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Article

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Identification of Factors Affecting Net Zero Emission Level in Indonesia

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ABSTRACT

Amid the rising risks of fossil fuel prices and uncertainties about the global energy supply, countries worldwide have the opportunity to strengthen the development of clean energy investments. This study analyzes the impact of economic growth and other variables, such as fossil fuel consumption, renewable electricity generation, and low-carbon energy use, on carbon dioxide emissions in Indonesia over the past 58 years, from 1965 to 2022. The analysis compares the findings with the Environmental Kuznets Curve (EKC) hypothesis using quadratic equations and cubic equations through the stepwise application of ordinary least square (OLS) methods. Projections suggest that this relationship could follow the Environmental Kuznets Curve (EKC) hypothesis with an inverted U-shape as GDP per capita increases, CO_2 emissions per capita rise until reaching a turning point at $12,440 GDP per capita, after which CO_2 emissions per capita potentially decrease with further GDP growth. The EKC is a theoretical framework that suggests that environmental degradation initially increases with economic growth, but it starts to decrease beyond a certain point. The analysis also shows that projections could follow an N-curve when variables such as fossil fuel consumption and low-carbon energy influence the NZE level. This indicates that Indonesia still needs to consider energy security in the short and medium term while advancing sustainable energy initiatives. There is also a need for support in research and development of environmentally friendly technologies to reduce emissions alongside national economic growth.

Keywords: Climate Changes, Energy, Environmental Kuznets Curve, Net Zero Emissions
JEL Classifications: A12, C12, C13, C21, C51, C52, Q42, Q47

1. INTRODUCTION

The concept of Net Zero Emission (NZE) arises from the need to avoid the worst climate impacts by achieving net-zero emissions of carbon dioxide, methane, and other greenhouse gases in the atmosphere (Matemilola and Salami, 2020). Countries that rely on fossil fuels, including Indonesia, are most vulnerable to the net-zero transition, as they need to invest more in physical assets, decarbonization, and low-carbon growth. This group of countries also faces the risk of stranded conventional assets (Krishnan et al., 2022). The period leading up to 2030 is crucial in the pathway to global NZE by 2050. To limit warming to 1.75°C, emissions must be reduced by 30% below 2019 levels by 2030, equating to an annual reduction of 3.2% (Kimmel, 2022).

This emission reduction must be supported by implementing new technologies and decommissioning polluting assets. Shutting down coal-fired power plants and gradually phasing out oil-fueled vehicles are crucial. The next few years will also require trials and advancements in new technologies for decarbonization. Despite uncertainties regarding the costs and commercialization of these technologies, which make the pathway to 2050 challenging, this should not deter countries and companies from taking action (Kimmel, 2022).

The performance of the global energy system and readiness for energy transition over the past decade have shown progress, though at a relatively slow pace (WEF, 2022). The declining development and economic growth trends since 2018 indicate that countries face challenges maintaining energy affordability while continuing the energy transition. 2019 and 2020 presented global, national, and energy sector economic challenges. In 2020, pandemic-related restrictions led to a significant decrease in global energy demand and a reduction in CO_2 emissions, demonstrating the impact of demand-side climate mitigation. However, conditions changed in 2021 with a surge in demand for products and services, marked by a solid and rapid global economic recovery. This economic growth, closely correlated with energy consumption, resulted in global demand for electricity and oil surpassing pre-pandemic levels and prices reaching their highest levels in years.

