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Investment in New Renewable Energy: Contributions to the Economy, Environment, and National Resilience

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ABSTRACT

Investment in renewable energy (RE) is significantly contributing to economic growth, environmental sustainability, and energy resilience. This economic growth is achieved by creating jobs, reducing greenhouse gas emissions, and decreasing dependence on fossil fuels. Despite the significant RE potential in Indonesia, challenges such as pollution, limited infrastructure, and price fluctuations still hinder national independence. Therefore, this study aimed to analyze the short-term and long-term relationships between renewable energy investment (REI) and economic growth, environmental sustainability, and resilience in Indonesia using the ARDL model and time series data from 2002 to 2022. Based on the analysis, the results showed that there was a significant cointegration relationship between the variables, suggesting the potential of REI to strengthen national resilience and support the transition to more sustainable energy. This study made an important contribution to understanding the dynamics of REI in Indonesia, providing policy recommendations to optimize economic and environmental benefits.

Keywords: Renewable Energy Investment, Economic Growth, Environmental Sustainability, Energy Resilience, Autoregressive Distributed Lag
JEL Classifications: E22, F43, Q30, Q40, Q50

1. INTRODUCTION

Energy is essential to foster economic growth and maintaining environmental sustainability (Gyimah et al., 2023). However, the reliance on fossil fuels as a primary source has posed significant challenges, including increasing greenhouse gas emissions, climate change, and insecurity. In response to these challenges, the shift to renewable energy (RE) is a strategic alternative requiring optimization to tackle the difficulties posed by climate change and significant reliance on fossil fuels (IEA, 2020). Omri and Belaïd (2021) stated that RE could balance social, economic, and environmental goals, although there are technological, economic, and social barriers. These social and cultural barriers include skilled labor, public awareness, community resistance, and incomplete information (Seetharaman et al., 2019). The primary technological and economic impediments include limited institutional capacity (Adenle et al., 2017), misaligned regulations between central and regional governments hindering investment acceleration (Pambudi et al., 2023), as well as inadequate infrastructure and technology (Simarmata et al., 2014; Suroso et al., 2022). Funding is also another critical issue due to limited financial resources, low investor confidence, and insufficient fiscal and non-fiscal incentives (Adenle et al., 2017; Eleftheriadis and Anagnostopoulou, 2015; Yildiz, 2014; Sambodo et al., 2022; IRENA, 2022), compounded by fossil fuel subsidies that diminish the competitiveness of RE alternatives (IEA, 2022).

The significant reliance on imported fossil fuels threatens long-term energy stability and undermines national security, despite the government's commitment to enhancing the proportion of RE (Langer et al., 2021; IESR, 2024). Indonesia ranks 48th on the climate economy index, showing its susceptibility to the effects of climate change (Guo et al., 2021). Therefore, there is a need to examine the contribution of RE development investment to economic growth, environment, and resilience. This is because investment in RE development has started to increase since 2010, particularly in Indonesia.

Recent studies on renewable energy investment (REI) have shown a positive impact on economic growth and environment. Singh et al. (2019) found a correlation between RE production and economic growth in Asia. Meanwhile, Yan et al. (2024) showed that accelerating RE in G20 countries could reduce carbon emissions and import dependence. Raza et al. (2020) emphasized boosting investment could drive technological advancements and enhance national capacity to develop and implement sustainable solutions. Alkout (2024) and Solangi and Magazzino (2025) suggested that investing could economic growth and stability. Considering environment, Shahbaz et al. (2019) found that RE and foreign direct investment (FDI) contribute to reducing carbon emissions. In comparison, Sitthivanh and Srithilat (2022) and Xuan (2025) found that FDI could increase CO_2 emissions without sustainable regulations and incentives in certain countries in ASEAN. Lee (2013) showed that FDI played an important role in driving economic growth and increasing CO_2 emissions. This provided crucial insights for clean transition to achieve the growth of an environmentally friendly economy. Mahmood (2018) found a causal relationship between high demand and supply gaps reducing GDP, as observed in Pakistan. Based on the background, this study aimed to analyze the dual impacts of REI on environmental sustainability and energy resilience in Indonesia, providing practical policy recommendations to overcome barriers and unlock their full potential.

