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Analysis of determinants of renewable energy consumption in Indonesia

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Abstract

Purpose: This study aims to examine the determinants of renewable energy consumption in Indonesia, focusing on Gross Domestic Product (GDP), energy subsidies (SUB), urban population (POPs), and carbon dioxide (CO_2) emissions over the period 1990–2023.

Research methodology: A quantitative descriptive approach is applied using time series data from 1990 to 2023. The analysis combines the Error Correction Model (ECM) to capture short-term dynamics and long-term equilibrium, and Ordinary Least Squares (OLS) regression for estimating the relationships between variables.

Results: In the short term, GDP and urban population exhibit a positive but insignificant effect on renewable energy consumption, while energy subsidies have a negative and significant effect. CO_2 emissions show a positive and significant effect. In the long term, GDP and CO_2 emissions maintain a positive and significant impact, energy subsidies remain negative and significant, and urban population continues to have a positive but insignificant influence. Simultaneous testing confirms that GDP, energy subsidies, urban population, and CO_2 emissions collectively influence renewable energy consumption in Indonesia.

Conclusions: The findings highlight the importance of economic growth and environmental pressures in driving renewable energy use, while energy subsidies negatively impact its adoption.

Limitations: The study is limited to four independent variables and does not account for technological innovation or policy changes beyond energy subsidies.

Contribution: This research provides empirical evidence for policymakers to design strategies promoting renewable energy consumption, emphasizing economic growth, emission control, and subsidy reform.

Keywords: *Carbon Dioxide Emissions, Energy Subsidies, Gross Domestic Product, Renewable Energy Consumption, Urban Population.*

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1. Introduction

The administration of President Prabowo Subianto has taken significant steps towards Indonesia's energy independence. Energy independence is National Priority 2 (PN2) in the 2025-2029 National Medium-Term Development Plan (RPJMN) document, which is to strengthen the State's defense system and promote national independence through self-sufficiency in food, energy, water, sharia economy, digital economy, green economy and blue economy. In the nation's independence, Indonesia needs to focus on achieving self-sufficiency in various crucial sectors which include the food sector as a pillar of the nation's life, the energy sector as a driver of innovation and progress, and the water sector as the foundation of a sustainable life. With abundant natural resources, a green economy will encourage sustainable economic growth while still taking into account the carrying capacity and carrying capacity of the environment. On the other hand, the blue economy will emphasize the important value of Indonesia's marine wealth. In order to support the achievement of National Priority 2 (PN2) in the 2025-

2029 RPJMN document, 6 (six) medium-term development goals have been formulated where energy security is the 3rd (third) target, namely increasing the use of clean energy with indicators of the portion of renewable energy in the primary energy mix and the direction of energy self-sufficiency policies (Presidential Decree Number 12 of 2025) (Aditya, Wijayanto, & Hakam, 2025; Apriliyanti, Nugraha, Kristiansen, & Overland, 2024; Marwa, Muizzuddin, Bashir, Andaiyani, & Cahyadi, 2024; Sabrina & Putra, 2025; Wibisono, Lovett, Chairani, & Suryani, 2024).

Energy self-sufficiency is important because energy is indispensable in carrying out Indonesia's economic activities, both for consumption needs and for production activities in various economic sectors. As a component of natural resources, energy must be utilized as much as possible for the prosperity of the people and its management must refer to the principles of *sustainable development* (Elinur, DS, Tambunan, & Firdaus, 2010). Based on the source of supply, Indonesia is a country rich in energy resources, both *unrenewable resources* and renewable energy resources. According to Kraft and Kraft (1978), all necessities in life require energy. This shows that along with the development of the times and the increase in the number of population, energy consumption will also increase, which reflects an increase in the economy. According to Eren, Taspinar, and Gokmenoglu (2019), energy is an essential factor for a country to achieve sustainable development. Energy consumption continues to increase to this day. Population growth, lifestyle improvement, increased production and economic competitiveness are some of the reasons for high energy consumption (Chontanawat, Hunt, & Pierse, 2008; Fahmi, 2025; Pandyaswargo, Wibowo, Sunarti, Risnawati, & Onoda, 2024; Pinar, 2025; Raheem & Yusuf, 2015).

Research conducted by Sasana and Ghozali (2017) states that the determining factor for a country to develop depends not only on its natural resources and geographical position, but also the existence of its energy source as a formidable force to accelerate a country's economic activities. Energy consumption will continue to increase in line with the increasing pace of economic growth and population growth while fossil energy sources are limited in availability. For this reason, it is necessary to develop renewable energy and conserve green energy or non-fossil energy, where if managed properly, these energy sources will not run out. The issue of *renewable energy* is one of the central issues in the world, considering that the number of fossil energy is limited in the long term and its environmentally friendly nature (Bhuiyan et al., 2022; Dirma, Neverauskienė, Tvaronavičienė, Danilevičienė, & Tamošiūnienė, 2024; Pasaribu, Cahyadi, Mujiono, & Suwarno, 2023).

Sadorsky (2009) revealed that economic growth and energy demand can affect the consumption of renewable energy. Increased economic growth and energy demand in developing countries are creating opportunities for these countries to increase the use of renewable energy. Nkomo (2007) stated that *supply* and access to energy greatly affect the development of a country, especially for developing countries. One of the indicators of economic development in a country is to measure economic growth in that country (N. S. Putri, Budiarti, Huboyo, & Haryanti, 2024; P. Putri, Suardi, & Basir, 2024). Jhingan (2000) defines economic growth as an increase in a country's capacity to produce goods and services for the long term. Michael P Todaro and Smith (2005) state that economic growth measures the long-term ability of a country to provide goods and services to its population. The relationship between energy consumption and economic growth has been the subject of academic research for decades. Saqib (2021) stated that energy consumption is closely related to economic growth. High economic growth is also indicated by the more efficient use of energy sources (Eyuboglu & Uzar, 2022; Marinaș, Dinu, Socol, & Socol, 2018; Singh, Nyuur, & Richmond, 2019).

Various studies on the factors affecting the consumption of renewable energy have been widely conducted in various countries. However, there is still little related research conducted in Indonesia. Indonesia is currently focusing on realizing sustainable national energy security guided by Presidential Regulation Number 22 of 2017 regarding the National Energy General Plan where the national energy mix has been determined, namely 23 percent of renewable energy in the primary energy mix in 2025 and 31 percent in 2050 and the 2025-2029 RPJMN document. Based on the results of several previous researches, the data displayed and the background that has been presented, it is necessary to see how the influence of Gross Domestic Product, energy subsidies, urban population, and carbon dioxide (CO2) gas emissions on renewable energy consumption in Indonesia. This study contributes to measuring the variables that affect the consumption of renewable energy in Indonesia.

