Chapter 4

Blockchain Solutions for Corporate Greenwashing: Causes, Mechanisms, and Practical Implications

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Abstract

The Corporate greenwashing has emerged as a major obstacle to achieving genuine sustainability, as misleading environmental claims weaken trust in ESG disclosures and distort market and policy outcomes. This book chapter aims to investigate the economic and institutional foundations of corporate greenwashing and to advance blockchain technology as a practical solution to this problem. Anchored in information asymmetry and signaling theory, the chapter frames greenwashing as a consequence of weak verification systems that allow firms to issue symbolic sustainability signals without credible enforcement.

The chapter pursues three interrelated objectives. First, it synthesizes the existing literature to identify the key incentives, mechanisms, and strategic behaviors that drive firms to engage in greenwashing. Second, it explains how blockchain's core characteristics can fundamentally restructure ESG reporting systems by embedding credibility and verifiability at the data-generation stage, rather than relying solely on ex post detection. Third, it reviews empirical and applied evidence on blockchain-enabled solutions, including ESG reporting platforms, supply-chain traceability systems, and smart contracts, illustrating how these applications reduce information asymmetry and limit opportunities for data manipulation.

By positioning blockchain as a foundational digital infrastructure for sustainability governance, the chapter clarifies its analytical priority relative to complementary technologies such as FinTech and artificial intelligence. The chapter concludes with practical implications for policymakers, regulators, and firms seeking to design credible sustainability frameworks, while highlighting avenues for future research on scalability, regulatory integration, and adoption across diverse economic contexts.

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1. Greenwashing From the Perspective of Sustainable Economic Growth

The concept of sustainability dates to the eighteenth century with the introduction of "sustainable yield" in forestry for responsible resource management. However, "sustainable development" rose to prominence as a central theme in international political and social. In response to this paradigm shift, companies have undertaken a diverse range of environmental initiatives, including participation in voluntary government programs, environmental innovations, environmental pay policies, the use of green labels and trademarks, and the adoption of various environmental management systems. Furthermore, firms communicate their sustainability efforts primarily to balance the three pillars of sustainability, which include environmental, social, and economic dimensions. Businesses have been producing sustainability reports and practices since the mid-1990s, and these are gradually taking the place of more conventional ways of conveying corporate social responsibility (CSR) (García-Rivas et al., 2023, p. 1). Recent practices have brought attention to the significance of Environmental, Social, and Governance (ESG) performance, showing that non-financial success based on ESG elements has a beneficial influence on business sustainability. Barko et al. (2022, P. 1) has been argued that companies neglecting environmental, social, and governance aspects are likely to engage in unsustainable management, thereby increasing their risk. ESG frameworks help measure and quantify social initiatives and are considered tools for controlling sustainability practices. Determine and report the degree to which companies convey a strong (symbolic) ESG focus without real (substantial) ESG participation, given the open and ambiguous nature of sustainability. Information asymmetry results from the lack of reviews for CSR reports and mandated disclosure standards, which keeps stakeholders from verifying companies' statements and gives them carte blanche to participate in corporate misconduct (Breuer et al., 2024, p. 78).

Chapter Objectives

- Identify causes of corporate greenwashing.
- Explain how blockchain's transparency and immutability can reduce greenwashing.
- Provide tools for critically assessing sustainability claims and applying digital solutions for responsible corporate practices.

The origins of the term "greenwashing" The origins of the term "greenwashing" are frequently attributed to journalist and environmental activist Jay Westerveld in 1986 (Spaniol et al., 2024, p. 2). According to

Webster's New Millennium Dictionary of English, greenwash is defined as the "practice of promoting environmentally friendly programs to deflect attention from an organization's environmentally unfriendly or less savory activities" (Merriam, 2024). The Oxford English Dictionary defines "greenwashing" as an attempt by a corporation or organization to give the impression that it cares about the environment, even when the nature of its operations is really harmful to the environment (Oxford, 2024). This definition has been well-received by various scholars, such as Mitchell & Ramey (2010, p. 41) and Ramus & Montiel (2005, p. 377). Additionally, Chen & Chang (2013, p. 489) embraced the term "greenwashing," which is defined by Greenpeace as "the act of misleading customers and investors concerning a firm's environmental policies or the positive environmental impact of commodities". Corporate sustainability initiatives are often met with skepticism, particularly when there is a perceived disconnect between rhetoric and action. When businesses have a low level of environmental legitimacy, they might pledge to carry out environmental practices but not really mean to follow through, which would separate their sustainability reporting from their commitment to sustainability (Gull et al., 2023, p. 3958). In a comparable context, Delmas & Burbano (2011, P. 67) claimed that greenwashing happens when a corporation has poor environmental performance but excellent communication. These companies give a false impression. Silent corporations do not provide information about their environmental performance. In contrast, chatty firms utilize publicity and marketing strategies to communicate favourably about their dedication to sustainability.