The objectives of this study include (i) to assess the impact of REI on environmental sustainability, particularly in mitigating carbon dioxide emissions, and (ii) to evaluate the role of REI in enhancing national resilience by decreasing reliance on fossil fuel imports to attain improved long-term energy resilience across Indonesia. This study is organized into five sections, where the introduction in Section 1 discusses the state of the art, including objectives and originality. Section 2 is a literature assessment on REI, economic growth, environment, and energy resilience. Section 3 describes the method in further depth, including the path analysis. Section 4 examines the results, while Section 5 gives conclusions and policy recommendations for the successful implementation of RE in Indonesia.

2. LITERATURE REVIEW

2.1. REI, Economic Growth, and Environmental Sustainability

REI plays a significant role in fostering economic growth by enhancing infrastructure, creating jobs, and improving efficiency. Bhuiyan et al. (2022) found that REI in developing countries positively impacted GDP by increasing sustainable electricity capacity. Similarly, Omri and Belaïd (2021) emphasized a significant reduction in reliance on fossil fuels while expanding access and stabilizing prices. Kerrouche and Zehri (2024) found positive impacts on GDP growth, capital inflows, and employment. Zhang (2022) found similar effects in OECD countries, while Jaradat (2022) reported that REI positively affected economic growth in UAE, Saudi Arabia, and Qatar, but not Bahrain, Kuwait, and Oman.

According to Apergis and Payne (2010), there is a causal relationship between RE consumption and economic growth in OECD countries. Further analysis conducted by Singh et al. (2019) showed an interdependence between RE production and economic growth across both developed and developing nations. Raza et al. (2020) also emphasized the importance of robust policies in accelerating GDP growth and promoting environmental sustainability. These results collectively showed that REI advanced clean transition, directly contributing to inclusive and sustainable economic development.

Based on the literature, REI is expected to significantly reduce carbon dioxide (CO_2) emissions, which is a major driver of climate change. Sahoo (2020) and Ullah et al. (2021) found a negative correlation between RE and environmental impact. Meanwhile, Usman and Makhdum (2021) reported a 0.2248% footprint reduction per 1% increase across BRIC-T nations. According to Makhdum et al. (2023), there is a strong institution, which further enhances environmental benefits in China. These studies emphasize the need for greater investment to limit environmental degradation. Yadav et al. (2024) used the CS-ARDL model to investigate the relationship between governance aspects, REI, and green finance in BRICS nations. The results showed that combining REI with strong governance and green finance, significantly reduced CO_2 emissions and promoted sustainable development. Abbas et al. (2023) found that green finance and environmental tax significantly showed a significant improvement in China.

Beyond technological advancements, policy frameworks and structural reforms play a critical role in maximizing the benefits of REI. Sorrell (2010) proposed five interconnected propositions regarding energy consumption, economic growth, and environmental sustainability. Specifically, it was assumed that efficiency improvements should be combined with the principle of sufficiency, suggesting the need for structural reforms and innovative policy methods to prioritize sustainability. Countries with strong policies and incentives have witnessed faster adoption and economic benefits. For instance, Kilinc-Ata and Dolmatov (2022) emphasized the importance of R&D investment as well as policy interventions in enhancing RE capacity. Yin and Qamruzzaman (2024) also found that public-private partnerships significantly promoted RE adoption. In contrast, regions with weak regulatory frameworks or high fossil fuel dependency face slower transition to clean energy.