2. Literature review

2.1 The Role of Government in the Economy

The government has an important role in regulating a country's economy. Economic freedom in practice faces various conflicts of interest caused by the absence of harmonious coordination in the interests of each individual. Leaving everything to market mechanisms will actually bring inequality (Kristiyani, Marlissa, & Urip, 2025; Ridwan & Nawir, 2021; Wamaer, Umar, & Hafizrianda, 2025). Mangkoesoebroto (2001) concluded that in a perfect competition system, the price mechanism can only guarantee efficiency in the allocation of consumer goods and the allocation of production factors. However, it cannot solve the problem of justice and in the distribution of goods consumption, because the efficiency achieved may cause one to get all the goods while the other consumers do not get any one item.

In renewable energy development, the government's allocation function is to ensure that limited energy resources are used efficiently and optimally to support the transition to clean and sustainable energy. The government has issued Minister of Finance Regulation (PMK) Number 103 of 2023 concerning the Provision of Fiscal Support through the Funding and Financing Framework in the Context of Accelerating the Energy Transition in the Electricity Sector. The issuance of this regulation is one of the implementations of the government's allocation function. This regulation provides a legal umbrella to support investment in renewable energy development and allows energy transition funding to be sourced from the state budget and other legitimate sources such as international funding cooperation. This policy is a follow-up to Presidential Regulation Number 112 of 2022 concerning the Acceleration of Renewable Energy Development.

2.2 Natural Resource Economic Theory

Natural resource economics is an economic science that focuses on the efficient management and utilization of natural resources in order to create a balance between human needs and environmental sustainability (Daly & Farley, 2011). This science discusses two main types of resources, namely renewable resources such as forests, water, air and non-renewable resources such as petroleum, natural gas and coal (Pearce & Turner, 1989). According to Daly and Farley (2011), the economics of natural resources should be seen as an integral part of the larger ecosystem.

The principle of sustainability is the main focus in the economy of natural resources. According to the Our *Common Future* report by the Brundtland Commission (WCED, 1987), sustainability includes the use of natural resources that do not damage the ability of future generations to meet their needs. This report emphasizes that sustainable development can only be achieved through the integration of three main pillars, namely: 1) The environment consisting of the preservation of ecosystems, biodiversity and natural resources; 2) Economy, namely fair and inclusive economic growth; 3) Social, namely poverty reduction and social inequality. In the context of sustainable development research, this report is a significant theoretical and practical foundation, both in national and international policies .

Natural resources are an input factor for economic activities. However, the definition of these resources is not limited to an *input* factor because the production process will also produce *output* (for example, waste) which then becomes *an input factor* for the continuity and availability of natural resources (Fauzi, 2004; Thalib, Suaib, Lawani, & Aldi, 2024).

2.3 *The Environmental Kuznets Curve* (EKC)

The Environmental Kuznets Curve (EKC) is a theory that describes the relationship between economic growth and environmental impact. Theoretically, the EKC has an "inverted U" curve shape that explains the relationship between per capita income (as a proxy for economic growth) and environmental degradation. The name "Kuznets Curve" comes from an analogy with the Kuznets curve that was originally introduced by Simon Kuznets to explain the relationship between economic growth and income inequality. Kuznets (2019) stated that the income gap will continue to increase along with an increase in economic growth. However, when it reaches *the Turning Point* , the income gap will actually decrease along with much better economic development. This concept states that in the early stages of economic growth, environmental degradation tends to increase. However, after reaching a certain level of income, environmental degradation begins to decline due to increased environmental awareness, regulation, and technological innovation (Mubarok & Hidayat, 2024; You & Grossmann, 2008).

Furthermore, in the phase of industrial *economies*, rapid economic growth is followed by faster environmental damage as well. This is because there is a transition from the agricultural sector to the industrial sector (secondary) which causes waste or pollution. In this phase, the industrial sector is the largest source of national income. The depletion of natural resources coupled with an increase in the amount of pollution causes environmental damage to accelerate. The last stage, namely the development phase *of post-industrial economies,* there are structural changes that lead to the tertiary services sector. The change in economic structure from the industrial sector to the service sector in this phase makes an increase in income followed by a decrease in the level of environmental damage.

2.4 Economic Growth Theory

Economic growth is defined as the development of activities in the economy that cause the goods and services produced in society to increase. The problem of economic growth can be seen as a macroeconomic problem in the long run. From one period to another the ability of a country to produce goods and services will increase. This increased ability is due to the fact that production factors will always increase in quantity and quality (Sukirno, 1995; Sutama, Dewi, & Rahayu, 2023). Economic growth is an important indicator in analyzing the economic development of a country.

2.5 Energy Consumption Theory

Energy consumption refers to the amount of energy used by an individual, industry, or country in a given period of time. Energy consumption can come from a variety of sources, such as fossil fuels (oil, gas, and coal), renewable energy (solar, wind, and biomass), and nuclear energy (IEA, 2022). Sadorsky (2012) stated that energy consumption is influenced by economic, social, and technological factors. Economic factors include GDP growth, energy prices, and industrialization rates, while social factors include population growth and people's consumption patterns. In economic analysis, energy consumption is often associated with various macroeconomic factors such as gross domestic product (GDP), industrialization rate, and population (Dwiyanti, Luh Putu Agustini Karta, Cintya, & Bendesa, 2023; Stern, 2004; Widanti, Dewi, Pinatih, & Mason, 2025). The following theories related to energy consumption are explained as follows:

2.6 Energy Demand Theory

Energy demand theory explains that energy consumption is influenced by economic factors, such as energy prices and people's income. In general, energy demand is elastic to prices and income (Bentzen & Engsted, 1993; Thalib, Kuntuamas, Umar, & Sulastri, 2023). According to the energy demand model of Bentzen and Engsted (1993), price elasticity and income elasticity play an important role in determining energy consumption. If energy prices rise, consumption tends to fall, while if income increases, energy consumption also increases. Bentzen and Engsted use the following log-linear regression model:

$$\ln E_t = \propto + \beta_1 \ln Y_t + \beta_2 \ln P_t + \varepsilon_t$$

Where:
E_t is energy consumption at *time t;*
Y_t is national income (proxy of GDP);
P_t is the price of energy;
$\propto$ is constant;
β_1 is the elasticity of income to energy consumption;
β_2 is the elasticity of prices to energy consumption;
ε_t Stupid *Term Error*
Bentzen and Engsted used *a cointegration* approach to look at the long-term relationship between these variables. Their results show that in the long run, energy consumption has a stable relationship with

energy income and prices. However, in the short term, economic fluctuations can cause differences in energy consumption patterns.

2.7 Population Growth

Population growth refers to the change in the number of people in an area over a given period. These changes can be caused by factors such as *fertility rates*, mortality *rates*, and migration. Population size, density, and population growth are important things that show the difference between developed and developing countries. At the beginning of growth, developing countries experienced slow population growth, but as industrialization continued, the rate of population growth increased. Critical problems that need to be addressed by the government to be able to formulate development policies that have an impact on the trend of increasing growth in urban areas.

The emphasis on industrial modernization, technological sophistication, and metropolitan growth creates a substantial geographical imbalance in the economy. This has led to rural migration to urban areas, thereby increasing population growth in urban areas (Handayani, Rusmana, & Warsidi, 2023; Michael P. Todaro & Smith, 2012).

