The object of this study is the ESG performance in emerging market energy companies. The problem to be solved is the identifying how internal strategic orientations translate into measurable sustainability outcomes. Despite the theoretical acknowledgment of GMO and MC as sustainability enablers, empirical evidence on their pathways to ESG outcomes remains limited.

The study examines the role of Aggressive Low Carbon Innovation (ALCI) as a mechanism through which GMO and MC exert their influence on ESG performance.

The findings indicate that MC has a significant indirect effect on ESG performance through ALCI ($\beta = 0.312$, $p < 0.01$), while its direct effect is not statistically significant ($\beta = 0.127$, $p > 0.05$). GMO shows a strong positive effect on ALCI ($\beta = 0.488$, $p < 0.001$), but its direct influence on ESG performance is also insignificant ($\beta = 0.089$, $p > 0.05$). In contrast, ALCI demonstrates a strong direct impact on ESG performance ($\beta = 0.446$, $p < 0.001$), confirming its role as a pivotal mediator.

These results suggest that the implementation of ALCI serves as a necessary bridge between strategic orientation and sustainability outcomes. The effectiveness of ALCI in improving ESG performance can be explained by its capacity to integrate environmental innovations into business operations aggressively, thereby enhancing compliance, reputation, and stakeholder trust. The findings are most applicable under conditions where organizational leadership is committed, market orientation supports sustainable value, and regulatory environments encourage innovation. This research provides actionable insights for firms seeking to enhance ESG outcomes through internal capability building and strategic innovation pathways

Keywords: aggressive low carbon innovation, firm's ESG performance, green market orientation, management commitment

UDC 658.514
DOI: 10.15587/1729-4061.2025.335639

IDENTIFYING THE ROLE OF AGGRESSIVE LOW CARBON INNOVATION ON A FIRM'S ENVIRONMENTAL, SOCIAL, AND GOVERNANCE PERFORMANCE

Andi Hendra Paluseri
Corresponding author
Doctoral Student of Management*
E-mail: apaluseri@student.ciputra.ac.id
Thomas S. Kaihatu
Doctor of Management, Professor*
Timotius F.C.W. Sutrisno
Doctor of Management, Assistant Professor*
Denny Bernardus
Professor*
*Graduate Program, School of Business and Management
Universitas Ciputra Surabaya
CitraLand CBD Boulevard, Surabaya, Indonesia

Received 24.04.2025
Received in revised form 23.06.2025
Accepted 05.07.2025
Published 27.08.2025

How to Cite: *Paluseri, A. H., Kaihatu, T. S., Sutrisno, T. F. C. W., Bernandus, D. (2025). Identifying the role of aggressive low carbon innovation on a firm's environmental, social, and governance performance. Eastern-European Journal of Enterprise Technologies, 4 (13 (136)), 38–47. https://doi.org/10.15587/1729-4061.2025.335639*

1. Introduction

Rising concerns about climate change and global efforts to transition to a low-carbon economy have brought sustainability into the spotlight in recent decades. Companies worldwide need to prioritize monetary profits, but they also need to develop strategies to control the social and environmental impacts of their operations. So, one of the most important ways to measure the success of a company's sustainability management is by looking at its ESG (environmental, social, and governance) performance. Important for attracting investors and increasing company competitiveness, ESG performance incorporates environmental, social, and governance factors [1].

As one of Indonesia's largest energy company, Pertamina plays a pivotal role in supporting the nation's energy needs while addressing global demands for sustainability. The company operates in a sector traditionally associated with high carbon emissions, which presents significant challenges in aligning its business operations with environmental sustainability goals. In light of Indonesia's efforts to fulfill its obligations under the Paris Agreement and the SDGs, Pertamina is under increasing pressure to transition into a more environmentally friendly entity [2]. This transition is not only vital for the company's competitiveness in the global market but also critical for its reputation and long-term viability. As such, adopting comprehensive sustainability strategies, including environmental, social, and governance (ESG) frameworks, is a top priority [3].

One strategic approach that can help Pertamina improve ESG performance is to adopt green market orientation (GMO). Through the use of GMO, companies are better equipped to understand the needs of environmentally conscious consumers and to advocate for solutions that reduce their impact on the planet. In the context of energy companies, GMO can be applied through the development of low-carbon products, adoption of renewable energy technologies, and management of carbon markets. GMO encourages companies to not only respond to current market demands but also anticipate future trends that focus on environmental sustainability [4]. By integrating environmental responsibility into fundamental market strategies GMO has a substantial impact on a company's ESG performance. Businesses that embrace GMOs intentionally link their goods with services, and operational practices

with environmentally conscious consumer demands and regulatory expectations, leading to improved sustainability outcomes. GMO enhances transparency, fosters stakeholder trust, and strengthens brand reputation, which are critical components of ESG performance.

Management commitment plays a pivotal role in shaping and enhancing a firm's ESG performance by driving strategic alignment, resource allocation, and cultural transformation towards sustainability goals. To tackle environmental, social, and governance issues head-on, companies need strong leadership support to incorporate ESG principles into corporate governance. In energy companies, management commitment plays a pivotal role in integrating sustainability into core business strategies by aligning long-term organizational goals with environmental priorities. Rather than treating sustainability as a peripheral initiative, committed leadership actively drives dual growth strategies enhancing traditional energy operations while simultaneously investing in low-carbon innovations. These efforts are reflected in the development of carbon capture and storage (CCS/CCUS) technologies, renewable energy infrastructure, and carbon credit mechanisms. Such strategic direction ensures not only the continuity of green initiatives through proper resource allocation, but also strengthens the firm's positioning in response to tightening environmental regulations and increasing ESG performance expectations [5].

Leaders who champion ESG initiatives inspire organizational buy-in, encouraging employees to embrace sustainability values and align their efforts with broader corporate objectives. Businesses may increase their market position and stakeholder relationships by attracting socially conscious investors and consumers via management's commitment to ESG objectives [6].

Therefore, research on the development of ESG performance through green market orientation, management commitment, and aggressive low-carbon innovation in the energy sector is relevant.

2. Literature review and problem statement

Prior studies have demonstrated that both management commitment and green market orientation (GMO) are critical drivers of sustainability performance within corporations. GMO enhances a company's capability to innovate in environmentally friendly products and processes, which in turn strengthens overall business sustainability [7] while simultaneously reinforcing the company's positioning and reputation as a leader in the environmentally conscious market segment. This dual function of GMO promoting innovation and enhancing brand image – underscores its strategic importance in sustainability-focused business practices. Green market orientation (GMO) and management commitment (MC) have been identified as pivotal organizational capabilities in promoting sustainability. GMO facilitates environmentally driven innovation in both products and processes, leading not only to enhanced sustainability performance but also to improved corporate reputation in green markets. However, much of this literature centers around product development benefits, often lacking depth in discussing how GMO supports broader strategic sustainability goals. Meanwhile, MC is widely acknowledged for its role in enabling the effective execution of sustainability strategies across organizational functions. According to [8], managerial commitment is a key enabler of green supply chain integration and internal alignment toward sustainability targets. Moreover [9], emphasizes that MC not only provides strategic direction and resources for environmental initiatives but also plays a moderating role in strengthening the impact of green innovation on firm performance. These studies affirm the significance of MC and GMO independently, yet they often examine them in isolation.

