Planning and Policy Direction for Utilization of Renewable Energy in Sustainable Development in Indonesia

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Abstract: - The Indonesian government through the National Energy Council (DEN) has a target for new renewable energy to be increased, starting from 2025 with a target of 23 percent to 2060 with a target of 66 percent, but ,new renewable energy in Indonesia only increases 0.55 percent per year. Indonesia has great potential, but can the potential be maximized by the government in the direction of a better and environmentally friendly energy policy. This study analyzes the movement of renewable energy and CO_2 emissions to the Indonesian economy from 1990-2021, using the Vector Error Correction Model (VECM) statistical method by considering short-term and long-term results in the model. The results show that in the long and short-term economy the role of GDP per unit of energy use for the economy is needed and has a positive effect, the role of carbon emissions in the short and long term CO_2 has a positive and significant direction, non-renewable energy in the long term and short term is still moving negative and significant, this indicates that renewable energy in Indonesia tends to be low, energy replacement must be carried out slowly and gradually, shock response conditions conclude when GDP energy use and CO_2 are affected by a negative shock will disrupt economic development, meanwhile, if there is a negative shock on consumption Renewable energy still tends to be stable and positive for the development of the Indonesian economy.

Key-Words: - Economy, Renewable Energy, CO_2 Emissions, VECM, Indonesia.

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1 Introduction

Indonesia is one of the developing countries with increasing economic growth, this can be seen from the continuous growth of Indonesia's GDP per capita every year. However, this economic growth is followed by an increase in carbon dioxide emissions every year so it has an impact on reducing environmental quality by the EKC hypothesis. Indonesia has established Government Regulation Number 79 of 2014 concerning the National Energy Policy (KEN). KEN as a product of public policy was determined after going through a "top-down" debate since 2010. The target of KEN is only to focus on energy supply, even though energy policy has shifted to the side of energy demand. KEN does not set greenhouse gas mitigation targets. To support the achievement of the KEN target regarding the mix of new and renewable energy (EBT), the Government of Indonesia has stipulated various regulations regarding the Feed-in Tariff for the selling price of electricity for EBT generators but it does not run optimally because the price is more expensive, this is an obstacle to the problem of using renewable energy in Indonesia, [1]. The government through the National Energy Council (DEN) has drawn up a roadmap for the energy transition towards net zero emissions in 2060. Every year the target for new renewable energy will increase, starting from 2025 with a target of 23 percent to 2060 with a target of 66 percent. The Indonesian government is trying to reach the target of 23 percent new renewable energy in 2025 but in fact, new renewable energy in Indonesia only increases 0.55 percent per year. The target that should be achieved by the government for the achievement of new renewable energy per year is 0.9 percent, [2].

Reviewing energy development in Indonesia is presented by several important findings. The increase in energy intensity in Indonesia is represented by an increase in energy in 33 provinces in Indonesia. Energy intensity at the provincial level in Indonesia is largely determined by regional economic activity. The role of the industrial sector influences energy intensity quite dominantly and is also supported by policies in the industrial sector that will greatly influence the achievement of government targets related to energy policy to reduce energy intensity by 1% per year, [3].

The increase in non-renewable energy in Indonesia cannot be simply minimized because the economic sectors in Indonesia are very dependent on the use of non-renewable energy usage which is very high and continues to increase every year. The following is an overview of data on CO_2 carbon emissions and the use of GDP per capita for energy activities in Indonesia.

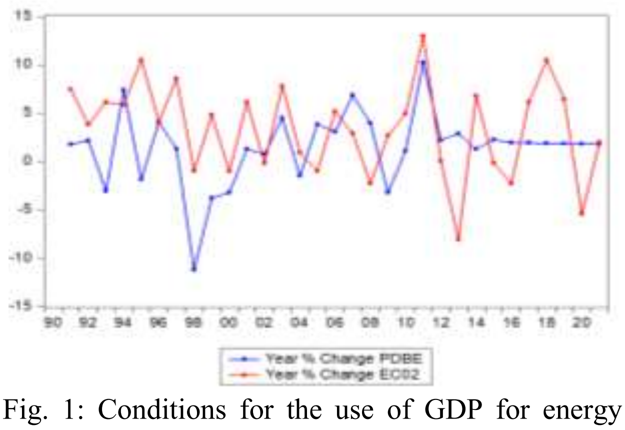

Fig. 1: Conditions for the use of GDP for energy against Indonesia's CO_2 emissions
Source: World Bank Indonesia Energy Data, 2023

Based on Figure 1, it can be seen that Indonesia has a state of increasing energy GDP use, where the use of energy GDP has a trend that continues to be high from 1990 to 2021 in Indonesia, this is also followed by an increase in CO_2 which continues to increase every year in Indonesia, according to several studies, carbon emissions in Indonesia are still contributed by non-renewable energy. Based on [4], excessive consumption of fossil fuels, especially for the combustion process, will increase emission levels in the atmosphere and is very unfriendly to the environment causing CO_2 emissions. The demand for fossil fuels is still high in several countries, including Indonesia, given that the manufacturing sector is the main consumer of fossil fuels in Indonesia and the development of Indonesia's manufacturing industry. Research from [5], the positive influence of value-added manufacturing and international trade on CO_2 emissions in the long and short term in Indonesia. High economic activity causes environmental damage.