2. Why Do Firms Engage in Greenwashing?

Previous research has identified various motivations for greenwashing. For instance, Horiuchi et al. (2009, P. 9) proposed five primary elements that encourage firms to engage in greenwashing: expanding customer demand for green goods, improving environmentally friendly product sales, the resilience of green demand during economic downturns, national economic policies prioritizing environmentally-oriented industries, and a lax greenwashing surveillance framework. Another study differentiates these motivations into external environmental and internal organizational causes (Lyon & Montgomery, 2015, p. 13). The motivations of greenwashing are defined as external, organizational, and individual (Delmas & Burbano, 2011, p. 68). External reasons involve influences from nonmarket players, including regulators and Non-Government Organizations (NGOs), and market actors, such as customer preferences, investment expectations, and competitive strategies.

2.1. External Non-Market Factors

A significant driver of greenwashing is the uncertain regulatory environment. Weak or ambiguous environmental regulations create loopholes that companies exploit to make unsubstantiated environmental claims. Research indicates that greenwashing is more widespread among enterprises facing minimal political scrutiny at the state level and those less reliant on regional and national regulatory bodies (Delmas & Montes-Sancho, 2010, p. 588). Additionally, firms headquartered in countries with weak activist scrutiny and relative isolation from global influences are likelier to engage in greenwashing (Marquis et al., 2016, p. 1). The absence of standardized definitions for key terms such as "sustainable" or "eco-friendly" facilitates subjective interpretations and deceptive marketing tactics (Hsu, 2011). Moreover, regulations that emphasize specific processes rather than overall environmental impact enable companies to highlight certain practices while neglecting the broader footprint of their operations.

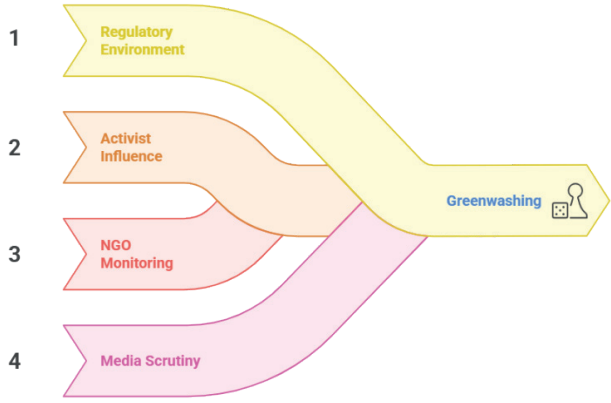

Figure 1- Non-Market External Greenwashing Drivers (Delmas & Burbano, 2011; Lyon & Montgomery, 2015; Marquis et al., 2016).

Activists, NGOs, and the media pose a danger of public disclosure for greenwashing, most likely discouraging some corporations from making overstated environmental claims (Delmas & Burbano, 2011, p. 71). Activist groups and NGOs can utilize negative media attention to expose environmentally detrimental practices of companies. Consequently, companies may resort to misleading environmental claims to deflect criticism and enhance their public image, despite lacking substantive operational changes. Although the external environment has a substantial influence on greenwashing actions, new evidence shows that the emergence of social media adds an extra aspect

to this interaction. Social media facilitates the detection and punishment of greenwashing by activists, potentially curbing such practices and influencing communication strategies among firms (Lyon & Montgomery, 2013, p. 14).

2.2. External Market Factors

Market factors significantly influence the prevalence of greenwashing. Consumer preferences, investor expectations, and competitive tactics collectively exert pressures that incentivize companies to mislead stakeholders regarding their environmental practices. The increasing focus on sustainability among consumers can be a double-edged sword (Zhu et al., 2012, p. 26). While it encourages companies to adopt genuine environmental practices, it also fosters an environment susceptible to greenwashing. According to Gatti et al. (2021, P. 229) People are less likely to invest in organizations that falsify promises and participate in manipulative activities than those who selectively reveal information or mask misbehaviors by emphasizing good practices.

Figure 2- External Market Factors (Delmas & Burbano, 2011).

Industry-specific competitive pressures might contribute to greenwashing. Organizations prefer to compare themselves to enterprises in their area that people perceive as more trustworthy or effective, and investigation indicates that this also extends to green practice implementation (Delmas & Toffel, 2008, p. 1049). This indicates that some companies may be speaking about alleged green practices to avoid falling behind competitors who have already begun to do so.

