ESG Standards and Impact Measurement in Cryptocurrency and Digital Financial Systems

Dr. Rachana Goswami*

Assistant Professor, Institution-Jodhpur Institute of Engineering and Technology, JIET Universe, Jodhpur, Rajasthan, India

rachana.goswami@jietjodhpur.ac.in

Abstract: Environmental, social, and governance considerations provide a useful framework for assessing digital finance, but their application to cryptocurrency requires attention to distributed responsibility and uncertain evidence. This article examines how sustainability principles can be adapted to blockchain networks, decentralised finance, and token-based governance. Using a qualitative review of technical documents, sustainability standards, and international regulatory materials, it distinguishes electricity consumption from emissions, access from financial inclusion, and publicly visible transactions from accountable governance. It proposes a measurement framework combining network data with independently verified information about energy sources, user outcomes, and organisational control. Ethereum's transition to proof of stake illustrates the environmental consequences of technical design, while concentrated voting and consumer vulnerability reveal limitations that energy efficiency alone cannot resolve. International developments demonstrate growing attention to disclosure and oversight without establishing a universal cryptocurrency ESG standard. The article concludes that credible assessment requires transparent boundaries, separate indicators for each ESG dimension, proportionate assurance, and effective remedies. Sustainability claims should remain open to verification rather than being treated as guarantees of social benefit or superior investment performance.

Keywords: Environmental Social and Governance Standards, Cryptocurrency, Blockchain, Impact Measurement, Decentralized Finance, Financial Inclusion, Sustainability Disclosure, Accountability

INTRODUCTION

Digital finance has changed how value can be transferred, recorded, and governed. Blockchain networks allow participants to maintain shared records without relying on a single database operator. Smart contracts extend this capacity by executing predefined instructions when specified conditions are met. These features create opportunities for payment services, asset representation, and financial coordination. They also raise a practical question: how should the benefits of digital financial systems be assessed alongside their environmental demands, social consequences, and distribution of power?

ESG offers a starting point because financial performance alone cannot establish whether an activity is responsible. A profitable service may impose environmental costs, expose

inexperienced users to avoidable losses, or concentrate control behind a decentralised identity. Conversely, a technically efficient network may support useful services without receiving an adequate assessment of their social effects. The appropriate object of inquiry is therefore the relationship between technological design, institutional conduct, and observable outcomes.

Cryptocurrency presents distinctive measurement problems. A blockchain protocol, its native asset, a custodial exchange, and an application operating on that blockchain are different units of analysis. Their risks overlap but cannot be combined indiscriminately. A network's electricity estimate does not reveal whether an exchange safeguards customer asset. An application's public transaction history does not establish whether its customers understand liquidation rules. ESG analysis must identify both the activity under assessment and the actors capable of changing it.

This article develops a conceptual framework rather than reporting an empirical test of investment returns. It synthesises foundational blockchain documents, environmental accounting principles, sustainability disclosure standards, and regulatory publications. Its contribution lies in clarifying measurement boundaries and proposing indicators that can be tested in subsequent research. It does not assume that cryptocurrency adoption necessarily produces financial inclusion or that higher ESG scores reliably predict stronger returns. Those propositions require independently collected evidence and appropriately designed comparative studies.

HISTORICAL BACKGROUND

The relationship between sustainability and finance developed before cryptocurrency. Earlier debates about corporate responsibility questioned whether shareholder returns adequately represented business performance when pollution, unsafe employment, and community displacement-imposed costs elsewhere. These concerns encouraged approaches that examined corporate conduct alongside financial accounts. Over time, responsible investment increasingly sought information that could connect such concerns with investment analysis. The historical importance of this shift is that environmental and social consequences became matters for systematic evaluation rather than occasional charitable activity. Digital finance inherits this demand for explanation even where its organisational structures differ from those of conventional companies.