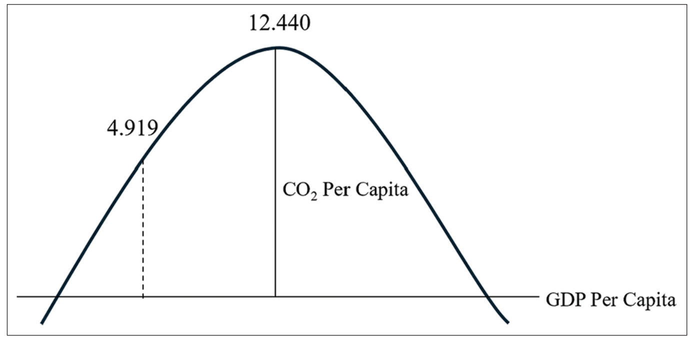
In early 2020, the COVID-19 pandemic significantly impacted the energy balance, leading to an unprecedented drop in energy demand. However, energy consumption rebounded in 2021. This resurgence caused a substantial imbalance in the energy market, triggering increased energy prices and a significant rise in Greenhouse Gas (GHG) emissions. The situation was further exacerbated by Russia's invasion of Ukraine, which drove up energy prices, posed risks to economic growth, and raised the cost of living globally. The challenges of high energy prices and economic obstacles could affect the energy transition process, and volatility might become a recurring phenomenon. Nevertheless, there is potential to develop mechanisms to mitigate energy supply shocks until the low-carbon energy system achieves the necessary scale and flexibility.

The volatility in the energy sector and geopolitical events over the past few years have increased the risk to energy resilience. The faster-than-expected economic recovery presents an opportunity for countries worldwide to strengthen energy resilience by diversifying fuels and energy mixes with low-carbon alternatives and enhancing energy efficiency. Energy resilience volatility provides a chance to accelerate the energy transition through clean energy investments and changing consumer energy consumption habits. In 2021, renewable energy capacity installations reached a record high, with 290 GW of wind and solar power added globally. However, this is still far below the 960 GW needed annually by 2030 to meet the net zero target by 2050 (WEF, 2022). Therefore, amid rising fossil fuel price risks and uncertainties about the global energy supply, countries worldwide can seize the opportunity to bolster the development of clean energy investments. This study aims to identify factors influencing Indonesia's net zero emission levels, which are expected to aid in developing clean energy.

2. LITERATURE REVIEW

The theory related to the relationship between environmental conditions and economic growth is the Environmental Kuznets Curve (EKC). This theory illustrates per capita income along the horizontal axis and environmental conditions per capita on the vertical axis for a specific country, forming an inverted U-shaped curve, as shown in Figure 1. In other words, environmental degradation increases in the early stages of economic development and decreases as income per capita surpasses a certain level.

Figure 1: EKC Hypothesis graph for model-2



Simon Kuznets discovered the relationship between national per capita income and income inequality. He hypothesized that this relationship increases in the early stages of economic development and decreases in the later stages (Kuznets, 1955).

Empirical studies have attempted to explain the level of environmental degradation per capita through a polynomial equation of per capita income (Grossman and Krueger, 1991). The hypothesis in this research tests the close relationship between economic development and environmental pollution. The EKC assumes an inverted U-shaped relationship between the development process and pollution; environmental pollution increases with rising per capita income in the initial development phase. However, the pollution level begins to decline once the income threshold is surpassed in the later stages of development. The EKC literature has been further extended by researchers such as Özcan dan Öztürk 2019.

Net Zero Emission (NZE) is theoretically similar to climate neutrality. This concept arises from the need to avoid the worst climate impacts by achieving net-zero emissions of carbon dioxide (CO_2), methane, and other greenhouse gases in the atmosphere. This is accomplished by eliminating all human-made greenhouse gas emissions through reduction measures, natural and artificial absorption, carbon offsetting, or not emitting at all to achieve net zero (Matemilola and Salami, 2020).

The idea of zero emissions was first conceptualized in 1991 by Gunter Pauli when he observed that the increasing demand for palm oil derivatives and by-products had exacerbated the destruction of rainforests in Southeast Asia. Net-zero emissions refer to technologies, processes, and other energy generation facilities that do not emit greenhouse gases or other waste products that can degrade environmental quality. Thus, zero-emission technologies such as bicycles, electric cars, hydrogen cars, and electric trains include zero-emission mobility. There are also zero-emission power plants like hydroelectric, solar, wind, and nuclear power plants. The primary approaches to achieving NZE involve removing carbon from the atmosphere through afforestation/reforestation, enhanced mineral weathering, or direct air capture of CO_2. Emission trading and emission reductions through energy efficiency and renewable energy sources are vital approaches (Matemilola and Salami, 2020).

