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The Influence Of Economic Factors And Energy Use On Co2 Emissions In Indonesia 1990-2022

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Abstract

CO_2 emissions are one of the environmental challenges faced by many developing countries, including Indonesia. The increase in economic activities and the use of fossil fuel-based energy can raise CO_2 emissions, which may lead to climate change and environmental degradation. This study aims to estimate the effect of electricity consumption, GDP, FDI, renewable energy, and fossil fuel consumption on CO_2 emissions in Indonesia during 1990-2022. This study uses time series data obtained from the World Bank and applies the Domowitz-Elbadawi Error Correction Model (ECM). The results show that in the short run, renewable energy use has a negative effect on CO_2 emissions, while electricity consumption, GDP, FDI, and fossil fuel consumption do not affect CO_2 emissions. In the long run, GDP, FDI, renewable energy use, and fossil fuel consumption have a negative effect on CO_2 emissions, while electricity consumption does not affect CO_2 emissions in Indonesia. Based on the findings, the government is expected to increase the use of renewable energy, encourage the adoption of environmentally friendly technology, and strengthen environmental management policies to support sustainable development.

Keywords: ***CO_2 emissions, electricity consumption GDP, Foreign Direct Investment, renewable energy, fossil fuel consumption, Error Correction Model.***

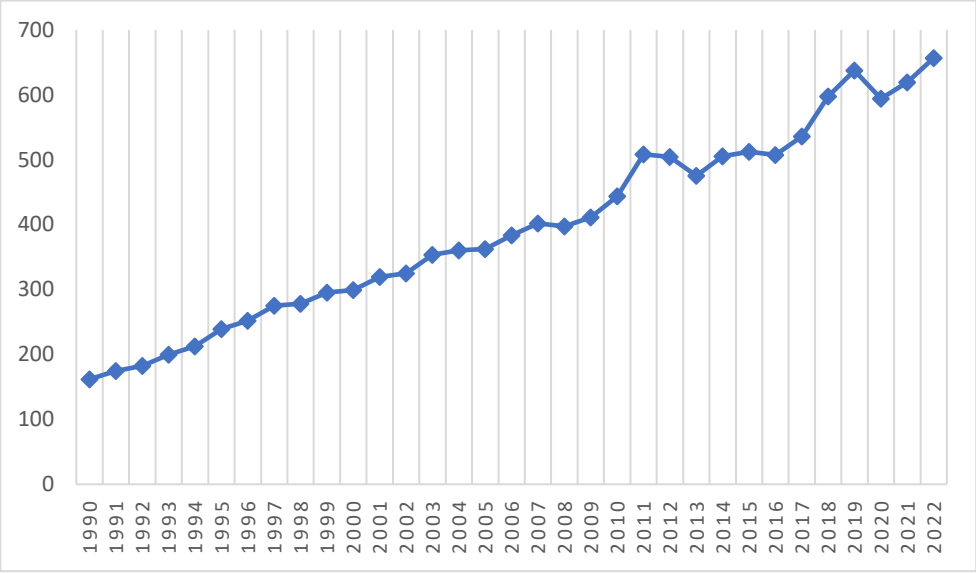
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INTRODUCTION

The environment has a very important role in supporting sustainable development because it is the main source for people's economic and social activities. Therefore, the use of natural resources needs to be done wisely considering the limited availability and vulnerability to damage due to human activities. Poor environmental management triggers environmental damage and climate change which is characterized by increased risk of natural disasters, ecosystem degradation, water and air pollution, and a decline in biodiversity. Environmental damage due to climate change can reduce the quality of human life thereby hindering sustainable development (Rahmat, 2024).

Graph 1 CO2 Emissions in Indonesia 1990-2022 (Million Metric Tons)



Source: *World Bank*

Based on Graph 1, it can be seen that the CO2 is likely to increase from about 162 million metric tons in 1990 to about 657 million metric tons in 2022, although in some years there has been a decline. This increase shows that growing economic activity, especially in the fossil fuel, transportation and industrial sectors, is putting increasing pressure on the environment. Emissions had peaked at around 637 million metric tons in 2019, then declined in 2020 due to a slowdown in economic activity during the *Covid-19*. However, after economic activity began to recover, CO2 emissions increased again until 2022. This condition shows that dependence on fossil energy is still quite high so that an