On the other hand, the potential for new renewable energy in Indonesia is quite large, including ocean, geothermal, bioenergy, wind, water, and sunlight. This potential needs to be developed. Energy policy in Indonesia is currently following international energy policies, namely reducing greenhouse gas emissions, transforming towards new renewable energy, and accelerating the economy based on green technology. Indonesia's commitment to supporting international energy policies includes increasing the use of new and renewable energy, reducing fossil energy, increasing the use of electricity in the household, industrial, and transportation sectors as well as the use of carbon capture and storage, [6]. In Figure 2, you can see a comparison of renewable energy consumption and non-renewable energy consumption in Indonesia.

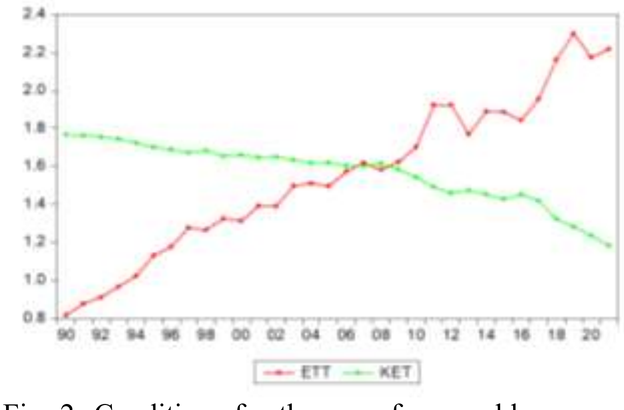

Fig. 2: Conditions for the use of renewable energy and non-renewable energy in Indonesia
Source: World Bank Indonesia Energy Data, 2023

A comparison of energy trends is shown in the following figure where non-renewable energy in 1990-2021 continues to experience an increasing and higher intensity of use throughout the year, of course, this is caused by an increase in the activity intensity of the production sector for the economy in Indonesia. On the other hand, the consumption of renewable energy has continued to decline from 1990-2021, where the trend has decreased, this is allegedly because the capacity for renewable energy in Indonesia is still minimal and has not been able to greatly support Indonesia's sectoral economic activity, so the intensity of its use tends to be low. Research from [7], from 2000-2019, the consumption of renewable energy did not have a positive and significant effect on the movement of GDP growth in Indonesia, due to the lack of attention in the process of developing the development as well as related to regulations and Indonesia which is currently still meeting its energy demand from non-renewable sources.

The other side of the process of developing renewable energy in Indonesia is [8]. Indonesia has experienced multi-aspect principal-agent problems between PT PLN, the agent with the sole authority to manage electricity transmission, and various principals, namely the Ministry of State-Owned Enterprises (BUMN), the Ministry of Energy and Mineral Resources, the Ministry of Industry (MOI) as intermediaries between the RE industry domestic and foreign, and the Ministry of Finance. While changes to the Ministry of Energy and Mineral Resources' feed-in-tariff (FiT) policy send uncertain policy signals, the Ministry of Finance's fiscal incentive policies other than FiT to encourage RE development in Indonesia remain suboptimal. Indonesia's potential policy direction has natural resources, especially abundant renewable energy resources, which can potentially succeed in realizing the energy transition. To create clean and renewable resources, Indonesia is trying to optimize energy use to ensure the availability of resources. Indonesia's target is that in 2025 the use of renewable energy will reach 23% and in 2050 it can reach 50%, [9]. Research from [10], In Indonesia all stakeholders consider these factors in the development of renewable energy and encourage the private sector to invest and assist acceleration based on providing an analysis of investment opportunities. Factors influencing the development of the energy sector include policies related to human capital, environmental protection, and energy efficiency. Based on [11], has large amounts of renewable energy resources both on land and at sea. this potential can enable a 100% renewable energy electricity system and meet future demand with limited impact on land availability.

Indonesia has great potential, but can the potential be maximized by the government in the direction of a better and environmentally friendly energy policy. This study will lead directly to how the direction of renewable energy policy in Indonesia is by looking at the short and long-term effects of CO_2, renewable energy, and GDP spent on economic activities on the sustainability of the Indonesian economy and looking at how the condition of CO_2, renewable energy and GDP for energy if a negative shock occurs, does it affect the sustainability of economic activity in Indonesia.

2 Literature Review

The assumption of Kuznets relates to the per capita income of the country's environment is known as EKC. His assumption shows the attention will be directed toward increasing the country's income if it is still relatively low, either through production or investment that encourages income growth, excluding issues of environmental quality Income growth is followed by increasing pollution and then it declines again if income growth conditions persist. This assumption is from the amount for the quality of the environment, which improves social control and government rules therefore, people are more prosperous, [12]. It will make a big contribution to the national products if the country's income improves in line with economic development, and manufacturing products. To conclude, industrialization starts in small industries and continues in large industries. The increment of using the natural resources and degradation of environment intensification degradation is the phase of middle-income level, the development phase dominates industrialization by increasing the share of its internal social items when industrial activity grows steadily. In this case, the utility of uncooked materials will decrease, and the elimination of waste per unit of production will increase.

The relationship between CO_2 and the economy from various studies has found the following results, short-term two-way panel causality between CO_2 emissions and employment and between available energy and employment. The results show a one-way causality of available energy and employment to GDP. The results of a long-term causal relationship show that the estimated ECT coefficient meets the requirements in the short and long term and has a close relationship between CO_2 emissions and GDP, [13]. The coefficient of economic growth is positive and significant with CO_2 emissions, showing an increase of 1 % in economic growth is associated with an increase in CO_2 emissions, the coefficient of renewable energy use is negative and significant, implying that a 1% increase in renewable energy use results in a reduction in CO_2

emissions in the long run. Empirical findings reveal that economic growth and expansion of agricultural land increase CO_2 emissions while increased use of renewable energy improves environmental quality by reducing CO_2 emissions. Research from [14], energy consumption worsens environmental quality through high carbon emissions, and economic growth is a significant determinant of positive carbon emissions. urbanization and population growth as a factor of carbon emissions. In the causal relationship in the middle of the series, there is a two-way causality between economic growth and carbon emissions, between energy consumption and economic growth, between economic growth and population growth, between energy consumption and urbanization, and between economic growth and urbanization, [15].