Net Zero Emission (NZE) is crucial, given the need to limit temperature changes to 1.5 or 2.0°C. This means the world must reduce CO_2 emissions to net zero and potentially below zero (Azevedo et al., 2021a). Current evidence indicates that warming can stop when CO_2 emissions reach net zero, implying that higher temperatures are unavoidable and the choice is to prevent the worst impacts of future warming.

A country's commitment to Net Zero Emission (NZE) in line with the Paris Agreement requires systemic transitions in societal habits and business practices across different regions. There are five "Net Zero Principles": understanding who bears the cost, policymakers need to foster the prosperity of the population, identifying options that can deliver short-term economic returns, recognizing that off-shoring is not a solution if it merely shifts emissions abroad, and understanding that achieving net zero is a social and public policy challenge, beyond just a technological one (Turner et al., 2020).

The IPCC definition distinguishes between carbon neutrality, net zero, and climate neutrality. Carbon neutrality requires balancing anthropogenic CO_2 emissions with deliberate atmospheric removals, also called net-zero CO_2 emissions. Net zero represents the same concept but applies to all greenhouse gas (GHG) emissions, not just CO_2. On the other hand, climate neutrality is a state where anthropogenic activities have no net effect on the overall climate system (Masson-Delmotte et al., 2018).

Research has been conducted on global climate mitigation efforts in several countries, such as Europe, the United States, Japan, and Australia (Schreyer et al., 2020). This research indicates that all regions have technological options and mitigation strategies to achieve carbon neutrality by 2050. Regional characteristics are primarily related to land availability, population density, and varying population trends. Japan has limited resources and few options for carbon dioxide removal, and its significantly declining population reduces future energy demand. In contrast, Australia and the United States benefit from abundant renewable resources but face challenges in curbing industrial and transportation emissions due to increasing populations and high per capita energy usage. In Europe, a lack of social acceptance or cooperation could jeopardize the ongoing transition to a renewable-based system.

Research in China indicates that improving energy efficiency among end-users will increase total energy consumption and CO_2 emissions (Liang et al., 2009). The recommended policy analysis suggests a combination of a carbon tax and subsidies for hydropower generation. Regarding the energy sector, net zero emission research has been conducted in several countries. One notable study (Williams et al., 2021) discusses the transition towards a net-zero energy system in the United States. The findings indicate that achieving net zero in the U.S. by mid-century is technically feasible and economically affordable but requires large-scale infrastructure transformation. The primary challenge is not cost but rather political economy. While the future holds many uncertainties, the priorities for the coming decade are clear. Beyond the risks of delaying emission reductions, there is another risk: setting targets without adequate attention to how they will be achieved. Wind and solar power plants are the primary energy sources in a net-zero system. However, the scale and speed of their deployment present significant challenges in terms of land use and infrastructure placement. Maintaining the current level of gas-fired generation capacity until 2030 is essential for reliability, though these plants will operate less frequently. Hydrocarbon fuels will still be necessary in a net-zero system. Carbon capture will be required across all net-zero systems, even those based 100% on renewable primary energy. Building electrification is essential, but poorly designed policies could lead to serious equity issues. Achieving a net-zero roadmap involves sacrifices. Technological and human behavior breakthroughs are not technically necessary to reach net zero but may be required if mitigation options are too limited.

Research has also been conducted to evaluate energy transition programs. One such study in Poland examines the development of Poland's energy mix with a perspective toward 2040, considering electricity production, electricity prices, the share of renewable energy sources in final energy consumption, and CO_2 emission reductions (Kochanek, 2021). Additionally, the analysis reveals the implications for Poland's economy and society following the implementation of diversification with nuclear energy and natural gas. However, this requires a significant increase in electricity prices, impacting the entire economy and raising the level of energy poverty in Poland.

The characteristics of the transition pose significant challenges for public and private sector leaders as they seek to support an orderly transition, seize opportunities, and mitigate risks. This adjustment must be well-supported through coordinated actions involving governments, businesses, and supporting institutions and by broadening planning and investment perspectives.