The 2004 report Who Cares Wins helped establish ESG as a recognisable vocabulary for financial markets. It connected environmental, social, and corporate governance issues with the work of financial institutions and investment professionals (United Nations Global Compact, 2004). Its significance was conceptual: investment analysis could consider how wider responsibilities affected long term business prospects. Applying that reasoning to cryptocurrency requires adaptation. A listed corporation can ordinarily identify its board and reporting entity, whereas a distributed protocol may involve developers, validators, foundations, token holders, and service providers. The historical vocabulary remains useful, but its institutional assumptions cannot simply be transferred unchanged.

Environmental accounting developed a parallel concern with consistent measurement. The revised Greenhouse Gas Protocol Corporate Standard distinguished emissions arising from owned operations, purchased energy, and other value chain activities (World Resources Institute & World Business Council for Sustainable Development, 2004). Such boundaries matter because reported reductions can reflect changes in accounting rather than physical improvements. Cryptocurrency introduces additional complications when network infrastructure spans countries and operators. The relevant historical lesson is methodological: an environmental figure becomes meaningful only when its organisational boundary, measurement period, assumptions, and sources are disclosed. A headline estimate without those details cannot support a reliable comparison.

Bitcoin's 2008 white paper proposed a system for electronic payments using cryptographic verification and a distributed transaction history (Nakamoto, 2008). Its proof of work mechanism addressed agreement over transaction ordering through computational competition. The design made resource expenditure part of the network's security arrangements. ESG questions were not the organising purpose of the proposal, but they followed from its implementation. As participation and specialised mining expanded, assessing the resources devoted to network security became increasingly important. This development illustrates how the consequences of a technical architecture can become subjects of public evaluation beyond the problem its original designers intended to solve.

Ethereum's white paper extended the blockchain concept towards a programmable platform for applications and smart contracts (Buterin, 2014). This broadened discussion from transferring a native asset to coordinating more varied economic relationships. Lending

arrangements, exchanges, and collective treasuries could be expressed through software. The change also widened the field of responsibility. A transaction might execute correctly while relying on defective price information or exposing a user to poorly understood risks. Historical developments in programmability therefore made governance and consumer protection central to sustainability analysis. Technical execution could support consistency, but it could not independently determine whether the underlying arrangement was fair.

The development of decentralised finance brought stronger claims about accessibility and reduced dependence on intermediaries. However, the absence of a conventional bank account requirement did not remove the need for connectivity, digital skills, liquidity, and protection against loss. Evidence on digital payments and account ownership provided a broader basis for understanding financial inclusion. The World Bank's 2022 presentation of Global Findex findings associated expanded digital payment use with new opportunities and financial resilience (World Bank, 2022). That evidence concerned financial services broadly; it did not establish equivalent benefits from speculative tokens. Historically, this distinction prevents cryptocurrency narratives from borrowing achievements demonstrated by other financial infrastructures.

Sustainability reporting also became more structured. The Global Reporting Initiative's 2021 Universal Standards strengthened an approach centred on organisational impacts on the economy, environment, and people (Global Reporting Initiative, 2021). In India, SEBI's 2021 BRSR circular established a corporate sustainability reporting framework for covered listed entities (Securities and Exchange Board of India [SEBI], 2021). These developments supplied useful reporting disciplines, including identifying material issues and explaining governance arrangements. They did not create a universal rating system for crypto assets. Their relevance is that reporting increasingly required identifiable responsibilities and consistent disclosures, both of which remain challenging when digital activities operate across organisational and territorial boundaries.

Ethereum's September 2022 transition from proof of work to proof of stake marked an important environmental turning point. The network's documentation describes an electricity reduction of approximately 99.95 percent associated with the Merge (Ethereum Foundation, n.d.). This demonstrates that consensus design can materially change operational energy requirements. It does not establish that every application on the network is socially beneficial

or that all life cycle impacts disappear. The event also illustrates the importance of separating historical estimates from current measurements. Environmental assessment should document which study, baseline, and system boundary underlie a reported reduction rather than treating a widely repeated percentage as a timeless measurement.