Aggressive low carbon innovation (ALCI), as introduced by [10], has emerged as a relevant framework for firms to respond decisively to environmental pressures, including regulatory constraints and evolving market demands. ALCI entails bold, transformative innovations aimed at drastically reducing carbon footprints, enhancing competitiveness, and fulfilling ESG expectations. Despite this, few empirical studies have integrated ALCI into the broader organizational strategy framework involving GMO and MC.

The study of firm adaptation and innovation under dynamic market and environmental pressures has been widely informed by dynamic capability theory (DCT) [11]. DCT emphasizes an organization's ability to integrate, build, and reconfigure internal and external competencies to navigate rapidly changing conditions. This theoretical lens is particularly relevant for understanding how firms in high-impact sectors like energy develop strategic agility to meet escalating regulatory standards and stakeholder demands related to sustainability.

However, while DCT has been used extensively to explore organizational responses to market turbulence and technological change, its application in explaining how specific capabilities such as Green market orientation and management commitment interact through innovation mechanisms like aggressive low carbon innovation (ALCI) to influence ESG performance remains limited. This gap may be attributed to the relatively recent conceptualization of ALCI and the traditionally siloed analysis of green innovation, management behavior, and ESG outcomes. As a result, the dynamic interactions among these variables particularly in carbon-intensive industries have not been fully captured within the existing DCT-based frameworks. Addressing this unexplored aspect provides a more holistic understanding of how firms can operationalize their dynamic capabilities to achieve sustainability objectives.

In paper [12], it is shown that firms that build dynamic capabilities are more likely to achieve innovation success under uncertainty. However, while DCT explains *why* agility and innovation matter, it does not always explain *how* firms operationalize these capabilities, especially in achieving environmental objectives such as ESG performance.

Paper [13] expanded this framework by emphasizing knowledge creation and continuous learning as part of dynamic capabilities. They showed that firms that can "sense" changes and "seize" new opportunities through organizational knowledge perform better in dynamic markets. However, specific mechanisms linking dynamic capabilities to ESG outcomes in energy firms remain underexplored.

Paper [14] demonstrated that management commitment plays a central role in enabling ESG-related innovations by allocating resources and shaping corporate culture. Yet, unresolved issues persist in identifying how management commitment interacts with market forces and sustainability initiatives to yield measurable ESG improvements. This may be due to the objective complexity of coordinating multiple internal and external sustainability drives in large firms.

Paper [15] introduced the concept of green market orientation (GMO), showing that firms aligned with green consumer demands are more likely to innovate sustainably. However,

integrating GMO with management commitment into a comprehensive ESG strategy presents cost-related challenges, particularly in energy companies where capital-intensive investments are required for green innovation.

Paper [16] proposed that aggressive low carbon innovation (ALCI) could serve as a mechanism for translating sustainability orientation and leadership commitment into tangible ESG results. ALCI, which includes bold investments in carbon-reducing technologies like CCS/CCUS, appears to close the gap between sustainability vision and practice. However, there is a lack of empirical testing of this mediating role within high-emission sectors like energy, making generalization difficult.

Paper [16] highlighted the importance of innovation in bridging environmental performance and competitive advantage. Their findings support ALCI as a transformative force, but they did not focus on sectoral differences – particularly the structural rigidity of national energy corporations, which limits innovation agility.

Paper [17] emphasized the need for leadership vision and cross-functional integration in driving green innovation, showing that fragmented commitment results in suboptimal ESG outcomes. However, the study lacked integration with market-facing orientations like GMO, leaving unanswered questions about how both internal leadership and external market pressures can be synchronized.

A promising way to overcome these difficulties may be the development of a conceptual model that combines green market orientation and management commitment, with aggressive low carbon innovation as a mediating mechanism to improve ESG performance. A partial attempt to address this integration challenge is reflected in the work of [1], who proposed a dual-growth strategy framework within Asia's energy markets, incorporating both conventional and low-carbon initiatives. Their study provides valuable descriptive insights into how firms balance traditional operations with sustainability goals. However, the research falls short in offering empirical evidence, particularly in the Indonesian context, which presents distinctive challenges such as regulatory uncertainty, constrained innovation ecosystems, and varying resource capabilities. These contextual factors highlight the need for further empirical investigation using robust modeling techniques to validate the relationships among organizational commitment, green orientation, innovation mechanisms, and ESG outcomes.

A critical review of existing literature reveals that most prior studies have treated green market orientation and management commitment in isolation or have concentrated predominantly on the manufacturing sector. There is a notable lack of research exploring how these two factors interact to shape ESG performance – particularly through the lens of aggressive low carbon innovation (ALCI) – in energy sector firms, where carbon reduction is a pressing imperative. Furthermore, empirical insights into the mediating role of ALCI remain limited, leaving a substantial gap in understanding how internal organizational capabilities can be strategically aligned to improve ESG outcomes.

All of this suggests that it is advisable to conduct a focused study on how green market orientation and management commitment can jointly enhance ESG performance through aggressive low carbon innovation, especially in emerging market energy companies such as Pertamina. Such a study will provide both theoretical contributions to dynamic capability theory and practical guidance for firms navigating the dual pressures of economic performance and sustainability.

3. The aim and objectives of the study

The aim of this study is to identifying how organizational capabilities specifically green market orientation and management commitment interact with innovation mechanisms to shape environmental, social, and governance (ESG) performance, with a particular focus on the mediating role of aggressive low-carbon innovation (ALCI). This will enable firms, particularly in the energy sector, to consider targeted strategies for improving ESG performance by enhancing their green orientation and leadership commitment to sustainability.

To achieve this aim, the following objectives are accomplished:

– to determine organizational drivers of aggressive low-carbon innovation;

– to determine mediation effect of aggressive low-carbon innovation on ESG performance;

– to determine the direct impact of aggressive low-carbon innovation on ESG outcomes

4. Materials and methods

4. 1. Object and hypothesis of the study

The object of this study is the ESG performance when using aggressive low carbon innovation in emerging market energy companies.

The main hypothesis of the study posits that ALCI serves as a mediating variable through which GMO and MC influence ESG performance. It is expected that higher levels of green orientation and leadership commitment will lead to stronger adoption of ALCI, which subsequently enhances ESG outcomes.

