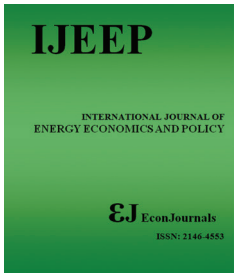

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Innovation under the Unique Pressures of Energy Transition: Can CSR Strategy Buffer ESG Controversies in EU Firms

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ABSTRACT

This study addresses issues related to Environmental, Social, and Governance (ESG) activities in the energy industry—namely, carbon emissions disputes, nuclear safety concerns, divestments in fossil fuels and bottlenecks in renewable transition—that affect carbon emissions disputes, nuclear safety concerns, divestments in fossil fuels and bottlenecks in renewable transition on firms' environmental innovation performance. It also investigates whether CSR strategy attenuates these effects, with a focus on industry-specific innovations such as carbon capture, smart grids, and renewables technologies. The study utilizes an unbalanced panel of 233 firm-year observations for European Union energy firms over the period 2015-2023, and uses fixed effects (FE), high-dimensional fixed effects (HDFE), as well as system GMM estimations to control for heterogeneity and endogeneity. The finding revealed that ESG controversies significantly curb environmental innovation at energy firms due to reputational harm, regulatory pressures, and reallocation of resources. Governance attributes, including board size, gender diversity, and leverage, encourage innovation, while the impact of audit committee independence and expertise is mixed. The CSR strategy does not have a significant impact on the controversy–innovation relationship, suggesting that the CSR endeavor alone is not sufficient to safeguard the ability to innovate in the energy industry. The results illustrate that ESG is a bottleneck for carbon neutrality and energy transition. Policymakers and business leaders need to embed ESG risk management in innovation strategies. This research contributes to insights into energy-ESG risks and their link to technology development necessary to achieve a sustainable transition.

Keywords: Environmental Innovation, ESG Controversies, CSR Strategy, Corporate Governance, EU Energy
JEL Classifications: G32, O32, M14

1. INTRODUCTION

The European energy industry operates in an increasingly disrupted landscape, primarily due to Environmental, Social, and Governance (ESG) imperatives. Unlike any other sector, energy companies face a dual challenge: They are not only the largest contributors to carbon emissions but also the primary drivers of low-carbon breakthroughs (Al-Awamleh et al., 2025). This paradox comes with increased scrutiny from regulators, investors and communities, and exposes the sector to heightened reputational and operational risk. The industry's shadow darkened in recent years following a few high-visibility scandals - oil spills, pipeline leaks, nuclear incidents and carbon emissions rigging-and community pushback on mega renewables have forced the sector

to come into the limelight of the ESG discussion (Zatonatska et al., 2024; Aladwan et al., 2023; Xinyu et al., 2025; Makridou et al. 2024; Kanaan et al., 2023).

This study is firmly grounded in the European energy context, as it seeks to understand how sector-specific ESG controversies (i.e., nuclear safety breaches, local opposition to renewable siting, delayed carbon capture projects and fossil fuel divestment pressures) directly frustrate sectoral innovations such as smart grids, offshore wind technology and hydrogen infrastructure. Unlike research in manufacturing or finance, however, we consider innovation pathways that are capital intensive, regulatorily complex and socially contested features of the energy transition.

This has been made more difficult by the regulatory backdrop. The ambitious decarbonization targets of the European Green Deal, the Energy Taxation Directive, and the EU Emissions Trading Scheme mean businesses must reduce their emissions while maintaining standards of transparency, morality in leadership, and provable innovation. However, as energy projects are capital- and long-cycle intensive, it is difficult to allocate resources in R&D on account of the ESG pressures entailing a threat to both transition timelines and technology leadership (Śmiech et al., 2025; Heubeck and Ahrens, 2024; Elmassri et al., 2023; Aljawarneh et al., 2025).

Corporate Social Responsibility (CSR) tactics, accordingly, have become a basic vehicle to support sectoral legitimacy (Abusharbeh et al., 2025; Aladwan et al., 2025; AlQudah et al., 2024). Such practices as community cooperation, introduction of renewable energy and reinforcement of responsibility function as not only a "license to operate" but also are responsible for elements determining symbolic compliance. Nevertheless, there are still gaps: for example, when comparing the environmental disclosures of Polish energy companies applying the GRI framework with EU requirements criterion ERS (European Environmental Reporting Standard) then it is manifested that local and CSR-driven standards are more that compliant itself (Almnadheh et al., 2025; Matuszak et al., 2025; Zrnic and Pekanov, 2023; Mohammad Aljawarneh et al., 2025).

Notwithstanding the acknowledged relevance of ESG controversies, there is an empirical gap on how controversial issues can affect firm resilience in the context of energy. Previous research, which has concentrated primarily on financial implications of such engagement with CSR performance (AlQudah et al., 2025; Dziri and Jarboui, 2024; Samara et al., 2025), has given comparatively little attention to determining if this cooperation can reduce the reputation and operational loss that ESG publicity may generate (Marsat et al., 2022; Mendiratta et al., 2023; Al Astal et al., 2025). Based on the stakeholder and institutional perspectives of legitimacy theory (Magness, 2006; Snider et al., 2003; Abu Huson et al., 2025), we investigate how CSR strategy can promote trust building, innovation-based R&D process and mitigated reputational risks in a heavily regulated industry characterized by carbon intensity (Sun et al., 2024; Li et al., 2021).

