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The Effect of Green Finance, Green Energy, and ESG Performance on Carbon Neutrality: Empirical Study on Energy Sector Companies in Indonesia

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Abstract: The objective aims to analyze the effect of green finance, green energy, and ESG performance on carbon neutrality firms registered on the IDX throughout the timeframe 2020–2022. The research sample consists of companies in the energy sector, transportation, industry, and basic materials that produce high intensive energy that were listed on the Indonesia Stock Exchange during the specified period and had published audited annual reports. Using a purposive sampling method, 26 companies were selected as samples, resulting in a total of 78 observational data points. This research employs panel regression analysis, utilizing annual and ESG-related reports. The results show that green energy and ESG Performance have a significant positive effect on carbon neutrality. Meanwhile, green finance does not have a significant effect on carbon neutrality.

Keywords: Green Finance, Green Energy, ESG Performance, Carbon Neutrality.

INTRODUCTION

In recent decades, climate crisis and temperature rise have become major worldwide issues. Anthropogenic actions—especially industrial production and fossil fuel combustion—are major contributors to the rise in carbon dioxide (CO_2) emissions, which in turn intensify the greenhouse effect (Zhou, Haseeb, Bousrih, & Wu, 2024). Among various greenhouse gases, CO_2 remains the largest and fastest-growing contributor, responsible for phenomena such as melting glaciers, irregular rainfall, rising ocean temperatures, decreased agricultural productivity, and reduced labor capacity (Sarwar et al., 2022, as cited in Zhou et al., 2024; Adrian, 2024).

The concept of carbon neutrality refers to a state where the amount of CO_2 released into the atmosphere is balanced by the amount absorbed or offset by mitigation efforts such as carbon taxes, renewable energy use, or emissions trading (Hikmah, Gunandi, Annisah, & Yulianty, 2024). As a resource-rich country, Indonesia bears significant responsibility in achieving carbon neutrality. According to the World Resources Institute (2020), Indonesia ranks among the top 10 GHG emitters globally, with the energy and industrial sectors

accounting for the majority of emissions (Asyari & Hernawati, 2023). The Indonesian authority has endorsed the Paris Treaty by legislation No. 16/2016, committing to a 29% emissions reduction by 2030, or 41% with international assistance (Winyswara, 2019, as cited in Siagian, et al., 2022).

Efforts to attain net-zero carbon emissions in Indonesia must prioritize the energy sector, which contributed over 43% of total national emissions in 2019, with CO_2 making up more than 95% of the sector's emissions (Pusdatin ESDM, 2020). Transitioning shift away from hydrocarbons to sustainable power is essential. According to Jia and Lin (2021), coal burning accounts for over 70% of CO_2 emissions in the energy sector, and replacing coal with green energy is crucial in achieving net-zero targets.

Green energy—defined as energy harnessing clean sources such as wind, sunlight, water, and organic matter—provides an environmentally friendly alternative to fossil fuels (Li et al., 2022). Ozolina et al. (2022) emphasize that adopting clean power and boosting energy productivity are critical strategies to reach decarbonization.

In parallel, sustainable finance has become a strategic tool to drive a carbon-light transition. Green finance allocates capital to projects promoting energy efficiency, renewable energy, and clean technology development (Zhang, 2024). Studies by Jian and Afshan (2023) show that sustainable investment substantially supports reducing emissions and enhancing the implementation of sustainable economic policies.

Another integral factor in achieving carbon neutrality is sustainability-driven corporate metrics. ESG frameworks provide strategic tools for companies to align environmental responsibility with profitability (Xie, 2024). Firms with strong ESG performance tend to lower carbon output via sustainable operations, improved energy use, and transparent governance.

This research is based on Stakeholder Theory, which emphasizes the importance of satisfying the interests of all stakeholders—including governments, communities, consumers, and investors—by aligning business practices with sustainability goals (Freeman, 1984; Donaldson & Preston, 1995). Additionally, the Resource-Based View (RBV) theory suggests that internal capabilities, such as technological innovation and environmental expertise, provide competitive advantages in achieving long-term sustainability (Barney, 1991).

Despite extensive studies in developed countries, limited empirical evidence exists regarding the influence of sustainable funding, clean energy, and ESG performance on carbon neutrality in Indonesia's energy sector. Therefore, this study aims to: (1) examine the effect of green finance on carbon neutrality among energy companies in Indonesia; (2) analyze the influence of green energy adoption on achieving carbon neutrality; and (3) assess the impact of ESG performance in supporting carbon neutrality initiatives within the Indonesian energy sector.

METHODS

This research applies a numerical method to empirically investigate the effect of green finance, green energy, and ESG performance on carbon neutrality in power industry firms registered on the IDX during the 2021–2023 period. The research relies on secondary data derived from publicly available corporate disclosures, particularly annual reports, sustainability reports, and ESG ratings.

The research subjects are energy-intensive companies operating in the energy, industrial, basic materials, or transportation sectors. Judgmental sampling method was used for firm selection that: (1) are listed on the IDX; (2) published both financial and sustainability reports consistently from 2020 to 2022; and (3) have ESG disclosure scores available through ESG Intelligence UNAIR. A total of 26 companies met these criteria and were included in the sample.

