The 2nd International Students Conference on Economics and Business Excellence (ISCEBE) 2025
e-ISSN: 3090-4811
Vol. 2 No.1/EC-ISCEBE (2025)

DETERMINANTS OF RENEWABLE ENERGY CONSUMPTION IN INDONESIA

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Abstract

Energy is one of the important indicators in the economy. Using information from the World Bank shows that renewable energy consumption in Indonesia from 1990 to 2021 shows a significant downward trend over time. This decline is influenced by various factors such as Foreign Direct Investment (FDI), CO2 emissions from transport, energy use, and urban population growth. The purpose of this to examine the short-term and long-term factors influencing Indonesia's use of renewable energy from 1990 to 2021. The Error Correction Model (ECM) is employed in this study to capture the dynamics of short-term relationships as well as the adjustment process towards long-term equilibrium. The analysis shows that an increase in FDI contributes to an increase in renewable energy consumption in both time horizons. In contrast, CO_2 emissions from transportation and energy use negatively affect the use of renewable energy consumption in both the short and long term. Meanwhile, demographic variables such as urban population growth areas show a positive but insignificant effect on renewable energy consumption. The negative and significant error correction coefficient (ECT) confirms the validity of the ECM model and shows that the system can return to equilibrium after short-term shocks. These findings emphasize the importance of policies that support sustainable investment, clean energy technology development, and emissions control to promote the transition to more optimal renewable energy utilization in Indonesia.

Keywords: renewable energy consumption, Foreign Direct Investment, CO2 emissions from transport, energy use, Error Correction Model

INTRODUCTION

Energy is one of the important indicators in the economy. Energy is needed by humans to fulfill daily life activities as well as in improving economic activities such as: transportation, household, business, and industry. Most energy comes from fossil fuels which are non-renewable resources. If the energy is continuously used, it will run out overtime so there needs to be an alternative, namely through renewable energy that can be used freely and continuously. Facts show that using renewable energy has no harmful impact on the environment compared to non-renewable energy (Destek, 2016).

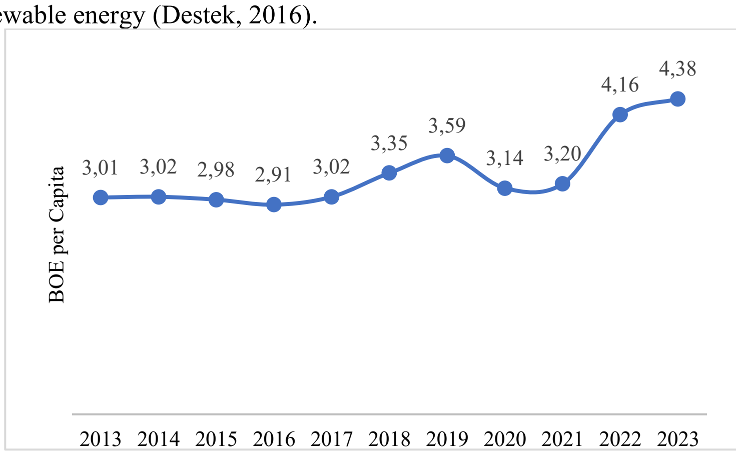

Figure 1 Final Energy Consumption Intensity per Capita in Indonesia

Source: Ministry of Energy and Mineral Resources Republic of Indonesia (2023)

Figure 1 shows that the intensity of energy consumption per capita in Indonesia in 2013-2023 experienced fluctuations where the intensity of energy consumption in 2013 amounted to 3.01 then in 2014 experienced a slight increase to 3.02. In 2015-2016 it decreased to 2.98 in 2015 and decreased again in 2016. This shows an increase in efficiency in energy use in that period. However, there was an increase in energy consumption intensity in 2017 from 3.02 to 4.38 in 2023. With a significant spike in the increase in energy consumption intensity, further action is needed to minimize excessive energy use.