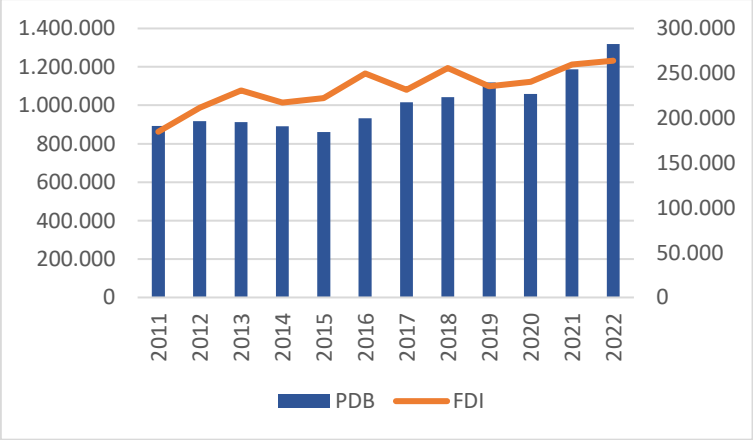
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increase in economic activity is often followed by an increase in CO2 emissions. Therefore, efforts to control emissions are needed through the development of renewable energy and more environmentally friendly energy policies (Arifah, L., & Shahmi, 2023).

Economic activities can increase the use of fossil energy such as oil, coal and gas so that it can increase emissions CO2. In the process of production and consumption, humans utilize natural resources which if excessive can cause pollution and environmental damage. These negative impacts reduce the quality of human life and threaten the sustainability of ecosystems. Therefore, maintaining environmental sustainability is very important so that the economic needs of the current generation are met without damaging the environmental capabilities for future generations. With good management, economic activities can run in balance with environmental sustainability so that the benefits can be felt in a sustainable manner (Armayani et al., 2022).

Graph 2 Gross Domestic Product (GDP, *Current* US$) and Foreign *Direct Investment* (FDI, Million Dollars) in Indonesia in 2011-2022



Source: *World Bank*

Based on Chart 2, it can be seen that Gross Domestic Product (GDP) Indonesia tends to increase from 2011 to 2022. This shows that economic activity in Indonesia continues to grow. However, there was a decline in GDP in 2015 and 2020. The decline in 2015 was caused by the global economic slowdown, the decline in commodity prices, especially the price of world crude oil, and international trade competition (BPS, 2015). Meanwhile, the decline in GDP in 2020 occurred due to *Covid-19* which causes

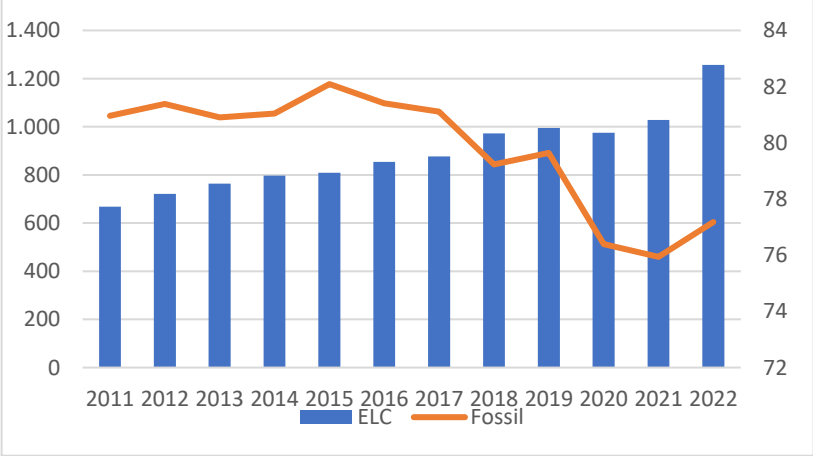
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production, trade, and investment activities to decrease. Meanwhile, *Foreign Direct Investment* (FDI) showed a fluctuating movement although it generally increased until 2022. The ups and downs of foreign investment flows are greatly influenced by the global economy, market stability, and a country's investment obligations. Nevertheless, FDI still plays an important role in encouraging economic growth through capital inflows, increased production capacity, and technology transfer that can increase productivity (Arifah, L., & Shahmi, 2023).

In addition to GDP and investment, electricity consumption and the use of fossil fuels can affect environmental sustainability because the use of fossil fuels such as petroleum, coal, and natural gas in power plants causes high CO2 emissions. The use of fossil energy can produce high CO2 emissions, so it can increase air pollution and accelerate climate change. Around 96% of energy consumption in Indonesia is still dominated by energy that is not environmentally friendly, so the increase in electricity consumption and fossil fuels can contribute to the increase in energy consumption Emissions CO2 and environmental damage. This condition shows that dependence on fossil energy is one of the causes of environmental degradation. Therefore, the development of renewable energy is needed to preserve the environment (Sasana, H., & Aminata, 2019).