From this perspective, the European energy industry represents a potential setting to explore the ESG–CSR–innovation link. Companies must consider sustainability, energy security and geopolitical issues, dealing with public concerns and laws requiring prudence in innovation (Al-Awamleh et al., 2025; Alslaibi and Abdelkarim, 2024; Aljawarneh et al., 2023). This paper thus has three contributions. First, it adds to our empirical knowledge toward legitimating the role of CSR as a mediating construct in ESG criticism–innovation link. Second, this research contributes to innovation management and ethical governance literature by investigating a highly regulated and high impact industry. Third, it offers useful indications for managers as well as for policy makers interested in incorporating CSR into the risk management process and sustainability long-term strategies (Hlioui and Yousfi, 2020; Cabaleiro-Cerviño and Mendi, 2024; Alshare et al., 2020).

The remainder of the paper is organized as follows: Section 2 presents the literature review and develops hypotheses. The methodology and data sources are presented in Section 3. The empirical analysis is presented in Section 4. Theoretical, managerial and policy implications are discussed in Section 5. Summary and recommendations for further research are presented in Section 6.

2. THEORETICAL FRAMEWORK AND HYPOTHESIS FORMULATION

2.1. ESG Controversies and Innovation Performance

ESG controversies are a huge corporate risk to reputation and solvency, especially in high-impact industries such as energy. The energy companies have a double challenge: They are among the major emitters of carbon, and, at the same time, they are expected to take the lead in an energy transition toward renewable and low-carbon technology. Such paradoxes are frequently invoked in the energy economics literature, and this is no different: a structural paradox of the energy transitions is that the very companies who master (and monopolize) supply chains for coalfired or hydrocarbon-based power must pioneer technologies for decarbonization (IEA 2023; Sovacool 2021). This conundrum increases exposure to brand and operating risk. Oil spills, pipeline breaches, nuclear belt safety concerns, emissions fraud, and community displacement for renewables all create moral and environmental dissonance which erodes trust and leads to sub-optimal deployment of capital (Aouadi and Marsat, 2018; DasGupta, 2022).

The capital-intensive nature and lengthy investment horizons of an energy project compound these risks: changes in the regional or global energy landscape associated with, for example, energy crises or regulatory changes could disrupt flows of innovation and compel a reallocation of resources away from R&D (Xu et al., 2021; Long et al., 2023). Firms that under perform on sustainability expectations stand to lose the confidence of investors, face potential divestment campaigns and become unsupported by regulation, thereby undermining their societal legitimacy (Waheed et al., 2024). Public reluctance (such as resistance to wind farms or nuclear waste disposal) adds an additional limitation for the adoption of innovative practices. Based on institutional theory,

firms in over-regulated areas like the EU should pay attention to the social norms to maintain their legitimacy (Duong and Huang, 2025). Therefore, it is resource loss of resources that are scarce, valuable and inimitable such as dedicated R&D teams, social licenses to operate and technological capabilities for low-carbon technology innovation (Elamer and Boulhaga, 2024; Li and Li, 2024).

Empirical evidence supports this view. Mendiratta et al. (2023) report that innovation performance is reduced in high-risk industries involved in ESG controversies. Likewise, Elamer and Boulhaga (2024) posit that innovation investment is reduced under ESG controversy if governance does not show the mitigate shocks. Wan et al. (2024) and Kweh et al. (2025) find that ESG controversies decrease innovation efficiency particularly when a firm is not strong in stakeholder integration. Thus, we put forth the following hypothesis:

H_1: ESG controversies negatively impact innovation performance of EU energy corporations.

2.2. CSR Strategy during ESG Dispute and Innovation Performance

The impact of ESG controversies on innovation is moderated by firms' CSR strategies, acting to attenuate the negative effect through enhancing stakeholder trust and legitimacy and reducing operating risk. For the energy industry, CSR surmounts to more than mere philanthropy or diversity initiatives you might find in industries such as tech or retail. But it also includes negotiating community benefit agreements for wind and solar projects, just transition funds for displaced coal workers, a transparent consultation process on where to place nuclear wastes and participatory planning of renewable infrastructure siting (Kuo et al., 2025; Le et al., 2024). They are not simply voluntary activities, but structural prerequisites to innovative acceptance and adoption in highly contested energy markets.

CSR governance features (e.g., CSR committees, sustainability reporting and ESG based operational strategies) protect energy companies from loss of reputation and help in sustaining the flow of innovative pipelines (Elamer and Boulhaga, 2024; Doni and Fiameni, 2024; Mukhtar et al., 2024; Doni and Fiameni, 2020). Given that carbon reduction necessitates capital-intensive innovation spun around regulation conformity, CSR secures R&D teams against under-resourcing and mis- alignment of stakeholder interests (Wan et al., 2024; Chen et al., 2024; Yu et al., 2024). Whereas from resource-based view (RBV), CSR enhances rare and inimitable capabilities - technology skills, legitimacy and adaptive governance- that protect innovation resilience during ESG crises.

To this end, CSR responds to the institutional complexity inherent in energy: managing the trilemma of affordability, decarbonization and acceptability. Investment in community projects, clear transition schemes and environmental technologies may alleviate resistance and expedite acceptance (Heubeck and Ahrens, 2024; Cabaleiro-Cerviño and Mendi, 2024). It has also been reported that companies with better CSR mechanisms do not lose their innovative performance when faced with a reputation crisis (Yoo et al., 2022; Doni and Fiameni, 2024). Embedding CSR in energy strategy therefore affords coherence between internal workings, regulatory desires and community buy-in. Here, we pose the hypothesis:

H_2 (Moderating effect): The moderation role of CSR strategy in the relationship between ESG controversy and innovation performance among firms with stronger CSR strategies.