Paul Ehrlich in his book *The Population Bomb* (Ehrlich & Ehrlich, 2009) warned that if the population continued to grow, the world would experience famine and an environmental crisis. Natural resources are not enough to sustain exponential population growth. Meanwhile, **Garrett Hardin** (Hardin, 1974) in *The Tragedy of the Commons* posits that when many people exploit shared resources without clear regulation, those resources will be depleted and cause environmental disasters. Neo-Malthusianism uses **the IPAT equation** to measure human impact on the environment:

$$I = P \ x \ A \ x \ T$$

Where:
I is environmental impact (*impact*);
P is population;
A is consumption per capita (*affluence*);
T is technology.

The conclusion is that the higher the population, per capita consumption and technology, the greater the impact on the environment.

2.8 Framework of thinking

The following is a thought framework chart.

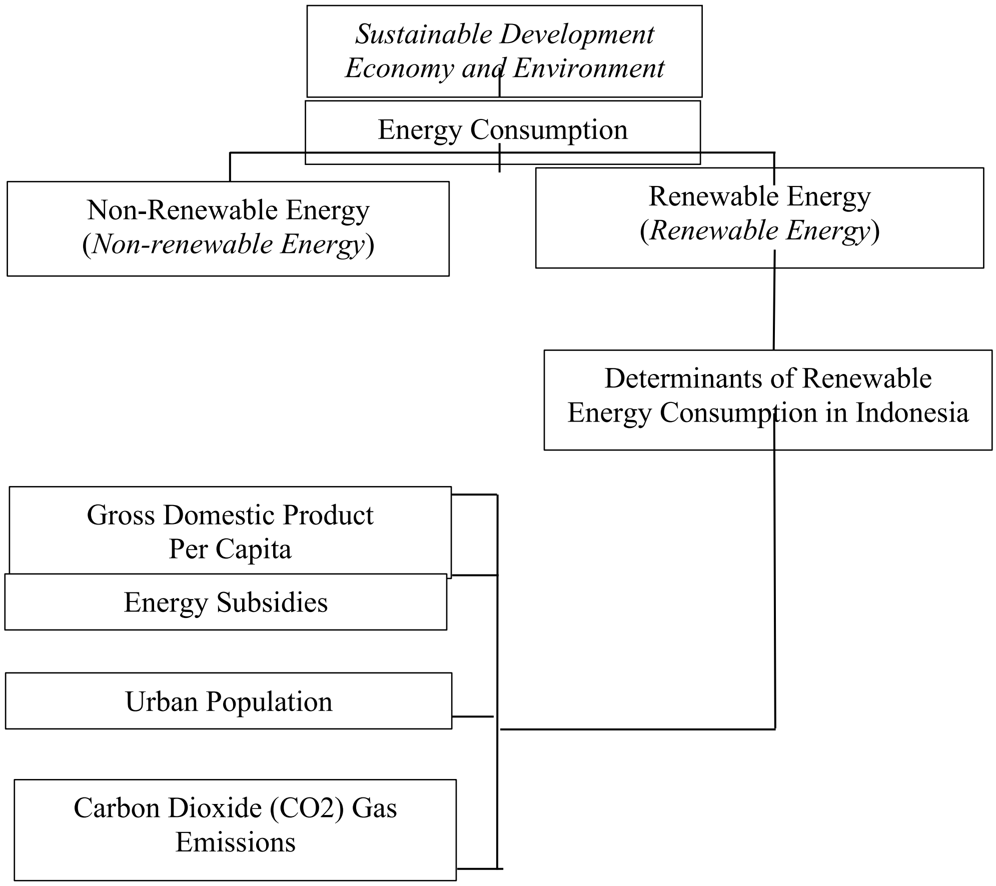

Figure 1. Framework of thinking

2.9 Hypothesis

Based on the background, description of the theoretical review, empirical review, problem formulation and research objectives, a hypothesis or provisional conjecture is obtained in this study which is explained as follows:

1. It is suspected that the variable Gross Domestic Product per capita has a positive and significant effect on renewable energy consumption in Indonesia.
2. It is suspected that the Energy Subsidy variable has a negative and significant effect on renewable energy consumption in Indonesia.
3. It is suspected that the Urban Population variable has a positive and significant effect on renewable energy consumption in Indonesia.
4. It is suspected that the variable Carbon Dioxide (CO_2) Gas Emission has a positive and significant effect on renewable energy consumption in Indonesia.
5. It is suspected that the variables of Gross Domestic Product, Energy Subsidies, Urban Population, and Carbon dioxide (CO_2) gas emissions have a joint effect on the consumption of renewable energy in Indonesia.

3. Methodology

3.1 Data Types and Sources

This type of research is a descriptive research with a quantitative approach to test theory and empirically through the measurement of research variables statistically and to understand the influence of independent variables on bound variables. This study uses the variables of Gross Domestic Product per capita (GDP per capita), energy subsidies, population, and carbon dioxide (CO_2) emissions as independent variables and renewable energy consumption as dependent variables. The data used in this study are secondary data according to the *time series* with the time range 1990-2023. The data was obtained from *Our World in Data*, *World Development Indicators,* and the Ministry of Finance of the Republic of Indonesia. The variables and data sources used can be seen in Table 2.

Table 1. Variables, Symbols, Units and Data Sources

Variable	Symbol	Unit	Data Source
Renewable Energy Consumption	REC	%	*Our World in Data*
Gross Domestic Product per capita	GDP	Billion US$	*World Development Indicators*
Energy Subsidies	SUB	Billion Rp	*Ministry of Finance of the Republic of Indonesia*
Urban Population	POP	Million	*World Development Indicators*
Carbon dioxide (CO2) emissions	CO2	Million Tons	*Our World in Data*

3.2 Variable Operational Definition

3.2.1 Renewable Energy Consumption

Renewable energy consumption is the amount of renewable energy including hydropower, solar power, wind, geothermal, bioenergy, waves and tides consumed by people in Indonesia during the period 1990-2023. Renewable energy consumption is measured as a percentage of renewable energy in total energy consumption. Renewable energy consumption data is obtained from *Our World in Data* and measured as a percentage of total final energy consumption.

3.2.2 Gross Domestic Product (GDP)

Gross Domestic Product (GDP) is a measure of a country's total economic output in a given period, usually annually. It includes all goods and services produced domestically by domestically based factors of production, both by domestic and foreign companies. GDP is often used as a measure of a country's welfare and economic growth. GDP is used as an income proxy that reflects economic growth. A country's economic growth is driven by the output produced in an economy where one of the inputs comes from the consumption of renewable energy. The GDP data used in this study is GDP per capita. The calculation of output per capita uses the total GDP approach divided by the number of population, so that economic growth with the output or GDP per capita approach can reflect an increase in the standard of living per individual in a country (Prawoto, 2020). GDP per capita data is obtained from *World Development Indicators* with a unit of US$ billion during the period 1990 -2023.