Graph 3 Electricity Consumption (ELC, KWh Per Capita) and Fossil Fuel Energy Consumption (*Fossil*, %) in Indonesia in 2011-2022



Source: *World Bank*

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Graph 3 shows that electricity consumption is likely to increase. This is due to the increasing energy needs of the community due to economic growth, industrial development, and increasing household activities and urbanization. Meanwhile, fossil fuel consumption tended to be stable in 2011-2017 and began to decline since 2018 due to the implementation of the biodiesel program by the government. The increase in electricity consumption needs to be balanced with the use of more environmentally friendly energy sources because most power plants still use fossil fuels that can increase CO2 emissions. In reality, the use of clean energy in Indonesia is still relatively low, this is due to the high price of NRE production, as well as the lack of support from the domestic industry and the difficulty of obtaining low-income funding are also factors that hinder the acceleration Transition to clean energy (Walujanto et al., 2018).

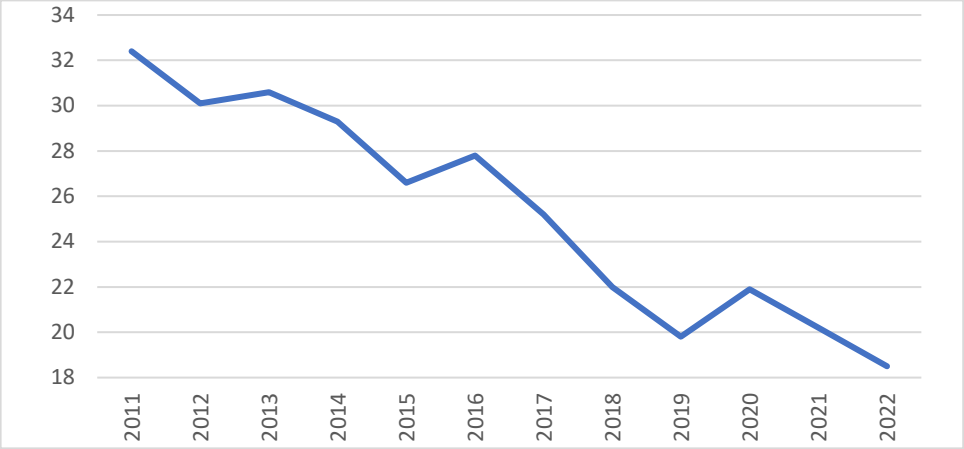
This can be seen from the national energy consumption structure which is still dominated by fossil energy compared to renewable energy, most of the electricity in Indonesia is still produced from fossil fuels such as coal, petroleum and natural gas so that it can increase CO emissions$_2$ which has a bad impact on the quality of the environment. Therefore, efforts are needed to increase the use of clean and environmentally friendly energy sources (Putra & Rusgianto, 2021).

One of the important efforts in preserving the environment is to use renewable energy. Renewable energy comes from natural sources such as solar, wind and water that can be renewable naturally so that it is more environmentally friendly compared to fossil energy. The use of renewable energy can also reduce CO emissions$_2$ which is one of the causes of climate change and helps maintain environmental sustainability (Haerani et al., 2023). In addition, the use of renewable energy can also reduce dependence on fossil energy and encourage people to be more aware of protecting the environment and can reduce excessive exploitation of natural resources (Rumahorbo, R. P. & Nursadi, 2023).

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Chart 4 Percentage of Renewable Energy Use in Indonesia in 2011–2022



Source: *World Bank*

Based on Chart 4, it can be seen that the use of renewable energy tends to decrease. This shows that renewable energy in Indonesia still faces various obstacles despite its abundant natural resource potential. One of the main problems is the limited investment in the development of renewable energy infrastructure, such as solar and wind power plants that require large funds and the right technology. In addition, dependence on weather conditions makes renewable energy production less stable. Limited infrastructure and technological support make renewable energy in Indonesia not used optimally (Solikah & Bramastia, 2024). On the other hand, complex policy and regulatory uncertainty slows down the implementation of renewable energy programs. The lack of research and technological innovation is also a challenge. This problem needs to be addressed so that the use of renewable energy can contribute to sustainable development in Indonesia (Firmansyah & Prasmasha, 2024).

The decline in environmental quality due to increasing CO_2 emissions is one of the important problems in sustainable development in Indonesia. Several economic factors such as economic growth, foreign direct investment, and increased electricity consumption, have the potential to increase CO_2 emissions. In addition, energy use is still dominated by fossil fuels which have the potential to increase CO_2 emissions which have an impact on climate change and a decrease in environmental quality. On the other hand, the use of renewable energy in Indonesia is still limited, so the transition to more environmentally friendly energy has not run optimally. Based on the background, this study aims to estimate the influence of economic growth, foreign direct investment,

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electricity consumption, fossil fuel use, and renewable energy use on CO_2 emissions in Indonesia.

