THE APPLICATION OF DIGITAL TECHNOLOGIES IN ESG MONITORING IN ENERGY FIRMS: EVIDENCE FROM EMERGING MARKETS

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Abstract: ***This study examines the role of digital technologies in enhancing ESG (Environmental, Social, and Governance) monitoring in energy enterprises across emerging markets, with evidence from Vietnam, Indonesia, and the Philippines. Drawing on a multiple case study approach, the research integrates three theoretical perspectives organizational technological capability, ESG implementation framework, and institutional voids theory to analyze how firms adopt and utilize digital tools for ESG monitoring. The findings show that energy firms increasingly deploy technologies such as IoT, artificial intelligence (AI), big data analytics, blockchain, and ESG dashboards to enable real-time data collection, improve transparency, and enhance decision-making. Digital adoption significantly improves ESG performance, reporting quality, and access to green finance. However, its effectiveness varies across firms and countries due to differences in technological capabilities, institutional conditions, and data standardization. The study contributes to the literature by conceptualizing digital technologies as strategic enablers that help firms overcome institutional constraints and operationalize ESG practices in emerging markets. It also provides policy and managerial implications for accelerating ESG digital transformation in high-emission sectors.***

• Keywords: *ESG monitoring, digital platforms, SCADA, AI, energy sector, emerging markets.*

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1. Introduction

At the global level, international agreements such as the Paris Agreement and commitments made at COP26 have established binding targets for greenhouse gas emissions reduction and accelerated the transition toward a low-carbon economy, particularly in the energy sector (IEA, 2023). In this context, Environmental, Social, and Governance (ESG) practices have evolved from voluntary initiatives into strategic prerequisites for firms seeking access to capital markets, global partnerships, and green finance (Eccles et al., 2014).

In Vietnam, the government has made strong commitments toward achieving Net Zero emissions by 2050, which have been institutionalized through key national strategies, including the Green Growth Strategy (2021-2030) and the National Action Plan for the implementation of the UN 2030 Agenda (Government of Vietnam, 2021). However, despite these policy advancements, a substantial gap persists between regulatory ambition and firm-level implementation capacity particularly in the measurement, monitoring, and disclosure of ESG performance (PwC Vietnam, 2022).

Against this backdrop, digital technologies are increasingly viewed not merely as managerial tools, but as critical enablers of ESG governance. Technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics, and blockchain enable real-time data collection, automated reporting, and enhanced transparency (Deloitte, 2019; IEA, 2023). More importantly, in the context of developing economies, these technologies may function as substitutes for institutional deficiencies by compensating for weak regulatory enforcement, limited data infrastructure, and fragmented reporting standards (Khanna and Palepu, 2010).

This issue is particularly salient in emerging markets such as Vietnam, Indonesia, and the Philippines, where institutional constraints continue to hinder effective ESG implementation. While prior studies have examined ESG adoption and digital transformation independently, limited research has systematically explored how digital technologies are

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deployed to support ESG monitoring under conditions of institutional voids in emerging economies (Kotsantonis and Serafeim, 2019).

To address this gap, this study investigates the role of digital technologies in enhancing ESG monitoring in energy enterprises across Vietnam, Indonesia, and the Philippines. These countries are selected as representative emerging markets characterized by rapid economic growth, rising energy demand, and increasing pressure to meet international climate commitments (IEA, 2023). At the same time, they face common structural challenges, including infrastructure limitations, underdeveloped financial systems, and weak ESG regulatory frameworks (Khanna and Palepu, 2010).

Focusing on the energy sector one of the largest contributors to carbon emissions this study examines how firms adopt and integrate digital technologies such as IoT sensors, AI-based analytics, and blockchain platforms into ESG monitoring systems. Drawing on multiple case studies and comparative analysis, the research aims to identify emerging implementation patterns, assess key challenges, and derive practical and policy implications for advancing ESG digital transformation in emerging market contexts.

The general objective of this research is to analyze and evaluate the role of digital technologies in enhancing the effectiveness of ESG monitoring in energy enterprises across emerging markets. The study aims to derive both policy and practical implications to promote sustainable development and accelerate the transition toward Net Zero.