Generally, balancing economic growth with environmental sustainability requires addressing potential trade-offs. Derouez et al. (2024) showed that technological advancements could influence economic growth, with a significant contribution to increased carbon emissions when not accompanied by sustainable practices. Therefore, policymakers must implement strategies such as carbon pricing, incentives for clean energy R&D, and circular economy models to mitigate negative externalities, while fostering economic development.

2.2. REI and National Energy Resilience

The relationship between REI and national consumption has become a key focus in global discussions on energy transition. This investment emphasizes a country's ability to generate energy at low costs, thereby meeting needs and minimizing risks to resilience. A report from Intergovernmental Panel on Climate Change (2012) showed that energy generation increased alongside REI, playing a crucial role in addressing pollution and mitigating climate change.

Mahmood (2018) examined the relationship between economic growth, demand, and energy resilience in both the short and long term. The result showed that REI was essential for reducing carbon emissions and fostering sustainable economic development, particularly in developing countries. Similarly, Ayuketah et al. (2024) reported that REI in developing countries enhanced resilience when supported by effective policies, fiscal incentives, and adequate infrastructure.

REI significantly enhances global security, with varying impacts in different regions. Kumar (2020) showed that the primary objective for deploying RE in India was to advance economic development, improve energy security, and enhance access. In India, integration has played a crucial role in economic growth by improving electricity access and addressing supply challenges (IEA, 2021). In Southeast Asia, a significant increase has been observed in energy resilience and sustainability (IISD, 2022). The ASEAN countries have recognized that RE has the potential to minimize dependency on fossil fuels, achieving targeted economic growth (Tran et al., 2024). Compared to other regions, Europe has led RE transition by implementing programs aimed at accelerating adoption to reduce reliance on fossil fuels (Fusiek, 2023). Osuma and Yusuf (2025) found some crucial insights into the dynamics of the EU's energy mix, as well as the significance of diverse renewable sources such as solar, wind, and bioenergy in improving energy security and sustainability. Therefore, effective REI strategies must be targeted to regional challenges and opportunities.

Despite the significant RE potential in Indonesia, energy sector remains highly dependent on fossil fuels and foreign investment. Wibowo (2023) reported that using environmentally friendly natural resources could enhance energy resilience by strengthening the national system. However, the country still faces structural challenges such as high renewable production costs, inadequate infrastructure, and reliance on external funding. This shows the need to address dependence on traditional sources (Sbia et al., 2014) and implement fiscal incentives to reduce renewable electricity.

Wang et al. (2023) identified key factors influencing renewable energy development (RED), including industrial infrastructure investment, research and development (R&D), as well as financial sector growth. According to Pambudi et al. (2023), the challenges faced in Indonesia include such as high production costs, limited domestic industrial support, and low interest funding. Therefore, policy recommendations such as increasing government budgets, fostering international cooperation, and implementing strategies should be established to accelerate RE adoption to meet Indonesia's climate commitments.

Governance and technological barriers hinder the country's transition to a low-carbon system. Sambodo et al. (2022) found that regulatory inefficiencies and inadequate technological infrastructure remain significant obstacles in RE sector. Meanwhile, Qamruzzaman and Karim (2023) found a positive relationship between green investment, technological innovation, financial openness, and RE consumption in MINT countries. These results suggest that REI is instrumental in strengthening national resilience, although addressing policy and infrastructure challenges is crucial for sustainable progress.

3. METHODS

3.1. Data

This study uses data from various related institutions, including the IEA, IRENA, and the World Bank for energy investment, and government reports for economic, labor, and GDP. Additionally, carbon emission and fuel import reports provide key environmental information. The dataset comprises annual time series spanning 2002-2022, incorporating both relevant dependent and independent variables. A quantitative method with time series analysis is applied using the Autoregressive Distributed Lag (ARDL) model. This enables the examination of both short-term and long-term relationships between REI and their impact on economic growth, environmental sustainability, and energy resilience.