2.3. Organizational Factors

Internal organizational dynamics significantly contribute to greenwashing practices. Mediating factors at the organizational level include company

features, incentive structures, ethical atmosphere, intra-firm interaction performance, and organizational inertia (Delmas & Burbano, 2011, p. 72). Larger, well-known brands tend to attract greater public scrutiny, prompting caution in making greenwashing claims. Similarly, industries with a history of poor environmental practices, such as oil and utilities, face heightened pressure from NGOs and activists, potentially leading to greenwashing as a defensive strategy. Profitability is also influential; firms with higher margins can better absorb reputational damage or fines for greenwashing compared to less profitable competitors. The financial capability of a firm, reflected in market size and profitability, affects its ability to implement ESG improvements and influences its ESG performance communication (Delmas & Burbano, 2011, p. 72). Furthermore, research has observed a positive and statistically significant correlation between the size of an organization's board and its greenwashing score (Gidage et al., 2024, p. 21861). Additionally, a firm's lifecycle stage impacts its propensity for greenwashing. Younger, growing firms might value short-term advantages above long-term environmental sustainability, thus resorting to greenwashing.

Ethical incentives are the extent to which ethical conduct is rewarded, and inappropriate conduct is penalized (Treviño et al., 1998, p. 452). As a result, corporate incentives and ethical contexts can predict a company's moral conduct. Greenwashing, an instance of immoral conduct, is more inclined to occur in brown firms with greedy, rather than benevolent or principled ethical attitudes (Delmas & Burbano, 2011, p. 74). The hypothesized moderating impact of loyalty to authority and ethical incentives on greenwashing was confirmed (Blome et al., 2017, p. 339). Thus, the setup of sustainable goods and supplier evaluation instruments should precede the application of ethical incentives. This allows an organization to acquire experience in using green practices and produce learning effects.

Organizational inertia results from excessive stability, leading to a slowdown in product manufacturing, technological development, and business management (Huang et al., 2013, p. 996). The speed at which an enterprise responds to environmental changes reflects the extent of its organizational inertia (Mikalef et al., 2021, p. 2). Higher levels of organizational inertia hinder enterprises from promptly adjusting their structures, allocating sufficient resources, and undertaking green innovation projects. This inertia is more prevalent in larger, older firms compared to smaller, newer ones (Delmas & Burbano, 2011, p. 74). Consequently, inertia impedes a firm's ability to adapt to evolving environmental regulations and consumer preferences for sustainability, potentially leading to the persistence of greenwashing practices to appear environmentally conscious despite outdated internal practices. High

inertia restricts a firm's capacity to allocate resources toward genuine green initiatives, often diverting them to maintain existing, potentially polluting operations. Thus, greenwashing may emerge as a more "cost-effective" strategy to project a sustainable image.

Figure 3- Organizational Factors (Delmas & Burbano, 2011).

Internal transmissions of information inside a business frequently become resistant or difficult to get, and inefficient internal transfer of knowledge can assist in explaining corporate behavior such as less innovation (Szulanski, 1996, p. 27). Knowledge transfer efforts in organizations might fail for a variety of reasons, including competitive intent and a lack of staff incentive to share information (Spraggon & Bodolica, 2012, p. 1275). Genuine environmental gains may be overshadowed by superficial greenwashing claims in the absence of good communication between product development, manufacturing, and marketing teams. For example, a marketing team may exaggerate a product's recycled content owing to a lack of clear communication between the purchasing and packaging departments.

2.4. Individual Factors

In addition to organizational issues, personal decision-making processes contribute to greenwashing. Psychological research, behavioural decision theory, and behavioural economics suggest that under circumstances involving ambiguity and restricted or incomplete knowledge, habits like limited decision construction, hyperbolic intertemporal discounting, and a positive bias grow more prominent which is frequently alluded to as restricted reasoning (Kahneman, 2003, p. 1468). Bounded rationality can intensify optimism bias by causing individuals to emphasize positive environmental information while minimizing or ignoring negative information. This can result in a skewed perception within departments, making greenwashing claims appear more credible internally, even if they are misleading to external audiences. Research

indicates that People are more likely to alter their opinions when the new knowledge provides pleasant news rather than negative news (Garrett & Sharot, 2017, p. 16). Consequently, departments may readily accept optimistic greenwashing claims from colleagues, despite contradictory underlying data. Optimism bias, defined as the tendency to hold unrealistically positive beliefs about the future, is driven by positively biased belief updating (Kube et al., 2024, p. 177). This bias manifests in three major ways: overly favorable self-evaluation, undue optimism about future occurrences and schedules, and a sense of control (Taylor & Brown, 1988, p. 199). Optimism bias can lead managers and employees to overestimate the environmental benefits of existing practices or planned initiatives, resulting in greenwashing as a means to communicate these overly optimistic assessments to stakeholders, even if the evidence does not fully support them.