International policy developments in 2023 further connected technological activity with institutional responsibility. The Financial Stability Board issued recommendations for crypto asset oversight, while IOSCO addressed market integrity and investor protection in decentralised finance (Financial Stability Board, 2023; International Organization of Securities Commissions [IOSCO], 2023). The European Union adopted MiCA, introducing a dedicated framework that includes environmental disclosure provisions. Alongside these developments, the ISSB issued IFRS S1 and S2 for sustainability related financial information and climate disclosures. These initiatives serve different purposes. Their historical convergence nevertheless shows increasing expectations that digital financial innovation should be accompanied by intelligible disclosures, identifiable accountability, and regulatory cooperation.

By the middle of the present decade, the central question had consequently widened from whether blockchains could support financial exchange to how their wider effects should be governed. This history cautions against technological determinism. Neither distributed record keeping nor corporate reporting automatically delivers sustainability. Each offers tools whose value depends on institutions, incentives, and verification. Understanding this progression helps frame contemporary ESG assessment as an evolving practice of evidence and accountability, rather than a label attached permanently to a particular consensus mechanism.

ENVIRONMENTAL IMPACT AND MEASUREMENT BOUNDARIES

Environmental assessment should begin with total resource demands over a stated period. Electricity consumption and greenhouse gas emissions are related but distinct: the same electricity demand can produce different emissions depending on generation sources and timing. Hardware production, cooling, replacement, and disposal can introduce further impacts. Cambridge's explanation of its revised Bitcoin electricity methodology demonstrates why hardware assumptions and changing equipment efficiency matter to estimated consumption (Cambridge Centre for Alternative Finance, 2023). Accordingly, this article

avoids assigning a fixed annual footprint to an entire network without a dated estimation method.

Per transaction comparisons require particular caution. Dividing network electricity by recorded transactions gives an allocation ratio, rather than a direct measurement of the additional electricity caused by one payment. Transactions can also represent different amounts of economic activity, and additional settlement layers complicate comparisons. A useful assessment should report both absolute network estimates and carefully defined service indicators, explaining what each figure captures. Otherwise, a superficially precise number can conceal differences in security arrangements, settlement functions, and reporting boundaries.

Environmental claims also require evidence outside the ledger. A blockchain can record a renewable electricity certificate, but the record does not itself establish the conditions under which the electricity was generated. Similarly, tokenising a carbon credit does not demonstrate additional emissions reductions or prevent double counting across disconnected registries. Independent verification remains necessary at the point where physical information enters the system. Sustainability reporting should distinguish operational reductions, purchased energy attributes, and offsets instead of combining them into an unexplained claim of carbon neutrality.

Environmental comparisons should also examine the service that would otherwise be provided. A proposed blockchain application might replace an existing process, supplement it, or create entirely new activity. These possibilities imply different assessment boundaries. Researchers should describe the counterfactual and avoid claiming avoided emissions merely because transactions move onto a ledger. Where renewable power is involved, local circumstances also matter: the same electricity could have alternative uses. Such questions require contextual investigation and cannot be answered by assigning a favourable label to a consensus mechanism alone.

SOCIAL INCLUSION AND CONSUMER PROTECTION

The social assessment of digital finance concerns whether users can obtain useful services safely and on reasonable terms. Permissionless access can reduce some entry barriers, but it does not prove affordability or improved welfare. For a household with limited savings, an accessible product may still be unsuitable if its price fluctuates sharply or its losses are

irreversible. Inclusion therefore requires consideration of service quality, user comprehension, and practical alternatives, rather than merely the number of people able to open wallets.

Wallet counts are particularly weak substitutes for demographic evidence. One individual may control many addresses, and a custodial address may represent many individuals. Automated transactions further complicate interpretation. Assertions that blockchain activity demonstrates rural participation, gender inclusion, or poverty reduction require additional data collected through defensible methods. In an Indian study, surveys and interviews could examine whether particular services reduce remittance costs, support productive activity, or improve resilience. Such research should compare outcomes with available banking and payment options instead of presuming that technological novelty creates an advantage.

Consumer protection belongs within ESG because avoidable financial harm is a social outcome. Relevant indicators include transparent fees, understandable risk warnings, complaint resolution, accessibility for users with disabilities, and procedures for responding to security incidents. Privacy deserves equal attention: publicly traceable transactions may expose sensitive behaviour even where addresses lack names. Responsible assessment should examine how services minimise unnecessary disclosure and explain data practices. A platform's technical availability should therefore be evaluated alongside its ability to respect users, communicate foreseeable risks, and offer meaningful assistance when problems occur.