Literature Review

Putri et al. (2022) Using *Error Correction Model* (ECM) examines the influence of economic growth, population growth, and energy consumption on emissions CO_2 in 1992-2020. The results of the study show that energy consumption has a positive effect on CO emissions$_2$ in the short term and in the long term, while population growth has a positive effect in the short term but in the long term it has a negative effect on CO emissions$_2$. Meanwhile, economic growth has no effect. Pratama and Panjawa (2022) also found that economic growth had no effect on CO emissions$_2$ in the short and long term. Meanwhile, energy consumption has a positive effect on CO emissions$_2$ in the long term even in the short term it has no effect. Then, the development of the financial sector and foreign investment has no effect on CO emissions$_2$ both in the short and long term in the 1990-2020 period in Indonesia. Then, Pongtuluran and Setyari (2026) in his research found that in the short term, renewable energy consumption, non-renewable energy consumption and GDP have no effect on CO emissions$_2$, while the population has a positive effect. Meanwhile, in the long term, renewable energy consumption, non-renewable energy consumption and population have a positive effect on CO emissions$_2$, while the consumption of renewable energy has a negative effect on CO emissions$_2$ in Indonesia in 1990-2023.

Rizki and Anggareni (2022) derive different results regarding the influence of GDP on CO emissions$_2$, where it was found that GDP had an effect in Indonesia from 1990-2022. It was also found that foreign investment (FDI) has no effect in the short term but has a negative effect in the long term on CO emissions$_2$. Domestic investment (PMND) has a positive effect on CO emissions in the long term$_2$. Meanwhile, Amalina et al. (2023) estimate the effect of GDP per capita and energy consumption on CO emissions$_2$ in 1992-2021, and found that GDP per capita and energy consumption had a positive effect on CO emissions$_2$ in the short and long term. then Nadeak and Nasrudin (2023) also found that GDP per capita and non-renewable energy consumption have a positive effect, while renewable energy consumption has a negative effect on greenhouse gas emissions in Indonesia. Then, the results of the ARDL regression showed that GDP per capita had no effect on greenhouse gas (GHG) emissions, while GDP per capita

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square lag, and renewable and non-renewable energy consumption had a positive effect on greenhouse gas emissions.

Shahbaz et al. (2018) Using Models *Autoregressive Distributed Lag* (ARDL) to estimate the impact of GDP per capita, energy consumption, domestic credit, FDI and energy innovation on emissions CO_2 in France in 1960-2016. The results show that GDP per capita, energy consumption, and FDI have a positive effect on CO emissions$_2$. Meanwhile, domestic credit and energy innovation have a negative effect on CO emissions$_2$. These findings are supported by Idroes et al. (2023) found that GDP, non-renewable energy and the number of natural disaster victims had a positive effect on CO_2, while renewable energy consumption has a negative effect on CO emissions$_2$ in Indonesia in 1980-2021. Hasbi (2024) find different outcomes, where economic growth negatively affects CO emissions$_2$ in ASEAN in 1990-2021, while urbanization, FDI, and population have a positive effect on CO emissions$_2$. Then, Rahayu et al. (2024) estimate the influence of GDP, population growth and renewable energy consumption on CO emissions$_2$ in Indonesia in 1990-2020. The results of the study showed that GDP and population growth had no effect on CO emissions$_2$, while renewable energy consumption has a negative effect on CO emissions$_2$.

Annisa and Bashir (2025) found that economic growth, depletion of natural resources, and income inequality have a positive effect on CO emissions$_2$ in Indonesia in 1990-2021. However, the effect of economic growth on CO emissions$_2$ not in line with findings Oluwaseun (2025) in his research in 1972-2021, where economic growth and renewable energy consumption had a negative effect on CO emissions$_2$ in the short term or long term, while in the short term the population has a positive effect even though in the long term it has no effect on CO emissions$_2$. Meanwhile, the use of fossil fuels and direct foreign investment has no effect on CO_2 both in the short and long term. Meanwhile, Magazzino (2016) found that GDP and energy consumption have a negative effect on CO emissions$_2$ in Kuwait, Oman and Qatar in 1960-2013. Mendonça et al. (2020) using a hierarchical regression model with fixed and random effects to estimate the influence of GDP and renewable energy on emissions CO_2 in the 50 countries with the largest economies in the world in 1990-2015. The results of the study show that GDP and population have a positive effect on CO emissions$_2$, while renewable energy has a negative effect on CO emissions$_2$.