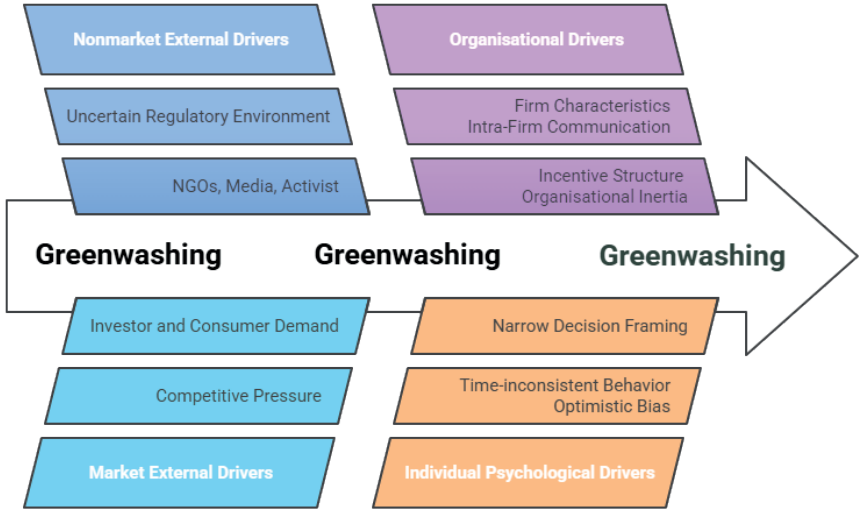

Figure 4- Greenwashing Drivers (Delmas & Burbano, 2011).

Hyperbolic discounting refers to a preference for immediate high returns and a declining rate of time preference (Thaler, 1981, p. 202). Managers driven by hyperbolic discounting could concentrate on short-term financial benefits above long-term sustainability initiatives. This can result in greenwashing, as companies seek to project an image of environmental responsibility while postponing or neglecting costly green initiatives. The hyperbolic discounting utility function has been applied to various issues, including growth, self-regulation, information acquisition, procrastination, and investment in human capital (Laibson, 1997, p. 443). Hyperbolic discounting can lead to dynamic

inconsistency, wherein decision-makers possess good long-term intentions but struggle to resist short-term temptations. Anticipating future environmental responsibility, firm leaders may initially choose green communication but later succumb to short-term pressures and resort to greenwashing (Delmas & Burbano, 2011, p. 76).

3. Solutions to Greenwashing: Blockchain Technology

Recent scholarly investigations have examined the influence of digital transformation (DT) on corporate greenwashing behavior. Multiple studies have converged on the finding that DT significantly curbs greenwashing practices, encompassing those related to ESG disclosures through divers mechanisms, such as enhancing internal control, alleviating financing constraints, improving information transparency, and fostering green technology innovation (Z. Li et al., 2024; Lu et al., 2023; Sun et al., 2023; Wang et al., 2024). Furthermore, heightened investor attention, both from retail and institutional investors, amplifies the suppressive effect of DT on ESG greenwashing (Sun et al., 2023).

Blockchain, FinTech, and Artificial Intelligence (AI) together form a powerful trio in combating greenwashing by enhancing transparency, accountability, and efficiency in corporate sustainability efforts. FinTech solutions, particularly in sustainable finance, leverage blockchain to ensure that green investments are tracked and verified, allowing investors to make informed decisions based on verifiable environmental performance. AI further strengthens this ecosystem by automating the analysis of vast amounts of corporate data, detecting discrepancies, and identifying patterns of greenwashing. Combined, these technologies create an integrated system where environmental claims can be verified, green investments are accountable, and any misrepresentation of sustainability practices is swiftly detected and addressed.

From an institutional economics perspective, greenwashing arises from information asymmetry between firms and stakeholders, in which firms possess superior knowledge of their true environmental performance and can strategically distort disclosures. According to signaling theory, sustainability claims function as signals intended to convey credibility; however, in the absence of credible verification mechanisms, these signals become susceptible to manipulation and opportunistic behavior. While AI and FinTech offer valuable analytical and financial tools for sustainability monitoring, this chapter prioritizes blockchain technology due to its structural capacity to directly address the root causes of greenwashing, particularly data manipulation, information asymmetry, and weak verification mechanisms. AI primarily functions as a detection and prediction tool, relying on the quality and integrity

of existing data, which remain vulnerable to strategic misreporting. In contrast, blockchain establishes a tamper-proof data infrastructure that ensures ex ante credibility rather than ex post correction. Therefore, blockchain is treated in this chapter as a foundational transparency and governance mechanism upon which other digital technologies can effectively operate.