This study makes several assumptions. It assumes that organizational leadership and orientation toward sustainability drive innovation behavior. It also assumes that ALCI effectively translates internal sustainability intent into measurable ESG impacts and that these relationships can be captured through quantitative modeling using SEM.

To manage complexity, several simplifications were adopted. The analysis focuses on internal variables only, without considering broader institutional or market-level influences. ALCI is treated as a single construct, and ESG performance is measured through managerial perceptions rather than objective ESG scores. Additionally, the study uses a cross-sectional rather than longitudinal approach.

4. 2. Research design

This study adopts a quantitative research approach with a correlational design, aimed at analyzing the structural relationships among multiple variables. The research utilized theoretical methods rooted in the dynamic capability theory, serving as the conceptual foundation for model development and hypothesis formulation.

To examine the hypothesized relationships and validate the proposed structural model, the study employed structural equation modeling (SEM) using the partial least squares (PLS) method. This approach was implemented via the SmartPLS 4.0 software, which is particularly suitable for exploratory research with complex models, especially when data normality cannot be assumed.

The research process involved several key methodological stages:

– instrument development: survey instruments were developed based on validated constructs from prior studies and subjected to expert review to ensure content validity;

– data collection: data were collected through a structured questionnaire administered to professionals in the Indonesian energy sector under standard conditions to maintain consistency and reliability;

– pre-analysis screening: prior to analysis, data underwent cleaning and normality checks to ensure quality and adequacy for SEM-PLS;

– measurement model evaluation: the validity and reliability of constructs were assessed through convergent validity, discriminant validity, and internal consistency checks, using indicators such as average variance extracted (AVE), composite reliability (CR), and Cronbach's Alpha;

– structural model testing: path coefficients, R^2 values, and predictive relevance (Q^2) were examined to evaluate the model's adequacy and predictive capacity.

The use of SEM-PLS in this study ensures robust model validation, even in the presence of non-normal data distributions or moderate sample sizes, offering a high degree of reliability and replicability for theoretical testing and model estimation.

The theoretical framework guiding this study is visualized in a structural model that depicts the hypothesized relationships among the variables. This framework illustrates the direct and indirect effects of green market orientation and management commitment on ESG performance, with aggressive low-carbon innovation acting as a mediating variable. The model also reflects the underlying logic based on dynamic capability theory and serves as the basis for the empirical analysis carried out in this study (Fig. 1).

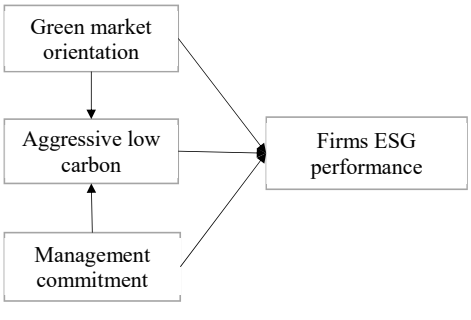

Fig. 1. Hypothesis framework

Green market orientation reflects a firm's strategic focus on environmental sustainability in its market activities, including product design, customer engagement, and operational practices. Businesses that include green market concepts are more likely to respond to growing stakeholder expectations for sustainable practices by aligning their operations with environmental, social, and governance (ESG) goals. This orientation enables firms to reduce environmental impact, build stronger relationships with eco-conscious customers, and improve their reputation, they all help to improve ESG performance. By prioritizing green initiatives in their market strategies, firms position themselves as responsible and forward-thinking, gaining competitive advantage and achieving sustainability objectives [18].

H1: Green market orientation positively influences a firm's ESG performance.

The commitment of top management to sustainability is critical in driving a firm's ESG performance. Management commitment ensures that ESG values are embedded in corporate strategy and daily operations, encouraging a culture of accountability and innovation. When leadership prioritizes ESG objectives, they allocate resources, set clear goals, and motivate employees to actively participate in sustainability efforts [19]. In addition to bringing the company into compliance with stakeholder expectations and regulatory requirements, this commitment from management builds credibility and confidence, which eventually improves the company's performance in terms of governance, social responsibility, and the environment [20].

H2: Management commitment positively influences a firm's ESG performance.

Green market orientation pushes businesses to invest in aggressive low carbon innovation in order to meet the increasing demand for eco-friendly goods and services [1]. This emphasis encourages businesses to investigate and use cutting-edge procedures and technologies that drastically lower carbon emissions, enabling them to satisfy consumer needs while tackling environmental issues. By aligning their market strategies with sustainability goals, firms can better allocate resources toward innovations that not only minimize their ecological footprint but also differentiate them from competitors. This approach fosters a proactive attitude towards tackling climate change through bold and impactful carbon reduction initiatives [21].

H3: Green market orientation positively influences aggressive low carbon innovation.

Strong management commitment to sustainability fosters a supportive environment for aggressive low carbon innovation. Leaders who prioritize reducing the company's carbon footprint set the tone for innovation by promoting a vision of environmental responsibility, encouraging research and development, and ensuring the necessary resources are available [15]. This leadership commitment motivates teams to focus on creative and impactful solutions for carbon reduction, leading to the development of groundbreaking technologies and practices. These developments allow businesses to aggressively address environmental issues while establishing themselves as leaders in the sector for sustainable practices [17].

H4: Management commitment positively influences aggressive low carbon innovation.

Aggressive low carbon innovation is a powerful driver of improved ESG performance, as it directly addresses critical environmental challenges while supporting social and governance goals [22]. By adopting bold and innovative carbon reduction strategies, firms can lower their environmental footprint, meet regulatory standards, and satisfy stakeholder expectations. Along with strengthening governance via open and accountable sustainability practices, these technologies also support societal advantages including advancing renewable energy and bettering public health. In the end, businesses that make significant investments in low-carbon innovation show that they are dedicated to ESG principles, which results in quantifiable gains in performance [23].

H5: Aggressive low carbon innovation positively influences a firm's ESG performance.

Green market orientation acts as a catalyst for aggressive low carbon innovation, which subsequently drives improvements in ESG performance. Firms that prioritize green market principles are more inclined to invest in innovative carbon reduction solutions to align with sustainability demands [24]. These advancements are the key that unlocks the potential for market orientation to enhance governance, society, and the environment. Firms may improve their sustainability performance by focusing on aggressive low carbon initiatives, which will help them bridge the gap between green market objectives and demonstrable ESG achievements [25].

H6: Aggressive low carbon innovation mediates the relationship between green market orientation and a firm's ESG performance.