2.3. Why the Energy Sector? Institutional and Structural Specificities

The focus of this study is not the background but the substance, the energy field. Its institutional and structural attributes mean that it is particularly vulnerable to ESG controversies – and particularly in need of innovation simply to survive. First, the capital intensity and long investment horizons of the sector mean that disputes can delay multibillion-euro projects, entrenching outdated technologies. Second, under its high regulatory complexity — in which EU directives, emissions trading schemes and national energy policies all overlap — compliance costs are among the key drivers of innovation pathways. Third, the sector's geopolitical entanglement — from energy security discussions to pressures around divesting from fossil fuels — imposes an external layer of exposure that few other industries must face. Finally, social contestation of infrastructure development (wind farms, nuclear sites, carbon capture facilities) underscores the need for CSR to maintain legitimacy.

These institutional and structural characteristics make the energy sector a particularly apt context to observe the ESG controversy–CSR–innovation nexus, as what is at stake is not simply the individual competitive fitness of firms but also society's need for decarbonization and security of supply.

3. RESEARCH METHODS AND DATA OVERVIEW

3.1. Sample Design and Selection

This paper focuses on the effect of ESG controversies on innovation performance at energy firms listed in the EU. The sample includes 233 firm-year observations during the period from 2015 to 2023 (see table 1). Figures were acquired from the EIKON Refinitiv database of the London Stock Exchange Group that represents a popular source of secondary ESG and financial data in academic work. This database has been exploited in prior research to study relationships between ESG and innovation (Elamer and Boulhaga, 2022; Kordsachia, 2019; Cek and Eyupoglu, 2018).

We purposively selected publicly traded energy companies for three reasons. For one, energy companies are central to the EU's decarbonization efforts, with heavy investments in renewables and low-carbon technologies. Second, their modes of innovation are structurally different from that of industries like finance or manufacturing as analyzed in 3.1.1, above. Third, information on listed firms is uniform and audited, which enhances the reliability of the empirical evaluation.

The selected period (2015-2023) encompasses recent evolution in ESG and CSR reporting, including most notably years before and

after the adoption of major EU regulations, such as Non-Financial Reporting Directive and the EU Taxonomy Regulation. The original sample had 387 firm-year observations. After eliminating observations with missing, inconsistent, and incorrect data our final sample amounted to 233 firm-year entities.

3.1.1. Sectoral specificity of energy innovation

Energy is first and foremost, structurally different from innovation in any other industry. Unlike the software, finance, or consumer goods industries, energy innovation suffers from long timelines to market and scale, capital intensive requirements and a complex web of stakeholders. It is these structural features that leave energy companies particularly vulnerable to ESG scandals of the kind that can derail decade-long projects and prompt billion-euro write-offs — certainly not something faced by companies in other sectors (see table 2).

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3.2. Operational Definitions of Key Variables

This paper adds to our understanding of factors influencing EIs research in current literature through the impact of ESG controversies for EU-listed energy companies and moderation of CSR policy (Table 3).

Table 1: Summary of sampling method and participant distribution

Panel A – Sample Selection		Observations
Initial firm-year records		387
Excluded due to missing/erroneous data		154
Final sample (2015-2023)		**233**
Panel B – Sample Breakdown by Year	**Observations**	**Share (%)**
2015	25	10.75
2016	26	11.11
2017	26	11.11
2018	26	11.11
2019	26	11.11
2020	26	11.11
2021	26	11.11
2022	26	11.11
2023	26	11.11
Total	233	100

Source: Author's Own Creation

The dependent variable (environmental innovation) is a proxy of the firm-level sustainable innovation. This includes green patents, investments in renewable and clean technologies, and R&D expenditure related to environmental projects. Energy innovation is structurally distinct from innovation in finance or manufacturing: it means heavy capital investment projects, with long periods for development, getting regulatory permission and involving a lot of stakeholders. In addition, Ren et al. (2024) suggested that innovation in energy companies should be strategically driven towards sustainability goals and there should be huge investment of managerial and financial resources leading to high susceptibility of ESG disagreements (Doni and Fiameni, 2024; Xu et al., 2024).

The independent variable, ESG controversies, reflects the involvement of a company in major high-profile environmental, social, or governance advocacy events, such as an oil spill, a pipeline break, a nuclear safety event, a labor dispute, or an abuse of regulation (KLD Research and Analytics, 2016). This variable is a severity-weighted index of controversies' frequency–severity. The frequency and severity of controversies is based only on a scale from 0 to 100, with the impact of false and true negatives weighing more than true and false negatives, respectively, as used in past literature (Aouadi and Marsat, 2018; Elamer and Boulhaga, 2024). This may distract the industry and undermine investor confidence with implications for R&D activity in the energy field.

The moderator, CSR strategy, measures the extent to which the CSR has been integrated into the firm's business strategies. This dummy takes the value of 1 if, in accordance with the presence of explicit written CSR policies, the presence of a sustainability committee, and the quality of disclosure, the firm is proactively managing ESG risks. A strong CSR orientation sustains the IS performance in the face of ESG controversies by protecting the resources, legitimacy, and stakeholder trust of the energy companies (Elamer and Boulhaga, 2024; Ab Aziz et al., 2024).