3.2. Econometric Model

The ARDL model is a regression model commonly used in economic studies to examine relationships between independent and dependent variables in time series data. Its widespread application is due to flexibility in handling data with varying levels of statistical significance and suitability for analyzing complex interactions. The model derives the regression equation from the interaction between variables, with variance expressed as the mean. ARDL is a widely used economic study method due to flexibility in analyzing short-term and long-term relationships between time series variables, thereby offering a more nuanced understanding of the policy implications (Yadav et al. 2024).

The short-term model in ARDL is derived from the long-term equation by incorporating the lagged differences of the variables. The general form for the short term is:

$$\Delta Y_t = \alpha + \sum\left(\beta_i \Delta Y_{t-i}\right) + \sum\left(\gamma_j \Delta X_{t-j}\right) + \lambda\left(Y_{t-1} - \varphi X_{t-1}\right) + \varepsilon_t$$

Where ΔY_t is the change in the dependent variable, ΔX_{t-j} is the change in the independent variable, *i* and *j* are the number of lags for the dependent and independent variables, *β, γ,* and *λ* are the coefficients of the variables, *Y□□□-φX□□□* is the Error Correction Term (ECT) of the long-term equilibrium deviation, ε□ is the error term and α is the constant.

The long-term relationship in the ARDL model is obtained from the level coefficients of the dependent and independent variables. When there is cointegration between the variables, the long-term relationship can be written as follows, where Y□ is the dependent variable at time t, X□□$_j$ is the independent variable with lag j; θ_i

and δ_j are the lag coefficients of the dependent and independent variables.

$$Y_t = \alpha + \sum\left(\theta_i Y_{t-i}\right) + \sum\left(\delta_j X_{t-j}\right) + \varepsilon_t$$

The conceptual framework of this study includes the relationship between REI variables and two main aspects, namely (1) environmental sustainability and (2) energy resilience. Model 1 emphasizes environmental sustainability (ENV) through carbon dioxide (CO_2) emission reduction as a climate change mitigation, influenced by investment in RE sector (INV), economic growth (GDP), and energy consumption (CONS). The structural ARDL equation for Model 1 is:

$$\Delta ENV_t = \alpha + \sum\left(\beta_i \Delta ENV_{t-i}\right) + \sum\left(\gamma_j \Delta INV_{t-j}\right) + \sum\left(\gamma_j \Delta GDP_{t-j}\right)\sum\left(\gamma_j \Delta CONS_{t-j}\right) + \varepsilon_t$$

Model 2 evaluates national energy resilience by assessing the impact of diversifying new and RE sources on reducing dependence on fossil fuels imports and ensuring supply stability. This is influenced by investment in RE (INV), economic growth (GDP), and emission (ENV). The structural ARDL equation for Model 2 is:

$$\Delta EGAP_t = \alpha + \sum\left(\beta_i \Delta EGAP_{t-i}\right) + \sum\left(\gamma_j \Delta INV_{t-j}\right) + \sum\left(\gamma_j \Delta GDP_{t-j}\right)\sum\left(\gamma_j \Delta ENV_{t-j}\right) + \varepsilon_t$$

The ARDL model includes several essential steps to ensure the validity and reliability of the analysis. Initially, a stationarity test is conducted to confirm that the time series data is stationary, with consistent mean, variance, and autocorrelation over time. Common methods such as the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests, and adjustments like differencing or log transformation are applied when the data is non-stationary. This is followed by classical assumption tests, which are performed to validate the regression model, including normality (Shapiro-Wilk or Kolmogorov-Smirnov), multicollinearity (Variance Inflation Factor), heteroskedasticity (Breusch-Pagan or White tests), and autocorrelation (Durbin-Watson or Breusch-Godfrey tests). The tests ensure the model is unbiased and meets standard econometric criteria. Subsequently, optimal lag selection is carried out using criteria such as the Akaike Information Criterion (AIC) or Schwarz Information Criterion (SIC), to capture both short-term and long-term dynamics accurately. The cointegration test is conducted using the Bounds Test to determine the existence of a stable long-term relationship among the variables. When cointegration is detected, an Error Correction Model (ECM) is used to integrate short-term adjustments with long-term equilibrium.