3.2.3 Energy Subsidies

The United Nation Environment Programme (2008), explains that energy subsidies are direct payments made by the government to energy producers or buyers to stimulate the production or use of certain energy or convert it to other forms of energy. Meanwhile, the *International Energy Agency* (IEA) defines energy subsidies as government actions that concern, especially the energy sector, that reduce the cost of energy production, increase the price received by energy producers or lower the price paid by energy consumers. The energy subsidy variable used in this study is the amount of energy subsidies provided by the Indonesian government during the period 1990-2023. Energy subsidy data is obtained from the Ministry of Finance of the Republic of Indonesia and measured based on units of Billion Rupiah.

3.2.4 Urban Population

The population of an urban is the total number of individuals who live or occupy within the administrative boundaries of an urban area. The population of urban residents is *de facto* the entire population with similar characteristics who live in the same place regardless of legal status and citizenship. Urban population density is an early indicator to detect the level of development of urban areas and all possible impacts caused. With the rapid growth of the urban population, the need for fuel, the need for clothing and food, and the waste produced will have a rapid effect on environmental problems (Darsono, 2013). The urban population data used was obtained from *the World Development Indicators* with a million inhabitants in the period 1990-2023.

3.2.5 Carbon Dioxide (CO2) Emissions

Carbon dioxide (CO2) emissions are one of the types of greenhouse gas (GHG) emissions that are the most important cause of increasing global warming, causing climate change. Carbon dioxide (CO2) emissions are largely generated from the use of fossil fuels and deforestation. High amounts of carbon dioxide (CO2) emissions will damage the air layer, and can disrupt economic activities. The use of renewable energy is one of the efforts in sustainable development and reducing carbon dioxide (CO2) emissions. Variable carbon dioxide (CO2) emission data is the total carbon dioxide (CO2) emissions in Indonesia for the period 1990-2023. The unit used to measure the level of carbon dioxide (CO2) emissions is million tons. Data is obtained from *Our World in Data*.

3.3 Data Analysis Methods

3.3.1 Stationary Test (Unit Root Test)

There are several tests that can be done to detect whether the *time series* data used is stationary or not. One of the tests that is often used is the unit root *test*. This test was first developed by David Dickey and Wayne Fuller and is known as *Augmented Dickey Fuller* (ADF). The basic concept of *Dickey Fuller's root test unit is described in the following model.*

$$Y_t = \rho Y_{t-1} + e_t \qquad -1 \leq \rho \leq 1$$

Where e_t is a *random* or stochastic disorder variable with a mean of zero, a constant and unrelated variant. If the value is =1, then it can be said that the random variable Y has a root unit (*ρroot unit*). If *the time series* data has a unit root, this means that the data moves randomly *(random walk)* and the data that moves randomly is said to be non-stationary. If a *time series data* is not stationary on the order of zero, I(0), then the stationarity of the data can be searched through the next order so that the level of stationarity in the nth order (*first difference* or I(1), or *second difference* or I(2), and so on.

3.3.2 Cointegration Test

The cointegration test is a test of whether there is a long-term relationship between independent variables and bound variables. This test is a continuation of the *stationary test*. If the variables are integrated, there is a stable relationship in the long term.and vice versa, if there is no cointegration between variables, then the implication is that there is no relationship in the long term. The term cointegration is also often referred to as *the term error*. This is because the deviation to the long-term equilibrium is gradually corrected through a partial series of short-term adjustments. There are several types of cointegration tests, including:

3.3.2.1 Johansen Cointegration Test

This cointegration test was developed by Johansen. The Johansen test can be used for multiple vector tests. This cointegration test is based on *cointegration system equations*. This test does not require a normal data distribution. For the Johansen cointegration test, the following hypothesis was used:
H_0 = no cointegration
H_a = there is cointegration
Where the testing criteria are
H_0 rejected and accepted, if the H_a*trace statistic value* > the trace *critical value*
H_0 accepted and rejected, if the H_a*trace statistic value* < the critical value *of the trace*

3.3.3 Error Correction Model (ECM)

The ECM test is performed to correct imbalances (*disequilibrium*) in the short term as well as long-term balance. This model was introduced by Sargan and popularized by Engle-Granger. In econometrics, this model is useful for overcoming non-stationary time series data and *spurious regression*. In general, the ECM model is as follows:

$$\Delta Y = \alpha_0 + \beta_1 \Delta X_{t-1} + \beta_2 EC_{t-1} + \varepsilon_t$$

The ECM model in this study is:

$\Delta REC_t = \alpha_0 + \beta_1 \Delta PDB_t - \beta_2 \Delta SUB_t + \beta_3 \Delta POP_t + \beta_4 \Delta CO2_t + +\varepsilon_t$

Where:

ΔREC = Renewable Energy Consumption (% of total final energy consumption)
ΔPDB = GDP per Capita (Miliat US$)
ΔSUB = Energy Subsidy (Billion Rp)
ΔPOP = Urban population (million people)
$\Delta CO2$ = CO2 emissions (million tons)

3.3.4 Multiple Linear Regression Analysis

This study uses data analysis techniques using multiple linear regression analysis to determine how much influence 8 independent variables have on renewable energy consumption in Indonesia from 2013 to 2023. The multiple regression model is a development of a simple linear regression model. Multiple linear regression models were developed to estimate or predict the value of dependent variables (Y) using more than one independent variable (X1.X2,X3,etc.) (Purwanto & Sulistyastuti, 2007). The multiple regression equation in general is as follows:

$$REC = \alpha + \beta_1 PDB_t - \beta_2 SUB_t + \beta_3 POP_t + \beta_4 CO2_t + \varepsilon_t$$

Where:

α = Constant
REC = Renewable Energy Consumption (% of total final energy consumption)
PDB = GDP per Capita (Billion US$)
SUB = Energy Subsidy (Billion Rp)
POP = Urban population (million people)
$CO2$ = CO2 emissions (million tons)
$\beta_1, \beta_2, \beta_3, \beta_4$ = Regression Coefficient
ε = *Error Term*

According to Gujarati and Porter (2012), there is a difference in the unit and quantity of variables causing regression equations to be made with logarithmic models to reduce the presence of heteroscedasticity symptoms and determine the sensitivity between variables. Logarithmic transformations reduce heteroscedasticity. This is because the transform that exposes the scale for the measurement of the variable reduces the difference between the two values from ten times to a twofold difference. In Gujarati and Porter (2012) the linear in logarithm of variables Y and X can be estimated using the *Ordinary Least Square* (OLS) regression method so that it is known as the double-log model or log-log and log-linear. The double-log model is used in this study, which aims to equalize the unit into linear and show the elasticity of Y as a dependent variable on X as an independent variable, i.e. the percentage change in Y for the percentage change in X. In the double-logarithm model, there are two variables (Y and X) that are transformed logarithmically. So that the multiple linear regression equations in this study are:

$REC = \alpha + \beta_1 PDB_t - \beta_2 SUB_t + \beta_3 POP_t + \beta_4 CO2_t + \varepsilon_t$

The *Ordinary Least Square* (OLS) method or the ordinary least square method. The OLS method is used to determine the magnitude of the influence of the free variable on the bound variable. With certain assumptions, the OLS method has some very interesting statistical properties that make it one of the most powerful and popular methods of regression analysis.