As the study is based on secondary documentation, it is not tied to a specific fieldwork location. The data were collected through documentation techniques from verified sources such as company websites, the official IDX platform, and ESG rating providers. CO_2 emissions and renewable energy usage data were extracted from the environmental sections of each company's sustainability report. The validity of the data was validated by triangulating with official company disclosures and ESG rating databases. As this study solely relies on publicly available secondary data, no ethical approval was required.

The variables in this study were operationalized as follows :

Carbon Neutrality

Carbon neutrality is proxied by carbon intensity, which reflects the amount of CO_2 emissions generated per unit of revenue. This indicator is widely used to assess how efficiently a company manages its emissions relative to its economic output. The lower the carbon intensity, the closer a company is to achieving carbon neutrality. Emission density is measured by the ratio of total CO_2 release by total revenue (Xie, 2024). CO_2 emissions data were sourced from sustainability reports, particularly under the environmental performance sections.

Green Finance

Green finance represents the extent to which companies allocate funds to environmentally friendly projects or instruments such as green bonds, green loans, or investments in clean technology. It is used to evaluate a company's financial commitment to sustainability. A higher green finance ratio indicates a stronger orientation toward supporting the green economy. The green finance ratio is obtained by dividing the total amount of green financing by the company's total assets (Brühl, 2023). Data were obtained from annual or sustainability reports, particularly sections disclosing project financing and environmental initiatives.

Green Energy

Green energy measures the share of clean energy in aggregate energy usage. This variable highlights a company's departure from non-renewable sources and adoption of clean energy alternatives, hydro, or biomass. The green energy ratio is measured through the fraction of green power over total use (Liu, 2022). Companies that invest heavily in renewable energy demonstrate proactive strategies in reducing their carbon footprint. Relevant data were collected from disclosures in sustainability reports.

ESG Performance

ESG performance is assessed using ESG scores provided by ESG Intelligence UNAIR, based on Global Reporting Initiative (GRI) indicators. This variable captures the extent to which a company implements responsible environmental practices, social responsibility, and strong corporate governance. Higher ESG scores indicate better transparency, stakeholder engagement, and risk management related to sustainability issues.

Panel regression was used for data interpretation, including evaluation of fixed and random models and random effect was determined through the Hausman test. Before running the regression, several classical assumption tests were carried out to verify model soundness, including the normality test (Kolmogorov-Smirnov), collinearity diagnostic (VIF), time-dependence analysis (Durbin-Watson), and heteroscedasticity test (Glejser).

The panel statistical regression was applied to analyze the link between independent variables—green finance, green energy, and ESG indicators—and carbon as the outcome variable neutrality. The strength and significance of the relationships were evaluated applying Adjusted R^2, F-statistic for global significance, and t-stat for parameter impact of each predictor variable, all conducted at a 5% level of significance (Ghozali, 2018).

This methodological design enables a robust empirical assessment of how green financial practices, renewable energy adoption, and ESG performance contribute to corporate progress toward carbon neutrality in Indonesia's energy sector.

Conceptual Framework

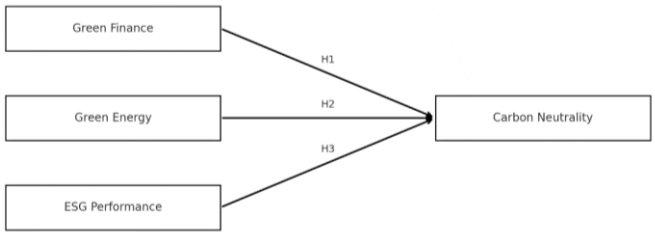


Figure 1. Research Framework

Based on the background, literature review, and theoretical framework, the following hypotheses are proposed in this study:

H1: Green finance has a positive influence on achieving carbon neutrality in energy sector companies in Indonesia.

H2: Green energy has a positive influence on achieving carbon neutrality in energy sector companies in Indonesia.

H3: ESG performance has a positive influence on achieving carbon neutrality in energy sector companies in Indonesia.

RESULTS AND DISCUSSION

Descriptive Statics

Table 1. Descriptive Statics Result

Variable	N	Mean	Max.	Min.	Std. Dev.
Carbon Neutrality	78	0.000002	0.000071	0.000000	0.000008
Green finance	78	0.001254	0.027073	0.000000	0.003733
Green Energy	78	0.164163	0.999846	0.000000	0.290334
ESG Performance	78	0.508576	1.000000	0.000000	0.255879