Management commitment to sustainability fosters an environment conducive to Aggressive low carbon innovation, which then leads to enhanced ESG performance. Leaders who emphasize the importance of reducing carbon emissions drive innovation by setting clear goals, providing resources, and inspiring teams to develop impactful solutions [26]. These innovations serve as the link between managerial priorities and improvements in environmental, social, and governance outcomes. Through this mediating effect, management's dedication to sustainability is effectively translated into significant advancements in the firm's ESG performance, demonstrating the transformative potential of leadership-driven innovation [27].

H7: Aggressive low carbon innovation mediates the relationship between management commitment and a firm's ESG performance.

The cross-sectional data collection design ensures that data is gathered from respondents at a single point in time, capturing a snapshot of the variables under investigation. This approach facilitates the evaluation of relationships among variables without the need for longitudinal tracking. SEM-PLS is especially suited for exploratory research contexts and provides robust results even when traditional assumptions of normality and large sample sizes are not met. By integrating SEM-PLS with a structured questionnaire and purposive sampling, this study provides a comprehensive framework for understanding how independent variables such as green market orientation and management commitment influence aggressive low carbon innovation and firm's ESG performance. This methodological approach ensures both rigor and flexibility, allowing for detailed analysis of complex relationships within the data set.

4. 3. Population and sample

The population for this study includes companies in Indonesia's energy sector, particularly those actively implementing sustainability strategies and ESG (environmental, social, and governance) reporting. The sample consists of 100 top management respondents from Pertamina group. These individuals were selected through purposive sampling based on the following criteria:

– companies in the energy sector that have implemented sustainability initiatives for at least three years;

– companies that actively publish ESG reports or participate in low-carbon innovation programs;

– respondents occupying managerial or leadership roles related to green market, sustainability, or innovation.

This sample size is considered adequate for SEM-PLS analysis, ensuring robust results even with small sample sizes. Purposive sampling ensures that the selected respondents are relevant to the research objectives, improving the validity and reliability of the study's findings.

4. 4. Data analysis

The data analysis was conducted in two stages: descriptive analysis and SEM-PLS analysis:

1. Descriptive analysis.

Descriptive statistics were used to summarize the characteristics of the sample, including company type, size, and the length of time sustainability practices had been implemented. Response distributions for each variable were analyzed and presented in percentages to provide an overview of the data.

2. SEM-PLS analysis.

The SEM-PLS analysis was conducted in two stages: evaluation of the measurement model (outer model) and evaluation of the structural model (inner model):

a) outer model evaluation:

– Convergent validity: measured by assessing the outer loading values of indicators, with a threshold of >0.70;

– Discriminant validity: evaluated using the Fornell-Larcker criterion to ensure that constructs are distinct;

– Reliability: tested using composite reliability (CR > 0.70), average variance extracted (AVE > 0.50), and Cronbach's Alpha ($\alpha > 0.70$);

b) inner model evaluation:

– path coefficients and t-values: tested to assess the significance of relationships between variables;

– R^2 (coefficient of determination): indicates the proportion of variance in the dependent variable explained by the independent variables;

– mediation analysis: assesses the mediating role of aggressive low carbon innovation in the relationship between green market orientation, management commitment, and firm's ESG performance.

5. Results related to the Impact of green market orientation and management commitment on firm's environmental, social & governance performance mediated by aggressive low carbon innovation

5. 1. Determination of organizational drivers of aggressive low-carbon innovation

Table 1 presents the distribution of responses concerning the demographic characteristics of the respondents. The data include gender, age, education level, and length of service. These characteristics help provide context for interpreting the results of the study and understanding the composition of the sample.

Table 1

Respondent characteristics

Characteristic variable	Frequency (*n*)	Percentage (%)
Gender		
Male	85	85.00%
Female	15	15.00%
Age		
31–35 years	8	8.00%
36–40 years	26	26.00%
41–45 years	30	30.00%
46–50 years	20	20.00%
> 50 years	16	16.00%
Educational level		
Bachelor's degree	24	24.00%
Master's degree	65	65.00%
Doctoral's degree	11	11.00%
Length of time worked		
0–5 years	2	2.00%
6–10 years	4	4.00%
11–15 years	40	40.00%
16–20 years	19	19.00%
21–25 years	22	22.00%
26–30 years	8	8.00%
> 30 Years	5	5.00%

From the data presented in Table 1, it is evident that the majority of respondents were male (85%), indicating a potential gender imbalance in the respondent pool. The age group 41–45 years represents the largest portion of participants (30%), suggesting that most respondents are in their mid-career phase. In terms of educational attainment, a significant number hold a Master's degree (65%), which may reflect the professional qualifications required in their roles. Regarding length of service, most respondents (40%) have worked for 11–15 years, indicating a substantial level of work experience among participants. This demographic profile is critical for understanding how professional maturity and educational background might influence perceptions of ESG performance and related constructs.

5. 2. Outer model of organizational drivers of aggressive low-carbon innovation

5. 2. 1. Convergent validity

To evaluate the measurement model, it is essential to assess the extent to which indicators in the reflective model are significantly associated with their respective latent constructs. This is typically examined through factor loadings, where values greater than 0.70 indicate acceptable convergent validity. Indicators that meet or exceed this threshold are considered to provide a reliable representation of the underlying construct [28]. The outer model analysis for this study is presented in Fig. 2.

All indicators have reasonably high values, which shows that the measuring model is strong and reliable, supporting the validity of the relationships being assessed. All items meet the required threshold for indicator reliability, as their factor loadings exceed the recommended criterion of 0.7. As a result, the indicators are guaranteed to accurately reflect the underlying components. Additionally, the discriminant validity is confirmed by the high loadings across the model, which guarantee that each construct is unique and does not overlap with other constructs. This strengthens the measuring model's legitimacy and confirms the stability of the links this investigation is looking at.