The relationship between renewable energy and economic growth. Efficient energy use is a prerequisite for economic development. However the excessive use of fossil fuels is detrimental to the environment. Because renewable energy emits no or low greenhouse gases, more and more countries are trying to increase their use of energy from renewable sources. that renewable energy does not hinder economic growth for both developing and developed countries, while the consumption of renewable energy (threshold level) is not so important. On economic growth for developed countries, [16], renewable energy consumption triggers an acceleration of GDP, compared to other energy variables considered in the model. Compared to the standard econometric model, this experiment can show and choose which input can produce the best target. The best output is GDP per capita. The positive variation, through the prediction process of the four ITEs, is due to the acceleration of renewable energy, policy measures intensifying the process of changing the energy structure by promoting a more intensive use of renewable energy, [17].

3 Methodology

3.1 Types and Sources of Data and Variable Operational Definitions

This research is in the form of descriptive quantitative problem-solving based on data, by presenting, analyzing, and interpreting it. The data used is secondary data, this data is obtained indirectly from various publications, publications of official data platforms, and publications of various data collection books. The data for the observation area is the coverage of the territory of the State of Indonesia, the data used is secondary data (time series) with the 1990-2021 time series. The following is a summary of the variables, units, descriptions, and data sources in the study:

1. Economic Growth (PE): Growth and development of income (GDP) from the value of goods and services produced in Indonesia.
2. CO_2 emission (ECO_2): Carbon dioxide emissions come from burning fossil fuels and manufacturing cement. This includes carbon dioxide produced by the consumption of solid, liquid, and gaseous fuels and the combustion of gases.
3. GDP per unit of energy use (GDP): GDP per unit of energy use is PPP GDP per kilogram of oil equivalent to energy use. PPP GDP is gross domestic product converted to constant 2017 international dollars using the purchasing power parity rate. The international dollar has the same purchasing power over GDP that the US dollar has in the USA.
4. Consumption of renewable energy (CET): Renewable energy consumption is the share of renewable energy in the total final energy consumption.

3.2 Vector Autoregression (VAR) Data Analysis Method

The analysis used in this study is a non-structural model using the Vector Autoregression (VAR) method. Data analysis was carried out using a descriptive quantitative approach. Quantitative is a research method based on positivism, used to view certain samples. The data used in this study is time series data, so it is necessary to analyze the interdependence between these variables. VAR is a model that can analyze the interdependence relationship between time series variables. According to [12], VAR has several model advantages:

1. There is no need to distinguish between exogenous and endogenous variables. All variables both exogenous and endogenous that are believed to be related should be included in the model. However, exogenous variables can also be included in the VAR.
2. To see the relationship between variables in the VAR requires several existing variable lags. This lag is necessary to capture the effect of this variable on other variables in the model.

This study uses the Vector Autoregressive (VAR) model framework, used to find out how the economic conditions are from various types of Energy variables. In terms of the direct impact of energy use using carbon dioxide emissions, conventional energy use uses GDP per unit of energy use and renewable energy uses the total final consumption of renewable energy. The structure of this model begins with 1) The relationship of energy conditions namely ECO_2, PDBE, and KET with Economic Growth. 2) Response of economic growth to shocks from energy conditions, namely ECO_2, PDBE, and KET. 3) how big is the contribution of the energy performance variables namely ECO_2, PDBE, and KET to Indonesia's economic growth. To answer all questions in this study using the VAR analysis method if not cointegrated, if cointegrated then VECM analysis will be used. The Long-Term Equation of Economic and Energy Growth in Indonesia:

$$PE_{nt} = \alpha_0 + \beta_1 \, ECO_{2\,t\text{-}j} + \beta_2 \, PDBE_{\,t\text{-}j} + \beta_3 \, KET_{\,t\text{-}j} + \varepsilon_t$$

Short-Term Equation of Economic and Energy Growth in Indonesia:

$$\Delta PE_t = \alpha_0 + \lambda_1 \, \Delta \, ECO_{2t} + \lambda_2 \, \Delta \, PDBE_{\,t} + \lambda_3 \, \Delta \, KET_{\,t} + \lambda_4 \, Ect + \varepsilon_t$$

Where:

PE	:	Economic growth (%)
ECO_2	:	CO_2 Emissions (Metric Tonnes Per Capita)
PDBE	:	GDP per unit of energy use (USD)
KET	:	Renewable energy consumption (%)
$\lambda_1, \lambda_2, \lambda_3, \lambda_4$,	:	Short term relationship coefficient
α_0	:	Constant Intercepts
$\beta_1, \beta_2, \beta_3$	:	Long term relationship coefficient
ECT	:	Error Correction Term
ε	:	Error Term
j	:	Parameters (lag 1, 2,.... etc.)

3.3 Data Analysis Procedures

The unit root test was first developed by Dickey-Fuller and is known as the Dickey-Fuller (DF) unit root test, [18]. The DF unit root test assumes that the disturbance variable et is bound with an average of zero, so that the variance becomes constant and has no relationship (non-autocorrelation). One of the formal concepts used to determine stationary data is through the unit root test. If a time series data is not stationary at zero order I(0), then the stationarity of the data can be searched through the next order so that the level of stationarity is obtained at the nth order (first difference or I(1), or second difference or I(2). , etc. The hypothesis for this test is:

1. H0 : d = 0, there is a unit root, not stationary
2. Ha : d ≠ 0, there is no unit root, stationary

If the test results reject the hypothesis that there is a unit root for all variables, it means that all are stationary or in other words, the variables are cointegrated at I(0), so the estimation will be carried out using linear regression.

