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Integrating Blockchain and Artificial Intelligence to Counter Greenwashing in ESG Investing: A Framework with Special Reference to India

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Abstract

The global surge in Environmental, Social, and Governance (ESG) investing—managing over $30 trillion by 2023—has been shadowed by widespread greenwashing, where firms exaggerate or falsify sustainability credentials. This study addresses the critical problems of fragmented data, lack of transparency, and over-reliance on self-reported corporate disclosures. The primary objective is to design and conceptually validate a synergistic framework combining blockchain's immutable ledger with artificial intelligence (AI) for real-time, tamper-proof ESG verification. The proposed architecture integrates IoT sensors, corporate systems, and alternative data; stores verified information on a permissioned blockchain; and applies natural language processing, anomaly detection, and continuous monitoring through AI. Key findings indicate that the framework enhances data integrity, automates compliance via smart contracts, and significantly reduces information asymmetry. Focusing on the Indian context—where ESG mutual funds exceeded ₹12,300 crore in 2024 and regulators like SEBI have introduced mandatory BRSR reporting and stricter green bond rules—the study identifies both opportunities and implementation challenges. The paper offers actionable recommendations for policymakers, financial institutions, and technology providers to foster trustworthy sustainable finance.

Keywords: Greenwashing; ESG Investing; Blockchain; Artificial Intelligence; Sustainable Finance; India; SEBI.

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Introduction

The Rise of Sustainable Finance and ESG Investing

Sustainable finance integrates environmental, social, and governance factors into investment decisions to promote long-term value creation. Although socially responsible investing emerged in the 1960s, the formal ESG framework gained momentum after the United Nations' 2004 report "Who Cares Wins" (International Banking Federation [IBF], 2023). By 2023, global ESG-linked assets under management had surpassed $30 trillion, driven by increasing climate awareness and regulatory pressure.

In India, ESG investing has grown rapidly. As of early 2024, ESG-focused mutual funds managed assets worth over ₹12,300 crore, reflecting a strong shift toward ethical portfolios (Bain & Company, 2025). Impact enterprises attracted $4.96 billion in ESG funding across 438 ventures in 2024, with projections suggesting $10-12 billion annually by 2030, potentially creating 150 "green unicorns" (Impact Investors Council [IIC], 2024). The Indian startup ecosystem, comprising 195,065 DPIIT-recognized ventures, is increasingly leveraging sustainability-linked instruments to obtain a 25% valuation premium (McKinsey & Company, 2025).

The Greenwashing Problem: Definitions and Consequences

Greenwashing occurs when organizations present misleading or exaggerated environmental and social claims to attract ESG-conscious capital. Common forms include selective disclosure, vague terminology, and favourable metric selection. The consequences are severe: misallocation of capital, investor distrust, regulatory penalties, and reputational harm. Globally, 42% of companies have been found to make false or exaggerated claims (India CSR, 2023).

In India, greenwashing is equally concerning. A 2023 Morningstar analysis found that only 38% of Indian companies reporting ESG data met global sustainability benchmarks (Morningstar, 2023). A PwC India survey (2024) revealed that 68% of institutional investors question the credibility of corporate ESG claims. KPMG (2025) reported that 55% of Indian start-ups face "greenwashing" risks.

Notable Indian cases include:

- Adani Group (2023): Following a Hindenburg Research report, three Adani companies were removed from the UN-backed Science Based Targets initiative (SBTi) for allegedly expanding fossil fuel operations while claiming Paris Agreement alignment (Renewable Watch Research, 2025).
- Gensol and BluSmart (2025): SEBI launched investigations into financial irregularities in ESG investments, prompting experts to call for independent audits and stricter penalties (Securities and Exchange Board of India [SEBI], 2025a).
- SEBI's cited examples: Whole-Time Member Amarjeet Singh highlighted a manufacturing firm that claimed no significant environmental impact despite facing environmental litigation, and an auto company that reported recycled material usage without verifiable data (India CSR, 2023).