Control variables explain company-specific traits and quality of governance, such as size, leverage, board size, independence, gender diversity, and skills. Such controls for firm size and R&D expenditures are also commonly used in ESG and innovation studies (Abusharbeh et al., 2023; Samara and Nassar 2023; Li and Li, 2024; Alslaibi et al., 2025) and allow us to better separate the effects of ESG controversies and the CSR strategy from other influences on an organization.

Through examining energy firms, this research highlights how structuring and strategizing innovation in the industry are complex. Compared to finance or manufacturing, energy innovation has to thread the needle of high capital intensity, long project cycles, regulatory vetting, and societal backlash. It therefore makes EU-

Table 2: Structural differences in innovation: Energy vs. other sectors

Dimension	Energy sector	Other sectors (e.g., Tech, manufacturing, finance)
Capital intensity	Very High (often billions per project)	Moderate to low
Project duration	5-20+years	1-3 years
Key stakeholders	Regulators, local communities, NGOs, investors	Customers, shareholders
Regulatory hurdles	Multi-level (EU, national, local) with strict compliance	Mostly market-driven, fewer public approvals
Example technologies	Smart grids, carbon capture and storage (CCS), nuclear small modular reactors (SMRs), offshore wind	Software, process automation, financial technologies

Table 3: Operationalization of key study variables

Variable name	Abbreviation	Definition	Type
Environmental innovation	EnvirInn	Proxy measure for firms' innovation efforts focused on environmental sustainability, including green patents, technologies, and clean processes.	Dependent variable
ESG controversies	ESGContro	ESG controversies measuring a company's exposure to environmental, social, and governance-related controversies in global media.	Independent variable
CSR strategy score	CSRStrat	Composite score reflecting a firm's CSR commitment, including formal policies, sustainability committees, and ESG disclosure quality.	Moderating variable
Board size	BS	Number of board members at the end of the fiscal year.	Control variable
Board independence (%)	IndB	Percentage of board members classified as independent by the company.	Control variable
Board gender diversity (%)	Bgend	Percentage of female members on the board of directors.	Control variable
Board skills score	BBS	Score based on board members disclosed professional experience, or skills.	Control variable
Audit committee independence score	AIndep	Percentage of independent members on the firm's audit committee.	Control variable
Audit committee expertise score	Aexp	Indicates whether the audit committee includes at least three members and at least one financial expert.	Control variable
ESG score	ESGP	Aggregate ESG score based on company disclosures related to environmental, social, and governance factors.	Control variable
ESG reporting scope (%)	ESGRep	Proportion of the company's activities is covered in environmental and social reporting (100%=full coverage).	Control variable
Leverage	LEV	Ratio of total liabilities to total assets	Control variable
Firm size	Fsize	Natural logarithms of total assets	Control variable

Variable definitions align with prior ESG and innovation literature. Source: Author's Own Creation

listed energy firms a particularly pertinent context in which to explore how ESG controversies and CSR strategies interact to shape environmental innovation.

3.3. Model Framework

Two empirical models are estimated to examine the hypotheses of the study one for each of the main questions. Model 1 tests the direct effect of ESG controversies on innovation performance, and Model 2 tests the moderating effect of CSR strategy on this relationship.

Model 1 is developed to examine H_1, that ESG controversies affect firms' innovative performance negatively in EU energy companies. The regression is given by:

$$Innovation_{it} = \beta_0+\beta_1 ESGControversies_{it}+\sum\beta_k Controls_{it}+\mu_i+\lambda_t+\varepsilon_{it}$$

Model 2 develops this logic to examine Hypothesis 2 (H_2), concerning whether the CSR model includes an interaction term between ESG controversies and CSR strategy, which is described by the following regression:

$$Innovation_{it} = \beta_0+\beta_1 ESGControversies_{it}+\beta_2 CSRStrategy_{it}+\beta_3(ESG\ Controversies_{it}\times CSRStrategy_{it})+\sum\beta_k Controls_{it}+\mu_i+\lambda_t+\varepsilon_{it}$$

Energy companies were selected because their pathways to innovation differ structurally from finance, manufacturing, or other industries. Unlike these sectors, innovation in the energy industry is capital-intensive, operates on long project cycles, and requires close coordination with regulators and local communities. This sector of innovation also includes activities like green patenting, investment in renewable energy, carbon capture technology, and development of smart grids—across which are entwined ESG-related reputational and operational risks. This means that ESG controversies can lead to a direct impact on management focus, cause project slippage, and redirect resources from strategic innovation.

To benefit from their respective advantages and minimize various biases, different estimation methods are adopted. First, baseline estimates are used to estimate the relationship between ESG and innovation using Ordinary Least Squares (OLS), which follows previous ESG-innovation research. Second, in the HDFE models, we account for unobserved heterogeneity at the firm and year level, thereby reducing the risk of omitted variable bias. Third, Two-Stage Least Squares (2SLS) estimation is used to attend to potential endogeneity in ESG controversies and CSR strategy by employing lagged CSR measures or regulatory stringency as instrumental variables. Last, we estimate System Dynamic Panel Data Models (Arellano–Bover/Blundell–Bond estimators) that allow for the persistence of innovation performance and the existence of feedback loops in energy-sector R&D.

These models offer a well-performing empirical and dynamic framework to assess how ESG controversies and CSR strategies drive environmentally focused innovation in EU energy, where innovation is structurally long-term, capital intensive, and strongly dependent on regulatory compliance and stakeholder legitimacy.