In determining the optimum lag, you can use the criteria put forward by Akaike (Akaike Information Criterion = AIC), [13]. These criteria can be written as follows:

$$\text{Ln } AIC = \frac{2\,k}{n} + \ln \frac{SSR}{n}$$

Where:
SSR = Sum of squares residual (sum of squares residual)
k = Number of estimated parameter variables
n = Number of observations

The length of lag chosen is based on the minimum AIC value by taking its absolute value. VAR stability needs to be tested before conducting further analysis because if the VAR estimation results to be combined with the error correction model are unstable, then the Impulse Response Function and Variance decomposition will be invalid. To test the stability of the estimated VAR that has been formed, stability conditions are checked in the form of roots of characteristic polynomials and inverse roots of AR characteristic polynomials.

The concept of cointegration is basically to find out the possibility of a long-term equilibrium relationship in the observed variables. In the cointegration concept, two or more non-stationary time series variables will be cointegrated if their combination is also linear over time, although it is possible that each variable is not stationary. As a basis for decision making, the following testing criteria can be used:

1. H0 : β = 0, The variables have no cointegration
2. Ha : β ≠ 0, The variables have cointegration

After the cointegration test is carried out on these variables, the next step is to form a VAR or VECM model. If there is a cointegration relationship between the research variables, then the estimation is done with VECM, whereas if there is no cointegration, the estimation is done with VAR. The independent variable is said to be significant in influencing the dependent variable. Meanwhile, to find out a negative or positive relationship is to look at the sign on the variable coefficient.

Forecasting in VAR is an extrapolation of the current and future values of all variables using all the information in the past. Impulse Response analysis is one of the important analyzes in the VAR model. Impulse Response analysis tracks the response of endogenous variables in the VAR system due to shocks or changes in the disturbance variable, [12]. Impulse Response analysis can see how much the independent variable is affected by shocks or shocks that occur in the dependent variable sometime in the future (in units of each variable), [19].

This test is used to measure the estimated error variance of a variable, namely how big a variable is in providing an explanation for another variable or for the variable itself. Basically, this is another method to describe the dynamic system contained in VAR. It is used to measure the estimated error variance of a variable. How big is the difference between the variants before and after the shock, both shocks originating from the variable itself and shocks from other variables, [14]. This variance decomposition will be used to help determine the determinants of the dependent variable on the independent variable because it can explain how much the independent variable can affect the dependent variable.

4 Result and Discussion

1. Stationarity test

The following are the results of the stationarity test used in this study using the unit root test using the Augmented Dickey Fuller Test (ADF test) (Table 1).

Table 1. Unit Root Test Test Results At Level

Variable	ADF T-Statistic	Prob	Result	Conclusion
PE	0.56033	0.9861	Accept H0	Not Stationary
KET	0.71265	0.0810	Accept H0	Not Stationary
CO_2	-0.78947	0.8082	Accept H0	Not Stationary
PDBE	0.71472	0.9906	Accept H0	Not Stationary

Results of the unit root test by comparing the value of the t-count with the critical value for each α, namely 1 percent, 5 percent, and 10 percent, it can be concluded that there are no variables that are stationary at the level, so that the unit test will be repeated root test on the first difference on each variable and the results can be seen in the following Table 2.

Table 2. Unit Root Test Test Results at Level 1

Variable	ADF T-Statistic	Prob	Result	Conclusion
PE	-5.121783	0.0002	Reject H0	Stationary
KET	-6.967049	0.0000	Reject H0	Stationary
CO_2	-5.679998	0.0001	Reject H0	Stationary
PDBE	-4.738180	0.0007	Reject H0	Stationary

The unit root estimation results at the first difference level for all variables are stationary. This means that the data used in this study are integrated at order one or can be shortened to I (1) so that the data is free from spurious regression problems. Therefore, the stationary requirements have been met, the next stage can be further data processing.

2. Optimum Lag Determination

Based on the Akaike Information Criterion (AIC) value, the optimum lag length is 2. So the lag value that will be used for further research is lag 2. The results of determining the length of the lag are shown in the following tables:

Table 3. Optimum Lag Determination Results

Lag	Akaike Information Criterion (AIC)
0	31.51178
1	16.98306
2	13.52191*

Based on Table 3 of determining the optimum lag used in the economic growth model (PE), GDP per unit of energy use (GDP), renewable energy consumption (KET), and carbon emissions (CO_2), the VAR/VECM equation model is at lag 2.

3. VAR Stability Test

Stable or not the estimated VAR that has been formed is checked for stability conditions using the roots of characteristic polynomial and inverse roots of AR characteristic polynomial.

Table 4. Results of Roots of AR Characteristic Polynomial Test

Equation Model	Modulus Range
Equation Model	0.374938 - 0.987435

Based on Table 4, shows that the modulus values of all equation models are less than 1 so it can be concluded that the VAR model is valid. Next, testing the stability of the VAR using the inverse roots AR characteristic polynomial is shown in the following Figure 3.