Outcome measurement should include people who abandon a service as well as those who remain active. Excluding unsuccessful users can make adoption appear more beneficial than it is. Researchers should ask why individuals leave, whether losses influence household spending, and whether complaints are resolved across language barriers. Consent and confidentiality are essential when collecting this information. These proposed practices would improve the evidential basis of inclusion claims while allowing users to describe benefits and harms in their own terms. They would also make adverse experiences harder to obscure behind aggregate transaction growth.

GOVERNANCE AND DISTRIBUTED ACCOUNTABILITY

Governance analysis asks who can change the system and whose interests those decisions serve. Token voting makes some decisions visible, but voting power may be concentrated among wealthy holders or delegated to a small group. Participation also depends on information, time, and transaction costs. A governance assessment should examine voting

concentration, proposal access, delegation practices, and conflicts of interest. Principles of disclosure and oversight remain relevant even where the institutional form differs from a corporation (Organisation for Economic Co-operation and Development [OECD], 2023).

Formal voting rules reveal only part of actual control. Developers may retain upgrade authority, administrators may hold emergency keys, and interfaces may determine which services most users can access. A credible report should identify these powers, explain safeguards, and distinguish routine decision making from emergency intervention. It should also examine treasury expenditure, security review, and post incident disclosure. These are proposed assessment questions, rather than findings that every decentralised organisation shares the same weaknesses. The purpose is to locate responsibility wherever it operates in practice.

Accountability also requires clarity about remedies. A public vote may authorise a change without providing a practical response for an injured user. Reports should therefore explain where complaints can be directed, which actors can investigate, and what remedies are realistically available. Technical audits should disclose their scope because reviewing software does not certify every economic assumption or future upgrade. These distinctions help readers understand what a governance safeguard actually covers and prevent the existence of an audit or voting mechanism from becoming a substitute for examining its effectiveness in practice.

PROPOSED FRAMEWORK FOR TRACKING ESG OUTCOMES

A defensible framework should present environmental, social, and governance indicators separately before considering aggregation. The environmental component would disclose network energy estimates, emissions assumptions, and hardware boundaries. The social component would combine service costs, verified user research, complaints, and loss related information. Governance indicators would examine control rights, participation, conflicts, and incident management. Every indicator should specify its source, measurement period, limitations, and assurance status. Missing information should remain visible rather than being replaced by optimistic assumptions that improve a project’s apparent performance.

The reporting architecture should combine regularly updated network observations with periodic independent review. Public ledgers can support verification of transactions, votes, and treasury movements. Surveys, organisational records, energy documentation, and technical audits are needed for matters that ledger data cannot establish. Automated

dashboards can improve timeliness, but their calculations should remain reproducible and open to correction. Artificial intelligence may assist anomaly detection; it should not turn uncertain inputs into apparently authoritative sustainability judgements. Human review is especially important when classifications affect access to capital or public reputation.

Composite ratings may eventually assist comparison, but weights should be justified through stakeholder consultation and sensitivity analysis. Assigning forty percent to environmental performance, for example, is a normative choice rather than a validated scientific rule. Severe governance failures should not disappear inside an average raised by low energy consumption. The proposed framework therefore favours minimum safeguards and separate pillar scores. Any subsequent claim that stronger ESG performance predicts superior returns would require longitudinal data, transparent asset selection, and controls for market conditions. This conceptual analysis supplies no such empirical finding.

Implementation could begin with a limited pilot involving comparable services rather than an immediate ranking of the entire market. Researchers would publish indicator definitions, collect baseline information, invite stakeholder review, and document disagreements. Subsequent reporting cycles could reveal whether metrics are reliable and whether providers change behaviour in response. An accessible correction procedure would allow errors to be challenged. The resulting framework should be revised when evidence shows that an indicator rewards cosmetic disclosure or overlooks substantial harm. This iterative approach treats measurement as a discipline requiring evaluation, rather than assuming that a sophisticated dashboard necessarily produces trustworthy knowledge.