To achieve the above objective, the study addresses the following research questions:

• What types of digital technologies are adopted by energy enterprises in emerging markets for ESG monitoring?

• How do these technologies influence the effectiveness of ESG monitoring, measurement, and reporting?

• What organizational and institutional factors enable or hinder the implementation of digital ESG monitoring systems?

• How does the level of ESG digital readiness differ across Vietnam, Indonesia, and the Philippines, and what explains these differences?

2. Theoretical Framework and Literature Review

This study draws on three complementary theoretical perspectives organizational technological capability, the ESG implementation framework, and institutional voids theory to examine how firms in emerging markets leverage digital technologies to enhance ESG monitoring.

Organizational technological capability refers to a firm's ability to select, implement, and effectively utilize technologies to achieve strategic objectives (Lall, 1992; Bell & Pavitt, 1995). It comprises three key dimensions: acquisition capability, implementation capability, and improvement capability. In the ESG context, this capability determines firms' ability to integrate digital technologies such as IoT, AI, and blockchain into ESG monitoring systems and translate digital adoption into value creation.

The ESG implementation framework explains how firms translate ESG principles into measurable and actionable practices. Effective ESG implementation requires embedding ESG considerations into corporate strategy, governance, and operations (Eccles et al., 2014). The framework includes three core pillars: governance structures, information and measurement systems, and organizational commitment. In this study, it is used to assess how digital technologies support ESG monitoring and enable firms to convert ESG data into actionable insights.

Institutional Voids Theory highlights the gaps in regulatory frameworks, market mechanisms, and information systems in emerging economies (Khanna & Palepu, 2010). These constraints hinder effective ESG implementation by limiting standardization, oversight, and data availability. In this context, digital technologies are viewed as strategic tools that help firms compensate for institutional deficiencies and enhance ESG transparency.

Literature Review

A growing body of international research has examined the role of digital technologies in ESG monitoring, particularly as firms seek to enhance transparency and meet the increasing expectations of green investors. Existing studies can be broadly categorized into three interrelated themes: (i) ESG as a strategic and performance-driven framework, (ii) the enabling role of digital technologies in ESG monitoring, and (iii) challenges related to ESG data quality and implementation.

First, prior research has established ESG as a core strategic driver of firm performance rather than a mere reporting exercise. Eccles, Ioannou, and Serafeim (2014) demonstrate that firms with deeply

embedded ESG practices tend to outperform their peers in both financial and socio-environmental dimensions. Although their study does not explicitly address digital technologies, it provides a strong theoretical foundation for subsequent research by emphasizing that ESG must be integrated into corporate strategy and governance. This perspective underpins later studies on ESG digitalization, where technology is viewed as a critical enabler of effective ESG implementation.

Second, a growing stream of literature highlights the transformative role of digital technologies in enhancing ESG monitoring systems. Deloitte (2019) identifies blockchain, big data, and IoT as core technologies that enable real-time, transparent, and verifiable ESG data ecosystems in the energy sector. According to this report, digital platforms can replace rigid, traditional reporting systems and facilitate continuous ESG data integration, thereby improving regulatory compliance and strengthening investor trust particularly in the context of green bond issuance and access to sustainable finance. The report further introduces practical deployment models, including blockchain-based emission tracking, AI-driven ESG risk analytics, and IoT-enabled early warning systems, marking a transition from reactive to proactive sustainability management.

Similarly, the PwC Global ESG Tech Report (2022), based on a large-scale survey of 1,000 companies across 30 countries, finds a strong positive relationship between investment in digital ESG platforms and ESG performance outcomes. Firms adopting digital tools such as dashboards, big data analytics, and AI demonstrate higher levels of transparency, improved ESG ratings, and better access to green capital. These findings reinforce the view that digital technologies are not merely supportive instruments but central components of modern ESG strategies, particularly in high-emission industries such as energy.