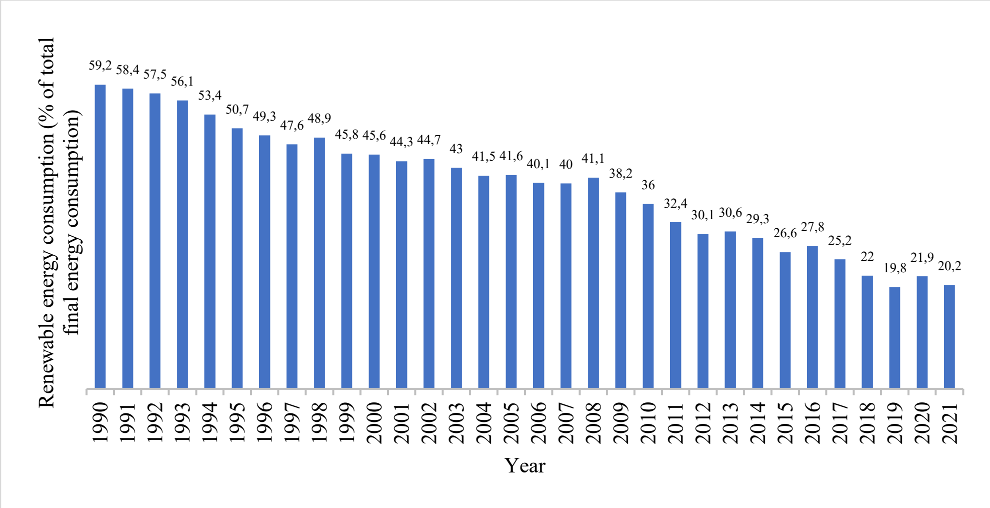

Figure 2 Renewable Energy Consumption in Indonesia

Source: World Bank (2025)

Figure 2 shows that the consumption of renewable energy in Indonesia from 1990 to 2021 shows a significant downward trend over time. This annual variation in renewable energy consumption is influenced by factors, such as: Foreign Direct Investment (FDI), CO2 emissions from transport, energy use, and urban population growth. FDI can encourage the use of renewable energy because foreign investors usually tend to utilize cheaper energy sources in their production activities (Qin & Ozturk, 2021). Increased FDI can also strengthen infrastructure investment and energy transfers to encourage the development of lessen reliance on fossil fuels and use renewable energy.

The connection between renewable energy consumption and CO2 emissions is negative, which means that the use of renewable energy is rising and can reduce CO2 emissions (Listiani Sukmawati et al., 2025). The concept of the Environmental Kuznets Curve (EKC) is very relevant in describing the level of environmental pollution and income levels. This concept explains that in the initial phases of economic development, the level of environmental pollution tends to increase. However, after reaching a certain income, environmental pollution decreases due to a decrease in CO2 emissions and improved environmental policies (Inglesi-Lotz & Dogan, 2018).

Urban population growth plays a role in the development of renewable energy and CO2 emissions along with the dense activities in big cities. The population growth results in an increase in the amount of CO2 emissions produced, so there is a need for energy development to be environmentally friendly and sustainable (Carley, 2009). On the other hand, the energy used determines the resulting emissions. Dependence on fossil fuels such as coal and oil will increase greenhouse gas emissions, while the transition to renewable energy such as solar, hydro, and biomass can be a solution to create a sustainable energy system.

Based on this explanation, this study's goal is to examine the variables that influence renewable energy consumption in Indonesia from 1990 to 2021. This study uses variables of FDI, CO2 emissions from transport, energy use, and urban population growth. The Error Correction Model (ECM) approach was used for this study's analysis because it can look at both immediate and long-term economic problems. This is because the need for renewable energy consumption is not only needed for the present, but also very necessary for the future in a long and sustainable period.

METHODS

Variable Operational Definition

Renewable energy consumption is the amount of renewable energy (hydroelectricity, solar, wind, geothermal, biomass and other) consumed by people in Indonesia during the period 1990-2021. Data for this variable is obtained from the World Bank and measured in percent. FDI is the net amount of foreign direct investment inflows to Indonesia during the period 1990-2021. Data for this variable was obtained from the World Bank and measured in %. CO2 emissions from transport are the total amount of carbon dioxide generated from transportation activities in Indonesia during the period 1990-2021. Data for this variable was obtained from the World Bank and measured in megatons (Mt) CO_2e. Energy use shows the level of energy consumption per individual in Indonesia during the period 1990-2021. Data for this variable was obtained from the World Bank and measured in kilograms of oil equivalent per capita. Urban population growth is the percentage increase in the number of people living in urban areas in Indonesia during the period 1990-2021. Data for this variable was obtained from the World Bank and measured in junaidipercent.