Source: *eviews*

Referring to the above table, all factors in this research consists of 78 observations. The Carbon Neutrality (CN) variable has a mean of 0.000002, with a maximum value of 0.000071 and a minimum of 0.000000. These results indicate that the overall level of carbon neutrality among energy companies is still extremely low. This suggests that most companies have not yet made significant efforts to reduce carbon emissions, and the variation among them is minimal.The Green Finance (GF) variable has a mean value of 0.001254, ranging from 0 to 0.027073. This implies that while some companies have started allocating funds to environmentally friendly initiatives, many others have yet to disclose any green finance activities.The Green Energy (GE) variable shows a mean of 0.164163, with a maximum value close to 1 (0.999846) and a minimum of 0.000000. Compared to the previous variables, green energy has a higher average, approximately 16.4%, indicating that although most companies still have limited use of renewable energy, a few are already utilizing it almost entirely.The ESG Performance (EP) variable has the highest average, with a mean of 0.508576, a maximum of 1.000000, and a minimum of 0.000000. This suggests that, in general, ESG performance in

the energy sector is at a moderate level. Some companies have achieved full ESG disclosure, while others have not disclosed any ESG-related information.

Chow Test

Table 2. Chow Test Result

	Statistic	d.f	Prob.
Cross-section F	1.119.334	-25,49	0,3588
Cross-section Chi-square	35.237.965	25	0,0840

Source: *eviews*

The Chow test can be used to choose which model is more suitable between Common Effects or Fixed Effects (Savitri et al., 2021). the probability value suggests CEM is appropriate (Napitupulu et al., 2021: 136). Then the Hausman test is not carried out and continued with the Lagrange Multiplier (LM).

LM Test

Table 3. LM Test Result

	Cross-section	Test Hypothesis Time	Both
Breusch-Pagan	0.018244 (0.8926)	0.796972 (0.3720)	0.815216 (0.3666)
Honda	-0.135072 (0.5537)	-0.892733 (0.8140)	-0.726768 (0.7663)
King-Wu	-0.135072 (0.5537)	-0.892733 (0.8140)	-0.895794 (0.8148)
Standardized Honda	0.189121 (0.4250)	-0.592430 (0.7232)	-4.936515 (1.0000)
Standardized King-Wu	0.189121 (0.4250)	-0.592430 (0.7232)	-3.497004 (0.9998)
Gourieroux, et al.	-	-	0.000000 (1.0000)

Source : *eviews*

The Lagrange Multiplier Test, or LM Test, can be used to choose which model is better between Common Effects or Random Effects (Savitri et al., 2021). Based on the table above, that the Prob Breusch-Pagan value is 0.8926> 0.05, then the CEM model is chosen (Napitupulu et al., 2021: 139). So the identified approach corresponds to the CEM model. Based on the results of the Chow test and Lagrange Multiplier (LM) test, the Common The CEM method was deemed the most fitting panel analysis. The estimated panel regression equation using the CEM is presented as follows:

$$CN_{it} = -0.491527 + 0.022557\ GF_{it} + 0.033427\ GE_{it} + 0.068166\ EP_{it} + e_{it}$$

CN = Carbon Neutrality for firm i for at time t
GF = Green Finance
GE = Green Energy
EP = ESG Performance
ε = error term

T Test

Table 4. T Test Result

Variable	Expected sign	Coefficient	t-Statistic	Prob.	Prob. One Tail	Decision
C		-0.491527	-0.995477	0.3227	0.16135	
GF	+	0.022557	0.326826	0.7447	0.37235	H1 Rejected
GE	+	0.033427	3.062807	0.0031	0.00155	H2 Accepted
EP	+	0.068166	8.799296	0.0000	0	H3 Accepted

Source: *eviews*

According to t-statistics findings, the Green Finance variable shows a positive but statistically insignificant effect on carbon neutrality ($p = 0.7447 > 0.05$), indicating that the allocation of green finance has no significant effect on reducing carbon emissions in energy sector companies in Indonesia. In contrast, Green Energy shows a positive and statistically significant influence ($p = 0.0031 < 0.05$), indicating that increased use of renewable energy makes a meaningful contribution to achieving carbon neutrality. Similarly, ESG Performance also has a positive and highly significant influence ($p = 0.0000 < 0.05$), indicating that better performance in environmental, social and governance aspects is associated with lower carbon emission intensity.

CONCLUSION

This study examines the influence of Green Finance, Green Energy, and ESG Performance on Carbon Neutrality, in alignment with the objective to evaluate how environmental financial strategies and corporate sustainability practices contribute to carbon emission reduction within Indonesia's energy sector. The empirical results indicate that sustainable power and ESG Performance show meaningful beneficial effects on carbon neutrality of firms, supporting the notion that companies investing in renewable energy sources and maintaining strong environmental, social, and governance standards are more likely to achieve lower emission intensity. However, Green Finance does not exhibit a statistically significant effect, suggesting that the current allocation and implementation of green financial instruments have not yet been sufficiently effective in promoting measurable carbon reductions. These results offer a scientific contribution by enriching the empirical evidence on the effectiveness of corporate-level sustainability indicators in achieving climate goals, particularly in the context of emerging economies. Furthermore, the study strengthens the theoretical understanding of the decarbonization process by emphasizing the differentiated roles of financial and operational sustainability strategies. This insight is expected to function as an effective reference for both scholars and professionals seeking to enhance industrial transitions toward low-carbon development.

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