INTERNATIONAL PERSPECTIVES

The European Union offers a comparatively explicit connection between crypto asset disclosure and environmental information. MiCA includes requirements concerning adverse climate and other environmental impacts of consensus mechanisms (European Parliament & Council of the European Union, 2023). Commission Delegated Regulation 2025/422 further specifies the content, methodologies, and presentation of sustainability indicators (European Commission, 2024). This approach supports comparability, but environmental disclosure should not be mistaken for certification that a token is sustainable. Nor should the existence of MiCA be read as automatically resolving every accountability problem associated with arrangements described as fully decentralised.

International sustainability standards provide complementary perspectives. IFRS S1 focuses on sustainability related risks and opportunities relevant to an entity's financial prospects, while IFRS S2 addresses climate related disclosures (IFRS Foundation, 2023a, 2023b). GRI's impact orientation asks a broader question about consequences for people and the environment. A digital finance report should explain which perspective it adopts and why. Combining the language of different standards without identifying reporting objectives can produce confusion, especially where a network lacks a single reporting entity able to obtain reliable information from all participants.

Global financial standard setters emphasise cooperation and comparable regulatory outcomes. The FSB's framework addresses financial stability risks, while IOSCO's DeFi recommendations address market integrity and investor protection. FATF's 2021 guidance supplies an important historical framework for virtual asset related financial crime controls, although it must be read with subsequent revisions rather than treated as an exhaustive statement of current requirements (Financial Action Task Force, 2021). Together, these materials illustrate why ESG cannot replace legal compliance. Environmental quality, consumer safeguards, and financial crime controls answer connected but different questions.

For India, corporate sustainability disclosure offers reporting lessons without establishing universal crypto specific obligations. SEBI's 2023 BRSR Core framework and 2024 industry standards illustrate efforts to make corporate metrics more consistent and capable of assessment (SEBI, 2023, 2024). Their application depends on the relevant entity and regulatory scope. A suitable research agenda would examine how comparable disclosure disciplines could support responsible digital finance while recognising differences among private crypto assets, regulated payment services, and central bank liabilities. Proposals for future regulation should be identified as recommendations rather than described as rules already applicable to every platform.

Cross border comparability should preserve legitimate differences in local needs. A service designed for remittances may require different outcome measures from a trading platform or a community treasury. Common disclosure definitions can coexist with additional context specific indicators, provided the basis for comparison remains explicit. Cooperation among researchers, consumer organisations, technical specialists, and public authorities could help identify this common core. Equally, smaller providers may need proportionate reporting

arrangements so that compliance costs do not eliminate useful experimentation. Proportionality should simplify the means of reporting while retaining truthful claims, clear responsibility, and access to remedies. These are proposed design principles for future assessment, not assertions that an internationally harmonised framework has already been achieved.

CONCLUSION

ESG assessment can improve understanding of cryptocurrency when it examines measurable consequences and identifiable responsibilities. Environmental analysis requires dated estimates and explicit boundaries; social analysis requires evidence of user outcomes; governance analysis requires an account of actual control. The public availability of blockchain records strengthens some forms of verification but cannot establish the accuracy of external information or the fairness of decisions. Technical design and institutional safeguards must therefore be assessed together.

The central recommendation is a reporting framework that preserves differences among ESG dimensions, makes uncertainty visible, and links disclosures to independent scrutiny and practical remedies. Ethereum's change in consensus illustrates the possibility of substantial operational energy reductions, but no single technical improvement resolves every sustainability concern. Responsible digital finance ultimately depends on whether claims can be tested and whether those exercising influence can be held accountable for resulting harm.

FUTURE SCOPE

Future research should test the proposed indicators across clearly defined categories of networks, exchanges, and applications. Longitudinal studies could examine energy reporting, governance concentration, complaint outcomes, and independently verified participation. Indian fieldwork could compare the practical benefits and risks of specific digital services for underserved users. Further work should assess assurance costs, privacy preserving verification, and the comparability of international disclosure requirements. Studies of investment performance should publish reproducible methods and distinguish correlation from causation before making claims about an ESG related financial advantage.

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