4. RESULT AND DISCUSSION

The analysis in this section is divided into two parts. The first discusses the results of a series of ARDL tests and the second analyzes the short-term and long-term results of both models.

4.1. ARDL Test Result

The stationarity of the variables is analyzed using the ADF test to determine their integration order. This test identifies whether a variable is stationary at level I(0) or requires differencing to achieve stationarity, which is essential for valid econometric model estimation in time series analysis. Table 1 shows that most variables are non-stationary at level I(0) but become stationary after first differencing, I(1), except for investment variable, which is stationary at level I(0). These results provide the foundation for constructing an appropriate econometric model.

The validity of regression model is confirmed through the classical assumption test. Specifically, the autocorrelation conducted using the Breusch-Godfrey test and heteroskedasticity with the White test (Table 2) showed significant F-statistic and Chi-square probabilities >0.05 for Models 1 and 2, respectively. This showed that there was no significant autocorrelation or heteroskedasticity, allowing a valid interpretation of the regression coefficients. The model stability test results confirmed the consistency and reliability of the regression in representing the relationship between variables, using the Chow test, CUSUM, and CUSUMQ methods. The results showed stable coefficients without structural changes or significant fluctuations throughout the analysis period, as presented in Figure 1.

The optimum lag test conducted using the AIC, Schwarz Criterion (SC), and Hannan-Quinn Criterion (HQ), ensures the accuracy and efficiency of the time-series analysis. As shown in Table 2, for Model 1 (with ENV as the dependent variable), the ARDL (3, 3, 2, 2) was selected, featuring an adjusted R-squared of 0.9939, an F-statistic of 214.56 (P = 0.00005), and optimum lags of 3 for ENV and GDP as well as 2 for INV and CONS. For Model 2 with EGAP as the dependent variable, the ARDL (3, 3, 3, 3) model was selected, with an adjusted R-squared of 0.9890, an F-statistic of 103.09 (P = 0.0096), and an optimum lag of 3 for INV, GDP, ENV, and EGAP. Based on the results, both models showed high stability and statistical significance, ensuring their reliability for explaining variable relationships as well as supporting further analysis and predictions.

Table 3 shows the cointegration test results, where the null hypothesis (H_0) assumes no cointegration among the variables, expressed as β□ = β_2 = β□ = β□ = β□ = β□ = 0. Using the Johansen method, the null hypothesis (H_0) is rejected, confirming the presence of cointegration among the variables. In Model 1, the Trace test identifies two significant cointegration relationships, while the Max-eigenvalue test identifies one, showing a strong long-term relationship between ENV, GDP, INV, and CONS. For Model 2, the Trace test detects four significant cointegration

Table 1: Stationary test at level I (0) and 1 difference

Variable	ADF	
	Level I (0)	1 difference I (1)
INV	0.0008	0.0001
ENV	0.9999	0.2035
GDP	1.0000	0.0154
CONS	1.0000	0.0370
EGAP	0.9645	0.0000