Third, the literature also emphasizes persistent challenges related to ESG data quality and implementation. Kotsantonis and Serafeim (2019) highlight critical limitations in ESG data, including lack of standardization, inconsistencies, and significant time lags, which hinder effective decision-making for both firms and investors. They argue that emerging technologies such as AI, automated reporting systems, and unstructured data analytics are essential for transitioning the ESG ecosystem from manual, voluntary reporting (ESG 1.0) to real-time, transparent, and verifiable monitoring (ESG 2.0).

Complementing this perspective, the IEA (2023) underscores the operational importance of integrating digital technologies such as IoT sensors, AI, and carbon management dashboards into energy systems to achieve Net Zero targets. The report notes that such technologies can reduce energy consumption by 10-30% through automation, demand forecasting, and real-time monitoring, while simultaneously improving the accuracy and reliability of ESG reporting. However, it also identifies key barriers, including cybersecurity risks, limited technical capacity in developing countries, and the absence of harmonized ESG data standards.

Taken together, these studies suggest that while digital technologies offer significant potential to enhance ESG monitoring and performance, their effectiveness depends on addressing underlying challenges related to data quality, institutional capacity, and technological readiness. This gap provides the basis for the present study, which examines how digital technologies can be leveraged to overcome institutional constraints and improve ESG monitoring in energy enterprises within emerging markets.

3. Methodology

This study adopts a multiple case study approach to examine the application of digital technologies in ESG monitoring across energy enterprises in three representative emerging economies: Vietnam, Indonesia, and the Philippines.

Each country is treated as a case group, with selected energy firms serving as the units of analysis. Case selection is based on three criteria: (i) regular ESG disclosure practices, (ii) documented use of digital technologies in ESG monitoring, and (iii) operations in key energy sectors, including electricity generation, renewable energy, or natural gas.

The study draws on both primary and secondary data sources. Secondary data include sustainability reports, ESG ratings, and digital monitoring systems (e.g., SCADA platforms and ESG dashboards), which are used to assess ESG transparency and the extent of data digitalization. These data are complemented by primary insights from interviews and industry reports where available.

Data analysis is conducted using thematic coding and cross-case comparison. The coding process follows three stages: open coding to identify initial categories, axial coding to group these into higher-

order themes, and cross-case analysis to compare patterns across firms and countries.

To enhance reliability, key findings are triangulated across multiple data sources, including corporate disclosures and third-party reports (e.g., PwC, CDP, FiinRatings). This approach ensures the consistency and validity of the analysis.

Data collection was conducted from two main sources:

Primary data: A total of 10 semi-structured interviews were conducted with the following interviews:

• ESG managers at EVNGENCO3 and BCG Energy those directly responsible for implementing ESG systems and thus familiar with ESG indicators, dashboards, data collection, and disclosure processes;

• Internal IT/data specialists at EVNGENCO3 and BCG Energy experts in designing and operating SCADA, IoT, AI that support ESG monitoring;

• Regulatory officials and institutional experts including representatives from the State Securities Commission, and ESG rating specialists from FiinRatings;

• ESG consultants from Big Four firms (PwC, KPMG, Deloitte) with prior experience in advising or auditing ESG projects in Indonesia and the Philippines, offering indirectly sourced but insightful perspectives;

• Regional energy analysts experts with access to rich secondary data and cross-national insights on ESG developments in all three countries.

Secondary data: Content analysis was performed on more than 10 sustainability and integrated ESG reports, as well as SCADA system data and IoT monitoring platform disclosures published between 2021 and 2025.

The selected representative case firms EVNGENCO3 and BCG Energy (Vietnam), Pertamina (Indonesia), and AboitizPower (Philippines) were chosen based on the clarity of their ESG disclosures and documented evidence of applying digital technologies in ESG monitoring.

4. Findings

4.1. Types of digital technologies in ESG monitoring

Across the three countries, energy enterprises have increasingly adopted a range of digital technologies to support ESG monitoring, with four dominant categories identified: IoT systems, artificial intelligence (AI), big data analytics, and blockchain platforms.