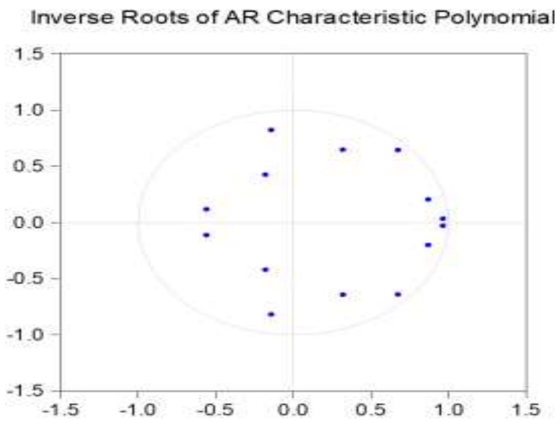

Fig. 3: VAR Model Stability Test

VAR stability by using the inverse roots of AR characteristic polynomial for all equation models shows that the points on the circle or the distribution of the data do not go outside the circle, this means that the data is valid for further analysis using VAR. Therefore, testing the stability of the VAR by using roots of characteristic polynomial and inverse roots of AR characteristic polynomial is valid, which means that the results of the analysis of the impulse response function and variance decomposition in the VAR estimation are valid.

3. Cointegration Test

Cointegration was carried out through the Johansen Cointegration test with an optimum lag of 2 according to the determination of the optimum lag based on the AIC that has been carried out previously. The Johansen Cointegration Test method is carried out by comparing trace statistics with critical values using a significance level of 5 percent. If the trace statistic is greater than the critical value, then there is cointegration in the system of equations. Cointegration test results in this study can be seen in the following Table 5.

Table 5. Cointegration Test Results Model Equation 1

Hypothesized	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.743201	64.07229	47.85613	0.0008
At most 1	0.513633	26.00741	29.79707	0.1285
At most 2	0.184002	5.825215	15.49471	0.7161
At most 3*	0.004689	0.131598	3.841466	0.0168

Based on the table above, shows that the trace statistic value r = 0 is greater than the critical value with a significance level of 5 percent, which is 64.07229 greater than 47.85613. This means that the null hypothesis which states that there is no cointegration in the variables used is rejected and the alternative hypothesis which states that there is cointegration is accepted. Thus, the results of the co-integration test indicate that in the equation model of the economic growth model (PE), GDP per unit of energy use (GDP), renewable energy consumption (KET), and carbon emissions (CO_2), have a stability/balance relationship and the same movement in the long run. Therefore, in each short-term period, all variables tend to adjust to each other to achieve long-run equilibrium. Thus the correct model to use in this study is the Vector Error Correction Model (VECM) instead of Variance Auto Regression (VAR) because the variables used are cointegrated and stationary at the first difference level.

4. Estimasi VECM

The results of first-order, stable and cointegration difference tests in the long and short term are estimated using an error correction vector model (VECM), along with the results of the equation can be seen in Table 6.

Table 6. Long-Term VECM Estimation Results

Variable	Coefficient	t-statistic	Description
PE (-1)	1.000000		
PDBE (-1)	2.027177	[8.22251]	Significant
KET(-1)	-1.165004	[5.48567]	Significant
CO_2 (-1)	21.91770	[22.8496]	Significant
C	-87.26952		

[ ] : t-statistic
* : Based on confidence level 99% (α=1%) = 1.31370
** : Based on confidence level 95% (α=5%) = 1.70329
*** : Based on confidence level 90% (α=10%) = 2.47266

The estimation results on the research variables obtained can be said to have a significant effect if the t-count value is greater than the t-table value with a significance level of (α=1%) = 1.31370, (α=5%) = 1.70329 and (α=10%) = 2.47266. In the long-term model, there is a significant influence between the variables per unit of energy use (PDBE), Renewable Energy Consumption (KET), and Carbon Emissions (CO_2) on the Indonesian economy in the 1990-2021 period.

Table 7. Short-Term VECM Estimation Results

Variable	Coefficient	t-statistic	Description
ECT	-0.623649	[-1.95734]	Significant
D(PDBE)(-1))	1.756400	[1.43908]	Significant
D(PDBE)(-2))	1.735481	[1.64131]	Significant
D(KET)(-1))	-0.766255	[-2.87565]	Significant
D(KET)(-2))	-0.245587	[-1.58332]	Signifikan
D(CO_2)(-1))	9.602310	[1.27149]	Not significant
D(CO_2)(-2))	15.02295	[2.15737]	Significant
C	-1.726701		

[ ] : t-statistic
* : Based on confidence level 99% (α=1%) = 1.31370
** : Based on confidence level 95% (α=5%) = 1.70329
*** : Based on confidence level 90% (α=10%) = 2.47266

The coefficient of Error Correction Term (ECT) shows the speed of adjustment, namely the speed of the residual/error in the previous period to correct changes in variable Y towards balance in the next period. Based on Table 7, it can be seen that the ECT coefisein is negative (-). This indicates the validity of the model specification. The VECM short-term estimation results show a negative ECT coefficient, which is -0.623649 and significant at a significance level of 0.05. This means that the conditions for short-term VECM estimation are met and the VECM model is declared valid. The negative sign in the coefficient indicates that the error is corrected by 0.62 percent annually in the equation for testing short-run balances.

5. Impulse Response Function (IRF)

the results of Impulse Response Function Analysis (IRF) to analyze the impact of shocks (shock) on economic growth on energy variables and carbon emissions, shocks on PDBE, KET, and CO_2. The results of IRF analysis are used to show how a variable responds to a shock in the variable itself and other endogenous variables. The following are the results of IRF.