Figure 1: Plot of CUSUM of square for model 1 and model 2

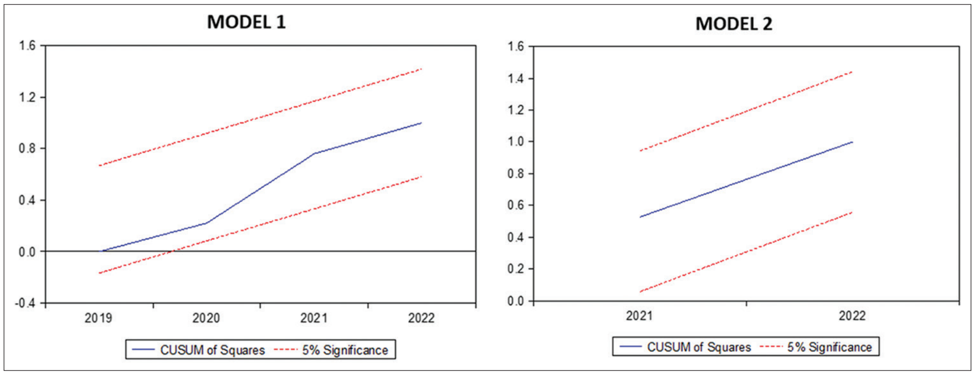

Table 2: Optimum lag test

Model 1			Model 2		
Variable	Akaike info criterion		Variable	Akaike info criterion	
	Coefficient	Probability*		Coefficient	Probability*
ENV(−1)	−0.394221	0.1127	EGAP(−1)	0.703377	0.0117
ENV(−2)	−1.637373	0.0021	EGAP(−2)	1.248779	0.0233
ENV(−3)	−1.881636	0.0073	EGAP(−3)	2.759982	0.0033
GDP	−0.016397	0.1434	INV	−0.081353	0.0622
GDP(−1)	0.045705	0.0127	INV(−1)	−0.010841	0.6968
GDP(−2)	−0.002536	0.8404	INV(−2)	0.118015	0.0069
GDP(−3)	0.104025	0.0040	INV(−3)	0.060853	0.0054
INV	−1.002952	0.0040	GDP	0.017187	0.0043
INV(−1)	−1.541247	0.0059	GDP(−1)	−0.008086	0.0154
INV(−2)	−0.291085	0.0227	GDP(−2)	−0.009325	0.0084
CONS	−0.553658	0.0389	GDP(−3)	−0.008938	0.0243
CONS(−1)	−0.085997	0.7118	ENV	−0.090111	0.0252
CONS(−2)	0.201217	0.2110	ENV(−1)	0.136467	0.0123
C	1640.791	0.0017	ENV(−2)	−0.061480	0.1706
			ENV(−3)	0.242860	0.0164
			C	−199.6467	0.0152
R-squared		0.998568			0.998708
Adjusted R-squared		0.993914			0.989021
F-statistic		214.5610			103.0925
Prob (F-statistic)		0.000050			0.009647
Autocorrelation test (Breusch-Pagan-Godfrey)					
Prob (F-statistic)		0.5654			0.5304
Prob Chi-Square		0.1392			0.3554
Heteroscedasticity (White test)					
Prob (F-statistic)		0.7887			0.9970
Prob Chi-Square		0.5412			0.9112

Table 3: Cointegration test

Model	Test method	Statistic	5% Critical value	Result
1	Trace test	72.67559	47.85613	2 Cointegrating at the 5% level
	Max-eigen test	42.07980	27.58434	1 Cointegrating at the 5% level
2	Trace test	88.33286	47.85613	4 Cointegrating at the 5% level
	Max-eigen test	43.14193	27.58434	2 Cointegrating at the 5% level

relationships, and the Max-eigenvalue test identifies two, showing a more complex long-term relationship among EGAP, INV, GDP, and ENV. These results show different long-term equilibria in each model.

4.2. Long-term and Short-term ARDL Outcomes with Diagnostic Testing

As shown in Table 4, the short-term and long-term results from the ARDL model aim to explore the relationships between the variables over different time horizons.

