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THE EFFECT OF RENEWABLE ENERGY CONSUMPTION AND ENERGY INTENSITY ON THE ECONOMY

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Abstract
This study aims to analyze the influence of Renewable Energy Consumption and Energy Intensity on the economy in ASEAN. The variables used in this study consisted of Renewable Energy Consumption (REC), Energy Intensity (EI), and Gross Fixed Capital Formation (GFCF). This research method uses panel data regression analysis with the Random Effect Model. Where cross-sectional data are 7 ASEAN member countries and time series data from 2010-2021. The results of the study show that all variables, namely REC, EI and GFCF, are all significant to GDP. REC with a coefficient of -6,921,893 and a significance of 0.0000 < 0.05 so that REC has a negative impact on GDP in ASEAN. EI has a coefficient of -76,701.51 and a significance of 0.0000 < 0.05 so that EI has a negative impact on GDP. Meanwhile, GFCF has a coefficient of 91,930.69 and a significance of 0.0000 < 0.05 so that GFCF has a positive impact on GDP. The R2 value of 0.6083 can be concluded that the variation of these independent variables contributes 60.83 percent in GDP. While the rest are influenced by other factors that are not described in the model.

Keywords: Renewable Energy Consumption, Energy Intensity, GFCF, GDP

1. Introduction

Economic growth is a process of developing an economy. Economic growth reflects a country's capacity to improve people's welfare and expand employment. Economic growth plays an important role in driving regional integration, reducing poverty, and accelerating infrastructure and technology development. The potential for abundant resources, demographic bonuses and a rapidly growing domestic market make ASEAN countries faced with the challenge of maximizing this potential so that economic growth is not only high but also inclusive and sustainable. Despite the progress in recent decades, the ASEAN region still faces various structural challenges that can hinder the pace of growth. Dependence on the primary and fossil energy sectors as well as external impacts such as the COVID-19 pandemic have caused significant economic fluctuations.

Efforts to encourage sustainable economic growth are in line with global commitments through the Sustainable Development Goals (SDGs). One of the key goals is SDG 8, which emphasizes the importance of inclusive and sustainable economic growth, higher productivity, and the creation of decent jobs. Targets such as economic diversification, improving resource efficiency, and productive investment are central aspects of ASEAN countries' development strategies. In this study, economic growth is represented through Gross Domestic Product (GDP) as a commonly used proxy in the economic literature. GDP is used because it is able to reflect the performance of a country's economic output in aggregate in a certain period, and is a standard indicator in macroeconomic analysis at the national and international levels. According to Sukirno (2019), GDP can describe real economic growth.

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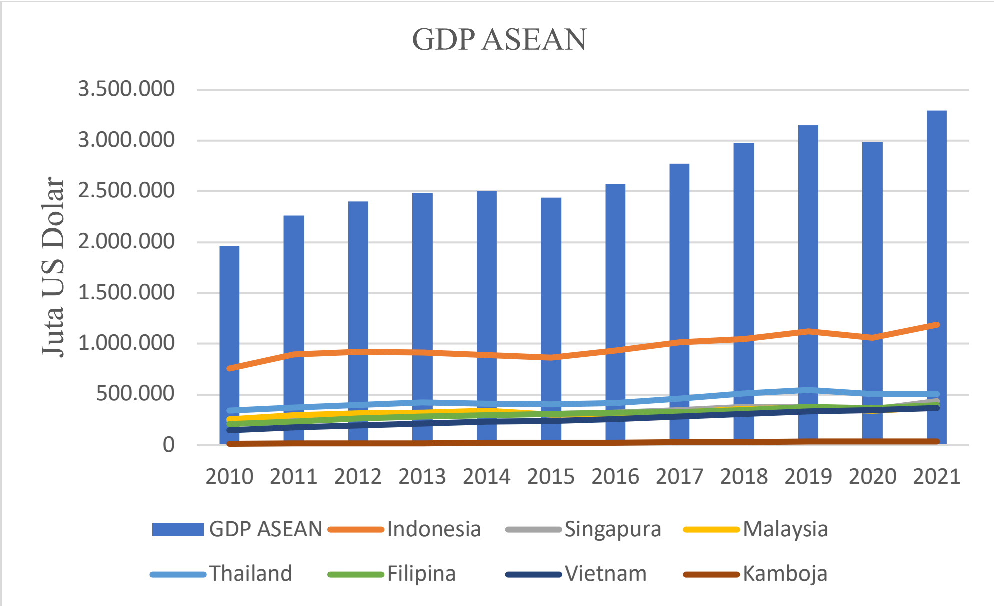