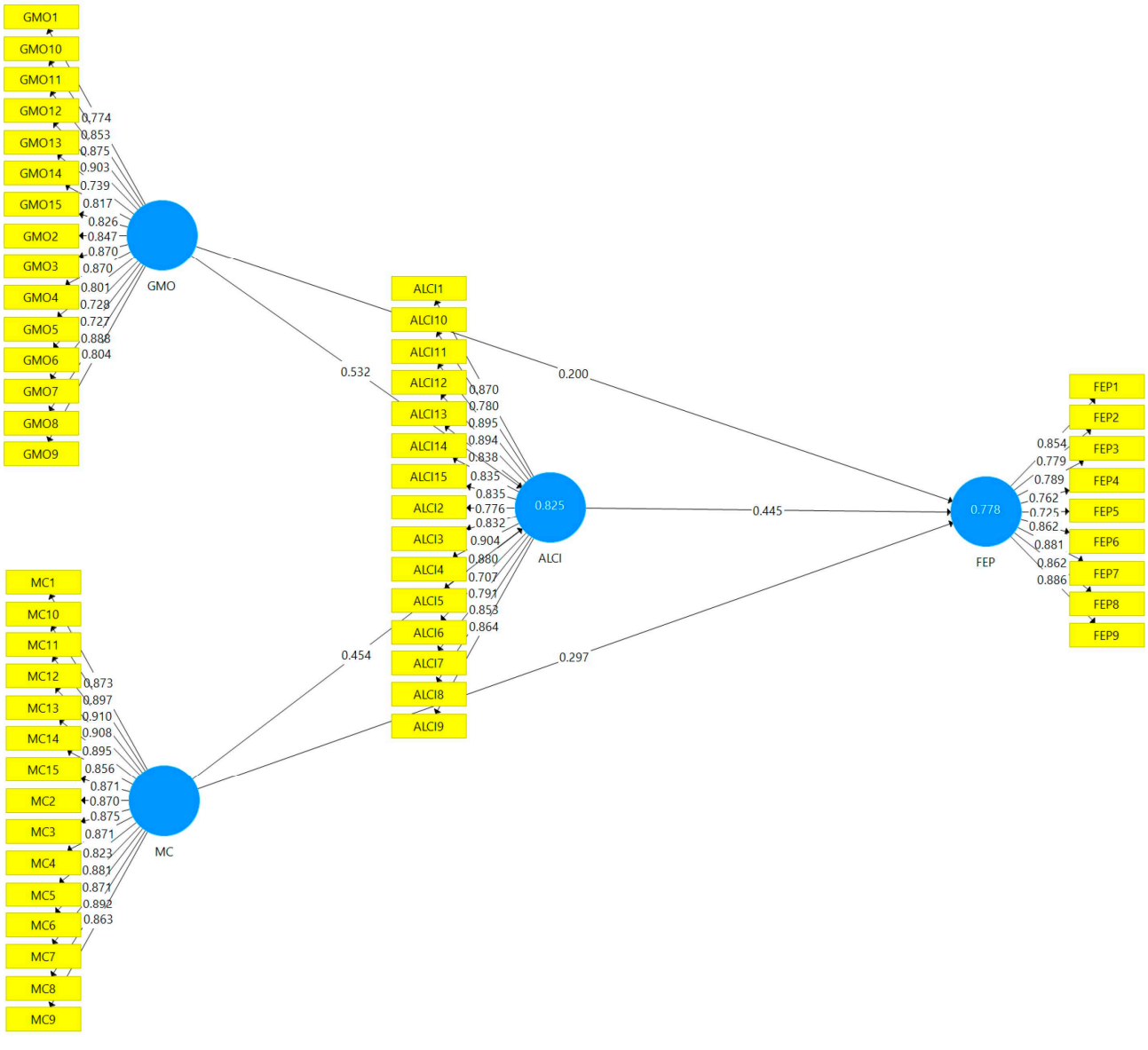

Fig. 2. Outer model

5. 2. 2. Reliability

To evaluate the reliability of the measurement model, internal consistency was assessed using composite reliability (CR) and Cronbach's Alpha (CA). Both values must exceed the threshold of 0.7 to indicate acceptable reliability. The detailed reliability values for each construct are presented in Table 2.

Table 2

Reliability

Variables	Cronbach's Alpha	rho_A	Composite reliability	Average variance extracted (AVE)
ALCI	0.970	0.971	0.973	0.703
FEP	0.940	0.942	0.950	0.679
GMO	0.966	0.968	0.969	0.678
MC	0.979	0.979	0.980	0.770

The findings of the reliability study show that every construct in the model satisfies the predetermined reliability standards, exhibiting strong internal consistency and validity. A valid and reliable tool, aggressive low carbon innovation (ALCI) has a Cronbach's alpha of 0.970, a rho_A of 0.971, and a composite reliability of 0.973. The minimum requirements for reliability and validity in a test, as laid forth by [28], are an AVE of more than 0.5 and Cronbach's alpha of more than 0.7. Due to the fact that all values are higher than these limits, the ALCI construct is very consistent and reliable. The dependability of the firm's ESG performance (FEP) is really high, with values such as 0.940 for Cronbach's alpha, 0.942 for rho A, 0.950 for composite reliability, and 0.679 for AVE. These values confirm that the construct is both reliable and valid, meeting all the recommended standards for reliability analysis.

For Green Market Orientation (GMO), the Cronbach's alpha is 0.966, rho_A is 0.968, composite reliability is 0.969, and AVE is 0.678. All these values exceed the recommended thresholds, indicating that GMO is a reliable and robust construct in the measurement model. Management commitment (MC) exhibits the highest reliability scores among the constructs. The reliability composite, alpha, AVE, Cronbach's alpha, and rho_A scores are 0.980, 0.770, 0.979, and 0.979, respectively. These numbers, which are far higher than the acknowledged norms, further substantiate the concept's dependability and validity. The four components – aggressive low carbon innovation, firm's ESG performance, green market orientation, and management commitment – demonstrate exceptional reliability and meet all criteria, with composite reliability (> 0.7), Cronbach's alpha (> 0.7), and AVE (> 0.5) all exceeding expectations. The findings show that the measuring model is reliable and strong.

5. 3. Inner model of organizational drivers of aggressive low-carbon innovation

5. 3. 1. Direct effect

To examine the relationships between constructs, direct effect analysis was conducted using the path coefficients from the SEM-PLS model. These coefficients indicate the strength and direction of influence between independent, mediating, and dependent variables. The statistical significance was assessed using bootstrapping procedures. The detailed results of the direct effects are presented in Table 3.

As a result of aggressive low carbon innovation, the firm's FEP (ALCI) is affected. According to the p-value of 0.027, t-statistic of 2.224, and path coefficient value of 0.445, there is a statistically significant association ($p < 0.05$) between aggressive low carbon innovation and the ESG performance of Firms. This implies that aggressive low carbon innovation is credited by the model with having a favorable and statistically significant impact on the company's ESG performance.

Table 3

Direct effect

Hypothesis	Original sample (O)	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	P values
ALCI → FEP	0.445	0.200	2.224	0.027
GMO → ALCI	0.532	0.089	5.957	0.000
GMO → FEP	0.200	0.146	1.368	0.172
MC → ALCI	0.454	0.099	4.582	0.000
MC → FEP	0.297	0.117	2.538	0.011

Instead of GMO, aggressive low-carbon innovation is taking over. Based on the t-statistic of 5.957, p-value of 0.000, and path coefficient value of 0.532, there is a statistically significant association ($p < 0.05$) between GMO and ALCI. Thus, the results show that the hypothesis is correct; aggressive low carbon innovation is positively and significantly affected by green market orientation.