3.1. Characteristics and Applications of Blockchain Technology

Blockchain is a decentralized and distributed ledger technology that facilitates the secure, transparent, and immutable recording of transactions within a peer-to-peer network. Each transaction is incorporated into blocks, which are cryptographically linked to create a chain, ensuring that any attempt to alter or tamper with data necessitates the modification of all subsequent blocks. This inherent security and transparency are attained through consensus mechanisms such as Proof of Work (PoW) or Proof of Stake (PoS), wherein nodes distributed across the network validate transactions without the necessity of a central authority. Consequently, blockchain technology presents a suitable framework for CSR reporting (Sarajoti et al., 2022, p. 1). The decentralized nature of blockchain mitigates the risk of single points of failure, thereby offering potential applications extending beyond cryptocurrencies, encompassing supply chain management, healthcare, and environmental sustainability initiatives. Furthermore, blockchain technology facilitates the tracking of investments, registers exchanges, and establishes a transparent methodology for managing all documentation requisite for business operations (Jain et al., 2020, p. 544). It also fosters relationships between investors and managers, thereby mitigating agency costs within a firm while concurrently augmenting trust between these stakeholders (Elst & Lafarre, 2017, p. 25). For further clarification, the primary characteristics of Distributed Ledger Technology (DLT) can be identified by referencing the attributes delineated in Table 1.

Table 1- Characteristics of Blockchain.

Attributes	Description
Public	The transactions on the system are accessible to everybody and are accessible for monitoring.
Shared	The ledger is distributed across multiple nodes that are often interconnected over the internet.
Accountability	Blockchains remove principal-agent separation and provide responsibility without explaining or defending actions utilizing consensus procedures and incentive alignment.
Transparency	Blockchain is transparent in capturing and modifying data since it verifies and authenticates operations. The ledger cannot contain fraudulent transactions from other parties or harmful users.
Permissioned	In order to write operations to the network, one must be accepted, which means that they have been granted the ability to submit transactions.
Autonomy	The primary goal of blockchain technology is to transfer confidence from a single centralised authority to a decentralised network of participants.
Immutability	Records are permanently kept in blocks and cannot be changed until there is an attempt to modify them.

Source: (Azevedo et al., 2023; Mulligan et al., 2024; Rahman et al., 2022)

3.2. Path Forward of Blockchain and Environmental Concerns

Although blockchain technology offers numerous benefits, such as enhanced transparency, security, and decentralization, it also presents significant drawbacks, particularly concerning environmental aspects. Consequently, many studies, such as (Schinckus, 2020, p. 5), advocate for more inquiry into the sustainability of blockchain technology. The energy consumption required to power blockchain networks, especially those using PoW consensus mechanisms, is immense. Bitcoin and Ethereum, for example, have been criticized for their high carbon footprints, raising concerns about the sustainability of technology itself. Mining activities in PoW blockchains contribute to significant greenhouse gas emissions, counteracting efforts to mitigate climate change. Some newer blockchain platforms, like those using PoS or other consensus mechanisms, are more energy-efficient, but the environmental debate around blockchain's impact remains ongoing. Thus, while blockchain holds promises for addressing sustainability and preventing greenwashing, its environmental footprint poses a critical challenge that must be addressed for it to be fully aligned with sustainable goals.

A notable case for blockchain technology lies in the enhancement of transparency in carbon footprint tracking. Blockchain can verify the accuracy of sustainability claims, thereby mitigating the risk of greenwashing by furnishing an auditable and trustworthy record of environmental impacts. The traceability, trustworthiness, synchronized transactions, and cost-effectiveness inherent to blockchain technology render it a preferable alternative to conventional corporate practices for promoting ecological sustainability (Mawrides et al., 2025, p. 5). The inherent data traceability and immutability characteristic of blockchain technology significantly hinder attempts to conceal or falsify information. Moreover, blockchain also empowers firms to monitor their waste (Kouhizadeh & Sarkis, 2018, p. 10), thereby facilitating recycling, reuse, or appropriate disposal of such waste. The utilization of smart contracts within blockchain technology addresses the issue of inconsistent information by mandating consensus from all participants prior to transaction execution. This ensures symmetry between upstream and downstream partners, while concurrently preventing corruption and errors (Venkatesh et al., 2020, p. 2). The past performance of supply chain participants, encompassing metrics such as on-time delivery or payments, can be recorded on the blockchain to foster stakeholder confidence and cooperation.

Blockchain technology demonstrates significant potential in mitigating ESG greenwashing by enhancing transparency and ensuring data integrity within sustainability reporting. Research suggests that blockchain-based information systems can offer superior protection against perceived greenwashing compared to conventional certification methods (Nygaard & Silkoset, 2023, p. 3801). The utilization of smart contracts within blockchain technology can streamline and validate ESG data collection and management processes (Richard et al., 2023, p. 104). The proposed integration of blockchain with Life Cycle Assessment (LCA) systems demonstrates the potential for automating the cross-validation of ESG disclosures across entire value chains, thereby enabling more reliable and comprehensive reporting (Jiang et al., 2022, p. 13).