Technology as an Enabler: Fintech, Blockchain, and AI

Financial technology (fintech) has digitized operations and enabled real-time data access. Artificial intelligence (AI) is already used in fraud detection and diagnostics; it can analyze large ESG datasets from sensors, reports, and external databases to detect anomalies. Blockchain provides a decentralized, immutable ledger that prevents data manipulation. Together, these technologies can transform ESG reporting from a static, self-declared process into a dynamic, verifiable system (Wikipedia, 2023). In India, the Reserve Bank of India (RBI) has introduced a Regulatory Sandbox with an "On Tap" facility to encourage fintech innovations, including those for green finance (RBI, 2025).

Research Problem and Rationale

The core problem is the lack of transparency, data fragmentation, and reliance on self-reported disclosures, which enable greenwashing. Advanced technologies like AI and blockchain are not yet fully integrated into ESG systems, leading to weak verification and limited real-time monitoring. This study's rationale is to propose a robust, technology-driven framework that enhances transparency, automates verification, and restores trust, with specific attention to the Indian regulatory and market context.

Research Objectives

Primary Objective: To develop and validate a synergistic framework integrating blockchain and AI that systematically prevents greenwashing by ensuring data integrity, transparency, and real-time verification of sustainability claims.

Secondary Objectives:

1. Analyse limitations of current ESG disclosure mechanisms.
2. Map complementary roles of blockchain (immutable storage) and AI (analytics).
3. Design a conceptual framework showing data flow, governance, and stakeholder interactions.

4. Propose mechanisms: tokenization of verified ESG attributes, smart contract compliance.
5. Evaluate the framework via simulated use cases (green bonds, corporate reporting, carbon credits).
6. Identify implementation challenges (scalability, bias, regulatory fragmentation).
7. Provide actionable recommendations for policymakers and financial institutions, with Indian focus.

Scope and Delimitations

This conceptual study focuses on the blockchain-AI framework for greenwashing prevention. It does not include empirical testing with live data but relies on simulated use cases and literature synthesis. The Indian context is examined through regulatory analysis and market data.

Paper Structure

Section 2 reviews literature on ESG standards, greenwashing typologies, blockchain and AI applications, and research gaps. Section 3 describes the methodology. Section 4 presents the synergistic framework. Section 5 evaluates the framework through use cases, including Indian examples. Section 6 discusses findings, implications, and limitations. Section 7 offers recommendations and future research. Section 8 concludes.

Literature Review

Evolution of ESG Reporting Standards

Major global frameworks include:

- GRI (Global Reporting Initiative): Multi-stakeholder standards for sustainability impacts.
- SASB (Sustainability Accounting Standards Board): Industry-specific, financially material disclosures.
- TCFD (Task Force on Climate-related Financial Disclosures): Four pillars – governance, strategy, risk management, metrics.
- EU Taxonomy: Regulatory classification for environmentally sustainable activities.

Disclosure can be voluntary (company-driven, often inconsistent) or mandatory (regulator-enforced, improving comparability). In India, SEBI has mandated **Business Responsibility and Sustainability Reporting (BRSR)** for the top 1,000 listed companies by 2025, requiring audited disclosures to combat greenwashing (SEBI, 2025b).

Typologies and Evidence of Greenwashing

Greenwashing is classified into:

- Corporate greenwashing: Exaggerating environmental/social performance.
- Financial product greenwashing: Marketing ESG funds that include non-ESG assets.
- Impact washing: Overstating actual social or environmental outcomes.

Global empirical evidence: In 2023, one in four climates-related ESG incidents involved greenwashing; private companies account for 70% of cases in Europe and North America; the oil and gas sector represents 14% of 2024 incidents (India CSR, 2023). High-profile cases include FIFA (2022 World Cup misleading carbon neutrality), Deutsche Bank's DWS ($25 million penalty), Volkswagen ($30 billion emissionsfraud), and H&M (overstated sustainability scores).

Blockchain for Sustainable Finance

Blockchain provides immutable ledgers, provenance tracking, and tokenization of green assets (carbon credits, renewable energy certificates, green bonds). Smart contracts automate compliance by adjusting loan terms based on verified ESG metrics. In India, green bond issuances in the domestic market reached ₹XX crore in the first half of 2025 (Renewable Watch Research, 2025). However, legal recognition of blockchain records remains uncertain in many jurisdictions, including India (Kilaru et al., 2025).