Company sustainability performance is affected by GMO. With a t-statistic of 1.368, p-value of 0.172, and path coefficient of 0.200, the correlation between a company's green market orientation and its environmental, social, and governance (ESG) performance is not notable ($p > 0.05$). Neither a company's Green Market Orientation nor its ESG performance seem to be strongly associated.

This study examines the connection between MC and ALCI. The presence of a statistically significant correlation ($p < 0.05$) between ALCI and management commitment is supported by the path coefficient value of 0.454, t-statistic of 4.582, and p-value of 0.000. Managerial dedication has a positive and substantial effect on aggressive low carbon innovation, lending credence to the theory.

Company ESG performance is influenced by management engagement. The study found a statistically significant association between management commitment and firm's ESG performance ($p < 0.05$), with a path coefficient value of 0.297, t-statistic of 2.538, and p-value of 0.011. Company ESG performance is positively and significantly affected by management's dedication.

5. 3. 2. Indirect effect

To further explore the mediating role of aggressive low-carbon innovation (ALCI) between green market orientation (GMO), management commitment (MC), and ESG performance, an indirect effect analysis was performed. This analysis helps to determine whether ALCI significantly channels the influence of GMO and MC on ESG outcomes. The detailed results of the indirect effects are presented in Table 4.

Relation between organization's ESG performance from aggressive low carbon innovation (ALCI) with a GMO shows a strong correlation (path coefficient = 0.236, t-statistic = 1.993, $p = 0.047$). Through ALCI, GMO appear to have a substantial and positive indirect effect on firm ESG performance. Based on these results, low-carbon innovation is a key strategy for enhancing corporate ESG performance, and ALCI is a significant mediator in the connection between GMO and FEP.

Table 4

Indirect effect

Hypothesis	Original sample (O)	Standard deviation (STDEV)	T Statistics (|O/STDEV|)	P values
GMO → ALCI → FEP	0.236	0.119	1.993	0.047
MC → ALCI → FEP	0.202	0.099	2.035	0.042

Through ALCI, MC indirectly affects the firm's ESG performance (FEP). Through ALCI, MC and FEP have a significant mediation route (path coefficient = 0.202, t-statistic = 2.035, $p = 0.042$). These findings provide further evidence that MC influences FEP indirectly via ALCI in a favorable and statistically significant way. This discovery highlights the importance of ALCI as a critical mechanism by which MC improves FEP, emphasizing the importance of management's commitment to fostering low-carbon innovation for achieving better ESG performance.

6. Discussion of results related to the impact of green market orientation and management commitment on firm's environmental, social & governance performance mediated by aggressive low carbon innovation

The empirical findings of this study provide a comprehensive explanation of how organizational strategic capabilities namely green market orientation (GMO) and management commitment (MC) influence environmental, social, and governance (ESG) performance through the mediating role of aggressive low-carbon innovation (ALCI). The relationships observed in Tables 3 and 4, along with the structural path visualization in Fig. 2, confirm the study's theoretical expectations and contribute to a more nuanced understanding of sustainability strategy in the energy sector.

First, the results in Table 3 show that GMO ($\beta = 0.532$, $p < 0.001$) and MC ($\beta = 0.454$, $p < 0.001$) both significantly predict the adoption of ALCI. These findings indicate that firms with strong market-driven environmental orientation and committed leadership are more inclined to pursue aggressive low-carbon strategies. This can be explained by the fact that GMO fosters proactive engagement with environmental trends, while MC ensures internal alignment and resource allocation. The strength of these relationships reflects the dynamic capabilities that allow firms to integrate external orientation with internal execution, as suggested by dynamic capability theory.

Second, the mediation effects presented in Table 4 show that both GMO and MC indirectly influence ESG performance through ALCI (GMO → ALCI → FEP: $\beta = 0.236$, $p = 0.047$; MC → ALCI → FEP: $\beta = 0.202$, $p = 0.042$). Although the direct effect of GMO on ESG is statistically insignificant ($\beta = 0.200$, $p = 0.172$), its indirect effect becomes significant when mediated by ALCI. In contrast, MC shows both direct ($\beta = 0.297$, $p = 0.011$) and indirect effects. These results highlight the critical bridging function of ALCI in transforming soft strategic factors into measurable ESG performance. This pattern fills the conceptual gap, where previous studies failed to integrate the three elements GMO, MC, and ESG through a dynamic innovation mechanism. The mediation effect confirms that innovation must not be viewed as a passive outcome but as an active enabler of sustainability.

Third, the results in Table 3 demonstrate a direct and significant effect of ALCI on ESG performance ($\beta = 0.445$, $p = 0.027$). This supports the assertion that innovation is not just an intermediate mechanism but also an independent contributor to ESG outcomes. Compared to prior studies that treated green innovation as a dependent or control variable [29, 30] the model presented positions ALCI as both a dependent (from GMO and MC) and independent (toward ESG) construct. Unlike [29], where innovation was linked generally to operational efficiency, this study validates a specific pathway aggressive low-carbon innovation thereby refining the model's predictive clarity and its application in high-carbon industries.

The methodological strength of this study lies in its comprehensive measurement model (Table 2) and the quality of respondent data (Table 1), which collectively enhance the reliability of the results. Respondents had significant experience and academic qualifications, increasing the credibility of the perceptions captured.

In contrast to previous studies that separated orientation and innovation into discrete or linear relationships, this research contributes by offering an integrated, empirically validated framework where strategic orientation, innovation mechanism, and performance outcomes form a cohesive structure. For example, unlike [31], which treated managerial commitment only as an antecedent of innovation, this study demonstrates MC's dual pathway direct and indirect toward ESG, offering a more realistic depiction of how leadership shapes sustainability results.

These results partially close the theoretical gap, especially regarding the lack of empirical models connecting GMO and MC to ESG through innovation in energy firms. The model presented confirms that ESG performance is best explained when organizational intent (GMO, MC) is mediated through targeted innovation efforts. This fills a niche in sustainability literature by linking internal strategic capacities with external performance indicators through a validated mechanism (ALCI), especially relevant for firms facing environmental regulation and carbon transition mandates.

However, the study is not without limitations. First, the cross-sectional design restricts causal interpretation; longitudinal data could capture the evolution of ESG improvements more accurately. Second, the measurement of ESG relies on perceptual data rather than third-party ESG ratings, which may introduce bias. Third, the generalizability of the results may be constrained by the specific industry context – the energy sector – where low-carbon innovation is more directly tied to ESG metrics. In less carbon-intensive industries, the relationship between the studied variables might differ. Besides this, cross-sectional data limits the ability to infer causality over time; future longitudinal studies are needed to validate the robustness and stability of these relationships across economic cycles and policy shifts. It is also important the measurement of ESG performance, though comprehensive, may still lack nuance across environmental, social, and governance subdimensions. Refinement in measurement or more granular ESG data could enhance the model's explanatory power [32].