3.3. Practical Implications of Blockchain in ESG Reporting

Numerous studies have consistently explored blockchain-based approaches to improving ESG reporting and mitigating greenwashing, employing. For instance, Jiang et al. (2022, p. 13) integrated Internet of Things (IoT) devices with blockchain to collect real-time ESG data throughout a product's life cycle. The data, recorded on the blockchain, guarantees immutability and transparency, while smart contracts autonomously verify data sources and flag discrepancies. This process effectively aids in detecting and preventing greenwashing. Similarly, Wu et al. (2022, p. 2) proposed a consortium

blockchain platform for ESG reporting, specifically targeting the Hong Kong apparel industry. By automating data collection and improving transparency, their system addresses issues such as manual reporting and data sharing reluctance. They argue that their platform enhances the credibility of ESG reporting through incentivizing high-quality disclosures, though they call for empirical studies to assess its effectiveness in practice. Building on these approaches, Miranda et al. (2023, p. 12) adopted a design science research methodology to develop a blockchain-based solution known as ESG Token. This system is designed to improve transparency, security, availability, and auditability in ESG reporting. Moreover, the ESG Token creates immutable records of social investments, while also verifying user identities, thereby minimizing the risk of greenwashing. This solution emphasizes the secure and reliable management of ESG data, making it a robust tool for enhancing accountability in ESG reporting.

In contrast, Shahzad et al. (2023, p. 150) employed quantitative techniques, such as quantile cross-spectral coherency and connectedness, to explore how blockchain affects ESG investments under different market conditions. Their results suggest that blockchain's influence on ESG investments is more significant during bullish market conditions. However, their study was limited by its focus on a small range of blockchain platforms and ESG indices, thereby highlighting the need for broader research across different economic environments. Focusing on transparency and traceability, Sanka et al. (2021, p. 197) and Alkhateeb et al. (2022, p. 1) both emphasize blockchain's decentralized nature as a solution to reduce the potential for data manipulation. They argue that these characteristics improve the reliability of ESG claims and complicate greenwashing efforts. Additionally, Alkhateeb et al. (2022, p. 13) suggested integrating blockchain with AI to further enhance ESG reporting, while addressing concerns related to energy efficiency. Similarly, Rahman et al. (2022, p. 73) also focus on blockchain's security features. By combining blockchain with Software-Defined Networking (SDN), they aim to improve privacy and security in ESG reporting.

In a related manner, Tyma et al. (2022, p. 1643) explored the notion of accountability in ESG reporting by examining how blockchain's decentralized structure can enhance transparency and prevent data manipulation. Their study shows that public and consortium blockchains can make it more difficult for companies to misrepresent ESG performance, thus reducing greenwashing opportunities. Moreover, S. Li et al. (2024, p. 1) employed a game-theoretical model to examine blockchain's role in China's green finance sector. Their findings indicate that blockchain can reduce regulatory intensity by improving information transparency and verification capabilities, particularly in relation

to greenwashing. Nonetheless, they acknowledge the need for future research to explore blockchain's application in other governance frameworks and regulatory environments. On the other hand, Pizzi et al. (2022, p. 545) utilized a case study of Banca Mediolanum's adoption of Ethereum-based non-financial reporting to analyze blockchain's potential for reducing information asymmetry between organizations and stakeholders. This study highlights the practical implications of blockchain in real-world ESG reporting, offering a compelling case for its use in improving transparency. Similarly, Xu & Tian (2023, p. 27457) developed an organizational model that uses blockchain to track green credit in the banking sector. Their model emphasizes that blockchain penalties are stronger disincentives to enterprise default or greenwashing, while banks are more sensitive to changes in blockchain costs.

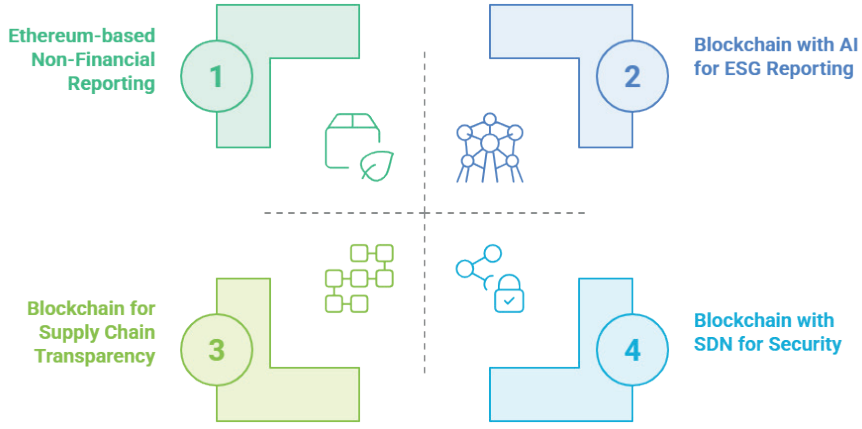

Figure 5- Blockchain Use Cases in ESG Reporting (Alkhateeb et al., 2022; Shahzad et al., 2023; Wu et al., 2022)

Furthermore, Nygaard & Silkoset (2023, p. 3801) employed structural equation modeling to analyze how blockchain impacts consumer trust in the sustainable food sector. Their results reveal that blockchain information significantlymore than certification systems safeguards consumers against the threat of greenwashing. However, the authors recognize limitations, particularly the cross-sectional nature of their study, and suggest expanding future research to other industries.