The policy implications from modeling Net Zero Emissions in Europe by 2050, which involves stakeholders from the electricity and gas sectors, indicate that achieving Net Zero depends on a massive scale-up of renewable electricity, biomethane, hydrogen, and carbon capture and storage technologies (Pollitt and Chyong, 2021). Failure to enhance these technologies could potentially jeopardize the achievement of the Net Zero target by 2050.

Most corporate and government pledges focus on the year of achieving net zero. However, they pay insufficient attention to the importance of emissions pathways in determining short-term and long-term climate outcomes (Sun et al., 2021). This research shows that early actions to reduce carbon dioxide and methane emissions simultaneously lead to the best climate outcomes across all timeframes. It then recommends that companies and countries complement their net-zero targets with dual-approach achievements because the nationally determined contributions approach might delay methane mitigation.

Research on net zero emissions at the national level has been conducted, including a study by (Chaturvedi, 2021), which analyzes a net-zero energy systemto achieve climate change mitigation policy goals in India, expected to play a significant role in the mitigation debate. This study highlights that public engagement, involvement of the energy sector workforce, carbon pricing, low-cost financing, and achieving co-benefits are vital to ensuring that India's net-zero vision can be realized.

Addressing climate change requires ambitious transformations, including the ambitious transformation of the energy system (Azevedo et al., 2021b). This may necessitate the design and implementation of "net-zero emissions energy systems," which are energy systems that do not emit CO_2 and potentially other greenhouse gases. This research provides a perspective on understanding net-zero emissions systems. It offers guidance for policymakers and decision-makers amidst ongoing uncertainties and challenges such as resource availability, costs, scalability, public acceptance, and interactions with other systems and society. Countries like Indonesia are projected to achieve net-zero greenhouse gas and CO_2 emissions domestically slower than the global average (van Soest et al., 2021). Therefore, Indonesia requires more attention than Brazil and the United States, which are projected to achieve this goal a decade earlier than the global average. The central government needs to support system with various policies in order to maintain the sustainability of renewable industry (Sadirsan et al., 2014).

Energy modeling can assist national decision-makers in determining strategies to achieve net-zero greenhouse gas emissions (Pye et al., 2021). Some findings from this research include that energy systems achieving net-zero greenhouse gas emissions will vastly differ from current systems, necessitating a reevaluation of modeling analyses. In mitigation models, a series of demand-side actions are often absent, leading to the risk of over-reliance on carbon dioxide removal. There is significant scope for improvement, including scenarios that help predict needed changes, techniques for adjusting strategies, and better alignment with broader policy goals.

The climate crisis and the global economic impact of the COVID-19 crisis imply an urgent need for an environmentally friendly and inclusive new approach to growth (Stern et al., 2021). Investment in clean innovation and its diffusion is critical to shaping this approach, accompanied by investments in complementary assets, including sustainable infrastructure and human, natural, and social capital. These investments will help achieve net-zero greenhouse gas emissions and improve productivity, living standards, and individual prospects. This research highlights the importance of a coordinated set of policies and institutions to rapidly and extensively encourage private sector investment in clean innovation and assets.

The climate debt due to CO_2 emissions is substantial and unevenly distributed across the global economy. In developed countries, the accumulation of climate debt up to 2018 was equivalent to $22,065/person, roughly twice the debt of emerging market countries and 11 times the debt of low-income countries. Among the largest emitters, the per capita climate debt is highest in the United States, 6 times higher than in China. Additional efforts from developed countries may be necessary for fair burden-sharing in combating climate change. Climate debt will be significantly reduced if countries can fully meet the Paris Agreement targets to limit temperature increases. However, implementing the necessary emission reductions will be challenging, considering that developed countries, which have accumulated most of the climate debt, have already significantly reduced their emissions based on their Nationally Determined Contributions (NDCs). Therefore, a more pragmatic approach to achieving fair burden distribution is increasing assistance from developed countries to developing nations, including climate financing (Clements et al., 2023).