Marwa et al. (2022) Using *Vector Error Correction Model* (VECM) to estimate the effect of economic growth and electricity consumption on CO emissions$_2$ in Indonesia in

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1971-2020. The results show that in the short term, economic growth has a negative effect on CO emissions$_2$, while electricity consumption has no effect on CO emissions$_2$. Meanwhile, in the long term, economic growth and electricity consumption have a positive effect on CO emissions$_2$. Juliani et al. (2021) obtain the same results, where economic growth has a negative effect on CO emissions$_2$ Even if it is only in the short term, while in the long term it has a positive effect. Fossil energy was found to have no effect on carbon emissions in the short or long term. Then, Koengkan and Fuinhas (2017) estimate the influence of economic growth, petroleum consumption, and renewable energy consumption on CO emissions$_2$ in the United States from 1980 to 2012. It was found that economic growth and petroleum consumption have a positive effect on CO emissions$_2$ in the short and long term. Meanwhile, renewable energy consumption has a negative effect on CO emissions$_2$ in the short term, while in the long term it has no effect on CO emissions$_2$.

The difference in this study from previous studies lies in the use of variables, analysis methods, and the scope of research. This study uses variables of electricity consumption and fossil fuel energy consumption that are still rarely used in previous research. In addition, this study uses *an Error Correction Model* (ECM) analysis tool that is able to analyze short-term and long-term effects and look at the adjustment process towards long-term equilibrium. In terms of research object, this study focuses on Indonesia with a longer period of time and the latest data, so that it can describe more actual conditions. Thus, this research is expected to contribute to enriching the study of factors that affect CO_2 emissions in Indonesia.

Research methods

This research is a quantitative research with secondary data obtained from the *World Bank* from 1990-2022. The data used in this study is *time series* data from 1990-2022 in Indonesia. The econometric equations to estimate the influence of electricity consumption, GDP, *Foreign Direct Investment* (foreign investment), renewable energy, and fossil energy on CO_2 emissions are as follows:

$$\begin{aligned}\Delta log\widehat{CO2_t} = {} & \hat{\gamma}_0 + \hat{\gamma}_1 \Delta logELC_t + \hat{\gamma}_2 \Delta logPDB_t + \hat{\gamma}_3 \Delta logFDI_t + \hat{\gamma}_4 \Delta Renew_t \\ & + \hat{\gamma}_5 \Delta Fossil_t + \hat{\gamma}_6 logELC_{t-1} + \hat{\gamma}_7 logPDB_{t-1} + \hat{\gamma}_8 logFDI_{t-1} \\ & + \hat{\gamma}_9 Renew_{t-1} + \widehat{\gamma_{10}} Fossil_{t-1} + \hat{\lambda} ECT_{t-1} + \hat{e}_t\end{aligned}$$

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where:

$\widehat{CO2}$	:	Carbon dioxide emissions (million metric tons)
ELC	:	Electricity consumption (kWh per capita)
PDB	:	Gross Domestic Product (dollars)
FDI	:	*Foreign Direct Investment* (million dollars)
$Fossil$	:	Fossil fuel consumption (%)
$Renew$	:	Renewable energy (%)
Δ	:	*First difference*
ECT	:	*Error Correction Term* $ECT_{t-1} = logELC_{t-1} + logPDB_{t-1} + logFDI_{t-1} + Renew_{t-1} + Fossil_{t-1} - logCO2_{t-1}$
$\widehat{\gamma_0}$	:	Constant
$\widehat{\gamma_1} \ldots . \widehat{\gamma_{10}}$	:	Coefficients of independent variables
λ	:	ECT Coefficient
t	:	*Time series* (1990-2022)
$\hat{e}$	:	Residual

The model existence test or *the F* test is carried out to find out whether the independent variables together have an effect on the dependent variables. *H0* in the *F* test states that *γ1 = γ2 = γ3 = ... = γ10* = 0 which means that electricity consumption, GDP, foreign investment, renewable energy, and fossil energy together have no effect on CO_2 emissions in Indonesia. *H0* is denied if the *F-statistical* probability < *α*.

Then, *a t-test* needs to be carried out to find out whether individual independent variables affect dependent variables in both the short and long term. *H0* states that $\gamma_i = 0$ (i = 1-10) which means that electricity consumption, GDP, foreign investment, renewable energy, and fossil energy respectively have no effect on CO_2 emissions in both the short and long term. The *HA* stated $\gamma_j < 0$ (j = 4 and 9), which means that renewable energy consumption has a negative effect on CO_2 emissions, while $\gamma_k > 0$ (k = 1-3, 5-8, and 10), which means that GDP, foreign investment, electricity consumption, and fossil fuel consumption have a positive effect on CO emissions$_2$.