Data Collection Technique

This research is a descriptive analysis with quantitative methods. In this investigation, time series data were utilized as secondary data for 1990-2021 in Indonesia. The data used are data on renewable energy consumption, FDI, CO2 emissions from transport energy, energy use, and urban population growth from the World Bank. This research was processed using the analytical tool E-Views 12.

Data Analysis Technique

The first stage in using ECM is to conduct stationarity tests on all variables. In this study, stationarity testing uses the Augmented Dickey-Fuller method (ADF Test). In the time series analysis using ECM, the variables used are not allowed to be stationary at the level, if all variables are stationary at the level, then the model used is sufficient with Multiple Linear Regression (RLB). To use the ECM model, all variables must be stationary in the same order (Widarjono, 2018). Next is to form a long-term equation by regressing at the level of the independent variable and the dependent variable. The following long-term equation is formed:

$$Y_{it} = \alpha + \beta_1 X_1 it + \beta_2 X_2 it + \beta_3 X_3 it + \beta_4 X_4 it + \mu_{it} \quad (1)$$

where:

Y	= renewable energy consumption
α	= constant
$\beta_1, \beta_2, \beta_3, \beta_4$	= regression coefficients on the long-term model
X_1	= FDI
X_2	= CO_2 emissions from transport
X_3	= energy use
X_4	= urban population growth
it	= period or series
μit	= t-period residual of the long-run model

After obtaining the model equation in the long run, the next thing to do is cointegration testing. Cointegration testing is done using the residual value of the long-term model (ut). This residual is referred to as the Error Correction Term (ECT). ECT variables that are stationary at level indicate that cointegration exists. The presence of cointegration indicates that there is a long run equilibrium relationship in the model that has been formed. After obtaining that there is cointegration in the long-term equation, the next thing to do is to form a short-term model or ECM. In the ECM model, the equation is formed by regressing the independent variable on the dependent variable at the same stationary order. In addition, the ECM model also adds the first lag of the residuals of the long-term equation. The following short-term model is formed:

$$\Delta Y_{it} = \alpha + \beta_1 \Delta X_1 it + \beta_2 \Delta X_2 it + \beta_3 \Delta X_3 it + \beta_4 \Delta X_4 it + \gamma ECT_{t-1} + \mu_{it} \quad (2)$$

where:

ΔY	= change in year-t renewable energy consumption
α	= constant
$\beta_1, \beta_2, \beta 3, \beta 4$	= regression coefficients in the short-term model
$\Delta X_1 t$	= change in FDI in year t
$\Delta X_2 t$	= change in CO_2 emissions from transport in year t
$\Delta X_3 t$	= change in energy use in year t
$\Delta X_4 t$	= change in urban population growth in year t
t	= period or series
γ	= speed of adjustment
ECT_{t-1}	= error correction term or first lag of residuals in the long run ε
μit	= t-period error of short-term equation

Short-term modelling in ECM can be said to be valid if the speed of adjustment (γ) has a value in the range of 0 to 1 and has a negative sign and significantly affects the dependent variable. This means that the model is valid in correcting short-term imbalances towards long-term equilibrium (Juanda and Junaidi, 2011).

After obtaining the ECM model, the next test of the meaning of the model includes the partial test using the t test, simultaneous test using the F test, and coefficient of determination (R2). T test aims to determine the effect of each independent variable on the dependent variable. F test aims to determine the effect of the independent variable on the dependent variable simultaneously. The coefficient of determination can describe how much variation of the dependent variable can be explained by the independent variables contained in the model. In this study using the adjusted r-squared value.

Furthermore, classical assumption testing is carried out on the short-term equation that has been formed. The classical assumption tests include normality, multicollinearity, heteroscedasticity, and autocorrelation tests. After testing the meaning of the model and successfully fulfilling the classical assumptions, the model can be said to be valid.

RESULTS AND DISCUSSIONS

Stationarity Test (Unit Root Test)

Testing for stationarity is crucial when performing regression analysis on time series data. This research employs the Augmented Dickey-Fuller (ADF) test for the unit root test.