3.3.5 Hypothesis Testing

3.3.5.1 Partial Hypothesis Test (T-Statistical Test)

The t-statistical test is used to determine whether partially/individually independent variables have a significant effect on the bound variables. This test is done by comparing the t-calculated or t-statistical value with the t-table. The stages of partial hypothesis test (t-statistics) are:

1. Specify Ho and Ha.
   If the hypothesis is positive, then Ho: $\beta 1 \leq 0$ and Ha: $\beta 1 > 0$
   If the hypothesis is negative, then Ho: $\beta 1 \geq 0$ and Ha: $\beta 1 < 0$
   The partial hypothesis test (t-statistical test) for each variable in this study is as follows:
   a. Gross Domestic Product Variables
      Ho: $\beta 1 \leq 0$ and Ha: $\beta 1 > 0$
      Gross Domestic Product variables have a positive effect on renewable energy consumption in Indonesia
   b. Energy Subsidy Variables
      Ho: $\beta 2 \geq 0$ and Ha: $\beta 2 < 0$
      Energy subsidy variables have a negative effect on renewable energy consumption in Indonesia
   c. Urban Population Variables
      Ho: $\beta 3 \leq 0$ and Ha: $\beta 3 > 0$
      Urban population variables have a positive effect on renewable energy consumption in Indonesia
   d. Carbon Dioxide (CO_2) Gas Emission Variables
      Ho: $\beta 4 \leq 0$ and Ha: $\beta 4 > 0$
      Carbon Dioxide (CO_2) Gas Emission Variables Have a Positive Effect on Renewable Energy Consumption in Indonesia
2. Determine the level of confidence
3. Define critical areas

3.3.5.2 Simultaneous Hypothesis Test (F-Statistical Test)

The F test is a hypothesis test to determine the influence of the independent variable together on the bound variable whether the influence is significant or not (Gujarati & Porter, 2012). The hypothesis used in the simultaneous test is:

If Ho: β_i= 0, then the variables Gross Domestic Product, Energy Subsidies, Urban Population, Carbon dioxide (CO_2) gas emissions together do not affect the bound variables.

If Ho: β_i≠ 0, then the variables Gross Domestic Product, Energy Subsidies, Urban Population, Carbon dioxide (CO_2) gas emissions together affect the bound variables.

With the provision of decision-making that:

If , then Ho was rejected. This means that the independent variables together have a significant effect on the bound variables.$F_{Hitung} > F_{tabel}$

If , then Ho is accepted. This means that the independent variables together do not have a significant effect on the bound variables.$F_{Hitung} < F_{tabel}$

3.4 Coefficient of Determination (R2)

The value of the determination coefficient (R^2) is used to measure how much the independent variables in the model can explain the dependent variables used in the study. This value indicates how close the estimated regression result line is to the actual data. The value of R^2 (R-Squared) lies between zero and one. The closer you get to the value of one, the better the model will be.

4. Results and Discussions

4.1 Descriptive Statistical Analysis

4.1.1 Renewable Energy Consumption

Renewable energy consumption (REC) has an average of 4.840882, which indicates relatively low renewable energy consumption in the sample. The median value recorded was 3.830000, which is slightly lower than average, signifying that most of the data is spread around the lower figures. The maximum value was recorded at 10.790000, while the minimum value was at 2.480000. With a standard deviation of 2.351176, the data shows a fairly high variability in renewable energy consumption in various regions. The data distribution has a *skewness* of 1.612744, which indicates a data distribution that tends to be skewed to the right, with some observations showing very high figures. Its curtosis of 4.130440, which is larger than the figure 3, indicates a sharper distribution than the normal distribution. The Jarque-Bera test yielded a value of 16.54903 with a probability of 0.000255, which indicates that this data is not normally distributed with a very high level of significance.

4.1.2 Gross Domestic Product

The Gross Domestic Product (GDP) has an average of 2569,588, which indicates that most of the countries in the sample have very large GDPs. The median GDP was recorded at 1999,500, this figure is lower than the average, indicating that half of the countries in the sample have lower GDPs. The maximum value of GDP was recorded at 4193,000, while the minimum value was at 1471,000. With standard 831.9904, GDP data shows significant variation in the sample. The data *skewness* was recorded at 0.507032, which indicates an almost symmetrical distribution or a slight skew to the right. The data kurtosis of 1.868722 shows a slightly wider distribution compared to the normal distribution. The Jarque-Bera test yielded a value of 3.269831 with a probability of 0.219913, indicating that this data may be close to the normal distribution at the usual level of significance.

4.1.3 Energy Subsidies

The energy subsidy (SUB) has an average of 78005.47, indicating that the countries in the sample provide considerable energy subsidies. The median value of the subsidy was recorded at 56264.50, which is lower than the average, indicating a larger distribution in countries with smaller subsidies. The maximum value was recorded at 299830.0, while the minimum value was 354000.0, showing a significant difference in energy subsidies between countries. With a standard deviation of 78490.28, energy subsidy data shows huge fluctuations between countries. The *skewness* of the data was recorded at 1.097691, which indicates a right-skewed distribution. Its curtosis of 3.467874 shows a somewhat wider distribution compared to the normal distribution, with some fairly high extreme values on the far right. The Jarque-Bera test yielded a value of 7.139185 with a probability of 0.028167, which indicates that this data is not normally distributed.

4.1.4 Urban Population

The urban population (POP) has a very large average, which is 9342560.0, which indicates a high concentration of population in urban areas. The median urban population is 9176466.0, this figure is almost the same as the average, which shows that the distribution of urban population data is quite symmetrical. The maximum value of the urban population is recorded at 11248839.0, while the minimum value is 8174756.0, this shows a large variation in the size of the population between countries or regions. With a standard deviation of 983942.3, urban population data show considerable variability between observations. *The skewness* of the data was recorded at 0.411227, which indicates a slightly skewed distribution to the right, although it is still within reasonable limits.

4.1.5 Carbon Dioxide (CO2) Emissions

Carbon dioxide (C02) emissions have a very large average, which is 8.250009, which indicates the high level of carbon emissions in the countries in the sample. The median value was recorded at 7.480009, this figure is almost the same as the average, indicating that the distribution of the data is quite symmetrical. The maximum value is recorded at 1.650010, and the minimum value is at 2.900009, indicating significant variations in the level of carbon emissions between countries or regions. With a standard deviation of 4.060009, the data shows high fluctuations in carbon dioxide (C02) emissions. *The skewness* of the data was recorded at 0.464330, which indicates a slightly skewed distribution to the right. Its curtosis is 2.022734, indicating a distribution close to normal, although there are still slight sharper peaks. The Jarque-Bera test yielded a value of 2.574734 with a probability of 0.275997, indicating that this data is close to the normal distribution.