4. RESULTS

4.1. Dataset Descriptive Profile

Descriptive statistics Descriptive statistics for 233 firm-year observations from EU energy firms are shown in Table 4. Environmental innovation (EnvirInn) has a mean of 39.01 (SD = 31.51), indicating heterogeneous green innovation endeavors. ESG controversies (ESGContro) are very high on average, 80.95, and many firms are rated at the maximum 100; hence, there are no significant reputational risks. Governance features are characterized by diversity: average board size (BS) of 10.37, board independence (IndB) at 54.32%, and female board representation (BGend) at 55.55%. The mean value of ESGP (average ESG performance score) is 62.22, whereas leverage (LEV) and firm size (Fsize) are 57.86% and 9.87 (log assets),

respectively. The variation inflation factor (VIF) of all variables is acceptable, and the multicollinearity problem does not exist (Salmerón-Gómez et al., 2020).

4.2. Correlation Analysis and Preliminary Findings

Pearson correlation coefficients of the main variables are given in Table 5. Interestingly, environmental innovation (EnvirInn) is negatively associated with ESG controversies ($r = –0.40$, $P < 0.01$), confirming the possibility that controversies could discourage innovative efforts. EnvirInn is positively correlated with board size (BS; $r = 0.29$), ESG performance (ESGP; $r = 0.35$), and firm size (Fsize; $r = 0.41$), indicating that larger and better-governed firms are investing more in environmental innovation. On the downside, ESGContro is negatively related with ESGP ($r = –0.47$) and Fsize ($r = –0.62$), suggesting that controversial firms may also possess weaker ESG and size metrics. There doesn't seem to be an issue of multicollinearity by looking at the moderate correlations between predictor variables (Gujarati, 2004; Hair et al., 2013).

4.3. Empirical Results from Regression Analysis

Results Table 6 presents results of our two main models for the relationship between ESG controversies and the firm's environmental innovation. Model 1 addresses the direct effect (H_1), and Model 2 introduces the interaction effect of CSR strategy (H_2).

As shown in Model 1, ESG controversy (ESGContro) has a significant negative impact on environmental innovation ($\beta = -0.209$, $P < 0.01$), suggesting that energy companies that are embroiled in controversies (e.g., carbon emission fines, oil spills, regulatory sanctions) displace resources from green R&D and clean energy projects, thereby reducing their innovation prospects. This finding provides support for H_1 and is consistent with the literature, which suggests that reputational damage and external pressure are barriers to innovation (Kweh et al., 2025; Aouadi and Marsat, 2018).

Control variables indicate that board size (BS), board gender diversity (Bgend), board skills score (BBS), ESG performance

Table 4: Descriptive statistics of key variables

Variable	N	Mean	Min	Max	SD	CV	p25	p50	p75	VIF
EnvirInn	233	39.013	0.00	98.611	31.508	0.808	0.00	36.000	62.5	-
ESGContro	233	80.946	5.556	100.000	30.330	0.375	69.565	100.000	100	1.80
BS	233	10.370	3	21	4.318	0.416	8	9.773	13	2.18
IndB	233	54.315	7.692	98.188	26.892	0.495	31.81818	53.049	81.019	2.50
Bgend	233	55.554	3.125	99.223	26.410	0.475	35.25641	58.889	77.868	1.15
BBS	233	49.229	0.00	61.111	11.371	0.231	50	50.543	52.315	1.22
AIndep	233	52.703	3.509	94.872	30.648	0.582	19.231	58.160	81.633	2.22
Aexp	233	53.921	1.924	73.179	28.867	0.535	57.573	69.763	70.973	1.27
ESGP	233	62.221	7.230	89.378	17.646	0.284	50.708	64.309	75.452	2.32
ESGRep	233	93.994	13.096	100.000	16.625	0.177	100.000	100.000	100.000	1.15
LEV	233	57.859	16.577	97.305	17.714	0.306	47.397	57.623	68.451	1.35
Fsize	233	9.865	8.378	11.453	0.771	0.078	9.454	9.853	10.223	3.60

Descriptive statistics summarize the distribution, central tendency, and dispersion of variables, supporting robust interpretation in regression models

Table 5: Correlation matrix of key variables

Variable	EnvirInn	ESGContro	BS	IndB	Bgend	BBS	AIndep	Aexp	ESGP	ESGRep	LEV	Fsize
EnvirInn	1											
	0.000											
ESGContro	−0.401	1										
	0.000	0.000										
BS	0.287	−0.306	1									
	0.000	0.000	0.000									
IndB	0.075	−0.309	0.164	1								
	0.252	0.000	0.012	0.000								
Bgend	0.046	−0.033	−0.262	0.108	1							
	0.483	0.614	0.000	0.101	0.000							
BSS	0.038	0.067	−0.203	0.135	0.179	1						
	0.560	0.312	0.002	0.039	0.006	0.000						
AIndep	−0.092	−0.153	0.112	0.607	0.137	0.127	1					
	0.166	0.022	0.095	0.000	0.040	0.058	0.000					
Aexp	−0.084	−0.230	0.313	0.212	−0.073	0.072	0.033	1				
	0.201	0.000	0.000	0.001	0.266	0.273	0.624	0.000				
ESGP	0.347	−0.474	0.419	0.482	−0.118	−0.036	0.125	0.402	1			
	0.000	0.000	0.000	0.000	0.073	0.589	0.061	0.000	0.000			
ESGRep	−0.162	0.265	−0.094	−0.179	0.028	−0.005	−0.109	−0.114	−0.107	1		
	0.014	0.000	0.154	0.006	0.677	0.945	0.102	0.082	0.104	0.000		
LEV	0.277	−0.145	0.419	0.257	−0.045	−0.070	0.033	0.004	0.211	−0.110	1	
	0.000	0.028	0.000	0.000	0.495	0.285	0.620	0.953	0.001	0.095	0.000	
Fsize	0.406	−0.619	0.620	0.477	−0.075	0.073	0.324	0.372	0.655	−0.282	0.318	1
	0.000	0.000	0.000	0.000	0.252	0.271	0.000	0.000	0.000	0.000	0.000	0.00