Table 1 Stationarity Test Results

ADF	Level		First Difference	
	t-Statistic	Probabilitas	t-Statistic	Probabilitas
Y	-0.373757	0.9018	-6.216516	0.0000
X1	-2.175792	0.2186	-5.267441	0.0002
X2	0.048868	0.9557	-4.810231	0.0006
X3	-0.693395	0.8340	-5.504551	0.0001
X4	-0.446416	0.8887	-5.205939	0.0002

Source: EViews 12, 2025

According to Table 1, every variable in this study is not stationary at the level since its probability value exceeds the significance criterion of α = 5% (insignificant). Following the results of non-stationary data, the test is then conducted at a higher level, specifically the first difference level, which demonstrates that all variables have been stationary because each variable's probability value is below the significant level α = 5%. This indicates that all variables have been stationary at the same level and satisfy the first ECM test requirement.

Cointegration Test

Table 2 Residual Value Test Results (ECT)

Variabel	Nilai Kritis ADF			ADF	Probabilitas
	1%	5%	10%		
ECT	-3.661661	-2.960411	-2.619160	-4.373473	0.0016

Source: EViews 12, 2025

Table 2 shows that the residual value (ECT) has a t-statistic value of -4.373473 greater than the critical value in the MacKinnon table at various confidence levels (1%, 5%, 10%). In addition, the residual probability value (ECT) is 0.0016 or smaller than the significance level α = 5%, which means that this research model has cointegration and between variables have short-term and long-term relationships so that this research model qualifies for the next step, namely ECM analysis.

Model Estimation Results and Statistical Test

T-Statistic Test

The independent variable regression model's partly significant impact on the dependent variable is assessed using the t-statistic test. To perform this test, the t-statistic and the t table are compared. The independent variable is considered to have an impact on the dependent variable if the t-statistic is greater than the t table.

Table 3 Long-Term Model Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	0.301155	0.166937	1.804008	0.0824
X2	-0.125422	0.014655	-8.558079	0.0000
X3	-0.051349	0.006004	-8.552378	0.0000
X4	2.139251	0.444624	4.811368	0.0001
C	75.69549	4.418981	17.12963	0.0000

Source: EViews 12, 2025

The long-term estimation results of the ECM model are displayed in Table 3 and the resulting equation is as follows:

$$D(Y) = 75.69549 + 0.301155*X1 - 0.125422*X2 - 0.051349*X3 + 2.139251*X4$$

a. The coefficient value generated by the FDI variable is 0.301155 with a probability value of 0.0824. The resulting probability value is greater than alpha (α = 5%). It can be concluded that if FDI increases by 1 percent, it will increase renewable energy consumption by 0.301155 in the long run with the assumption of ceteris paribus.

b. The coefficient value generated by the CO_2 emissions from transport variable is -0.125422 with a probability value of 0.0000. The resulting probability value is smaller than alpha (α = 5%). It can be concluded that if the increase in CO_2 emissions from transport by 1 percent, it will reduce the consumption of renewable energy by -0.125422 in the long run with the assumption of ceteris paribus.

c. The coefficient value generated by the energy use variable is -0.051349 with a probability value of 0.0000. The resulting probability value is smaller than alpha (α = 5%). It can be concluded that if the increase in energy use is 1 percent, it will reduce renewable energy consumption by -0.051349 in the long run with the assumption of ceteris paribus.

d. The coefficient value generated by the urban population growth variable is 2.139251 with a probability value of 0.0001. The resulting probability value is smaller than the alpha ($\alpha = 5\%$). It can be concluded that if the increase in urban population growth is 1 percent, it will increase renewable energy consumption by 2.139251 in the long run with the assumption of ceteris paribus.