3. DATA AND METHOD

Several methods were used in the analysis, including stepwise regression and literature review. This study analyzes the impact of economic growth and other variables, such as fossil fuel consumption, renewable electricity generation, and low-carbon energy use, on carbon dioxide emissions in Indonesia over the past 58 years, from 1965 to 2022. The analysis compares the findings with the Environmental Kuznets Curve (EKC) hypothesis using quadratic equations (Yang Chng, 2019; Azwar, 2019; Adila et al., 2021) and cubic equations (Day and Grafton, 2003; De Bruyn, 1997) through the stepwise application of Ordinary Least Square (OLS) methods (Day and Grafton, 2003; Sambodo, 2005).

$$(lnCO_2pc)_t = \beta_0 + \beta_1 (lnGDPpc)_t + \varepsilon \quad (1)$$

$$(lnCO_2pc)_t = \beta_0 + \beta_1 (lnGDPpc)_t + \beta_2 (lnGDPpc)^2_t + \varepsilon \quad (2)$$

$$(lnCO_2pc)_t = \beta_0 + \beta_1 (lnGDPpc)_t + \beta_2 (lnGDPpc)^2_t + \beta_3 (lnGDPpc)^3_t + \varepsilon \quad (3)$$

$$(lnCO_2pc)_t = \beta_0 + \beta_1 (lnGDPpc)_t + \beta_2 (lnGDPpc)^2_t + \beta_3 (lnGDPpc)^3_t + \beta_4 (lnFossilFuelCons)_t + \varepsilon \quad (4)$$

$$(lnCO_2pc)_t = \beta_0 + \beta_1 (lnGDPpc)_t + \beta_2 (lnGDPpc)^2_t + \beta_3 (lnGDPpc)^3_t + \beta_4 (lnFossilFuelCons)_t + \beta_5 (lnRenewableElectricityGen)_t + \varepsilon \quad (5)$$

$$(lnCO_2pc)_t = \beta_0 + \beta_1 (lnGDPpc)_t + \beta_2 (lnGDPpc)^2_t + \beta_3 (lnGDPpc)^3_t + \beta_4 (lnFossilFuelCons)_t + \beta_5 (lnRenewableElectricityGen)_t + \beta_6 (lnLowCarbonEnergy)_t + \varepsilon \quad (6)$$

$$(lnCO_2pc)_t = \beta_0 + \beta_1 (lnGDPpc)_t + \beta_2 (lnGDPpc)^2_t + \beta_3 (lnGDPpc)^3_t + \beta_4 (lnFossilFuelCons)_t + \beta_5 (lnLowCarbonEnergy)_t + \varepsilon \quad (7)$$

The CO_2 variable is the total level of annual CO_2 emissions per capita nationally (tonnes per person) from the 2023 Global Carbon Budget (OurWorldInData), GDP is the per capita economic level (constant 2015, US$) from the World Development Indicators (World Bank). FossilFuelCons is the total consumption of fossil fuel in terawatt-hours, RenewableElectricityGen is renewable electricity generation, and LowCarbonEnergy is the consumption of low-carbon energy in terawatt-hours (Twh) which is the total use of nuclear, hydropower, solar, wind, geothermal, wave and bioenergy from the Energy Institute - Statistical Review of World Energy 2023 (OurWorldInData).

4. RESULTS

The analysis examines whether relationship between GDP per capita and CO_2 emissions per capita potentially follows the EKC hypothesis, resembling an inverted U-shape (Uchiyama, 2016) or

N-shape curve. Several potential projections of the relationship (Day and Grafton, 2003; Sambodo, 2005) if:

a. $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$, show a monotonic increase.
b. $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$, show a monotonic decrease.
c. $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 = 0$ shows an inverted U-shaped relationship consistent with the EKC hypothesis, with a turning point at $GDP^*pc = -(\beta_1/2\ \beta_2)$ or $GDP^*pc = e^{-\beta 1/2\ \beta 2)}$ when using the logarithmic form.
d. $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3 = 0$ show a U-shaped relationship in the quadratic equation.
e. $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 > 0$ show an N-shaped relationship in the cubic equation.
f. $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3 < 0$ show an inverted N-shaped relationship in the cubic equation.
g. $\beta_1 = \beta_2 = \beta_3 = 0$, showing that GDP does not influence emissions.