Despite the growing recognition of blockchain's potential to enhance ESG reporting and mitigate greenwashing, much of the existing research is concentrated on developed economies and technologically advanced sectors.

There is a significant lack of studies exploring how blockchain can be applied to ESG reporting in developing regions, particularly those with underdeveloped financial infrastructures and limited regulatory oversight. Furthermore, the challenges of scalability, energy consumption, and integration with local governance systems in these regions have not been adequately examined. This thesis aims to address these gaps by investigating how blockchain technology can be tailored to support ESG transparency in developing markets, while also developing governance mechanisms that ensure authentic ESG reporting amidst the socio-economic and environmental challenges specific to these regions.

4. Results

This chapter explores the potential of blockchain technology to mitigate greenwashing across various sectors. Through a comprehensive review of existing literature and practical case studies from diverse industries, we have highlighted the key characteristics of blockchain that contribute to combating greenwashing. The analysis presented in this chapter strongly supports the overarching argument that blockchain technology offers a robust and innovative solution to address the pervasive issue of greenwashing. The findings, derived from a synthesis of theoretical frameworks and empirical evidence, demonstrate how the inherent characteristics of blockchain directly counter the mechanisms by which greenwashing is perpetrated.

Firstly, the transparency and immutability afforded by blockchain are paramount in fostering genuine environmental accountability. As highlighted by Wu et al. (2022), the ability of consortium blockchains to facilitate smart ESG reporting with token-based incentives underscores the potential for verifiable and tamper-proof data. This aligns with our observation that blockchain's distributed ledger technology creates an unalterable record of sustainability claims, making it exceedingly difficult for companies to manipulate or misrepresent their environmental performance. This stands in stark contrast to traditional reporting mechanisms, which are often susceptible to selective disclosure and data manipulation, as implicitly acknowledged by the rise of greenwashing concerns. The studies reviewed, such as those focusing on supply chain transparency (e.g., Xu & Tian, 2023, regarding blockchain-enabled enterprise bleaching green regulation), consistently demonstrate that blockchain can provide an end-to-end audit trail for products and processes, from raw material sourcing to consumer delivery. This level of verifiable information allows stakeholders, including consumers, investors, and regulators, to independently assess the veracity of green claims, thereby

significantly reducing the information asymmetry that greenwashing thrives upon.

Secondly, the decentralized nature of blockchain platforms plays a critical role in enhancing trust and reducing the reliance on centralized intermediaries, which can sometimes be complicit or lack the capacity to adequately verify environmental claims. The chapter's exploration of various industrial applications revealed that blockchain-based solutions empower multiple stakeholders to participate in the validation process, thereby distributing accountability and reducing the risk of single points of failure or corruption. This resonates with the findings of Barko et al. (2022), who argued that companies neglecting environmental, social, and governance aspects face significant risks. Blockchain, by democratizing access to verified sustainability data, enables a more collective oversight mechanism. For instance, in agricultural supply chains, blockchain can track certifications and sustainable farming practices directly from the source, as opposed to relying solely on a company's self-reported data, which can be prone to "greenwashing by digitization" as explored by Wang et al. (2024).

Thirdly, the traceability and verifiability inherent in blockchain technology are crucial for authenticating environmental initiatives. The examination of practical applications showed how blockchain can meticulously track the lifecycle of products, the origin of sustainable materials, and the impact of environmental projects. This capability directly addresses the challenge of "bleaching green," where companies might superficially present themselves as environmentally friendly without substantive action. By providing verifiable evidence of environmental performance, blockchain enables a shift from mere claims to demonstrable proof. This is particularly relevant in areas like carbon credits, where blockchain can ensure that each credit corresponds to a real, verified emission reduction and is not double-counted, a problem that has historically plagued these markets. The ability to link specific environmental actions to transparent, immutable records fosters genuine accountability and discourages deceptive practices.

In summation, the findings of this chapter, supported by the referenced literature, unequivocally establish that blockchain technology offers a powerful antidote to greenwashing. Its core characteristics – transparency, immutability, decentralization, traceability, and verifiability – directly address the systemic vulnerabilities that allow greenwashing to flourish. The integration of blockchain into environmental reporting and supply chain management not only enhances the credibility of sustainability claims but also empowers

stakeholders with the information needed to make informed decisions and hold corporations accountable for their environmental impact.