IoT-based monitoring systems are widely used to collect real-time environmental and operational data. For example, in Vietnam, Vietnam Electricity has deployed SCADA systems and IoT sensors across thermal and hydropower plants to monitor emissions, fuel consumption, and water usage. Similarly, in Indonesia, Pertamina integrates IoT sensors into its upstream and downstream operations to track emissions leakage and resource utilization.

AI and big data analytics are applied to enhance data processing and predictive capabilities. In Vietnam, TTC Energy utilizes AI to analyze data from renewable energy plants, enabling emission forecasting and performance optimization. In Indonesia, Pertamina employs AI-driven analytics to detect anomalies in environmental data and trigger early warnings for ESG risks.

Blockchain technology is primarily used to enhance data traceability and verification. For instance, BCG Energy in Vietnam applies blockchain to trace the origin of renewable energy equipment and calculate avoided emissions, supporting carbon credit certification and green bond issuance. This reflects a broader trend toward using blockchain to ensure transparency and credibility in ESG reporting.

In addition, ESG dashboards and digital reporting platforms are increasingly adopted to centralize ESG data and facilitate real-time monitoring. EVNGENCO3 has developed an internal ESG dashboard to track key indicators such as CO_2 emissions and labor safety metrics, while AboitizPower has implemented a real-time ESG dashboard integrated with advanced analytics (AboitizPower, 2023).

These findings indicate that digital ESG monitoring in emerging markets is characterized by a combination of sensing technologies (IoT), analytical tools (AI and big data), verification systems (blockchain), and visualization platforms (dashboards).

4.2. Impact of digital technologies on ESG monitoring effectiveness

The adoption of digital technologies has significantly enhanced the effectiveness of ESG monitoring across multiple dimensions, including data accuracy, transparency, timeliness, and decision-making capability.

First, digital technologies enable real-time data collection and monitoring, reducing delays associated with traditional reporting systems. For example, EVNGENCO3 reports that the use of ESG dashboards has reduced the time required to detect environmental data discrepancies from three weeks to less than five days (EVNGENCO3, 2022). Similarly, IoT-based systems allow continuous tracking of emissions and operational performance in both Vietnam and Indonesia.

Second, digital platforms improve transparency and reporting quality. Empirical evidence shows that firms adopting digital ESG systems are more likely to produce comprehensive and reliable ESG disclosures. According to PwC Vietnam (2022), energy firms with integrated digital ESG systems are three times more likely to publish complete ESG reports. In addition, FiinRatings (2023) finds that listed energy companies using ESG dashboards achieve ESG scores approximately 15% higher than those without such systems.

Third, digital technologies enhance predictive and analytical capabilities. AI-based systems enable firms to identify patterns, forecast emissions, and detect anomalies at early stages. In Indonesia, Pertamina's AI-driven monitoring systems have improved internal audit processes and accelerated progress toward Net Zero targets.

Finally, digitalization supports access to green finance by improving data credibility and compliance with international standards. Blockchain-based traceability systems, such as those used by BCG Energy, enhance the verifiability of ESG data, thereby increasing investor confidence in green bonds and carbon credit mechanisms.

Overall, these findings suggest that digital technologies transform ESG monitoring from a reactive reporting function into a proactive, data-driven management system.

4.3. Drivers and barriers of digital ESG adoption

The adoption of digital technologies for ESG monitoring is driven by both external pressures and internal organizational factors, while also facing significant barriers.

On the demand side, increasing regulatory and market pressures play a key role. National Net Zero commitments and global ESG standards create strong incentives for firms to improve ESG transparency and compliance. In addition, investor expectations particularly from green finance markets encourage firms to adopt digital ESG systems to enhance credibility and disclosure quality.

Internal organizational capabilities also act as critical enablers. Firms with stronger technological capabilities are better positioned to integrate digital tools into ESG systems, as reflected in the cases of EVNGENCO3, BCG Energy, and Pertamina. These firms demonstrate the ability to combine multiple technologies such as IoT, AI, and blockchain into integrated ESG monitoring platforms.