For cases 3 and 4, it is required that$|\beta_2| << |\beta_1|$, and for cases 5, 6, and 7, it is required that $|\beta_3| << |\beta_2| << |\beta_1|$.

The modeling results for the seven equations are shown in Table 1.

Overall, all models are significantly acceptable according to the F-test with Sig <0.05, although some models have individual variables that are not significant. Model 1 shows that the model follows a monotonic increasing relationship, meaning that an increase in GDP per capita is significantly followed by an increase in CO_2 emissions. Model 2 is a quadratic equation with results β1 > 0 and β2 < 0, indicating a significantly inverted U-shaped relationship by the EKC hypothesis. The GDP turning point in Model-2, using the formula $GDP^*pc = e^{-(\beta 1/2\ \beta 2)}$, results in a GDP per capita of $12,440, as shown in Figure 1.

However, the GDP per capita for 2023 is still $4,919 (BPS, 2024). The projection of when Indonesia will reach a GDP per capita of $12,440 depends on the economic scenario. According to the March 2024 projection by The Economist Intelligence Unit from the IMF's International Financial Statistics, a GDP per capita

Table 1: Estimation results of the models

Variable	Coeff	t Stat	P-value	F	Sig F	R Square
Model-1				1,812.38	0.000	0.97
Intercept	−8.77	(42.74)	0.000			
lnGDPpc	1.18	42.57	0.000			
Model-2				2,041.56	0.000	0.99
Intercept	−23.71	(13.15)	0.000			
lnGDPpc	5.28	10.70	0.000			
$lnGDPpc^2$	−0.28	(8.31)	0.000			
Model-3				1,338.15	0.000	0.99
Intercept	(30.96)	(1.16)	0.251			
lnGDPpc	8.27	0.75	0.455			
$lnGDPpc^2$	(0.69)	(0.46)	0.649			
$lnGDPpc^3$	0.02	0.27	0.787			
Model-4				1,729.01	0.000	0.99
Intercept	(101.56)	(4.36)	0.000			
lnGDPpc	40.21	4.10	0.000			
$lnGDPpc^2$	(5.50)	(3.98)	0.000			
$lnGDPpc^3$	0.25	3.92	0.000			
lnFossilFuelCons	0.52	6.28	0.000			
Model-5				1,430.88	0.000	0.99
Intercept	(69.76)	(2.34)	0.023			
lnGDPpc	27.39	2.22	0.031			
$lnGDPpc^2$	(3.80)	(2.24)	0.029			
$lnGDPpc^3$	0.18	2.28	0.027			
lnFossilFuelCons	0.56	6.59	0.000			
lnRenewableElectricityGen	(0.04)	(1.67)	0.100			
Model-6				1,218.52	0.000	0.99
Intercept	(99.06)	(2.78)	0.008			
lnGDPpc	39.49	2.68	0.010			
$lnGDPpc^2$	(5.44)	(2.69)	0.010			
$lnGDPpc^3$	0.25	2.73	0.009			
lnFossilFuelCons	0.53	6.06	0.000			
lnRenewableElectricityGen	0.07	0.85	0.400			
lnLowCarbonEnergy	(0.11)	(1.46)	0.151			
Model-7				1,470.00	0.000	0.99
Intercept	(77.84)	(3.07)	0.003			
lnGDPpc	30.78	2.92	0.005			
$lnGDPpc^2$	(4.26)	(2.91)	0.005			
$lnGDPpc^3$	0.20	2.94	0.005			
lnFossilFuelCons	0.56	6.78	0.000			
lnLowCarbonEnergy	(0.05)	(2.07)	0.043			

Dependent Var: $lnCO_2pc$

of \$12,400 can be achieved by 2037 (Economist Intelligence Unit, 2024).

Model 3 is a cubic equation with results $\beta1 > 0$, $\beta2 < 0$, and $\beta3 > 0$, showing a significant N-shaped relationship. Indonesia's economic growth not only increases the welfare of its people but also raises carbon dioxide emissions, contributing to global warming. However, emissions are not solely caused by real income per capita (Sambodo, 2005), which necessitates additions such as in Model-4, a modification of Model-3 with the inclusion of fossil fuel consumption as a variable. The results of Model 4 show that all coefficients are significant.