5. Conclusion

Based on the comprehensive analysis presented in this chapter and the supporting evidence from the literature, we offer the following recommendations for academics and policymakers across various sectors to effectively mitigate greenwashing practices:

Develop Standardized Blockchain Architectures for ESG Reporting: Academic researchers should focus on developing standardized, open source blockchain architectures specifically designed for ESG reporting. This includes defining common data schemas, smart contract templates for sustainability metrics (e.g., carbon emissions, water usage, waste reduction), and interoperability protocols. This standardization would facilitate widespread adoption and ensure comparability of sustainability data across different companies and industries. Future research could build upon the work of Wu et al. (2022) to explore the optimal design of token-based incentive mechanisms within these standardized platforms.

Conduct Empirical Studies on Blockchain's Impact on Greenwashing Perception and Trust: While theoretical arguments for blockchain's anti-greenwashing potential are strong, more empirical research is needed to quantify its actual impact on consumer perception, investor trust, and regulatory effectiveness. Academics should design studies that measure changes in public trust in corporate sustainability claims after the implementation of blockchain-verified reporting, perhaps using methodologies akin to Wimbush et al. (1997) in examining ethical climate and behavior but applied to digital transparency. Longitudinal studies tracking the adoption of blockchain in specific industries and correlating it with reductions in documented greenwashing incidents would be particularly valuable.

Explore the Interplay of Blockchain with Other Emerging Technologies: Research should investigate how blockchain can be synergistically combined with other advanced technologies, such as AI, IoT, and big data analytics, to further enhance the fight against greenwashing. For instance, AI could be used to analyze blockchain-verified data for anomalies or patterns indicative of greenwashing, while IoT devices could provide real-time environmental data directly to the blockchain. This interdisciplinary approach could lead to more sophisticated and robust greenwashing detection and prevention systems.

Address the Challenges of Blockchain Adoption and Scalability in Sustainability: Academic inquiry should also delve into the practical challenges

of implementing blockchain solutions for sustainability, including scalability issues, energy consumption concerns of certain blockchain protocols, regulatory hurdles, and the need for skilled personnel. Research should propose solutions and best practices to overcome these barriers, ensuring that blockchain-based anti-greenwashing initiatives are both effective and sustainable themselves. This could involve exploring more energy-efficient consensus mechanisms or developing frameworks for phased blockchain integration.

Investigate the Evolution of Greenwashing in a Blockchain-Enabled Environment: As blockchain adoption increases, greenwashing tactics may evolve. Academics should anticipate and research potential new forms of blockchain-enabled greenwashing or sophisticated attempts to circumvent transparency. This proactive research, building on insights from Wang et al. (2024) regarding greening by digitization, will be crucial for developing countermeasures and ensuring the long-term efficacy of blockchain as an anti-greenwashing tool.

Develop Clear Regulatory Frameworks for Blockchain-Based Sustainability Reporting: Governments and regulatory bodies should prioritize the development of clear, technology-agnostic regulatory frameworks that recognize and encourage the use of blockchain for sustainability reporting. These frameworks should define standards for data integrity, security, and interoperability of blockchain-based environmental claims. This would provide legal certainty for companies adopting these technologies and facilitate enforcement against false claims. Drawing lessons from the evolution of financial reporting regulations, similar robust frameworks are needed for ESG.

Incentivize Companies to Adopt Blockchain for Green Claims: Policymakers should introduce incentives for companies to voluntarily adopt blockchain technology for verifying their environmental claims. This could include tax breaks, preferential access to government contracts, or recognition programs for companies demonstrating verifiable sustainability efforts through blockchain. Such incentives would accelerate the adoption rate and create a competitive advantage for genuinely sustainable businesses.

Establish Public-Private Partnerships for Blockchain Piloting and Rollout: Governments should actively foster collaborations between public sector entities, private companies, and blockchain technology providers to pilot and scale up blockchain solutions for combating greenwashing. These partnerships could focus on specific high-risk sectors (e.g., fashion, food, electronics) to demonstrate the effectiveness of blockchain in improving supply chain transparency and reducing misleading environmental claims. This aligns

with the broader push for sustainable development and responsible resource management highlighted in the chapter's introduction.

Invest in Education and Capacity Building: Policymakers should invest in educational programs and capacity-building initiatives to equip regulators, industry professionals, and the general public with the knowledge and skills necessary to understand and utilize blockchain technology for sustainability verification. This includes training on blockchain fundamentals, data interpretation, and the implications for greenwashing detection. A well-informed ecosystem is critical for effective oversight and enforcement.

Promote International Collaboration and Interoperability: Greenwashing is a global issue, and its mitigation requires international cooperation. Policymakers should work towards establishing international standards and protocols for blockchain-based sustainability data to ensure interoperability across borders and supply chains. This would enable seamless verification of environmental claims for multinational corporations and prevent companies from exploiting regulatory arbitrage. This global perspective is crucial for effective green regulation banking evolution.

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