Table 4 Short-term Model Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(X1)	0.361753	0.185267	1.952607	0.0621
D(X2)	-0.090706	0.023895	-3.796097	0.0008
D(X3)	-0.032383	0.007852	-4.124288	0.0004
D(X4)	1.194268	0.868478	1.375127	0.1813
ECT(-1)	-0.690069	0.173408	-3.979450	0.0005
C	-0.452818	0.215651	-2.099775	0.0460

Source: EViews 12, 2025

The short-term estimation results of the ECM model are displayed in Table 4 and the resulting equation is as follows:

$$D(Y) = -0.452818 + 0.361753*D(X1) - 0.090706*D(X2) - 0.032383*D(X3) + 1.194268*D(X4) - 0.690069*ECT(-1)$$

a. The requirements that must be met in using the ECM analysis method are that the ECT coefficient must be negative and significant. The resulting ECT value has a coefficient value of -0.690069 and a probability of 0.0005, so the conditions have been met, and the research model is considered valid.

b. The regression coefficient value of the FDI variable is 0.361753 with a probability value of 0.0621. The probability value is greater than alpha ($\alpha = 5\%$). It can be concluded that an increase in FDI by 1 percent will increase renewable energy consumption by 0.361753 in the short term, but the effect is not significant with the assumption of ceteris paribus.

c. The regression coefficient value of the CO_2 emissions from transport variable is -0.090706 with a probability value of 0.0008. The probability value is smaller than the alpha ($\alpha = 5\%$). It can be concluded that an increase in CO_2 emissions from transport by 1 percent will reduce renewable energy consumption by -0.090706 in the short term, but the effect is significant under the assumption of ceteris paribus.

d. The regression coefficient value of the energy use variable is -0.032383 with a probability value of 0.0004. The probability value is smaller than the alpha ($\alpha = 5\%$). It can be concluded that an increase in energy use by 1 percent will reduce renewable energy consumption by -0.032383 in the short term, but the effect is significant under the assumption of ceteris paribus.

e. The regression coefficient value of the urban population growth variable is 1.194268 with a probability value of 0.1813. The probability value is greater than alpha ($\alpha = 5\%$). It can be concluded that an increase in urban population growth by 1 percent will increase renewable energy consumption by 1.194268 in the short term, but the effect is not significant with the assumption of ceteris paribus.

F-Statistic Test

The F-statistic test is done by looking at the probability value. If the probability value (prob value) > 0.05, then H0 is accepted, while if the probability value < 0.05, then Ha is accepted.

Table 5 Long-term F-statistic Test Results

F-statistic	794.3438
Prob(F-statistic)	0.000000

Source: EViews 12, 2025

F-statistic value is 794.3438 with a significance value of 0.000000 < 0.05 so that Ha is accepted. This shows that all independent variables in the long term jointly affect renewable energy consumption in Indonesia.

Table 6 Short-term F-statistic Test Results

F-statistic	10.59487
Prob(F-statistic)	0.000015

Source: EViews 12, 2025

F-statistic value is 10.59487 with a significance value of 0.000015 < 0.05 so that Ha is accepted. This shows that all independent variables in the short term jointly affect renewable energy consumption in Indonesia.

Test Coefficient of Determination (R2)

Table 7 Long-Term R^2 Test Results

e-ISSN: 3090-4811
Vol. 2 No.1/EC-ISCEBE (2025)

R-squared	0.991574
Adjusted R-squared	0.990326
S.E. of regression	1.156243
S.D. dependent var	11.75547

Source: EViews 12, 2025

R-squared value is 0.991574, which means that the variation of independent variables can explain 99.1574% of the variation in renewable energy consumption, while the remaining 0.8426% is explained by other variables outside the model.

Table 8 Short-term R^2 Test Results

R-squared	0.679382
Adjusted R-squared	0.615258
S.E. of regression	0.926238
S.D. dependent var	1.493268

Source: EViews 12, 2025

R-squared value is 0.679382, which means that the variation of independent variables can explain 67.9382% of the variation in renewable energy consumption, while the remaining 32.0618% is explained by other variables outside the model.

Classical Assumption Test

Multicollinearity Test

Table 9 Multicollinearity Test Results

Variable	Centered VIF
D(X1)	1.289934
D(X2)	1.198909
D(X3)	1.301611
D(X4)	1.066532

Source: EViews 12, 2025

Based on the above calculations, the VIF value is still below the requirements for multicollinearity, which is less than 10. So, it can be concluded that there is no multicollinearity in this study.