All coefficients are below 0.70, minimizing multicollinearity concerns for regression analysis

Table 6: Regression of key variables

Variable	Model 1: Direct effect (H_1)	Model 2: Moderation effect (H_2)
ESGContro	–0.209***	–0.203**
CSRStrat	–	0.08
ESGContro×CSRStrat	–	0.0003
BS	1.085*	1.070*
IndB	–0.040	–0.025
Bgend	0.131*	0.132*
BBS	0.300*	0.286*
AIndep	–0.260***	–0.250***
Aexp	–0.316***	–0.307***
ESGP	0.386***	0.360**
ESGRep	–0.132	–0.123
LEV	0.237**	0.228**
Fsize	9.847**	8.451*
_ Constant	–67.982*	–58.422
Observations (n)	233	233
R^2	0.408	0.41
Adjusted R^2	0.378	0.374
Breusch and Pagan Test	χ^2 (1)=445.29***	χ^2 (1)=446.04***
Hausman Test	χ^2 (11)=24.48**	χ^2 (11)=33.05***

The legend indicates significance levels with P<0.10, P<0.05, and P<0.01

Table 7: High-dimensional fixed effects regression

Variable	Model 1: Direct effect (HDFE)	Model 2: Moderation effect (HDFE)
ESGContro	–0.230***	–0.238***
CSRStrat	—	0.055
ESGContro×CSRStrat	—	0.001
BS	1.132*	1.150*
IndB	–0.236**	–0.222*
Bgend	0.272***	0.278***
BBS	0.092	0.074
AIndep	–0.109	–0.096
Aexp	–0.189**	–0.195**
ESGP	0.395*	0.339
ESGRep	–0.097	–0.082
LEV	0.331**	0.324**
Fsize	7.207*	6.389
Constant _	–51.578	–46.245
Observations	233	233
R^2	0.68	0.682
Adjusted R^2	0.631	0.629
P-value	0.000	0.000

Standard errors in parentheses. *P<0.10, **P<0.05, ***P<0.01. Both models include firm and year fixed effects

(ESGP), leverage (LEV), and firm size (Fsize) positively influence environmental innovation (Farza et al., 2022). For energy companies, greater gender diversity on boards has positive effects for stakeholder engagement in renewable projects, and larger boards are associated with more effective strategic management responding to climate policies and energy transition obstacles. On the other hand, audit committee independence (AIndep) and audit committee expertise (Aexp) negatively affect innovation, which may illustrate the limitation of financial control by new devices of future energy using high-risk technology such as smart grids or nuclear energy. The model accounts for 41% of the variance in innovation ($R^2 = 0.408$).

Model 2 with the CSR strategy interaction shows that the ESG controversy has a negative impact ($\beta = -0.203$, $P < 0.05$). The CSRStrat presents a positive, but non-significant, impact, and the interaction is non-existent ($\beta = 0.0003$), indicating a sector distrust in CSR in the energy sector, particularly in fossil fuel firms where CSR is often perceived by stakeholders as greenwashing.

Finally, the Breusch-Pagan test rejects the joint zero random effect, and the Hausman test favors fixed effect. Our findings suggest that ESG controversies are significantly negative to innovation in the energy sector, where traditional CSR instruments may prove inadequate in mitigating controversy-induced disruptions.

4.4. Robustness Checks

Table 7 reports summary statistics from high-dimensional fixed effects (HDFE) linear regressions for the effect of ESG controversies on environmental innovation. Model 1 shows a negative and statistically significant impact of ESG controversy on innovation, while greater board size and degree of gender diversity on the board have positive effects on innovation. There are important negative associations between both audit committee experience and board independence. Model 2 adds CSR strategy as a moderator, but both its direct and interaction effects are positive but insignificant. Control variables such as leverage and firm size remain positively and significantly related to innovation. Both specifications display high explanatory power, accounting for close to 63% of variation after controlling for fixed effects, thus confirming the soundness of controlling for firm features heterogeneity.

The direct and interacting effects of ESG controverises on firms' environmental innovation. We further explore how the association of ESG controverises with firms' environmental innovation is conditioned by firms' CSR strategy and governance characteristics. Using a sample of 233 firm-year observations over 2015-2023, we employ high-dimensional fixed effects (HDFE), two-stage least squares (2SLS), and the dynamic panel data models to cater for model invariance. The study aims to examine CSR strategic engagement can moderate the detrimental consequences of ESG controversies. By investigating the durability of innovation and firm-level heterogeneity, this study contributes to a more comprehensive comprehension of ESG risk and innovation strategy fit.