Figure 1. Total GDP and GDP of each ASEAN member country 2010-2021
Source: World Bank (2025), data processed

As seen in Figure 1, the GDP of ASEAN countries experienced a fluctuating trend during the period 2010 to 2021 Although 2012-2019 showed a steady increase, global shocks such as COVID-19 caused economic contraction in 2020. This reflects the region's economic vulnerability and the need for more resilient and adaptive policies.

As pressure on the environment increases and the need to transition to a low-carbon economy, the role of renewable energy consumption is becoming increasingly important in supporting sustainable economic growth. Renewable energy, such as solar, wind, hydro, and biomass energy are considered more environmentally friendly than fossil energy and can strengthen national energy security. The transition to clean energy is also part of the commitment to SDG 7, which is to ensure access to affordable, reliable, sustainable, and modern energy for all. However, the contribution of renewable energy to the national energy mix in most ASEAN countries is still relatively low. Table 1 below shows the portion of renewable energy consumption to total final energy consumption in several ASEAN countries.

Table 1. Renewable Energy Consumption in ASEAN

Year	Indonesia	Singapore	Malaysia	Thailand	Philippines	Vietnam	Cambodia
2010	36.00	0.50	2.00	22.80	32.70	34.60	5.05
2011	32.40	0.50	2.20	23.00	33.80	36.30	4.81
2012	30.10	0.50	2.50	23.60	34.10	37.90	4.68
2013	30.60	0.60	2.80	23.20	33.10	37.40	4.47
2014	29.30	0.60	3.00	24.40	32.40	36.70	4.50
2015	26.60	0.70	3.40	22.60	30.80	27.80	4.58
2016	27.80	0.70	4.40	22.40	28.60	26.80	4.74
2017	25.20	0.70	5.20	22.20	27.80	28.30	4.59
2018	22.00	0.80	5.30	23.70	27.60	24.30	4.58
2019	19.80	0.90	5.70	23.90	26.90	20.40	4.85
2020	21.90	0.90	7.00	20.90	29.10	18.90	5.09
2021	20.20	1.10	7.50	19.00	28.00	24.20	4.96

Source: World Bank (2025), data processed

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As shown in Table 1, the portion of renewable energy consumption such as Indonesia, the Philippines and Vietnam in 2010-2021 has generally decreased. As for Singapore and Malaysia, the proportion is gradually increasing from year to year, but the portion is still below 10%.

In addition to renewable energy consumption, the energy intensity factor also has an important role in explaining the efficiency of energy use in the economic production process. Energy intensity describes the amount of energy used to produce one unit of economic output (per GDP). The lower the energy intensity value, the more efficient a country is in utilizing its energy. Countries with high energy intensity tend to face challenges in reducing carbon emissions and increasing competitiveness. In the context of sustainable development, improving energy efficiency is also an integral part of SDG 7 targets, especially target 7.3, which is to improve energy efficiency globally.

Another factor that is no less important is the Gross Fixed Capital Formation (GFCF), which reflects long-term productive investments, such as the construction of infrastructure, machinery, and industrial facilities. GFCF is seen as the main driver of economic growth, as it contributes to increasing production capacity and modernizing economic sectors. In many empirical studies, GFCF has been shown to have a positive correlation with GDP, especially in developing countries that still need basic infrastructure and productive technologies. In the ASEAN region, the dynamics of the GFCF show variations that reflect differences in each country's development strategy.