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Results and Discussion

To estimate the factors that affect CO_2 emissions in Indonesia during the period 1990-2022 in the short and long term, the *Domowitz-Elbadawi* Error Correction Model (ECM) approach is used.

Table 1 Domowitz-Elbadawi ECM Estimation Results

Variable	Coefficients	Prob. *t*
D(LogELC)	0,284	0,485
D(LogPDB)	-0,005	0,910
D(LogFDI)	-0,003	0,948
D(Renew)	-0,016	0,037*
D(Fossil)	0,000	0,939
LogELC(-1)	-0,114	0,655
LogGDP(-1)	-0,520	0,036*
LogFDI(-1)	-0,531	0,026*
Renew(-1)	-0,523	0,029*
Fossil(-1)	-0,526	0,027*
ECT	0,525	0,028*
R2 = 0.660; Prob. *F-stat* = 0.040		
* Significant at *α* 0.05		

Based on Table 1, it is known that the value of the ECT coefficient (λ) is 0.524 which means that it qualifies $0 < \lambda < 1$. This coefficient has a probability value of 0.028; which means significant at $\lambda = 0.05$ These two conditions show that the estimated model is indeed an ECM model, so the ECM in this study can be used to estimate the short-term and long-term effects of electricity consumption, GDP, foreign investment, renewable energy, and fossil energy on CO_2 emissions in Indonesia.

Table 2 Diagnosis Test Results

Detection	Test	Criteria	Conclusion
Residual normality	Jarque-Bera	Prob. JB = 0.877	Normal distributed residual
Autocorrelation	Breusch-Godfrey	Prob. $\chi 2$ = 0.945	No autocorrelation

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Heteroscedasticity	White	Prob. $\chi 2$ = 0.475	Residual homoskedastis
VIVID	*ΔlogELC* = 3.741 *ΔlogGDP* = 2.214 *ΔlogFDI* = 2.414 *ΔRenew* = 2.272	*ΔFossil* = 1.939 *logELCt-1* = 408,681 *logPDBt-1* = 780,892 *logFDIt-1* = 1499,656	*Renewt-1* = 127133,300 *Fossilt-1* = 42851.170 *ECTt-1* = 17180,330

Based on the results of the classical assumption test in Table 2, it is known that the research model has met the classical assumption test. The results of the Jarque-Bera test showed a probability value of JB 0.877 (> α 0.05) so that the residual was normally distributed. In addition, the regression model also meets the assumption that there is no autocorrelation as evidenced by *the probability of* $\chi 2$ in the Breusch-Godfrey test of 0.945 and the homoscadastric residual as evidenced by the probability *of* $\chi 2$ of 0.475 in the White test. However, the results of the detection of multicollinearity showed that some variables had a VIF value of more than 10 so that there were symptoms of multicollinearity in the model. This condition is still tolerated in ECM due to the long-term relationship between variables and the use of lag in the model.

Table 3 Calculation of Long-Term Constants and Coefficients

Variable	Coefficients	Calculation		
C	*γ0*	0,520/0,524	=	0,991
LogELC	*γ6*	(-0,114 + 0,524)/0,524	=	0,782
LogPDB	*γ7*	(-0,520 + 0,524)/0,524	=	0,008
LogFDI	*γ8*	(-0,531 + 0,524)/0,524	=	-0,013
Renew	*γ9*	(-0,523 + 0,524)/0,524	=	0,002
Fossil	*γ10*	(-0,525 + 0,524)/0,524	=	-0,002

From the results of calculating the parameters of the long-term model, the long-term estimated model is obtained as follows:

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$$\Delta log\widehat{CO2_t} = 0{,}991 + 0{,}782\log ELC_t + 0{,}008\log PDB_t - 0{,}013\log FDI_t + 0{,}002 Renew_t - 0{,}002 Fossil_t$$

Table 1 shows that the *F-statistical* probability value is 0.0406 < α *(0.05) so that* H0 *is rejected, and it can be concluded that* electricity consumption, GDP, foreign investment, renewable energy, and fossil fuel consumption together affect CO_2 emissions in Indonesia in 1990-2022.

The determination coefficient (*R2*) of 0.6606 means that 66.06% of the change in CO_2 emissions is due to electricity consumption, GDP, foreign investment, renewable energy, and fossil energy to CO_2 emissions in Indonesia, while the remaining 33.94% is due to other variables outside the model.

