocorrelation Test

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0,251	*Prob. F(2,24)*	0,779
*Obs*R-squared*	0,615	*Prob. Chi-Square(2)*	0,735

Source: Data Processed, 2025

The *value of the prob chi-square(2)* in Table 3 is 0.735 > 0.05. This means the research model passed the autocorrelation test.

2) Estimated Output

Based on the results of the data calculation using multiple linear regression, see Table 4.

Table 4. Multiple Linear Regression

Variable	*Coefficient*	*t-Statistic*	*Prob.*
C	-7,525	-0,936	0,357
PI	-0,200	-3,731	0,000**
EBT	-1,090	-1,999	0,056*
LNETBT	4,538	2,742	0,010**

Source: Data Processed, 2025

Note: **=significant at α = 1%, * = significant at α = 10%,

Based on the results of multiple linear analyses in Table 4, the following are the results of the data interpretation:

a) The climate change coefficient (PI) is -0.200, significant at the 1% level, indicating that a 1% increase in climate change is associated with a 0.200% decrease in economic growth.
b) The renewable energy coefficient (NRE) is -1.090, α = 10%, which means that when renewable energy increases by 1 percent, economic growth decreases by 1.090 percent.

c) The non-renewable energy coefficient (ETBT), valued at 4.538, $\alpha = 1\%$, implies that a 1 percent increase in non-renewable energy is associated with a 1.090 percent increase in economic growth.

The results of the joint test (F-statistics) for the dependent variables against the independent variables are shown in Table 5.

Table 5. F-Statistics Test

F-statistic	5,605
Prob(F-statistic)	0,004

Source: Data Processed, 2025

Based on Table 5. The P-value is 0.004 < 0.05, indicating that all independent variables together have a significant effect on the dependent variables.

3) Coefficient of Determination

The coefficient of determination was calculated to assess the extent to which the independent variables explain changes in the dependent variable. The results of the calculation are presented in Table 6.

Table 6. Coefficient of Determination

R-squared	0,392
Adjusted R-squared	0,322

Source: Data Processed, 2025

Table 6 shows that the R-squared is 0.392, indicating that the independent variables account for 39.20 percent of the variance in the dependent variable.

3.2. Discussion

a. The influence of climate change on economic growth

Climate change indicators (measured by the percentage of the population that has access to electricity) negatively affect economic growth. This means that climate change is degrading the quality and/or reliability of electricity access (or making its expansion more expensive/fragile), and this effect is depressing economic productivity**.** In other words, it is not only the number of people with access to electricity but also how climate change affects the availability, stability, and cost of electricity services, which, in turn, reduces economic activity.

These findings also confirm the critical role of electricity supply reliability and resilience in supporting economic activity. Climate change increases the risk of infrastructure damage, increases peak loads (cooling demand), and reduces the output of natural resource-based plants, resulting in blackouts and higher production costs. Therefore, policy steps must focus on *climate-proofing* the grid, increasing storage capacity, diversifying energy sources, and strengthening adaptation financing mechanisms so that expanding access to electricity truly provides sustainable economic benefits.

The findings can also be explained by the mechanisms of resilience and the quality of electricity services. First, climate change increases the frequency and intensity of extreme events (floods, storms, heat waves, droughts) that damage generation, transmission, and distribution infrastructure; As a result, there are supply disruptions and significant repair costs, so that the productivity of the energy-intensive sector decreases [9]. Second, heat waves increase cooling demand and strain network operations, thereby increasing the risk of outages during peak hours and causing economic losses [10][11]. Third, countries or regions that depend on hydrological plants experience a decrease in output during droughts, which reduces electricity supply and makes production difficult [12]. Fourth, the indicator of "share of population connected" does not necessarily reflect reliability or affordability; If connectivity is high but reliability is low, the economic benefits of such access are small or even negative [13].

Overall, these empirical results confirm that the quality and resilience of electricity services often mediate the impact of climate change on economies. When access is not backed by reliability, climate change can make that access fragile, thereby stifling growth. Therefore, further analysis should include reliability indicators (frequency & duration of blackouts) and direct climate variables (temperature anomalies, extreme rainfall) to test the mechanistic channel [9][14]. Recommended policies include *climate-proofing* infrastructure, diversification of energy sources and storage capacity, ring-fencing network adaptation funding, and demand-side management programs to reduce peak loads — measures that have been proven to reduce the vulnerability of power systems to climate shocks and safeguard the economic benefits of expanded access to electricity [15][4][11].

b. The effect of renewable energy consumption on economic growth

The study's results show that renewable energy consumption negatively affects economic growth, a phenomenon that can be explained by several mechanisms. First, an Initial investment in renewable energy development generally entails high costs, including power generation infrastructure, energy storage, and smart power grids. Allocated funding for this need can suppress other productive investments in the short term, thereby reducing economic performance [16]. Second, the intermittent nature of solar and wind energy can incur additional costs to maintain supply stability. Without support from storage technologies and network reinforcement, this supply variability can disrupt the operations of the energy-intensive sector and reduce productivity [17].