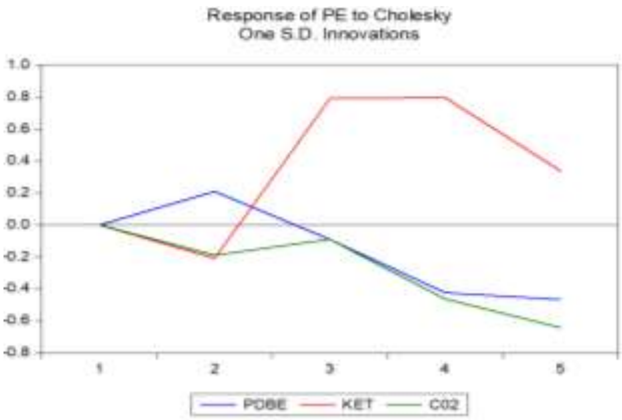

Fig. 4: Impulse Response Function

The Figure 4 shows the positive response of economic growth to GDP shocks per unit for energy use (GDP) in period 1 to period 5, if GDP shocks occur the economic growth tends to be stable and positive, increasing or decreasing GDP per unit for energy use (GDP) in periods 1- 2 is classified as stable, whereas if there is a shock or a decrease in GDP on economic growth in periods 3-5 it tends to have a negative effect which will reduce or disrupt the economy. Economic growth against shocks to the consumption of renewable energy (PE) for periods 1-5, if there is a shock to consumption of renewable energy (PE) for economic growth in periods 1-2 tends to have a negative effect that will reduce or disrupt the economy, whereas if there is a shock to renewable energy consumption (CET) on economic growth tends to be stable and positive, the increase or decrease in consumption of renewable energy (CET) in the 3-5 period is relatively stable. The response to carbon emissions (CO_2) in periods 1-5, shows negative results, if there is a shock or reduction in carbon emissions (CO_2) on economic growth in periods 1-5 it tends to have a negative effect which will reduce or disrupt the economy.

6. Variance Decomposition

Variance decomposition is used to compile the forecast error variance of a variable, namely how big the difference is between the variance before and after the shock, of other variables to see the relative effect of the research variables on other variables.

Table 8. Variance decomposition Results

Period	PDBE	KET	CO_2
1	0.000000	0.000000	0.000000
2	0.011068	0.004354	7.315931
3	0.417272	0.160550	8.378486
4	0.715882	0.181632	8.574870
5	0.804131	0.253077	8.730641

Based on Table 8, it can be found that the contribution of high carbon emissions is the same as an indication of the improvement of the Indonesian economy. The Variance decomposition figure in periods 1-5 has the highest contribution to carbon emissions with 8.37% influencing and contributing to Indonesia's economic growth in 1990-2021.

4.2 Discussion

The direction of energy policy from several studies on Indonesian energy is reviewed through several findings, [20], energy consumption and economic growth in Indonesia tend to have short and long-term effects. energy consumption leads to economic growth because industrial energy consumption tends to increase output as well as unemployment which adds to the value of a country's GDP and hence, Indonesia has enjoyed increasing economic growth over the last 19 years from 2000-2019. Research from [21], The case in Indonesia of carbon dioxide emissions and consumption of renewable energy-hydropower is significantly positive for economic growth in the long term and short term, while consumption of renewable energy-thermal earth, biomass, and other sources have a significant negative effect on economic growth, during 1990-2020. Research from [22], CO_2 emissions encourage Indonesia's economic growth because pollution control is less than optimal in the short term. Indonesia needs to implement development policies that prioritize pollution control, emission taxes, and energy conservation on electricity consumption, such as the use of renewable energy consumption. can be an alternative for controlling CO_2 emissions, increasing Indonesia's carbon emissions cannot be avoided because it is dependent on non-renewable energy and this indicates Indonesia's economic activity has increased from 1971-2020.

The results of the study show the direction of energy policy in Indonesia seen from the results for the 1990-2021 period showing statistical findings in the sphere of influence of GDP per unit for energy use (PDBE), renewable energy consumption (KET), carbon emissions (CO_2) on the Indonesian economy. In the long term, the accumulation of GDP per unit for energy use (GDP) has a positive and significant effect with a 1% increase in value affecting and increasing economic growth by 2.02%, renewable energy consumption has a negative and significant direction, every 1% increase will decrease economic growth of 1.16% and carbon emissions have the highest impact, every 1% increase will increase 21.9% of Indonesia's economic growth.

In the short-term accumulation, results show that GDP per unit for energy use (GDP) in the short term has a positive and significant effect on lags 1 and 2, if there is an increase of 1% GDP per unit for energy use (GDP) in the first lag it will increase economic growth of 1.75% and in the second lag economic growth will increase by 1.73%. Consumption of renewable energy (CET) in the short term has a negative and significant effect on lags 1 and 2, so if there is an increase of 1% Renewable energy consumption (CET) in the first lag will reduce economic growth by 0.76% and in the second lag economic growth will decrease by 0.24%. Carbon Emissions (CO_2) in the short-term estimate have a positive and insignificant effect on lag 1, Carbon Emissions (CO_2) on lag 2 have a positive and significant influence with a coefficient value of 15.02295, so if there is an increase of 1% Carbon Emissions (CO_2) in the second lag will increase economic growth by 15.02%. Looking at the trend graph between the 3 variables regarding energy in Indonesia is presented through the following Figure 5.