4.2.1. Model 1

In Model 1, focusing on environmental sustainability (ENV), the short-term results show INV, GDP (lag 2), and CONS have a significant negative effect on ENV. This shows that in the short term, the shift toward RE sources, along with the increase in GDP and CONS, leads to improvements in environmental sustainability. Specifically, the negative relationship with ENV shows that higher REI accelerates the transition from fossil fuels, leading to reduced emissions. As economy adopts renewable sources in both production and consumption, their overall carbon footprint

Table 4: Long-term and short-term results

Model 1		
Variable	**Coefficient**	**Probability**
D (ENV(−1))	3.519009	0.002
D (GDP(−2))	−0.104025	0.0021
D (INV)	−1.002952	0.0050
D (CONS)	−0.553658	0.0036
CointEq(−1)	−4.913230	0.0012
Cointeq=ENV − (0.0266*GDP−0.5771*INV−0.0892*CONS+333.9537)		
Long run coefficients		
GDP	0.026621	0.0000
INV	−0.577071	0.0002
CONS	−0.089236	0.0036
C	333.9537	0.0000
Model 2		
D (EGAP(−1))	−4.008762	0.0087
D (INV(−1))	−0.118015	0.0108
D (GDP)	0.017187	0.0061
D (ENV(−2))	−0.242860	0.0213
CointEq(−1)	3.712138	0.0101
Cointeq=ENV − (−0.0233*INV+0.0025*GDP−0.0613*ENV+53.7821)		
Long run coefficients		
INV	−0.023349	0.2744
GDP	0.002468	0.0289
ENV	−0.061349	0.0894
C	53.78213	0.0126

decreases. Similarly, Kell et al. (2020), showed that REI could rapidly reduce emissions, particularly in transitioning from fossil-based systems. This suggested that in countries with high fossil fuel dependency, investment could accelerate the shift to cleaner sources, leading to quicker-than-expected emission reductions. Due to the high integration of RE, energy mix becomes cleaner, decoupling GDP growth from CO_2 emissions. This decoupling is supported by Kratzenberg et al. (2021), who emphasize that REI can achieve substantial emission reductions in a shorter time frame, particularly in regions historically reliant on fossil fuels.

The long-term effects of REI are consistent with the observations of Zhang et al. (2024), where trade-offs between economic growth and environmental degradation in developing nations can be mitigated by adopting sustainable solutions. Siddiqui et al. (2023) also showed that adopting RE alternatives can alleviate environmental challenges of growing economy, causing significant long-term improvements. These studies collectively confirm that REI provides immediate environmental benefits, enabling a sustainable, and low-carbon growth trajectory.

Long-term results show that GDP has a positive impact on CO_2 emissions, underscoring Indonesia's dependence on fossil fuels for economic growth such as coal, oil, and gas. Similarly, economic growth often leads to higher energy consumption, primarily met by fossil fuels, thereby increasing emissions. As observed by Yan et al. (2024) and Chen et al. (2023), this growth-emissions dilemma showed the difficulty in decoupling economic development from environmental degradation without a transition to cleaner energy sources. Despite high dependence on fossil fuels, Nguyen and Le (2023) and Bashir et al. (2022) emphasized that a shift towards RE was crucial to mitigating long-term emissions. Without significant investment in renewable and energy efficiency, Indonesia's emissions trajectory has the potential to depend only on growth of fossil fuel consumption, as increasing GDP continues to be related with rising emissions.

Based on the results, INV and CONS show a significant negative impact on CO_2 emissions (ENV). This shows that long-term emissions reductions are achievable through high REI sources such as solar, wind, and hydro. The use of RE helps reduce emissions by replacing fossil fuels. Ata and Dolmatov (2023) for OECD and BRICS countries, Zhu et al. (2022) observed the long-term environmental benefits of REI in reducing reliance on fossil fuels. Meanwhile, Bashir et al. (2022) discussed the importance of RE for achieving low-carbon growth. Considering the significant potential of RE in Indonesia, these results underscore the importance of accelerating transition to reduce dependence on fossil fuels. Integrated efforts in policies and investment are also necessary to optimally use the great potential of RE, thereby supporting sustainable and low-carbon economic growth.