Normality Test

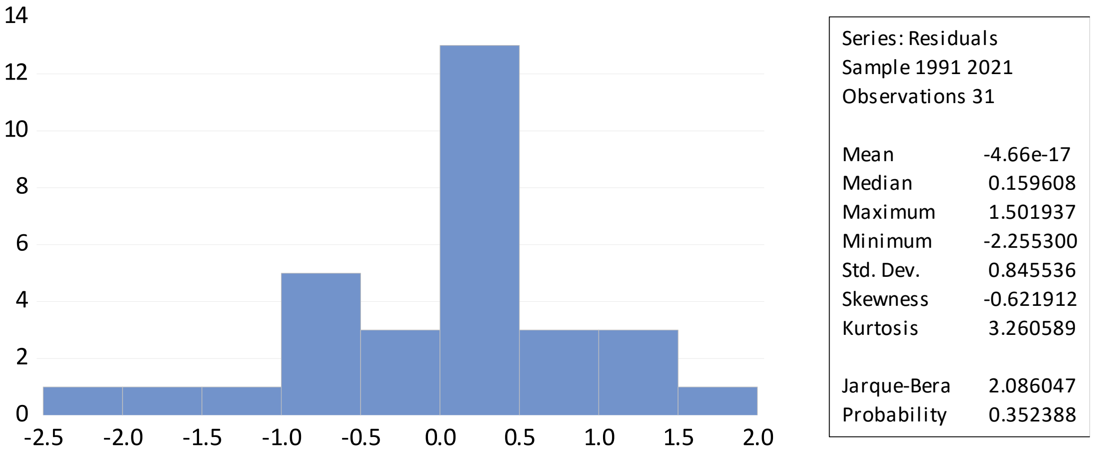

Figure 3 Normality Test Results

Source: EViews 12, 2025

The probability value is 0.352388 > 0.05 (5%). It can be concluded that H0 is accepted, which means that the residual value is normally distributed, and it can be said that the regression model is normally distributed.

Autocorrelation Test

Table 10 Autocorrelation Test Results

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.560412	Prob. F(2,23)	0.2315
Obs*R-squared	3.703770	Prob. Chi-Square(2)	0.1569

Source: EViews 12, 2025

The result of Prob. Chi-Square of 0.1569 where the value is greater than the predetermined alpha (α = 5%), it can be concluded that there is no autocorrelation problem in this model.

Heteroscedasticity Test

Table 11 Heteroscedasticity Test Results

F-statistic	0.260782	Prob. F(5,25)	0.9302
Obs*R-squared	1.536702	Prob. Chi-Square(5)	0.9088

Source: EViews 12, 2025

It is known that the test conducted resulted in Prob. Chi-Square of 0.9088 where the result is greater than the alpha set (α = 5%), it is stated that the data does not have a heteroscedasticity problem.

Conclusion

1. FDI variables have a positive effect on renewable energy consumption in Indonesia in the long and short term, but this effect is not significant. The positive direction of the relationship between FDI and renewable energy consumption reflects the potential contribution of FDI in supporting the energy transition. However, its insignificance indicates that incoming foreign investment has not yet been directly directed to the renewable energy sector, or that there are still structural barriers to channeling FDI into this sector.
2. The CO_2 emissions variable has a negative and significant effect on renewable energy consumption in Indonesia in the long and short term, meaning that an increase in transportation emissions is accompanied by a decrease in renewable energy use. This indicates that the increase in transportation emissions is still in line with high fossil fuel use, while the integration of renewable energy in the transportation sector remains low. This reflects the lack of optimal synergy between energy policy and the transportation sector.
3. The energy use variable has a negative and significant impact on renewable energy consumption in Indonesia in the long and short term. This indicates that the increase in per capita energy consumption is still dominated by fossil fuel sources, not renewable energy. Dependence on conventional energy hinders the transition to clean and sustainable energy sources.
4. The urban population growth variable has a positive but insignificant effect on renewable energy consumption in Indonesia in the long and short term. This finding indicates that although urbanization has the potential to encourage the use of renewable energy technology, urban growth in Indonesia has not been accompanied by the implementation of renewable energy in urban areas.

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Acknowledgement

The writer wishes to convey his appreciation to Allah SWT for his bounties and mercy, which have enabled this article to be completed successfully. The author would also like to thank his supervisor and all those who have provided support, guidance, and valuable input during the writing and compilation of this article. Hopefully, this work can make a positive contribution in the advancement of renewable energy studies in Indonesia.