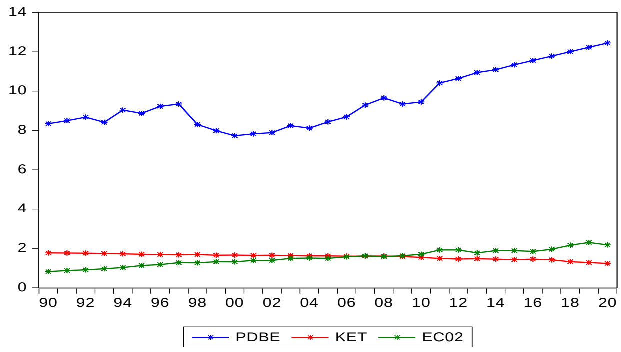

Fig. 5: Indonesia's Energy Consumption Trend in 1990-2021

The trend shows that throughout the year the GDP per unit for energy use (GDP) for Indonesia 1990-2021 has fluctuated, but throughout 2010-2021 it has continued to increase, this is due to increasing economic activity in Indonesia, in terms of renewable energy in Indonesia such as energy Solar, water, wind, biomass, and geothermal trends show a continuous decline seen in 2006-2021. It is also alleged that Indonesia's renewable energy has not been able to support domestic energy supply and demand so Indonesia is still dependent on non-renewable energy such as coal, natural gas, and oil, thereby increasing the trend of Indonesia's carbon emissions. From this trend, from 1990-2021 carbon emissions have continued to increase in Indonesia.

Indonesia is still not able to lead the direction of energy policy towards the use of renewable energy, according to several studies also explain, [23], The development of Indonesia's economic potential in various sectors affects national energy needs as a whole significantly. The economic sector is mainly industry, services, and activities in the transportation support sector. Indonesia's energy needs for the next 40 years will adjust to developments in population growth, increasing GDP, technological developments, and people's lifestyles according to the times. Energy needs will increase until 2060 by almost 3. This is a challenge for Indonesia to meet energy needs in the future by considering green and environmentally friendly trends. Research from [24], from 1990 to 2019. Renewable energy consumption harms Indonesia's economic growth. This is because the production of renewable energy is still limited, but the level of consumption continues to increase. Consumption of non-renewable energy has a positive effect on Indonesia's economic growth. In general, energy consumption has a positive impact on Indonesia's economic growth. When the two are combined, both make a positive contribution to the national economy, [25], energy consumption is dominated by energy produced from fossils, namely oil, coal, and gas. Meanwhile, renewable energy has been used since the early 2000s with a big jump in solar energy consumption. Indonesia has the opportunity to switch to geothermal energy which contributes 3.6% to the national energy supply but is still classified as a low value.

5 Conclusion

Indonesia has great potential in developing renewable energy due to its wealth of natural resources and regional characteristics, the results of the study show that in the long and short term, the role of GDP per unit of energy use for the economy is very much needed and has a positive effect, the role of carbon emissions in the short and long term CO_2 has the positive and significant direction tends to be quite high and indicates sectoral activity in the Indonesian economy has increased quite a bit and automatically the use of non-renewable energy tends to be still high. The role of non-renewable energy in the long term and short term is still moving negatively and significantly. This indicates that renewable energy in Indonesia tends to be still low, when renewable energy is increased it tends to make the economic sector temporarily have a temporary shortage of energy intake if it is replaced directly and will reduce the economy. Energy replacement must be carried out slowly and gradually, the condition of the shock response concludes that when the GDP of energy use and CO_2 is affected by a negative shock it will disrupt economic development, whereas if there is a negative shock the consumption of renewable energy still tends to be stable and positive for Indonesia's economic development.

The direction of the policy transition from non-renewable energy to renewable energy must be carried out by the Indonesian government in stages. The first step is that the Indonesian government must be able to meet the needs of foreign investment for renewable energy, which is calculated for medium and long-term needs. The economic sectors will temporarily be unstable when the energy shift is due to fuel changes, of course, the Indonesian government must prepare an economic stability policy as the value of economic output temporarily decreases due to a temporary decrease in activity. Renewable energy use policy regulations must be applied to all provinces in stages and simultaneously, each region must be able to utilize regional resources for renewable energy.

References:

[1] LOMA Wahid, "Analysis of National Energy Policy as a Product of Indonesia's Energy Transition Policy (Analisis Kebijakan Energi Nasionalsebagai Produk Kebijakan Transisi Energi Indonesia)," *J. Energy and Environment.,* vol. 13, no. 1, pp. 7–16, 2020, doi: 10.29122/elk.v13i1.4255.

[2] DEN, "National Energy Balance 2019 (Neraca Energi Nasional 2019)," *Lap. Review. Review of the Nas Energy Balance. 2020,* p. 14, 2020.

[3] R. Azaliah and D. Hartono, "Determinants of Energy Intensity in Indonesia: Panel Data Analysis (Determinan Intensitas Energi Di Indonesia : Analisis Data Panel)," *J. Ekon. and Developer.,* vol. 28, pp. 192–214, 2020.

[4] M. Constantia, "Determinants of CO_2 Emission Intensity: Manufacturing Firm-Level Evidence in Indonesia," *J. Perenc. Developer. Indonesia. J. Dev. Plans.,* vol. 6, no. 3, pp. 402–419, 2022, doi: 10.36574/jpp.v6i3.296.

[5] VK Sari, "The impact of macroeconomic indicators on carbon emissions in Indonesia," *J. Perspekt. Financing and Development. Drh.,* vol. 10, no. 1, pp. 53–62, 2022, doi: 10.22437/ppd.v10i1.17532.

[6] Ministry of Energy and Mineral Resources, "National Policy on New Renewable Energy and Energy Conservation (Kebijakan Nasional Energi Baru Terbarukan dan Konservasi Energi)," *Ministry. ESDM,* pp. 1–32, 2019.