The Environmental Kuznets Curve (EKC) hypothesis in Indonesia may yield different results compared to other countries due to variations in historical data and other influencing variables. For instance, the EKC hypothesis is not valid in Azerbaijan (Huseynli, 2024), whereas it is valid in Morroco (Benali and Benabbou, 2023), Africa (Teklie dan Yağmur, 2024), and India (Raihan et al., 2024). Moreover in United States, the variables GDP and GDP^2 were found to be insignificant, while energy consumption positively impacts CO_2 emissions (Bunnag, 2023).

Model-5 modifies Model-4 by adding the renewable electricity generation variable, which affects the coefficients of other variables, making them less favorable compared to Model-4, and the t-test results for the renewable electricity generation variable are not significant. Model 6 further adds the low-carbon energy variable. The results of Model-6 still yield an insignificant t-test for the renewable electricity generation variable, leading to its removal in Model-7. Model-7 shows significant results for all additional coefficients, namely fossil fuel consumption and low-carbon energy, adding novelty to this research.

A previous study also demonstrated that the relationship among independent variables, such as the consumption of oil, gas, and biomass fuels, has a positive and significant impact on economic growth in Indonesia (Purnomo et al., 2023). Moreover, previous studies support the conclusion that GDP per capita has a positive and significant effect on CO_2 emissions in Indonesia, both in the short term and the long term (Wahyudi et al., 2024).

5. CONCLUSIONS AND POLICY IMPLICATIONS

On the national level, projections suggest that this relationship between GDP per capita and CO_2 emissions per capita could follow the EKC hypothesis with an inverted U-shaped curve, where an increase in GDP per capita is followed by an increase in CO_2 emissions per capita up to a turning point at a GDP per capita of \$12,440, after which CO_2 emissions per capita could potentially decrease as GDP per capita continues to rise. The analysis also shows that projections could follow an N-shaped curve, including variables such as fossil fuel consumption and low-carbon energy, which influence net-zero emissions (NZE). This indicates that Indonesia needs to focus on energy resilience in the short and medium term while advancing sustainable energy initiatives. Additionally, there is a need for research and development support for environmentally friendly technologies to reduce emissions alongside economic growth. Therefore, the balance of the energy trilemma can differ substantially between developed and developing countries. Support from developed countries for developing nations is necessary to encourage investment in new technologies, which can ultimately reduce costs. This is a matter of justice, as developed countries have historically utilized hydrocarbons before the world understood global warming; for the energy transition to be successful and fair, countries need to strengthen energy resilience to ensure that emission reductions do not compromise economic growth and human development. Additionally, clear legal frameworks in Indonesia can enhance transparency and ease of doing business, supported by regulations defining stakeholders' authority and responsibilities.

From the company perspective, energy companies need to prioritize energy supply and security amid the energy transition. Indonesia cannot quickly transition away from oil and gas production. However, energy companies can increase investments and activities in the energy transition to support government policies fully. These companies should continue prioritizing technologies that help the country achieve renewable energy and fossil fuel decarbonization targets, thereby maintaining their business as fossil fuel producers while using Carbon Capture, Utilization, and Storage (CCUS) technologies, supported by synergies between state-owned and private companies. This approach aligns with the EKC hypothesis of an inverted U-shaped curve at the national level, which can be implemented at the corporate level.

This study focuses solely on the energy sector. Therefore, further research is needed to address other sectors, such as forestry and agriculture, contributing to Indonesia's environmental emissions. This is important because Indonesia is among the top three countries for agricultural emissions, along with Brazil and China, accounting for 53% of global agricultural emissions (Food and Agriculture Organization, 2021). Additionally, Indonesia has the highest emissions globally in the forestry and land-use change sector, with 0.7 Gt CO_2eq (Food and Agriculture Organization, 2023).

Methodologically, this study has explored and provided findings on the relationship between GDP and CO_2 emissions per capita using stepwise regression within strategic management. However, a more scientific review of economic methods is needed, as demonstrated by previous research in other countries (Sorge and Neumann, 2020).

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