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Original Article

The Role of Financial Technology in Advancing Environmental Sustainability – A Critical Review

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Abstract:

Financial Technology (FinTech) has emerged as a revolutionary tool for advancing environmental sustainability by restructuring capital mobilization, improving risk management, and facilitating environmentally responsible economic processes through financial systems. Digital innovation can more effectively finance sustainable initiatives by automating the issuance, trading, and management of green financial instruments, while reducing transaction costs and market-entry impediments for FinTech. Online financial products such as mobile banking, online investment platforms, and financial applications can expand access to sustainable finance for institutional investors, small and medium investors, and underserved communities, and enable inclusive green growth. Other aspects in which FinTech has played a central role in improving are transparency, efficiency, and accountability in environmental and financial markets. The digital high-tech infrastructure can be deployed to enhance the integrity of carbon and environmental markets, including easier transaction tracing, fraud mitigation, and stable monitoring of emissions and sustainability performance. The instant data collection and automatic verification instruments improve the assessment of conditions and enable a more efficient response to climate through a market-oriented approach. At the same time, analytics driven by artificial intelligence improves the quality of environmental, social, and governance (ESG) information by enabling proper scoring, risk assessment, and compliance controls, enabling informed decision-making, and reducing the risk of information asymmetry and greenwashing. FinTech may play a facilitating role in the transition to the circular economy by financing resource-efficient, waste-reducing, and lifecycle-oriented business models and by enhancing supply chain visibility through digital tracking and data integration.

Keywords: Fintech; Sustainabalaty; Digital Innovation; Financial Markets

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Introduction:

Financial Technology (FinTech) and its significance in promoting environmental sustainability is a critical intersection of digital transformation and sustainable, as well as emerging, regulatory approaches. The growing threat of climate change, biodiversity loss, and resource depletion has underscored the need for financial systems that are not only efficient and transparent but also inclusive and able to mobilize capital to support environmentally friendly projects. The conventional financial system has been accused of inefficiencies, limited accessibility, and varied sustainability indicators, which has created a fertile environment for FinTech to emerge as a transformative enabler. FinTech promotes greater precision of environmental, social, and governance (ESG) data, efficient capital allocation, and financial inclusion through the implementation of innovative technologies into the green finance mechanisms, including blockchain, artificial intelligence (AI), Internet of Things (IoT), big data analytics, and regulatory technology Shala et al (2024), (Huang et al,. 2025), (Vimal et al., 2024).

The contribution of FinTech to sustainability may be approached using a multi-layered model that covers technological enablers, financial mechanics, regulatory frameworks, and socio-economic outcomes. Digital innovations also offer the platform to scalable green finance solutions, which allow the creation and management of green bonds, carbon markets, ESG investment portfolios, and renewable energy crowdfunding platforms (Omeragić et al,, 2024), (Bai et al.,2025), (Rezaie et al., 2024). These initiatives are also being helped by regulatory sandboxes, standardized ESG disclosure standards, and RegTech tools to make them more governable and scalable (Dev et al.,2025) (Allen et al., 2019), (Filliung et al., 2025). These socio-economic advantages should encompass financial inclusion, empowerment of small and medium-sized businesses (SMEs), and facilitation of circular economy practices (Xiao et al., 2024), (Hidayat-ur-Rehman et al, (2023), (Udeagha et al., 2023). Notably, FinTech environmentality is subject to interactions of technological maturity, regulatory compliance, and socio-economic environment, (Habib et al., 2024).

At the macro level, several global trends are driving the adoption of FinTech for environmental sustainability. Digital revolution in finance, including mobile banking, digital wallet, and online investments, has reduced transaction costs and increased access to sustainable investment opportunities (Shala et al., 2024), (Boulila et al., 2024). Financial institutions are becoming increasingly transparent and open in sustainability reporting as climate policy and ESG regulation, like the EU Corporate Sustainability Reporting Directive (CSRD) and the Sustainable Finance Disclosure Regulation (SFDR), are driving them to become increasingly transparent and accountable in sustainability reporting (Contipelli et al., 2024), (Bodellini et al., 2023). The real-time monitoring of the environment, automated compliance, and fraud-resistant carbon trading can be realized through technological convergence, which involves AI, blockchain, and IoT (Zhang et al., 2024), (Yadav et al., 2025), (Enescu et al., 2025). Also, there is an increasing investor and consumer interest in sustainable products, which has generated market incentives for FinTech innovation (Huang et al., 2025), (Roy et al., 2025).