The t-test is carried out to find out whether the independent variable is persial or individual affecting the dependent variable. Based on Table 1, it can be seen that the t-static probabilities *γ1, γ2, γ3,* and *γ5 are* more than 0.05; therefore, it can be concluded that in the short term, electricity consumption, GDP, foreign investment and fossil energy have no effect on CO_2 emissions, while renewable energy has a negative effect on CO_2 emissions . Meanwhile, in the long term, electricity consumption has no effect on CO_2 emissions, while GDP, foreign investment, and fossil energy have a negative effect on CO_2 emissions in Indonesia in 1990-2022.

In the short term, *the RENEW* coefficient of -0.016 with a log-linear relationship pattern shows that an increase in renewable energy consumption of one percent will reduce CO_2 emissions by 1.6 percent, then the coefficients of electricity consumption, GDP, foreign investment, and fossil fuel consumption do not need to be interpreted because they are insignificant. Meanwhile, in the long term, the GDP coefficient is -0.520 with a log-log relationship pattern which means that a one percent increase in GDP will reduce CO_2 emissions by 0.520 percent. Then, the foreign investment coefficient of -0.531 with a log-log relationship pattern, means that an increase in foreign investment of one percent will reduce CO_2 by 0.531 percent. Furthermore, *the RENEW* coefficient of -0.523 with a log-linear relationship pattern means that an increase in renewable energy consumption of one percent will reduce CO_2 emissions by 52.31 percent. Meanwhile, *the FOSSIL* coefficient of -0.526 with a log-linear relationship pattern, means that an increase in fossil energy consumption by one percent will reduce CO_2 emissions by 52.60 percent. The coefficient of electricity consumption in the long term does not need to be interpreted because it is insignificant.

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Table 4 Five Largest Contributor Sectors to Indonesia's GDP in 2018-2022

Year	Contribution rating				
	1	2	3	4	5
2018	Processing industry	Trade	Agriculture, forestry and fisheries	Mining and quarrying	Construction
	(19,86)	(13,02)	(12,81)	(8,08)	(10,53)
2019	Processing industry	Trade	Agriculture, forestry and fisheries	Mining and quarrying	Construction
	(19,70)	(13,01)	(12,71)	(7,26)	(10,75)
2020	Processing industry	Trade	Agriculture, forestry and fisheries	Mining and quarrying	Construction
	(19,87)	(12,91)	(13,70)	(6,43)	(10,70)
2021	Processing industry	Trade	Agriculture, forestry and fisheries	Mining and quarrying	Construction
	(19,24)	(12,96)	(13,28)	(8,97)	(10,44)
2022	Processing industry	Trade	Agriculture, forestry and fisheries	Mining and quarrying	Construction
	(18,34)	(12,85)	(12,40)	(12,22)	(9,77)

Electricity consumption is one of the variables whose influence is proven to be not in accordance with the research hypothesis because it is proven that it does not have a significant effect on CO emissions$_2$ both in the short and long term. These findings are in line with the findings Marwa et al. (2022) which states that electricity consumption has no effect on CO emissions$_2$ in Indonesia. Other factors are considered more dominant in influencing CO emissions$_2$, especially economic activities, the use of fossil fuels, and industrial activities. This condition shows that electricity use has not been the main factor driving the increase in CO emissions$_2$ in Indonesia.

The insignificance of electricity consumption to CO_2 emissions can be caused by

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Indonesia's economic structure which is not completely dominated by a very electricity-intensive sector. Based on Table 4, it appears that most economic activity comes from the trade, agriculture, and other supporting services sectors that do not produce emissions as much as the energy and power generation sectors. This condition indicates that economic activities that drive national output growth are not always directly related to increased electricity consumption that produces carbon emissions. Thus, an increase in electricity consumption is not always followed by a significant increase in carbon emissions.

Based on the regression results, it is known that in the short term, GDP has no effect on CO2 emissions. The findings in this study are in line with Rahayu et al. (2024) which states that GDP has no influence on CO2 emissions. The increased economic activity comes not entirely from the industrial and manufacturing sectors, but also from the services, trade and communication sectors that produce CO emissions$_2$ so that the change in GDP has not made any real change to CO emissions$_2$. Meanwhile, in the long term, it is known that GDP has a negative effect on CO2 emissions. These findings support the findings Magazzino (2016) which states that GDP has a significant negative effect on CO2 emissions. Increasing economic growth can encourage technological development and innovation so that energy use becomes more efficient and dependence on polluting fossil energy can be reduced. In addition, the implementation of stricter environmental policies and the use of renewable energy can reduce CO2 emissions. However, the results of this study are not in line with the Mendonça et al. (2020) where GDP has a positive effect on CO2 emissions in the 50 countries with the largest economies in the world in 1990-2015. Meanwhile, Idroes et al. (2023) also found that GDP had a positive effect on CO2 emissions in Indonesia in 1980-2021. Higher economic growth can encourage industrial activity, production, transportation, and energy consumption. That way, the use of fossil fuel energy also increases and can ultimately increase CO2 emissions.