Based on this description, this study aims to analyze the influence of renewable energy consumption, energy intensity, and gross fixed capital formation on economic growth in ASEAN countries, with GDP as a proxy. This study is expected to make an empirical contribution to the literature examining the linkages between economic development and energy sustainability, as well as provide input for policy formulation that supports the simultaneous achievement of SDG 7 and SDG 8.

2. Theoretical Background

One of the widely used frameworks in analyzing economic growth is Solow's neoclassical growth model (1956), which places capital and labor as determinants of output, as well as recognizing the role of technology as residual factors. This model is generally operationalized through the Cobb-Douglas production function, which describes the relationship between production inputs and economic outputs. In the expanded version, energy (both in the form of total consumption and renewable energy consumption) can also be included as an additional production factor. Stern (2004) shows that energy is not just a complementary input, but a vital component in supporting productivity and growth. According to Stern (2004), energy should be considered equal to capital and labor in influencing output.

Furthermore, Arbex & Perobelli (2007) developed an input-output model that combines Cobb-Douglas functions expanded with energy (including renewables and fossil fuels) and found that energy availability limits sectoral output growth when supply is constrained. In Romer's (1990) model of endogenous growth, renewable energy consumption can be considered part of technological advances or innovations that drive long-term productivity. Apergis and Payne (2010) show empirically that renewable energy consumption contributes positively to economic growth in OECD countries, especially when accompanied by technology investment and supportive regulations.

Furthermore, energy intensity, defined as energy consumption per unit of GDP, is used to measure energy efficiency in economic activities. According to Ang (2008), high

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energy intensity often occurs in the early stages of industrialization, when production activities are still dependent on energy-intensive processes. However, in the long run, the reduction in energy intensity reflects increased efficiency and structural transformation to high-value-added sectors. Within the Cobb-Douglas production framework, a decrease in energy intensity can be associated with an increase in total factor productivity (TFP), which will ultimately strengthen growth.

Gross Fixed Capital Formation (GFCF), which represents investments in fixed assets such as buildings, infrastructure, and machinery. In Solow's theory, capital accumulation is a key component in economic growth. GFCF directly increases production capacity, strengthens economic connectivity, and creates a multiplier effect through job creation and increased demand for capital goods. De Gregorio (1992) found that GFCF is positively correlated with economic growth in Latin American countries, especially in the context of public investment that supports private sector productivity. Based on this issue, the hypothesis of this research is renewable energy consumption, energy intensity affects productivity and economic growth. Gross fixed capital formation affects economic growth.

3. Methods

This study uses a quantitative approach, namely multiple linear regression. The data used is in the form of a data panel. The data panel is a combination of cross section and time series data. Cross section data is taken from 7 ASEAN member countries, while Time series data for the period 2010-2021. The independent variables used in this study are renewable energy consumption, energy intensity, gross fixed capital formation. The bound variable is Gross Domestic Product. The similarities:

$$GDPit = \beta 0 + \beta 1RECit + \beta 2EIit + \beta 3ln(lnGFCFit) + \mu it$$

Where:

GDP : Gross Domestic Product (Million US Dollars)
REC : Renewable energy consumption (Percent)
EI : Energy intensity (Ratio)
GFCF : Gross fixed capital formation (Million US Dollars)

4. Results and Discussion

Some of the approaches in the data panel are the common effect model, dixed effect model, and random effect model. The tests to find the most appropriate model are the chow test, the thirst test and the LM (langrange multiplier) test.

4.1 Chow Test

Table 2. Chow Test Result

Effect Test	Statistics	D.F.	Prob.
Cross-section F	166.303094	6,74	0.0000
Cross-section Chi-Square	224.535947	6	0.0000

Source: Data Processing Results with EViews, 2025

Table 2 shows the results of the chow test that the selected model is FEM with a probability value of 0.000 < 0.05. Then a thirst test will be carried out to choose the FEM or REM model.