4.2.2. Model 2

The results of energy resilience (EGAP) in Model 2 as proxied by import quantities, both short-term and long-term show that INV and environmental sustainability (ENV) have a significant negative impact on EGAP, while GDP positively affects EGAP. This suggests that increasing REI reduces reliance on imported energy, thereby enhancing resilience. However, when economy depends on energy imports, the transition to RE may initially pose significant challenges. For European countries, Neverauskienė et al. (2025) suggested that RE policies must be well-balanced, strategically implemented, and targeted to national conditions to avoid economic trade-offs.

The negative impact of REI on EGAP may seem counterintuitive but underscores the role of domestic development in reducing import dependency. Aidoo (2024), Taher (2024), and Humbatova et al. (2024) emphasized that countries relying on imports could strengthen their security by accelerating local RE projects. The results showed that achieving energy independence was crucial in fostering sustainable economic growth, as higher investment in solar, wind, and biomass with strong coordination could significantly reduce Indonesia's reliance on fossil fuel imports.

The results showed a significant negative relationship between CO_2 emissions (ENV) and EGAP. This suggests that as EGAP increases, CO_2 emissions tend to decline due to the diversification of cleaner sources. For instance, rising imports of LPG/LNG help reduce dependency on kerosene and coal, which have higher emissions. A similar pattern has been observed in the European Union and Japan, where high LNG imports have contributed to lower CO_2 emissions.

The results show a significant positive relationship between GDP and EGAP. This implies that economic growth, when not accompanied by a rapid transition, can drive higher imports, thereby increasing vulnerability to external supply risk. Chen et al. (2023) also stated that security risk in countries with rapidly growing economy was due to high demand compared to domestic supply capabilities. Asif et al. (2024) further emphasized that energy stability was a critical factor in ensuring the long-term sustainability of economic growth in OECD and BRIC countries. This suggested that reliance on imports could expose economy to external shocks, such as global price fluctuations and geopolitical disruptions, making energy resilience a crucial policy concern. Nguyen and Le (2022) stated the need for coordinated policies to reduce import dependency by diversifying sources and improving efficiency.

In the short term, without a well-managed transition, GDP growth tends to continue driving demand for fossil fuels and imports, reinforcing the risks to energy security. Therefore, to achieve independence, Indonesia must accelerate INV, reduce CO_2 emissions (ENV), and enhance the efficiency of domestic use. Without a proactive transition, continued economic expansion may further deepen reliance on imported fossil fuels.

5. CONCLUSIONS AND POLICY IMPLEMENTATIONS

In conclusion, REI played a crucial role in promoting environmental sustainability, particularly in reducing carbon dioxide (CO_2) emissions. The results showed that high investment enhanced the transition toward more efficient, clean energy sources, and gradually replaced the reliance on fossil fuels contributing to rising emissions. In the long term, developing the RE sector could significantly lower CO_2 emissions while supporting low-carbon economic growth. Therefore, investing in RE not only promoted environmental sustainability but also contributed to building a greener economy in Indonesia.

The results showed that REI had a dual benefit, namely reducing environmental degradation and supporting economic sustainability. Policies that incentivize investment in solar, wind, and hydro energy projects were critical to this transition. Additionally, public-private partnerships could be established to mobilize funding and drive innovation in RE technologies. Integration into national strategies also had the potential to solidify Indonesia's commitment to achieving its carbon neutrality goals.

To strengthen national resilience, Indonesia must reduce reliance on fossil fuel imports. The results showed that high investment in RE could reduce the dependency on fossil fuel imports, cushion the effects of global price fluctuations, and accelerate the path to independence. This was particularly essential because of the vulnerability of energy markets to geopolitical tensions and supply chain disruptions.

This study suggested that GDP growth driven by fossil fuel use could lead to a short-term increase in imports. To address the challenge, policies promoting efficiency, leveraging domestic resources, accelerating transition, and developing strategic reserves should be established to ensure long-term stability in Indonesia. A holistic and integrated policy framework was also recommended to achieve the dual objectives of environmental sustainability and energy resilience. This framework should include regulatory support, education and awareness, infrastructure development, and cross-sector collaboration.

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