[7] D. Muhammad Ferro Berlianto and R. Setya Wijaya, "The influence of the transition from fossil energy consumption to new renewable energy on gross domestic product in Indonesia (Pengaruh transisi konsumsi energi fosil menuju energi baru terbarukan terhadap produk domestik bruto di Indonesia)," *e-Jurnal Perspekt. Econ. and Developer. Drh.,* vol. 11, no. 2, pp. 105–112, 2022, doi: 10.22437/pdpd.v11i2.17944.

[8] A. Halimanjaya, "The Political Economy of Indonesia's Renewable Energy Sector and Its Fiscal Policy Gap," *Int. J. Econ. Financ. Manag. Sci.,* vol. 7, no. 2, p. 45, 2019, doi: 10.11648/j.ijefm.20190702.12.

[9] NA Kusnadi, JA Aprilya, APA Dea, Durrotunnisa, and R. Dinasty, "Energy Transition: Indonesia-IEA (International Energy Agency) Cooperation on the Development of Renewable Energy (ransisi Energi: Kerjasama Indonesia-IEA

(International Energy Agency) Terhadap Perkembangan Energi Terbarukan)," *Semin. Nas. TREnD Technol. Renew. Energy Dev.,* pp. 40–49, 2022.

[10] A. Boediman, RA Rahadi, and BA Nugraha, "An Overview of Indonesian Renewable Energy Studies and Its Investment Opportunities," *Indonesia. J. Energy,* vol. 4, no. 2, pp. 87–100, 2021.

[11] J. Langer, J. Quist, and K. Blok, "Review of Renewable Energy Potentials in Indonesia and Their.pdf," *Energies,* vol. 14, no. 21, p. 14, 2021.

[12] R. Mason and T. Swanson, "The costs of uncoordinated regulation," *Eur. Econ. Rev.,* vol. 46, no. 1, pp. 143–167, 2002, doi: 10.1016/S0014-2921(01)00087-3.

[13] P. Mitić, A. Fedajev, M. Radulescu, and A. Rehman, "The relationship between CO_2 emissions, economic growth, available energy, and employment in SEE countries," *Environ. Sci. Pollut. Res.,* vol. 30, no. 6, pp. 16140–16155, 2023, doi: 10.1007/s11356-022-23356-3.

[14] A. Raihan and A. Tuspekova, "The nexus between economic growth, renewable energy use, agricultural land expansion, and carbon emissions: New insights from Peru," *Energy Nexus,* vol. 6, no. March, p. 100067, 2022, doi: 10.1016/j.nexus.2022.100067.

[15] H. Chen and T. Lin, "Does energy consumption, economic growth, urbanization, and population growth influence carbon emissions in the BRICS? Evidence from panel models robust to cross-sectional dependence and slope heterogeneity," *Environ. Sci. Pollut. Res.,* vol. 29, no. 25, pp. 37598–37616, 2022, doi: 10.1007/s11356-021-17671-4.

[16] M.A. Bhuiyan, Q. Zhang, V. Khare, A. Mikhaylov, G. Pinter, and X. Huang, "Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review," *Front. Environ. Sci.,* vol. 10, no. April, pp. 1–21, 2022, doi: 10.3389/fenvs.2022.878394.

[17] C. Magazzino, M. Mele, and G. Morelli, "The relationship between renewable energy and economic growth in a time of COVID-19: A machine learning experiment on the Brazilian economy," *Sustain.,* vol. 13, no. 3, pp. 1–24, 2021, doi: 10.3390/su13031285.

[18] A. Widarjono, *Econometrics Introduction and Its Applications Dissertation Guide EViews,* 5th ed. Yogyakarta: UPP STIM YKPN, 2018.

[19] D. Gujarati, *Basic Econometrics,* 5th Editio. New York: McGraw-Hill, 2009.

[20] ND Dat, N. Hoang, MT Huyen, DTN Huy, and LM Lan, "Energy consumption and economic growth in Indonesia," *Int. J. Energy Econ. Policy,* vol. 10, no. 5, pp. 601–607, 2020, doi: 10.32479/ijeep.10243.

[21] N. Alfisyahri, I. Abdi Prawira, and I. Harmain, "Renewable Energy Consumption and Economic Growth in Indonesia: Evidence from VECM Causality," *Sustain. Theory, Pract. Policy,* vol. 2, no. 2, pp. 111–222, 2022.

[22] T. Marwa, A. Bashir, DP Atiyatna, I. Hamidi, M. Mukhlis, and S. Sukanto, "The Link between Economic Growth, Electricity Consumption, and CO_2 Emissions: Evidence from Indonesia," *Significant J. Ilmu Econ.,* vol. 11, no. 2, pp. 253–272, 2022, doi: 10.15408/sjie.v11i2.26286.

[23] E. Liun, D. Dewi, and JS Pane, "Indonesia's Energy Demand Project on Unt il 2060," vol. 12, no. 2, pp. 467–473, 2022.

[24] K. Aswadi, A. Jamal, S. Syahnur, and M. Nasir, "Renewable and Non-renewable Energy Consumption in Indonesia: Does it Matter for Economic Growth?," *Int. J. Energy Econ. Policy,* vol. 13, no. 2, pp. 107–116, 2023, doi: 10.32479/ijeep.13900.

[25] WA Prastyabudi and Isa Hafidz, "Energy Consumption Data Analysis: Indonesia Perspective," *J. Comput. Electrons. Telecommun.,* vol. 1, no. 1, pp. 1–10, 2020, doi: 10.52435/complete.v1i1.47.

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- Ukhti Ciptawaty wrote the research.
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