4.2 Ordinary Least Square (OLS) and Error Correction Model (ECM) Test Results

The *Ordinary Least Square* (OLS) method or the smallest square method is commonly used to determine the magnitude of the influence of the free variable on the bound variable. Meanwhile, the *Error Correction Model* (ECM) test is carried out to correct imbalances in the short term and long-term balance.

4.2.1 Stationary Test Results

Stationaryness or unit roots are related to the consistency of the movement of time *series* data. The stationarity test in this study was using *the Augmented Dickey-Fuller Test* (ADF) method using the help of *Eviews software*. The results of the unit root test by comparing the results of the t-count with *the critical value of MacKinnon.* If the absolute t-calculated value is greater than the absolute MacKinnon critical value, then H0 is rejected meaning that *the time series data* is stationary and if it is the other way around, then H0 is accepted which means that *the time series data is* not stationary. In the case if the t-calculated value is negative, then it can be said that if the t-calculated value is smaller than *the MacKinnon* critical value, then H0 is rejected meaning that *the time series data is* stationary, if on the contrary H0 is accepted, it means that *the time series* data is not stationary (Gujarati & Porter, 2012).

Table 2. Stationary Test Results (*Unit Root Test*) at Level Level

Research Variables	t-count	Critical Value of Mac Kinnon (1%)	Critical Value of Mac Kinnon (5%)	Critical Value of Mac Kinnon (10%)	Prob.	Ket.
REC	-1,4818	-3,6537	-2,9571	-2,6174	0,5298	Not Stationary
GDP	-0,9747	-3,7114	-2,9810	-2,6299	0,9949	Not Stationary
SUB	-0,4570	-3,6537	-2,9571	-2,6174	0,8870	Not Stationary
POP	-5,3291	-3,7240	-2,9862	-2,6326	0,0002	Stationary
CO2	-1,5103	-3,6463	-2,9540	-2,6158	0,5160	Not Stationary

Source: Eviews, Data processed, 2025.

Table 2 shows the results of the stationary test (*unit root test*) at the level level. Based on the test results, it is known that there are variables that are not stationary at the level level, namely the variables of renewable energy consumption (REC), Gross Domestic Product (GDP), energy subsidies (SUB) and carbon dioxide (CO_2) emissions. Meanwhile, the stationary variable at the level level is the urban population variable (POP). This can be seen from the t-calculated values greater than *the MacKinnon* critical values of 5% and 10%, and the probability values of 4 variables, namely GDP, SUB and CO2, greater than 0.05. In this study, all variables must be stationary, so the next step is to conduct a stationary test at the *first difference level*. The following are the results of the stationary test (*unit root test*) at *the first difference* level:

Table 3. Stationary Test Results (*Unit Root Test*) at the First Difference *Level*

Research Variables	t-count	Critical Value of Mac Kinnon (1%)	Critical Value of Mac Kinnon (5%)	Critical Value of Mac Kinnon (10%)	Prob.	Information
REC	-7,6741	-3,6537	-2,9571	-2,6174	0,0000	Stationary
GDP	-5,1985	-3,6998	-2,9762	-2,6274	0,0002	Stationary
SUB	-8,1649	-3,6537	-2,9571	-2,6174	0,0000	Stationary

POP	-5,0168	-3,7378	-2,9918	-2,6355	0,0005	Stationary
CO2	-5,5370	-3,6537	-2,9571	-2,6174	0,0001	Stationary

Source: Eviews, Data processed, 2025.

Based on the results of the stationary test (*unit root test*) at *the first difference* in Table 3, it is known that renewable energy consumption (REC), Gross Domestic Product (GDP), energy subsidies (SUB), urban population (POP) and carbon dioxide (C02) emissions are stationary at the *first difference level.* This is evidenced by the t-calculated values smaller than *the MacKinnon critical values* of 1%, 5% and 10% and the probability values of 5 variables, namely renewable energy consumption (REC), Gross Domestic Product (GDP), energy subsidies (SUB), urban population (POP) and carbon dioxide (C02) emissions significantly smaller than 0.05. So it can be concluded that all variables used in stationary research are at *the first difference* level.

4.2.2 Cointegration Test Results

The next stage after the stationary test (*unit root test*) is to conduct a cointegration test. The purpose of the cointegration test is to see whether or not there is a long-term relationship between the free variable and the bound variable. The cointegration test in this study used *the Engel-Granger* (EG) cointegration test method . If the absolute t-calculated value is greater than the *absolute MacKinnon* critical value, then the cointegrated residual means that there is a long-term relationship between the free variable and the bound variable. In the case if the t-count value is negative, then it can be said that if the t-count value is smaller than the *MacKinnon critical value*, then the cointegrated residual means that there is a long-term relationship between the free variable and the bound variable. Here are the results of the cointegration test:

Table 4. Results of *the Engel-Granger* (EG) Cointegration Test

Research Variables	**t-count**	**Critical Value of Mac Kinnon (1%)**	**Critical Value of Mac Kinnon (5%)**	**Critical Value of Mac Kinnon (10%)**	**Proba bility**	**Information**
Ect(-1)	-10,143	-3,6537	-2,9571	-2,6174	0,0000	Stationary

Source: Eviews, Data processed, 2025.

Based on the results of the *Engel-Granger* (EG) cointegration test, it is known that the residual *Error Correction Term*/ECT(-1) is stationary at the level level that can be seen from the t-calculated values that are smaller than *the MacKinnon critical values* of 1%, 5%, and 10%. This shows that the residual is integrated, meaning that there is a long-term and short-term relationship between the free variable and the bound variable. The ECM model can be said to be valid if the cointegrated variables are supported by significant and negative ECT coefficient values. If the ECT coefficient is positive, then the direction of the variables used will be further away from the long-term equilibrium so that the ECM model cannot be used (Lumonang, Masinambow, & Mandeij, 2018).

4.3 Results of Long-Term Estimation of Ordinary Least Square Model (OLS)

Based on the results of the stationary and cointegration tests, it is known that to determine the influence of independent variables and bound variables in the study, it can be done in two stages, namely long-term and short-term relationships. The results of this regression are to determine the direction of the relationship between independent variables and dependent variables and to see the results of the coefficient magnitude obtained. Table 10 shows the results of long-term estimation of data with Indonesian observations in the period 1990-2023 or 34 years, so it can be concluded that the results of the *Ordinary Least Square Model* (OLS) regression equation are as follows:

Table 5. Results of Long-Term Estimation *of Ordinary Least Square Model* (OLS)

Dependent Variable: REC

Method: Least Squares

Sample: 1990 2023
Included observations: 34

Variable	Coefficient	Std. Error	t-Count	Prob	Information
C	54,92129	22,48132	2,442975	0,0209	-
GDP	0,484159	0,053864	8,988501	0,0000*	Significant
SUB	-12,45780	2,074010	-6,006624	0,0000*	Significant
POP	0,165904	0,100737	1,646896	0,1104	Insignificant
CO2	14,31750	5,256960	2,723532	0,0108*	Significant

Source: Eviews, Data processed, 2025.