4.2 Hausman Test

Table 3. Hausman Test Result

Test Summary	Chi-Sq. Statistics	Chi-Sq. D.F.	Prob.
Cross-section random	6.253008	3	0.0999

Source: Data Processing Results with EViews, 2025

The probability value on the thirst test is 0.0999 > 0.05 which means that the REM model is more appropriate than the FEM model.

4.3 Test Langrange Multiplier

Table 4. Test Langrange Multiplier

	Test Hypothesis	Time	Both
	Cross-section		
Breusch-Pagan	333.7099	5.296298	339.0062
	(0.0000)	(0.0214)	(0.0000)

Source: Data Processing Results with EViews, 2025

The probability value on the LM test is < 0.05 which means that the most appropriate model to use is the REM model.

4.4 REM Estimation Results

Table 5. Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-228091.1	267293.1	-0.853337	0.3960
REC	-6921.893	1495.185	-4.447532	0.0000
EI	-76701.51	17245.86	-4.629455	0.0000
LNGFCF	91930.69	20464.09	4.492293	0.0000
Effect Specification				
			S.D.	Rho
Cross-section random			206856.6	0.9622
Idiosyncratic random			41001.15	0.0378
Weighted Statistics				
R-squared	0.608347	Mean Dependent Var		21631.39
Adjusted R-squared	0.593660	S.D. Dependent var		65615.48
S.E. of regression	41826.45	Sum Squared resid		1.40E+11
F-statistic	41.42084	Durbin Watson stat		0.617488
Prob(F-statistic)	0.000000			

Source: Data Processing Results with EViews, 2025

The equation model based on the processing results in table 5 is:

$$GDPit = -228091.1 - 6921.893\ REC_{it} - 76701.51\ EIit + 91930.69\ ln(lnGFCFit) + \mu it$$

4.5 Classic Assumption Test

The results of the multicollinearity test showed that the correlation between the free variables did not exceed 0.8 so that the data escaped multicollinearity. Then in the heteroskedasticity test, the entire probability of the free variable exceeds 0.05 so that the data is said to be free from the heteroskedasticity problem.

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4.6 T test

Table 6. T test result

Independent variables	T-Statistics	T-Table	Prob	Conclusion
REC	-4.629455	1.990	0.0000	Minus H0/Influential
EI	-4.447532	1.990	0.0000	Minus H0/Influential
GFCF	4.492293	1.990	0.0000	Minus H0/Influential

Source: Data Processing Results with EViews, 2025

Table 6 shows the results of the t test to see if each free variable has a significant effect on the bound variable. From the table, it can be seen that all variables have a probability of < 0.05 so that renewable energy consumption, energy intensity, and gross fixed capital formation have a significant effect on GDP.

4.7 F Test F

Table 7. F test result

DF1	DF2	α	F-Table	F-stat	Prob	Conclusion
3	84	0.05	2.71	41.42084	0.0000	Influential

Source: Data Processing Results with EViews, 2025

The F test is a test used to see if all the independent variables used have an effect together on the bound variables. In the table above with a probability value of < 0.05, it can be concluded that all independent variables together affect the bound variables i.e. GDP significantly.

4.8 Coefficient of Determination

The R2 value in this study is 0.608347 which means that the independent variable used in this study is able to explain the bound variable by 61% while 39% is explained or influenced by other variables outside the model.

4.9 Renewable energy consumption to economic growth

Based on the results of the regression variable, renewable energy consumption has a negative and significant influence on GDP. In some empirical studies, the relationship between renewable energy consumption and economic growth is not always positive linear, especially in the early phases of adoption or when the supporting infrastructure and technologies are immature. Titalessy's (2021) study found that renewable energy consumption has a negative and significant coefficient for economic growth, while energy from combustible waste actually has a positive effect. This suggests that high-cost burdens and initial inefficiencies in the implementation of renewable energy can lower national productivity, especially in the short term or without adequate scale of adoption.