AI Applications in ESG

- Natural Language Processing (NLP): Analyses corporate disclosures, detects vague or misleading language.
- Machine Learning: Anomaly detection and greenwashing risk scoring by identifying unusual patterns.
- Predictive analytics: Forecasts future ESG risks.
- Alternative data: Satellite imagery, IoT sensors, supply chain records for independent verification.

In India, fintech 5.0 solutions integrating AI, blockchain, and quantum computing are enabling green finance and lowering transaction costs (Selvaraj, 2025).

Gaps in Existing Literature

Current research treats ESG reporting, data verification, and risk assessment in isolation. There is a lack of integrated frameworks that combine blockchain's data integrity with AI's analytical power. Moreover, most studies are Western-centric, with limited attention to emerging markets like India, where regulatory environments and adoption barriers differ significantly.

Research Methodology

Research Paradigm

This study adopts a **design science research** paradigm, suitable for developing and evaluating an artifact (the framework) to solve a real-world problem (greenwashing).

Framework Development

The framework was developed through an iterative process:

- Systematic literature synthesis of ESG, blockchain, and AI research;
- Analysis of greenwashing cases and reporting standards (including SEBI's BRSR and ESG debt securities framework);
- Mapping technical capabilities to greenwashing prevention requirements.

Validation Approach

Validation was conducted via case-based evaluation using three simulated scenarios: green bond issuance, corporate ESG reporting, and carbon credit tracking. Indian regulatory requirements (e.g., SEBI's third-party verification mandates) were incorporated.

Data Sources

Secondary data included academic articles, industry reports (Bain, PwC, KPMG), regulatory documents (SEBI, RBI), technical whitepapers (Hyperledger, Ethereum), and global frameworks (GRI, SASB, TCFD).

A Synergistic Framework for Greenwashing Prevention

Core Principles

- Data provenance: Traceability from source.
- Transparency: Open access to verified information.
- Automation: Real-time monitoring via AI and smart contracts.
- Accountability: Verifiable and auditable ESG claims.

Framework Architecture

Data Layer

Collects ESG data from IoT sensors (emissions, energy use), corporate systems (sustainability reports, operational metrics), public records (regulatory filings), and alternative data (satellite imagery, supply chain). AI-driven cleaning removes inconsistencies.

Blockchain Layer

A permissioned blockchain (e.g., Hyperledger Fabric) is chosen for controlled access by authorized participants (companies, regulators, auditors). Immutable storage permanently records verified ESG data. Smart contracts embed ESG criteria to automate verification and reporting. In India, such a layer could align with SEBI's requirement for independent third-party review of green debt securities (SEBI, 2025c).

AI Analytics Layer

- NLP analyzes corporate disclosures (e.g., BRSR reports) to flag vague or unsupported claims.
- Machine learning performs anomaly detection and greenwashing risk scoring.
- Continuous monitoring triggers real-time alerts for inconsistencies.

Stakeholder Interface Layer

Dashboards provide role-specific views for investors, regulators, issuers, and auditors. Tokenized green assets carry embedded metadata (origin, certification, ownership history), ensuring every token is verifiable.

Data Flow and Process

Raw data → AI cleaning → Blockchain storage → AI analysis (NLP, anomaly detection) → Verified ESG ratings & risk scores → Integration with existing reporting cycles (e.g., annual BRSR filings).

Governance and Consensus Mechanisms

Validators verify and approve data before blockchain recording. Auditors provide oversight of smart contracts and compliance. Decentralized identity (DID) authenticates stakeholders. In India, a governance model could involve SEBI, stock exchanges, and empanelled third-party reviewers.

Comparison with Traditional ESG Infrastructure

Feature	**Traditional**	**Proposed Framework**
Data source	Self-reported, periodic	Multi-source, real-time
Storage	Centralized databases	Immutable blockchain
Verification	Manual audits	AI-driven continuous monitoring
Compliance	Periodic, retrospective	Smart contract-based, automated
Transparency	Limited	Full traceability

Evaluation and Use-Case Demonstration

Use Case 1: Green Bond Issuance and Monitoring

Global context: Smart contracts automatically verify that proceeds are allocated to pre-approved green projects using IoT and supply chain data. AI monitors environmental outcomes in real time.