The practical application the results of this study must consider institutional readiness, regulatory frameworks, and industry-specific constraints. ALCI may not be uniformly applicable across all contexts, particularly in firms lacking innovation infrastructure or where leadership is not aligned with ESG goals. Thus, scalability requires cautious adaptation.

In addition to limitations, several disadvantages should be noted. The study assumes managerial intentions are aligned with execution, which might not always hold true in practice. Strategic signaling without implementation – so-called "greenwashing" – could distort the relationships found

here. Moreover, the reliance on self-reported survey data raises the risk of social desirability bias, which may inflate the perceived commitment to sustainability or innovation.

Looking ahead, this research opens several promising avenues. A potential development is to expand the model to include regulatory and institutional factors as moderating variables. These could shed light on how external environments shape the innovation – ESG link [33]. From a methodological standpoint, combining qualitative case studies with quantitative SEM analysis may yield richer insights into the mechanisms underlying ALCI adoption. Another worthwhile direction is exploring technological infrastructure as both a predictor and enabler of low-carbon innovation, especially in digitally transforming firms.

Future research could explore this model in multi-sector contexts or incorporate external variables such as policy support, investor pressure, or digital innovation. Furthermore, expanding the model to longitudinal settings or integrating sustainability reporting metrics from ESG rating agencies would strengthen validation and applicability. The dual role of ALCI could also be tested in reverse causality frameworks to better understand feedback loops in innovation and performance.

7. Conclusions

1. The results demonstrate that both green market orientation (GMO) and management commitment (MC) significantly influence the adoption of aggressive low-carbon innovation (ALCI). GMO exhibits a strong positive effect on ALCI ($O = 0.532$, $t = 5.957$, $p < 0.001$), indicating that firms that proactively respond to environmental market demands are more likely to implement aggressive carbon-reduction strategies. Likewise, MC has a substantial impact on ALCI ($O = 0.454$, $t = 4.582$, $p < 0.001$), reinforcing the role of leadership commitment in directing innovation efforts toward sustainability. These findings extend beyond conventional views of innovation as a purely technological function by highlighting the importance of strategic orientation and organizational culture as key enablers of low-carbon innovation.

2. The mediation analysis reveals that ALCI significantly mediates the relationship between both GMO and MC with ESG performance. While the direct impact of GMO on ESG outcomes is not significant ($O = 0.200$, $t = 1.368$, $p = 0.172$), the indirect pathway via ALCI is statistically significant ($O = 0.236$, $t = 1.993$, $p = 0.047$), suggesting that green market orientation must be complemented by innovation mechanisms to produce measurable sustainability improvements. In contrast, MC has both a significant direct ($O = 0.297$, $t = 2.538$, $p = 0.011$) and indirect effect through ALCI ($O = 0.202$, $t = 2.035$, $p = 0.042$) on ESG performance, positioning it as a more comprehensive driver of sustainability outcomes. These results emphasize the dual influence of MC and the need for organizations to institutionalize innovation-led ESG strategies under strong leadership direction.

3. Aggressive low-carbon innovation shows a significant direct effect on ESG performance ($O = 0.445$, $t = 2.224$, $p = 0.027$), underscoring its strategic importance as a key performance enabler. This finding confirms that firms integrating bold, innovation-driven carbon reduction into their corporate strategies are more likely to achieve higher ESG outcomes. It highlights that ALCI is not only an intermediary but also an independent driver of performance, making it a central component for companies aiming to lead in sustainability transformation – particularly in high-emission sectors such as energy.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, whether financial, personal, authorship or otherwise, that could affect the study, and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

Data will be made available on reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Yenita, Widodo, L. (2023). Environmental, social and governance (ESG) strategy implementation plan during the Covid-19 pandemic at retail company "X" in Jakarta. AIP Conference Proceedings, 2485 (1), 080025. https://doi.org/10.1063/5.0105059
2. Mila, G., Primasari, B., Aziz, R. (2021). Application of Life Cycle Assessment (LCA) On Green Tea Product (Case Study in the X Company). IOP Conference Series: Materials Science and Engineering, 1041 (1), 012025. https://doi.org/10.1088/1757-899x/1041/1/012025
3. Yusmar, Q. C. M. M., Sumirat, E., Sudrajad, O. Y. (2023). Company Fair Valuation Considering Esg Factor (Case Study: Pt Pertamina Geothermal Energy, Tbk). European Journal of Business and Management Research, 8 (5), 95–101. https://doi.org/10.24018/ejbmr.2023.8.5.2086
4. Wang, C. H. (2020). An environmental perspective extends market orientation: Green innovation sustainability. Business Strategy and the Environment, 29 (8), 3123–3134. https://doi.org/10.1002/bse.2561
5. Sharma, P., Singh, S. P., Iqbal, H. M. N., Parra-Saldivar, R., Varjani, S., Tong, Y. W. (2022). Genetic modifications associated with sustainability aspects for sustainable developments. Bioengineered, 13 (4), 9509–9521. https://doi.org/10.1080/21655979.2022.2061146
6. Niu, S., Park, B. I., Jung, J. S. (2022). The Effects of Digital Leadership and ESG Management on Organizational Innovation and Sustainability. Sustainability, 14 (23), 15639. https://doi.org/10.3390/su142315639
7. Andreassen, Å., Brandtzæg, P., Aasmo Finne, M., Lorentz Holck, A., Jevnaker, A.-M., Junttila, O. et al. (2020). Final Health and Environmental Risk Assessment of Genetically Modified Maize 59122. European Journal of Nutrition & Food Safety, 242–245. https://doi.org/10.9734/ejnfs/2019/v11i430169
8. Andreassen, Å., Brandtzæg, P., Aasmo Finne, M., Lorentz Holck, A., Jevnaker, A.-M., Junttila, O. et al. (2020). Environmental Risk Assessment of Insect-resistant and Herbicide-tolerant Genetically Modified Maize 1507 x 59122 for Food and Feed Uses, Import and

Processing under Regulation (EC) No 1829/2003 (EFSA/GMO/NL/2005/15). European Journal of Nutrition & Food Safety, 221–224. https://doi.org/10.9734/ejnfs/2019/v11i430164