We conducted Two-Stage Least Squares (2SLS) regressions on environmental innovation in Table 8 to study the impact of ESG controversies and CSR strategy. In model 1, I find a significant and negative effect of ESG controversy on environmental innovation, in line with our hypothesis 1 and previous literature, with a value of -0.209 ($p < 0.01$). Board size, gender diversity, audit committee independence and expertise, and leverage have a positive impact on innovative performance. Model 2 introduces the moderation effect of CSR strategy and its interaction with ESG controversies, but neither CSR strategy nor the interaction term is statistically significant. Both models give a good fit, as seen from your R-squared values of about 0.41. The findings suggest that ESG controversies negatively impact innovation, whereas the CSR strategy does not significantly moderate it (Cabaleiro-Cerviño and Mendi, 2024; Costa and Fonseca, 2022; Nirino et al., 2021).

These results are based on the instrumental variable regression that controls the potential endogeneity issue.

Results of dynamic panel data on ESG controversies, CSR strategy, and environmental innovation over time are presented in Table 9. Both models have the lagged dependent variable, which indicates a considerable level of persistence of innovation (coefficients 0.65 and 0.74, $P < 0.1$). Findings reveal that the complicated mechanisms behind environmental innovation are more about governance and ESG quality than a direct ESG-related controversy.

5. DISCUSSION

Based on this conceptual framework and drawing on institutional theory, strategy real-options view, financial real-options perspective, and ESG controversy literature in prior research studies, we investigate how the ESG controversy influences a firm's level of environmental innovation (EIO) as well as whether corporate social responsibility (CSR) strategy moderates this EIO effect. In line with H_1, ESG controversies have been found to adversely influence environmental innovation of EU-listed energy companies (Juca et al., 2024; Aouadi and Marsat, 2018; Mendiratta et al., 2023). Controversies are exceptionally disruptive in the energy sector given its high capital intensity, long lead times for projects and intense public scrutiny. Disasters like oil spills, pipeline blowouts, nuclear-safety failures or long delays in deploying renewables not only cost companies reputational capital; they also require them to redirect limited financial and human resources away from the pursuit of innovation toward that of remediation, compliance and litigation. A case in point is the 2021 activist backlash that led to the scrapping of a multibillion-dollar North Sea carbon-capture project, which vividly demonstrates how ESG controversy can kill strategically important, long-cycle innovation endeavors. Penalties and fines are another budget-slash against green technologies—smart grids, low-carbon hydrogen, and CCS—leading to innovation delay or contraction (Duong and Huang, 2025; Cabaleiro-Cerviño and Mendi, 2024). Unlike in industries that can retool quickly, like software or consumer electronics, companies cannot redeploy resources over short horizons because their innovations are infrastructure-based and path dependent.

Table 8: Two-stage least squares (2SLS) regression

Variable	Model 1: Direct effect (2SLS)	Model 2: Moderation effect (2SLS)
ESGContro	−0.208***	−0.203***
CSRStrat	—	0.079
ESGContro×CSRStrat	—	−0.001
BS	1.084**	1.070*
IndB	−0.040	−0.025
Bgend	0.131**	0.131**
BBS	0.299*	0.285*
AIndep	−0.259***	−0.249***
Aexp	−0.316***	−0.307***
ESGP	0.386***	0.359**
ESGRep	−0.131	−0.123
LEV	0.237**	0.228**
Fsize	9.847**	8.451*
Constant	−67.982*	−58.422
Observations	233	233
R-squared	0.408	0.409
P-value	0.000	0.000

P<0.10, **P<0.05, ***P<0.01. Robust standard errors used. Models include firm and year fixed effects

Table 9: Dynamic panel data regression

Variable	Model 1: Direct effect (Sys. Panel)	Model 2: Moderation effect (Sys. Panel)
L1. EnvirInnov_w	0.738*** (0.032)	0.653***
ESGContr	0.010	–0.047
ESGContro×CSRStrat	—	–0.090*
BS	−0.463***	–0.403
IndB	0.035*	0.077**
Bgend	0.031*	–0.026
BBS	0.042*	0.043*
AIndep	0.008	–0.016
Aexp	−0.047**	–0.059**
ESGP	0.429***	0.443***
ESGRep	−0.075***	–0.093***
LEV	0.068***	0.087***
Fsize	–1.218***	−0.178
Observations	200	200
Number of Groups	25	25
Wald Chi^2	460,305	1.40E+08
Prob>Chi^2	0.00	0.00
Sargan test	18.81, P=0.13	14.61, P=0.33
Arellano–Bond test	Z=0.96, P=0.33	Z=0.98, P=0.32

Robust standard errors; models control for country, year effects; instruments valid per Sargan test; no second-order autocorrelation detected

Governance effects are heterogeneous. Board size and gender diversity are positively related with environmental innovation, which might suggest that the broader composition of the board enhances crucial strategic deliberation regarding conflicting issues such as – local communities for renewables; trade-offs between energy security and social acceptance; stakeholder sensitive innovation choices (Farza et al., 2022; Mukhtar et al., 2024). In contrast, more rigorous audit-committee monitoring, measured in the dimensions of independence and financial expertise, is negatively related to innovation outcomes at least in some specifications. This is credible because heavy financial surveillance can limit the level of risk tolerance and exploration investment required for transformational, capital-heavy projects like nuclear safety upgrades, offshore wind R&D and CCS pilot projects (Heubeck and Ahrens, 2024; Xu and Zhu, 2021). With respect to innovation, leverage is positively related to it -indebted firms have high propensities to undertake radical projects because they seek to obtain competitive positions in the long term under pressures due to transition.