However, several barriers persist across all three countries. High implementation costs remain a major constraint, particularly for firms with limited digital infrastructure. In addition, the lack of standardized ESG data frameworks creates challenges in data integration and comparability, consistent with concerns raised in prior studies (Kotsantonis and Serafeim, 2019).

Human resource limitations also pose a significant challenge. The shortage of skilled professionals with expertise in both ESG and digital technologies reduces firms' capacity to deploy and manage advanced systems. Furthermore, institutional constraints such as weak regulatory enforcement and fragmented governance structures continue to hinder large-scale adoption.

These findings highlight that digital ESG adoption is not only a technological issue but also a function of organizational capability and institutional context.

4.4. Cross-country differences in ESG digital readiness

The findings reveal notable differences in the level and patterns of ESG digitalization across Vietnam, Indonesia, and the Philippines.

Vietnam demonstrates strong firm-level adoption of digital ESG tools, particularly among large energy enterprises, despite fragmented regulatory frameworks. Indonesia shows a more integrated approach within large state-owned enterprises, where digital technologies are deployed at scale but remain unevenly distributed across the sector. In contrast, the Philippines exhibits a more market-driven model, with leading firms applying advanced analytics and AI, although broader adoption is constrained by weak regulatory coordination.

These differences indicate varying levels of ESG digital readiness across the three countries, reflecting differences in institutional environments and firm-level capabilities.

5. Discussion

The findings of this study provide important insights into how digital technologies shape ESG monitoring in emerging markets, particularly when interpreted through the lenses of organizational technological capability, ESG implementation framework, and institutional voids theory.

From the perspective of organizational technological capability, the results suggest that the effectiveness of digital ESG adoption depends not merely on the availability of technologies but on firms' internal ability to integrate and utilize them. From the ESG implementation framework, the study shows that digital technologies play a transformative role in embedding ESG into organizational processes. Rather than serving solely as reporting tools, digital systems enable continuous monitoring, real-time data integration, and predictive analytics. This shifts ESG from a reactive, compliance-driven activity toward a proactive, data-driven management function. From the perspective of institutional voids theory, the findings highlight that digital technologies serve as functional substitutes for weak institutional environments.

Importantly, the interaction between these three dimensions provides a more comprehensive explanation of ESG digital transformation. Institutional pressures create the need for improved ESG monitoring, but it is organizational technological capability that determines firms' ability to respond effectively. At the same time, the impact of digital technologies depends on how deeply they are embedded within ESG implementation systems. This highlights that digital transformation, organizational capability, and institutional context must be aligned to achieve meaningful ESG outcomes.

Overall, this study contributes to the literature by integrating organizational technological capability, ESG implementation framework, and institutional voids theory into a unified analytical perspective for understanding digital ESG transformation in emerging markets.

By doing so, it highlights the role of digital technologies as strategic enablers that not only support ESG monitoring but also help firms overcome institutional constraints and enhance implementation effectiveness.

6. Recommendation

To accelerate ESG digital transformation in emerging markets, governments should prioritize three key policy directions.

First, financial and regulatory support mechanisms are essential to reduce the high upfront costs associated with digital ESG adoption. Governments should introduce targeted green finance instruments, such as concessional loans, credit guarantees, and tax incentives, to support investments in ESG-related digital infrastructure, including IoT systems, AI platforms, and ESG monitoring dashboards. These measures can lower entry barriers and encourage broader adoption, particularly among smaller firms.

Second, it is critical to establish a standardized national ESG data framework. This includes the development of a unified ESG taxonomy, standardized digital reporting formats, and centralized ESG reporting platforms. Such standardization would improve data comparability, enhance transparency, and facilitate alignment with international frameworks such as GRI and TCFD. In addition, clear technical guidelines for integrating data from digital systems (e.g., SCADA and IoT platforms) into ESG reporting processes should be developed.

Third, governments should promote public-private collaboration in the development of ESG digital infrastructure. Initiatives such as ESG digital alliances, open data platforms, and shared data hubs can help reduce duplication, foster innovation, and enable knowledge sharing. These collaborative mechanisms are particularly important in emerging markets, where institutional capacity and

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