9. Andreassen, Å., Brandtzæg, P., Finne, M. A., Holck, A. L., Jevnaker, A.-M. G., Junttila, O. et al. (2020). Food/Feed and Environmental Risk Assessment of Insect-Resistant and Herbicide-Tolerant Genetically Modified Maize Bt11 from Syngenta Seeds for Food and Feed Uses, Import and Processing under Regulation (EC) No 1829/2003 (EFSA/GMO/RX/Bt11). European Journal of Nutrition & Food Safety, 35–38. https://doi.org/10.9734/ejnfs/2020/v12i330206
10. Jeong, W., Gaggioli, C. A., Gagliardi, L. (2021). Active Learning Configuration Interaction for Excited-State Calculations of Polycyclic Aromatic Hydrocarbons. Journal of Chemical Theory and Computation, 17 (12), 7518–7530. https://doi.org/10.1021/acs.jctc.1c00769
11. Kumar, M., Tsolakis, N., Agarwal, A., Srai, J. S. (2020). Developing distributed manufacturing strategies from the perspective of a product-process matrix. International Journal of Production Economics, 219, 1–17. https://doi.org/10.1016/j.ijpe.2019.05.005
12. Goaill, M. M., Al-Hakimi, M., A. (2021). Does absorptive capacity moderate the relationship between entrepreneurial orientation and supply chain resilience? Cogent Business & Management, 8 (1). https://doi.org/10.1080/23311975.2021.1962487
13. Barko, T., Cremers, M., Renneboog, L. (2022). Shareholder Engagement on Environmental, Social, and Governance Performance. Journal of Business Ethics, 180 (2), 777–812. https://doi.org/10.1007/s10551-021-04850-z
14. Fuadah, L. L., Mukhtaruddin, M., Andriana, I., Arisman, A. (2022). The Ownership Structure, and the Environmental, Social, and Governance (ESG) Disclosure, Firm Value and Firm Performance: The Audit Committee as Moderating Variable. Economies, 10 (12), 314. https://doi.org/10.3390/economies10120314
15. Du, Y., Wang, H. (2022). Green Innovation Sustainability: How Green Market Orientation and Absorptive Capacity Matter? Sustainability, 14 (13), 8192. https://doi.org/10.3390/su14138192
16. Paluseri, A. H., Kaihatu, T. S., Christian, T. F. (2025). Aggressive low carbon innovation (ALCI): A conceptual framework for sustainable business competitiveness. Jurnal Indonesia Sosial Teknologi, 6 (2), 952–964.
17. Tjahjadi, B., Soewarno, N., Hariyati, H., Nafidah, L. N., Kustiningsih, N., Nadyaningrum, V. (2020). The Role of Green Innovation between Green Market Orientation and Business Performance: Its Implication for Open Innovation. Journal of Open Innovation: Technology, Market, and Complexity, 6 (4), 173. https://doi.org/10.3390/joitmc6040173
18. He, R., Chen, X., Chen, C., Zhai, J., Cui, L. (2021). Environmental, Social, and Governance Incidents and Bank Loan Contracts. Sustainability, 13 (4), 1885. https://doi.org/10.3390/su13041885
19. Senadheera, S. S., Gregory, R., Rinklebe, J., Farrukh, M., Rhee, J. H., Ok, Y. S. (2022). The development of research on environmental, social, and governance (ESG): A bibliometric analysis. Sustainable Environment, 8 (1). https://doi.org/10.1080/27658511.2022.2125869
20. Bernardi, C., Stark, A. W. (2018). Environmental, social and governance disclosure, integrated reporting, and the accuracy of analyst forecasts. The British Accounting Review, 50 (1), 16–31. https://doi.org/10.1016/j.bar.2016.10.001
21. Mavlutova, I., Fomins, A., Spilbergs, A., Atstaja, D., Brizga, J. (2022). Opportunities to Increase Financial Well-Being by Investing in Environmental, Social and Governance with Respect to Improving Financial Literacy under COVID-19: The Case of Latvia. Sustainability, 14 (1), 339. https://doi.org/10.3390/su14010339
22. Venkataramanan, V. S., Shahrukh, M., Papageorgiou, D. J., Rajagopalan, S., Srinivasan, R. (2024). Identifying Key Drivers for a National Transition to Low Carbon Energy using Agent-based Supply Chain Models. Computers & Chemical Engineering, 182, 108541. https://doi.org/10.1016/j.compchemeng.2023.108541
23. Lu, J., Li, H. (2024). The impact of ESG ratings on low carbon investment: Evidence from renewable energy companies. Renewable Energy, 223, 119984. https://doi.org/10.1016/j.renene.2024.119984
24. Bakenne, A., Nuttall, W., Kazantzis, N. (2016). Sankey-Diagram-based insights into the hydrogen economy of today. International Journal of Hydrogen Energy, 41 (19), 7744–7753. https://doi.org/10.1016/j.ijhydene.2015.12.216
25. Matsuhashi, R., Takase, K. (2015). Green Innovation and Green Growth for Realizing an Affluent Low-Carbon Society. Low Carbon Economy, 6 (4), 87–95. https://doi.org/10.4236/lce.2015.64010
26. Sovacool, B. K., Griffiths, S. (2020). The cultural barriers to a low-carbon future: A review of six mobility and energy transitions across 28 countries. Renewable and Sustainable Energy Reviews, 119, 109569. https://doi.org/10.1016/j.rser.2019.109569
27. Llamas-Orozco, J. A., Meng, F., Walker, G. S., Abdul-Manan, A. F. N., MacLean, H. L., Posen, I. D. et al. (2023). Estimating the environmental impacts of global lithium-ion battery supply chain: A temporal, geographical, and technological perspective. PNAS Nexus, 2 (11). https://doi.org/10.1093/pnasnexus/pgad361
28. Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M. (2017). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). SAGE Publications.
29. Nalule, V. R., Anaman, P., Acheampong, T.; Acheampong, T., Kojo Stephens, T. (Eds.) (2022). Energy Transition and Africa's Oil and Gas Resources: Challenges and Opportunities. Petroleum Resource Management in Africa. Cham: Palgrave Macmillan, 523–572. https://doi.org/10.1007/978-3-030-83051-9_16
30. Gautam, M., Lele, U., Kartodihardjo, H., Khan, A., Erwinsyah, Ir., Rana, S. (2000). Indonesia: The challenges of World Bank involvement in forests. Washington: World Bank Group. https://doi.org/10.1596/0-8213-4763-2
31. Sun, L., Saat, N. A. M. (2023). How Does Intelligent Manufacturing Affect the ESG Performance of Manufacturing Firms? Evidence from China. Sustainability, 15 (4), 2898. https://doi.org/10.3390/su15042898
32. Tsang, A., Frost, T., Cao, H. (2023). Environmental, Social, and Governance (ESG) disclosure: A literature review. The British Accounting Review, 55 (1), 101149. https://doi.org/10.1016/j.bar.2022.101149
33. Rajesh, R. (2020). Exploring the sustainability performances of firms using environmental, social, and governance scores. Journal of Cleaner Production, 247, 119600. https://doi.org/10.1016/j.jclepro.2019.119600