Furthermore, Chen et al (2020) found that in 103 countries (1995-2015) the consumption of renewable energy had a negative effect on GDP if the level of adoption was low. This implies that if the proportion of renewable energy is still below the optimal threshold, the initial costs of implementation such as infrastructure development, expensive technology, and system adaptation can depress productivity and overall economic output. Before the clean energy transition reaches economies of scale or adequate subsidy support, the use of new energy can add to the economic burden.

Qi & Li (2017) show that the consumption of renewable energy in the early stages often leads to a decrease in economic efficiency, especially if it is not accompanied by adequate capital and labor substitution capacity. For example, the cost of electricity from

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renewable energy plants is still much higher than that of fossil energy in many developing countries, triggering a shift of resources from the productive sector to the energy investment sector. For ASEAN to reflect the transition phase, renewable energy has not reached optimal scale, infrastructure and subsidies are not enough, thus having a negative effect on GDP.

4.10 Energy intensity to economic growth

Based on the regression results, energy intensity variables have a negative and significant influence on GDP. The results are in line with Zhou et al (2021) in a panel analysis of 21 countries found that economies facing high energy intensity will experience cost constraints, as resources are allocated to process and utilize relatively wasteful energy, not to increase productivity. The high energy intensity is a burden for growth, especially in countries with energy-intensive industrial structures. In ASEAN, where the economic structure is still dominated by heavy industry and efficiency technologies are not evenly distributed, high energy intensity tends to be an inhibitor to growth.

Research conducted by Sueyoshi & Goto (2023) found a negative relationship between energy intensity and economic growth, high energy intensity (EI) is an indicator of energy inefficiency, where more energy is needed to produce one unit of GDP. Countries with high energy intensity are considered to be less efficient operationally. Thus, the higher the energy intensity, the lower the efficiency, and this negatively impacts economic growth. In the context of ASEAN, high energy intensity can be an indicator that economic resources are being locked into energy-intensive and less productive sectors. Without energy reform, technological transition, and efficiency incentives, ASEAN countries will continue to face obstacles in fostering quality economic growth.

4.11 Gross fixed capital formation on economic growth

Based on the results of the regression variable, gross fixed capital formation has a positive and significant influence on GDP. This result is in accordance with Solow's growth theory where gross fixed capital formation serves as the main driver of physical capital accumulation needed to increase national production capacity. This result also shows the same results as De Gregorio's (1992) study on Latin American countries and also shows that investment has a strong effect on growth, especially in developing countries that are still building basic infrastructure. Investment in the form of GFCF not only strengthens the production sector, but also creates a multiplier effect on domestic demand and household consumption.

In the context of ASEAN, many countries such as Indonesia, Vietnam, and Cambodia are in a phase of massive infrastructure development. The increase in GFCF in these countries contributes directly to job creation, regional development, and economic capacity expansion. Countries such as Indonesia, Vietnam, and Thailand are actively boosting public and private spending in road, port, energy, and industrial estate infrastructure to attract investment and accelerate growth. This finding is proof that capital investment-based development strategies are still relevant and effective in encouraging economic growth.

5. Conclusion

First, renewable energy consumption surprisingly shows a negative and significant coefficient of GDP. These results indicate that in the early stages of the energy transition in ASEAN countries, the use of renewable energy has not been fully able to drive economic growth. This can be caused by the high initial investment cost, limited

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infrastructure, and the lack of optimal technology used in the implementation of clean energy.

Second, energy intensity also has a negative and significant effect on GDP, indicating that energy efficiency in the ASEAN region is still a challenge. Countries with energy-intensive industrial structures face the burden of high production costs, which ultimately suppress productivity and the pace of economic growth. These results are in line with previous research that shows that high energy intensity is an indicator of inefficiency and an obstacle to sustainable economic development.

Third, gross fixed capital formation shows a positive and significant influence on economic growth, as has been emphasized by classical growth theory and previous empirical results. Investment in fixed assets such as infrastructure, machinery, and production facilities has been proven to contribute to increased output, efficiency, and expansion of national economic capacity.

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