Only weak support is found for the buffering effect of CSR (H_2). More established CSR programs are modestly associated with higher baseline innovation in performance levels, but do not significantly moderate the negative impact of ESG controversies on core models of EIO. This trend mirrors sectoral mistrust and the controversial status of energy initiatives. CSR's muddied reputation Stakeholders are suspicious of CSR actions by fossil incumbents, and concerns about green washing abound; crises—whether they be large and visible (spills, safety failures) or forced relocations—can swamp out CSR investments and

community efforts (Tang et al., 2012; Yu et al., 2024). In other words, CSR is useful for building long-term legitimacy but does not seem to act in and of itself as a shock absorber of high-impact sudden controversies in energy subsectors ruled by legacy fossil assets.

Dynamic panel models provide evidence of strong persistence in EIO, which is expected given the long gestation and path dependence process of energy investments. Mega-projects, including nuclear power station, coastal wind array and national smart-grid implementation come with multi-year build cycles and capability accumulation that amplify the ESG shocks effect on future innovation trajectories (Wan et al., 2024; Xu et al., 2021). Robustness checks with high-dimensional fixed effects and alternative specifications confirm that ESG incidents lead to lasting adverse impact, the preferred models explain more than 60% of the variation in patenting outcomes.

This study contributes to ESG literature by revealing that Firm-level vulnerabilities in the energy sector strengthen the disrupting effect of controversies on environmental innovation and common governance-CSR mechanisms are generally unable to buffer these shocks (Elmassri et al., 2023; Owusu et al., 2024). Drawing on regulatory, economic and institutional viewpoints, the results demonstrate mechanisms whereby controversies lead to deferred or abandoned energy innovations. For managers, the findings indicate that energy companies may benefit more from a customized governance and risk management set-up than a type of one-size-fits-all CSR oversight. Practical steps would be setting corporate-level innovation-risk committees with technical competence to protect long-cycle R&D budgets; KPIs at the executive level tied to ESG-adjusted innovation outcomes, such as milestone-based funding triggers based on community agreements; and quick, transparent crisis management about crises like spills in real time and structured stakeholder engagement as a component of siting and decom decisions.

For policy makers, the results highlight the importance of pairing punishment measures with incentives to innovate that are resilient to risk of controversy. Options could include conditional fast-tracking of permitting for renewables at the highest standard of community benefit, separate funds for innovation that are disbursed as a default in case of bona fide controversies and differentiated regulatory tracks reflecting sub-sectoral risk and innovation profiles – tougher headwinds for legacy fossil investments, quicker accelerations/subsidy approvals (or pausing) for known renewables. For investors, the findings suggest that when it comes to ESG controversy exposure, this is something which should be incorporated into long-term valuation models as controversy risk can potentially erode future capability to innovate and through time long-run value. Notably, such effects could vary between utilities, fossil generators and renewable operators.

Future research Agenda Moving forward, future work should seek to further unpack external contingencies that may influence when governance and CSR are effective in enhancing performance – such as sub-sector legal regimes, geopolitical energy risks, market maturity, public acceptance and institutional trust. Mixed-method studies such as case studies of cancelled projects, matched difference-in-differences alongside regulatory changes and stakeholder surveys could help to shed light on causal pathways and the heterogeneity between utilities, upstream fossil producers and renewable operators. ESG risk management needs to be aligned to sector-specific innovation strategy for European energy companies aiming at resilience and long-term competitiveness in the low carbon transition.

6. CONCLUSION

This paper shows that there is a sector-specific risk of ESG controversies on innovation in the context of EU energy industry. Energy projects (like offshore wind permitting or nuclear plant construction, or deploying a hydrogen pipeline) are so capital-intensive, so wrapped up in regulation and the social license they require, that shocks to reputation outright stymie innovation. Our results indicate that standard CSR policies and governance procedures are not enough; specific energy- innovation governance instruments are needed, ones able to safeguard R&D continuity under controversy risk. ESG controversies cast a long and consistent shadow, acting as a visible condom that energy companies must penetrate when aiming to marry their sustainability ambitions with tech development – green innovation and ESG risk mgmt. in action.

The findings have direct practical importance. Energy firms are advised to pre-emptively manage ESG controversies and incorporate ESG issues into the planning of innovations by using an ESG-risk-adjusted measure for R&D; creating an innovation-risk committee featuring dedicated ESG roles; and involving stakeholders at an early stage in renewable, transition and pilot projects. For regulators, ESG controversies reflect a need to integrate regulatory enforcement with incentives for innovation while being cognizant of sectoral risks, especially in high-emission or high-risk subsectors (e.g. fossil fuels, nuclear energy). Long-term value creation potential for utilities and energy producers can be scored by investors using ESG controversy exposure to measure innovation resilience.

Despite these findings, the study has some limitations. The sample of firms covered is limited to EU-listed energy companies and does not necessarily reflect practices of other industries or unlisted enterprises. Exclusion of missing or inconsistent data might result in selection bias, and some firm level factors – ownership, market position, financial restrictions- were included only to a limited extent. Suggested that further research may enlarge the sample size, pool more context variables along with applying a mixed- study multilevel approach to represent the complex interaction among governance, CSR and innovation behaviors.

On a deeper level, our study adds value to CSR and responsible innovation literature by demonstrating that it has now become strategically imperative to incorporate ESG risk management into energy innovation strategy. By specifying how ESG controversies uniquely impinge technological innovation within the energy

context, it furthers a domain-specific comprehension and identifies actionable governance tools that can turn ESG challenges into sources of SD advantage in the low carbon transition.

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