In addition to technical and financing factors, negative outcomes can also be related to policies and energy consumption structures themselves. Subsidies and incentives that are not on target often create distortions in energy prices and fiscal burdens, thereby reducing the optimal positive impact of renewable energy consumption on the economy [18]. Furthermore, the composition of the renewable energy used also affects the results. In many developing countries, renewable energy remains dominated by traditional biomass, which is associated with low productivity and potential environmental degradation, so its contribution to growth is negative [19]. These findings also align with cross-border empirical evidence indicating that the relationship between renewable energy consumption and growth is heterogeneous, depending on energy structure, technological capacity, and institutional quality [19].

Thus, negative results do not mean that renewable energy is not worth pursuing; rather, they underscore the importance of *sequencing* and *complementary policies*. The Government needs to accelerate investment in the electricity grid and storage technologies, encourage private capital participation to avoid crowding out fiscal space, and design incentives that focus on improving efficiency and fostering innovation**.** Selain itu, Energy transition policies should be combined with labor *reskilling* programs and technology incentives so that the long-term effects of renewable energy consumption continue to support sustainable economic growth [16][17]. Recent studies indicate that renewable energy consumption can negatively affect economic growth when the share remains low or has not exceeded *a certain* threshold [20][21][22] Similar results were shown in the analysis of a panel of developing countries, where infrastructure limitations and integration costs make the effects of renewable energy counterproductive to growth [23].

The influence of non-renewable energy on economic growth

Research findings indicating that non-renewable energy consumption (NREC) has a positive effect on economic growth are consistent with empirical studies at both national and international levels. These findings can be explained through several key mechanisms.

First, fossil fuels (petroleum, natural gas, and coal) remain the most reliable energy sources, providing a continuous, relatively low-cost supply, particularly in developing countries. Stable energy availability enables energy-intensive industrial sectors, such as manufacturing, steel, cement, and petrochemicals, to operate at full capacity, thereby driving output growth and job creation. A cross-border panel study conducted by *Energies* (2022) shows that fossil energy consumption is positively correlated with economic growth, especially in developing countries where the energy mix is still dominated by fossil fuels [24].

Second, non-renewable energy consumption is closely related to the industrialization phase. Many studies emphasize that the increase in fossil fuel consumption is a consequence of industrial expansion and increased export capacity. This is evident in the ASEAN region, including Indonesia, which remains heavily dependent on coal to meet industrial electricity needs. The *Financial Times* report (2024) highlights that although the energy transition is underway, many developing countries still rely on fossil energy to support their economic expansion [25].

Third, the fossil energy sector also makes a significant contribution to state fiscal revenue through taxes, royalties, and energy commodity exports. This revenue plays an important role in financing infrastructure development and public investment programs that contribute to economic growth. [26][27], in a study conducted in Indonesia, found that non-renewable energy consumption has a positive impact on long-term economic growth, while renewable energy consumption has the opposite effect. Thus, fossil energy consumption not only functions as a production input but also as a source of development financing.

However, these positive relationships are both contextual and temporal. Some studies emphasize that although NRECs provide a short-term boost to economic growth, in the long term these effects can entail trade-offs due to increased costs associated with environmental externalities, such as CO_2 emissions and environmental degradation. Studies conducted by Environmental Science (2024) indicate that Indonesia's data for the period 1965–2022 confirm that non-renewable energy contributes to growth but also worsens the country's ecological footprint [28]. Therefore, the results of this study should be understood as evidence that fossil energy remains the primary engine of economic growth today, but that it requires a careful transition strategy to transform its short-term benefits into the foundation for a sustainable energy transition.

The policy implication of these results is the need for a *sequencing* strategy in the energy transition. The Government can leverage the contribution of fossil fuels to growth and state revenues as capital to fund investments in renewable energy infrastructure, energy storage, and improvements in the power grid's reliability. Thus, the reliance on non-renewable energy that drives growth today can be gradually shifted to strengthen future renewable energy capacity. This approach will ensure that economic growth is not sacrificed in the transition process to sustainable development.

c. Policy Recommendations

The study's results, which show a negative effect of renewable energy consumption on economic growth, indicate that Indonesia's energy transition still faces several structural challenges. Relatively high investment costs, limited power grid infrastructure, and delays in mastering technology have prevented renewable energy from making an optimal contribution to economic growth. Therefore, more adaptive, gradual policies are needed to ensure the energy transition continues to support sustainable development.

First, the Government needs to strengthen fiscal incentives and financing schemes for the renewable energy sector to reduce production costs, which remain high. Targeted subsidies, feed-in tariffs, and access to low-interest credit can accelerate the competitiveness of renewable energy relative to fossil fuels. Second, the development of supporting infrastructure, such as smart grids and energy storage technologies, must be accelerated to enable more efficient integration of renewable energy into the electricity system without compromising supply stability.

In addition, the energy transition policy should be implemented gradually while maintaining a balanced energy mix. Low-emission fossil fuels, such as natural gas, can still be harnessed in the medium term as a counterbalance, while simultaneously increasing research capacity, technological innovation, and human resource skills in clean energy. Thus, the energy transition is not only oriented towards reducing emissions, but also encouraging the creation of new jobs and green industrialization.