Indian context: In June 2025, SEBI introduced a framework for ESG-labelled debt securities (excluding green bonds), mandating third-party verification for social bonds, sustainability bonds, and sustainability-linked bonds (SEBI, 2025c). Our framework would complement this by providing automated, continuous verification and reducing "purpose-washing" risks.

Use Case 2: Corporate ESG Reporting (BRSR)

Global context: Immutable audit trail of reported metrics. AI anomaly detection flags inconsistencies between reported data and alternative sources.

Indian context: SEBI's BRSR mandate for top 1,000 listed companies requires audited disclosures. Integrating blockchain would create an immutable record of each BRSR submission, while AI could cross-verify claims against satellite-derived environmental data (e.g., flaring intensity at industrial plants) or employee sentiment from social media, as demonstrated in recent Indian research (Kilaru et al., 2025).

Use Case 3: Carbon Credit Tracking

Global context: Blockchain tokenization ensures unique, traceable credits. AI verifies additionality by analysing historical emissions and project impact.

Indian context: India's carbon market is evolving. The framework could prevent double-counting and fraudulent credits, which is particularly relevant given that 55% of Indian start-ups face greenwashing risks (KPMG, 2025).

Assessment Against Greenwashing Prevention Goals

- Transparency gains: All stakeholders access immutable records.
- Reduction in information asymmetry: Verified data reduces reliance on self-reports.
- Investor trust: Automated, tamper-proof verification increases confidence.

Discussion

How the Synergy Overcomes Standalone Limitations

Blockchain alone ensures data integrity but cannot analyze content. AI alone provides powerful analytics but depends on input data quality. The synergy combines immutable storage with intelligent analysis, enabling real-time verification and risk scoring.

Implications for Stakeholders

- Asset managers: Verified real-time data improves investment decisions.
- Regulators (e.g., SEBI, RBI): Enhanced monitoring and compliance enforcement.
- Standard-setters: Technology-driven systems enable more consistent frameworks.
- Technology providers: Opportunities to design scalable, integrated solutions.

Challenges and Limitations

- Scalability and interoperability: Blockchain networks may struggle with high-volume ESG data; different platforms may not communicate.
- Algorithmic bias and AI explain ability: AI models may inherit biases; lack of explain ability hinders trust.
- Regulatory fragmentation: No uniform ESG/blockchain regulations across jurisdictions. In India, while SEBI has advanced rules, legal recognition of blockchain records as evidence remains uncertain (Kilaru et al., 2025).
- Adoption barriers: High costs, shortage of skilled professionals, and legacy systems. In India, only a fraction of companies has the technical capacity to implement such frameworks.

Comparison with Alternative Approaches

Traditional audits are periodic and manual. Centralized platforms risk data manipulation. Single-technology solutions (blockchain-only or AI-only) are incomplete. The integrated framework offers secure storage, real-time analysis, and automated verification.

Recommendations and Future Research

Recommendations for Policymakers and Regulators

- Globally: Harmonize standards for blockchain-based attestations; legally recognize smart contracts and blockchain records.
- In India: SEBI should consider mandating blockchain-based audit trails for BRSR filings. The proposed dedicated ESG oversight body (Parliamentary Standing Committee recommendation, August 2025) should include technical expertise in AI and blockchain.

Recommendations for Financial Institutions

- Pilot the framework in specific asset classes (e.g., green bonds, carbon credits).
- Invest in data interoperability and upskilling. In India, collaborate with fintech start-ups (e.g., those in RBI's Regulatory Sandbox) to co-develop solutions.

Future Research Directions

- Empirical testing with live ESG data from Indian companies.
- Integration with zero-knowledge proofs for privacy-preserving verification.
- Cross-jurisdictional comparative studies (India vs. EU vs. US).

Conclusion

This study proposed a synergistic blockchain-AI framework to counter greenwashing in ESG investing. By combining immutable data storage with intelligent analytics, the framework ensures data integrity, enables continuous monitoring, and automates compliance. The Indian context—with its rapidly growing ESG market, proactive SEBI regulations, and significant greenwashing risks—provides a compelling case for adoption. While challenges such as scalability, regulatory fragmentation, and adoption barriers remain, coordinated efforts by policymakers, financial institutions, and technology providers can pave the way for trustworthy sustainable finance. Ultimately, every sustainability claim must be traceable, every metric verifiable, and every investment aligned with genuine impact.

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