Information :
[ ] : Indicates t-count
* : Based on 95% confidence level (α=5%)
R-squared = 0,869101 Durbin-Watson Stat = 2.079792
F-stat = 48,13628 Prob (F-stat) = 0,000000

Table 5 shows the results of the long-term estimation *of the Ordinary Least Square Model* (OLS). The results of the estimate are then transformed into mathematical forms, so the mathematical model by including the equation value of the regression is as follows:

$$RECt = 54.92129 + 0.484159PDBt - 12.4578SUBt + 0.165904POPt + 14.3175CO2t$$
$$[2.442975]\ [8.988501]\ [6.00662]\ [1.64689]\ [2.72353]$$

Based on the results of the Ordinary Least Square *Model (OLS)* long-term estimation, the *probability value* of each variable can be obtained. In this case, the R-squared is 0.869101, indicating that the model explains about 86.91% variation in the near-perfect data. *R-square* interprets the percentage of the influence of all independent variables on the dependent variables. This means that in this study, the independent variables, namely Gross Domestic Product, energy subsidies, urban population, and carbon dioxide (CO2) emissions, had an effect on renewable energy consumption by 86.9%, while the remaining 14.1% were influenced by other variables that were not included in the research model.

4.4 Short-Term Estimate Results of Error Correction Model (ECM)

After the data stationarity test and the cointegration test were carried out, the results were obtained that all variables used in the stationary research at the *level of first difference* and residual were integrated which means that there is a long-term equilibrium relationship between the free variable and the bound variable, and in the short term there may be an imbalance which means that there is a difference with what economic actors want and what happens so that adjustments are needed. A model that includes adjustments to correct for imbalances is called *the Error Correction Model* (ECM), and here are the short-term estimated results:

Table 6. Short-Term Estimate Results *of Error Correction Model* (ECM)
Dependent Variable: D(REC)
Method: Least Squares
Sample: 1990 2023
Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Count	Prob	Information
C	0,26342	0,87901	0,29968	0,7667	-
D(GDP)	0,13185	0,73140	0,18027	0,8583	Insignificant
D(SUB)	-7,73749	2,37499	-3,25790	0,0030*	Significant
D(POP)	0,10246	0,07392	1,38607	0,1771	Insignificant
D(CO2)	4,80981	5,78794	3,83100	0,0133*	Significant
ECT(-1)	-0,91605	0,17127	-5,34855	0,0000	Significant

Source: Eviews, Data processed, 2025.

Information:

[ ]	: Indicates t-count		
*	: Based on 95% confidence level (α=5%)		
R-squared	= 0,557580	Durbin-Watson Stat	= 1.891020
F-stat.	= 6,805598	Prob (F-stat)	= 0,000000

In Table 6, all variables are differentiated in the ECM model to find out the short-term relationship. The short-term equations obtained are:

$$\Delta(RECt)= 0.26342 + 0.13185\Delta PDBt - 7.73749\Delta SUBt + 0.10246\Delta POPt + 4.80981\Delta CO2t - 0.91605ECT(-1)$$

[0.29968] [0.18027] [3.25790] [1.38607] [3.83100] [5.34855]

Based on the results of the short-term estimate *of the Error Correction Model* (ECM) above, the *probability value* of each variable can be obtained. In this case, *the R-squared* is 0.557580, which indicates that the model explains about 55.75% variation in the data. *R-square* interprets the percentage of the influence of all independent variables on the bound variable. This means that in this study, 55% of the independent variables affect renewable energy consumption (REC), while the remaining 45% are influenced by other variables that are not included in the research model. The value of the constant (C) is 0.26342 and is marked positive. This means that without the influence of free variables, renewable energy consumption will change by 0.26%.

A Durbin-Watson statistic of 1.891020 shows that the residual value of the model is close to 2, which means there is no indication of significant autocorrelation in the data. Although slightly lower than 2, this value still indicates that the model does not have any serious autocorrelation issues. A statistical F-value of 6.805598 with a probability of F-stat (*p-value*) of 0.000000 indicates that the model as a whole is very statistically significant. A very small P-value indicates that there is at least one independent variable that has a significant influence on the dependent variable. Overall, despite the lower value of the coefficient of determination (R^2), this regression model still shows strong significance and can be used to explain the relationship between the variables analyzed.

4.5 Hypothesis Test

4.5.1 T-Statistical Hypothesis Test

The t-statistical test in this study was carried out to determine the level of significance of each free variable at each of its regenerative coefficients with a confidence level at t-table 0.05. In the equation model, the DF used is Df = n-k-1 (Df = 34 – 4 – 1 = 29) with a degree of freedom of 1.699. By comparing the t-satistics and t-tables, the influential variables are described in the following table:

Table 7. t-Statistical Test Results at 95% Significance Level and Df=29

Long-Term Testing			
Independent Variables	**Coefficient**	**Probability**	**Conclusion**
GDP	0,484159	0,0000	Ho rejected
SUB	12,45780	0,0000	Ho rejected
POP	0,165904	0,1104	Ho is accepted.
CO2	14,31750	0,0108	Ho rejected
Short-Term Testing			
Independent Variables	**Coefficient**	**Probability**	**Conclusion**
D(GDP)	0,13185	0,8583	Ho is accepted.
D(SUB)	7,73749	0,0030	Ho rejected
D(POP)	0,10246	0,1771	Ho is accepted.

D(CO2)	4,80981	0,0133	Ho rejected

Source: Eviews, Data processed, 2025.

4.5.1.1 Gross Domestic Product (GDP)

Based on the results of the t-statistical test calculation, it is known that in the long-term equation, the t-calculation for the Gross Domestic Product (GDP) variable is 8.988501, this value is greater than the t-table value which is 1.699 at the level of α = 5 percent and df = 29. Because of the value, Ho was rejected. This means that $t_{tabel} \leq t_{hitung}$ the Gross Domestic Product (GDP) variable in the long term partially has a significant impact on renewable energy consumption (REC) in Indonesia in the period 1990-2023.

In the short-term equation, based on the results of the t-statistical test calculation, the t-calculated value for the Gross Domestic Product (GDP) variable was 0.18027, this value is smaller than the t-table value which is 1.699 at the level of α = 5 percent and df = 29. Because of the grade$t_{tabel} \geq t_{hitung}$, Ho was accepted. This shows that the Gross Domestic Product (GDP) variable in the short term partially does not have a significant effect on renewable energy consumption (REC) in Indonesia in the period 1990-2023.

4.5.1.2 Energy Subsidy (SUB)

Based on the results of the calculation of the t-statistical test, it is known that in the long-term equation the t-calculated value for the energy subsidy variable (SUB) is 6.00662. This value is greater than the t-table value of 1.699 at the level of α = 5 percent and df = 29. Because the value $t_{tabel} \leq t_{hitung}$ of Ho is rejected, so that the variable energy subsidy (SUB) in the long term partially has a significant effect on renewable energy consumption (REC) in 1990-2023 in Indonesia.