The regression results also show that in the short term, foreign investment has no effect on CO2, while in the long term, foreign investment has a negative effect on CO2 emissions. These results are in line with the findings Rizki and Anggareni (2022) which states that in the short and long term foreign investment has a negative effect on CO2 emissions in Indonesia in 1990-2022. Increased foreign investment can encourage multinational companies to use more advanced production technologies and more efficient use of energy. In addition, the application of clean energy technologies and better environmental standards encourage a reduction in CO2 emissions in the long term.

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However, the results of this study are not in line with the Shahbaz et al. (2018) where FDI has a positive effect on CO emissions$_2$ in France in 1960-2016. Hasbi (2024) also found that FDI has a positive effect on CO emissions$_2$ in ASEAN countries from 1990-2021. Increased foreign investment can encourage industrial and production activities to be even greater. That way, energy use also increases so that CO emissions$_2$ resulting in higher yields.

Based on the regression results, it is known that renewable energy has a negative effect both in the short and long term. These findings are in line with the findings Koengkan and Fuinhas (2017) which states that the use of renewable energy has a negative effect on CO_2. The use of renewable energy can reduce the use of fossil energy such as coal, petroleum, and natural gas so that the resulting CO2 emissions are lower. In addition, the use of renewable energy such as solar, water, wind and biomass tends to be more environmentally friendly because it produces lower CO2 emissions than fossil fuel energy so that it is able to reduce CO2 emissions. These findings also support the findings Oluwaseun (2025) which states that in the short and long term the consumption of renewable energy has a negative effect on CO emissions$_2$ in 1972-2021. Nadeak and Nasrudin (2023) It also found that renewable energy consumption has a negative effect on greenhouse gas emissions. Increased use of renewable energy can help reduce greenhouse gas emissions, as renewable energy produces lower levels of pollution than fossil fuel energy so that less CO2 emissions are produced.

Based on the regression results, it is known that fossil fuel consumption in the short term has no effect on CO2. These results are in line with the findings Juliani et al. (2021) which states that fossil fuel consumption has no effect on CO2 emissions in the short term. This shows that increasing emissions from fossil energy use does not necessarily directly affect CO emissions$_2$ due to CO emissions$_2$ It is also influenced by efficiency, production technology, and environmental policies. Meanwhile, in the long term, the use of fossil fuels has been shown to have a negative effect on CO emissions$_2$. These results support the findings Pongtuluran & Setyari (2026) which states that in the long run, the use of fossil fuels supported by modern technology and more environmentally friendly energy management can make energy use more efficient. That way, the CO2 emissions produced are lower so that they can reduce CO2 emissions. However, the results of this study are different from Nadeak and Nasrudin (2023) which found that the consumption of non-renewable energy has a positive effect on CO emissions$_2$ both in the short and long term. Increased consumption of non-renewable energy can increase CO emissions$_2$ because most of the CO2 emissions generated come from the energy sector. That way,

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the higher the use of non-renewable energy, the CO2 emissions produced will also increase.

Closing

CO_2 emissions are one of the environmental challenges faced by many countries in the world, especially developing countries, including Indonesia. Increased economic activity and the use of fossil fuel-based energy can increase CO_2 emissions that have an impact on climate change and a decrease in environmental quality. The government has an important role in preserving the environment through sustainable development policies. The purpose of this study is to estimate the direction and magnitude of the influence of electricity consumption, GDP, foreign investment, fossil fuel consumption, and renewable energy on CO_2 emissions in Indonesia.

To achieve the objectives of this study, the Domowitz-Elbadawi *Error Correction Model* (ECM) method was used as an analysis model. The regression results show that in the short term, the use of renewable energy has a negative effect on CO_2 emissions, while electricity consumption, GDP, foreign investment, and fossil fuel consumption have no effect on CO_2 emissions. Meanwhile, in the long term, GDP, foreign investment, the use of renewable energy, and the use of fossil fuels have a negative effect on CO_2 emissions, while electricity consumption has no effect on CO_2 emissions in Indonesia in 1990-2022.

Based on the results of the research, the government is expected to strengthen environmental management policies through increasing the use of renewable energy and reducing dependence on fossil energy. In addition, the government is expected to encourage the use of more efficient and environmentally friendly technology in industrial, transportation, and power plant activities so that CO_2 emissions can be controlled. The development of investments that support clean energy and increase public awareness in protecting the environment also needs to be improved. With policies that support economic development, environmental sustainability and CO_2 emission control in Indonesia are expected to be more effective and sustainable.

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