Overall, a more measurable, incentive-based, and technology-driven energy transition strategy can reduce the short-term negative impact of renewable energy on economic growth. This approach will ensure that environmental sustainability goals remain achieved without sacrificing the national economic growth agenda.

Evidence from other countries indicates that the negative impact of renewable energy on economic growth can be mitigated through appropriate policy design. For example, China has significantly reduced the cost of renewable energy through subsidies for solar panel technology and massive support for research and development (R&D). This makes the renewable energy industry not only an energy provider but also a driver of national industry growth [20].

In Germany**,** the energy transition (*Energiewende*) is being implemented in stages, with the establishment of stable feed-in tariffs and guaranteed electricity prices for renewable energy. This policy provides certainty for investors while creating new jobs in the green energy sector. However, Germany also maintains a balanced energy mix by retaining natural gas as a transitional energy source until renewable energy capacity can fully sustain the system [29].

Meanwhile, India is implementing a renewable energy zones model, with the construction of specialized electrical infrastructure in areas with renewable energy potential. This strategy reduces logistics costs, accelerates integration into the national power grid, and attracts large-scale private investment [15].

Lessons from these countries indicate that Indonesia needs to combine fiscal incentives, infrastructure development, and gradual transition strategies. Thus, the short-term negative impact of renewable energy on economic growth can be minimized while ensuring the long-term achievement of the Sustainable Development Goals. A comparative synthesis of the differences and similarities in strategies across countries is presented in Table 7.

Table 7. Comparative Synthesis Table of Differences and Similarities of Strategies Between Countries

Country	Key Strategies	Policy Instruments	Impact on the Economy	Lessons for Indonesia
China	Renewable energy technology subsidies	Fiscal subsidies, R&D support, and solar panel industry development	Reducing production costs, renewable energy is the engine of industrial growth	The importance of targeted subsidies and research support to make renewable energy more competitive
Germany	*Energiewende* (gradual transition)	Feed-in tariffs, guaranteed electricity prices, and an energy mix with natural gas	Climate stability investment, green job creation, sustained growth	The transition needs to be gradual by maintaining a balance in the energy mix
India	*Renewable energy zones*	Special infrastructure development, integration into national networks, and private investment incentives	Reduced logistics costs, accelerated integration of renewable energy, and increased investment	The importance of dedicated infrastructure and private investment support for efficiency

The comparison table above shows that each country employs a different strategy to address the negative impact of renewable energy on economic growth. China emphasizes subsidies and research support to reduce production costs; Germany is pursuing a gradual transition through feed-in tariffs and energy mixes; and India focuses on building dedicated infrastructure to accelerate the integration of renewable energy.

From this experience, an important lesson for Indonesia is that the energy transition cannot be achieved with a single approach. Indonesia needs to combine subsidies and fiscal incentives to reduce costs, build more efficient energy infrastructure, and implement a gradual transition strategy that balances low-emission and renewable energy sources. Thus, short-term negative impacts can be minimized while the long-term benefits of renewable energy for economic growth are realized.

4. Conclusion

The study's results show that renewable energy consumption continues to have a negative impact on economic growth in Indonesia. These findings indicate that the energy transition is not yet fully prepared to support optimal economic development, particularly due to high investment costs, limited infrastructure, and low technological capacity. Therefore, the energy transition needs to be designed more strategically so that it is not only oriented towards reducing emissions, but also making a real contribution to national economic growth.

Policy recommendations include strengthening fiscal and financing incentives to reduce the cost of renewable energy, accelerating the development of supporting infrastructure such as smart grids and energy storage, and maintaining an energy mix strategy by utilizing low-emission fossil fuels as a transition fuel. In addition, expanding research, technological, and human resource capacity in the clean energy sector should be prioritized to reduce production costs and enhance competitiveness.

International learning also provides relevant guidance. China highlighted the importance of subsidies and research support to lower the cost of renewable energy, and Germany emphasized a gradual transition through feed-in tariffs and energy mix policies. At the same time, India accelerated the integration of renewable energy by establishing renewable energy zones. These practices can be adapted to Indonesia's context to ensure that the energy transition proceeds more effectively and sustainably.

Thus, the energy transition strategy in Indonesia needs to combine an incentive approach, infrastructure development, and a measurable, gradual transition. This approach will reduce the short-term negative impact of renewable energy on economic growth while ensuring that the Sustainable Development Goals are still achieved.

To mitigate these impacts, a more measurable energy transition strategy is needed, supported by fiscal incentives, energy infrastructure development, and the development of technological and human resource capacities. Lessons from China, Germany, and India indicate that targeted subsidies, a gradual transition to the energy mix, and the creation of special energy zones can be effective practices for Indonesia. With this combination of policies, the energy transition can support economic growth while realizing sustainable development.

5. Acknowledgement

The authors express their most profound appreciation and gratitude to the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia and Jenderal Soedirman University for supporting the research through the Higher Education Research Program. This research is supported by Research Contract No.14.595/UN23.34/PT.01/V/2025.

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