In the short-term equation, based on the results of the calculation of the t-statistical test, a t-calculated value for the energy subsidy variable (SUB) was obtained of 3.25790, this value is greater than the t-table value of 1.699 at the level of α = 5 percent and df = 29. Because the value $t_{tabel} \leq t_{hitung}$ of Ho is rejected, so that in the short term, the variable energy subsidy (SUB) partially has a significant effect on renewable energy consumption (REC) in 1990-2023 in Indonesia.

4.5.1.3 Urban Population (POP)

In the long-term equation based on the results of the t-statistical test calculation, the t-calculated value for the Urban Population variable (POP) was obtained of 1.646896, this value is smaller than the t-table value which is 1.699 at the level of α = 5 percent and df = 29. Because of the grade$t_{tabel} \geq t_{hitung}$, Ho was accepted. Thus, the urban population variable (POP) in the long term partially does not have a significant effect on Renewable Energy Consumption (REC) in 1990-2023 in Indonesia.

Meanwhile, in the short-term equation, based on the results of the t-statistical test, the t-calculated value for the urban population variable (POP) was obtained of 1.38607, this value is smaller than the t-table value of 1.699 at the level of α = 5 percent and df = 29. Because of the grade$t_{tabel} \geq t_{hitung}$, Ho was accepted. This shows that in the short term, the urban population variable (POP) partially does not have a significant effect on renewable energy consumption (REC) in 1990-2023 in Indonesia.

4.5.1.4 Carbon Dioxide (CO2) Emissions

Based on the results of the calculation of the t-statistical test, the results were obtained that in the long-term equation, the t-calculated value for the carbon dioxide (CO2) emission variable was 2.723532, this value was greater than the t-table value of 1.699 at the level of α = 5 percent and df = 29. Because of the value$t_{tabel} \leq t_{hitung}$, Ho was rejected.This shows that in the long term, the variable carbon dioxide (CO2) emissions partially have a significant effect on renewable energy consumption (REC) in 1990-2023 in Indonesia.

4.5.2 F-Statistics Test Results

The F-statistical test is used to test the significance of the influence of the independent variable on the bound variable as a whole. The F-statistical test in this study was carried out at a confidence level of 95% ($\alpha = 0.05$) with *the numerator degree of freedom* (df1) = k – 1 or (df1) = 4 – 1 = 3 and *the denumerator degree of freedom* (df2) = n – k or (df2) = 34 – 4 = 30, with the test criteria for k being a variable and n being the number of observations. The following are the results of the F-statistics test with the test criteria as follows:

1. H0 is accepted and Ha is rejected if it meets the requirements of F-calculate < F-table
2. H0 is rejected and Ha is accepted if it meets the requirements of F-calculate > F-table

Table 8. Test F Results at 95% Significance Level and df1 = 3 and df2 = 30

Long-term			
Bound Variables	**F-count**	**F-Table**	**Conclusion**
1	48,13628	2,922	H0 rejected
Short-term			
Bound Variables	**F-count**	**F-Table**	**Conclusion**
1	6,805598	2,922	H0 rejected

Source: Eviews, Data processed, 2025.

Based on the results of the F-statistical test in Table 8, it shows in the long term and short term the value of F-calculation > F-table. The values of the F-count and F-table in the long and short term are 48.13628 > 2.922 and 6.805598 > 2.922. According to the F-Statistical test test criteria, if the value of F-calculated is greater than the F-table then Ho is rejected, this means that the independent variable being tested has a real effect on the bound variable. These results show that the variables of Gross Domestic Product (GDP), Energy Subsidy (SUB), Urban Population (POP) and carbon dioxide (CO_2) emissions together affect the consumption of renewable energy (REC) in Indonesia.

5. Conclusion

5.1 Conclusion

Based on the results of the research in the previous chapter, it can be concluded that several things can be concluded below:

1. The influence of the Gross Domestic Product (GDP) variable on renewable energy consumption in Indonesia in the period 1990-2023 shows a positive but not significant influence. Meanwhile, in the long term, the Gross Domestic Product (GDP) variable shows a positive and significant influence on renewable energy consumption in Indonesia in the period 1990-2023. This can be interpreted as an increase in Gross Domestic Product (GDP) will increase renewable energy consumption in Indonesia in the period 1990-2023.
2. The variable energy subsidy has a negative and significant effect on renewable energy consumption in Indonesia in the period 1990-2023. This means that an increase in energy subsidies, in this case fossil energy subsidies, will reduce renewable energy consumption in Indonesia in the period 1990-2023.
3. Urban population variables have a positive but insignificant influence on renewable energy consumption in Indonesia in the period 1990-2023. This is because the energy consumption of the population in Indonesia is still dominated by fossil energy consumption where when there is an increase in the population, people will consume fossil energy, not renewable energy.
4. The variable carbon dioxide (CO_2) emission has a positive and significant effect on the consumption of renewable energy in Indonesia. This means that increasing carbon dioxide (CO_2) emissions will increase renewable energy consumption in Indonesia in the period 1990-2023.
5. The variables of Gross Domestic Product (GDP), Energy Subsidy (SUB), Urban Population (POP) and carbon dioxide (CO_2) emissions together affect the consumption of renewable energy (REC) in Indonesia in the period 1990-2023.

5.2 Suggestion

Based on the results of the discussion and conclusions that have been explained earlier, some suggestions that can be given are as follows:

1. In order to increase Gross Domestic Product (GDP) to increase renewable energy consumption, the government needs to: 1) Increase the capital factor by facilitating investment, both domestic investment and foreign direct investment (FDI) and efficient capital use; 2) Developing technological innovation, economic digitalization and adoption of the use of foreign technology to accelerate industrialization; 3) The use of natural resources with sustainable management by diversifying the economy; 4) Maintaining the sustainability of the environmental ecosystem, where the transition to renewable energy can be one of the drivers of Gross Domestic Product (GDP) growth in the future.
2. In order to achieve the energy transition target from fossil energy to renewable energy, it is necessary to carry out reforms related to energy subsidy policies with the following steps: 1) Diverting energy subsidies that were originally commodity-based, but became targeted direct energy subsidies. This diversion can also be allocated for the development of renewable energy infrastructure; 2) Increasing investment in the development of renewable energy infrastructure as well as providing subsidies and incentives for the use of renewable energy. This will accelerate the energy transition and reduce dependence on fossil fuels.
3. Related to urban population variables, the government needs to promote family planning policies where family planning programs can help control population growth so that the pressure on energy demand can be managed better, efficiently and sustainably. The government also needs to integrate renewable energy in development plans. In this case, the energy needs of the growing population must be directed towards environmentally friendly resources. In addition, renewable energy infrastructure should be designed to support energy demand in areas with high populations. Educating about efficient energy consumption is important to reduce fossil energy consumption and choose renewable energy sources. Furthermore, the government can use population data for future energy planning. Energy consumption will continue to increase as the population grows. Therefore, integrating population data and energy consumption can help governments to design targeted energy policies.
4. The study of the determinants of renewable energy consumption in this study still has limitations. There are many other variables that may have an influence on renewable energy consumption, one of which is technology variables. So for further research, technology variables can be added to see how technology affects renewable energy consumption in Indonesia.

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