FinTech offers opportunities for environmental sustainability in many ways. Digital platforms enable the mobilization of green finance to simplify the issuance and trading of green bonds, which allow the movement of more capital to renewable energy, sustainable infrastructure, and conservation projects (Omeragic et al., 2024), (Mertzanis et al., 2025). Carbon credit systems are also made more efficient using blockchain-based systems, which increase the transparency of the carbon market, decrease the cost of transactions, and avoid being counted twice, which further enhances integrity of the carbon markets (Rezaie et al., 2024), (Mohan et al., 2025), (Sathio et al., 2024). ESG data and analytics enjoy the advantage of the AI-driven tools that enhance the quality and comparability of ESG data, allowing investors to make a good decision and regulators to track compliance effectively (Fei et al., 2025), (Gaurav et al., 2025), (Zhou et al., 2025). Moreover, FinTech also enables the circular economy, as it contributes to financing of resource-efficient and waste-reducing business models, often in the SME sector (Xiao et al., 2024), (Hidayat et al., 2023), (Azimi et al., 2025) . There are no problems with the introduction of FinTech into environmental sustainability. The idiosyncrasy of regulatory frameworks - through irregular ESG reporting and the absence of globalized standards - impedes the scalability of sustainable FinTech solutions across cross-border borders (Dev et al., 2025), (Vimal et al., 2024), (Dorhetso et al., 2024). The risk of greenwashing will not go away easily; unless well-established verification systems are in place, the digital platforms will be passive particles of propagating greenwash (Pawlak et al., 2024), (Wu et al., 2025). In the case of the emerging economies, technological and social disparities, such as the absence of digital infrastructure, poor financial literacy, and unequal access to technology, limit the spread of green FinTech (Appiah et al., 2025), (Habib et al., 2024), (Singla et al., 2025). Moreover, the digitization of financial services increases the risk of cyber threats and poses a risk to cybersecurity and privacy, which, in turn, contributes to the loss of confidence towards sustainable finance platforms (Hassan et al., 2025), (AL-Okaily et al., 2024).

The study on FinTech and sustainability has grown at a fast pace, it is still disjointed among the different fields, as it has been defined in different ways, has multiple methodologies, and measures. The current reviews are frequently restricted in scope and limited to particular technologies or local settings, and need further analysis in a more integrated, cross-disciplinary way. The purpose of this review is to connect the theoretical framework with empirical findings and provide a complete insight into how digital financial innovations can be exploited to achieve the global goals in climate and sustainability, as well as reduce the risks connected to it (Huang et al., 2025), (Galeone et al., 2024), (Vimal et al., 2024). The interdisciplinary character of the role of FinTech in sustainability that gives links to finance, environmental science, regulatory policy, and social innovation.

Theoretical Framework:

The theoretical model of explaining the role of Financial Technology (FinTech) in promoting environmental sustainability should be viewed as a multi-layered and interdisciplinary approach involving technological innovation, financial processes, regulatory governance, and socio-economic consequences. In its simplest form, this framework

acknowledges that the environmental effects of FinTech rely on the dynamic interaction between the maturity of technologies, policy harmonization, and situational socio-economic factors (Shala et al., 2024), (Huang et al., 2025), (Vimal et al., 2024), (Habib et al., 2024). The technological enablers layer (first) includes digital innovations that include blockchain, artificial intelligence (AI), Internet of Things (IoT), big data analytics, and RegTech, which jointly offer the infrastructure of transparent, efficient, and scalable green finance solutions (Zhang et al., 2024), (Song et al., 2025), (Enescu et al., 2025). An example is blockchain, which provides immutability and traceability in the trading of carbon credit, lowers fraud and transaction costs, and supports smart contracts to establish automated, trustless transactions (Rezaie et al., 2024), (Mohan et al., 2025), (Sathio et al., 2024). AI supplements ESG integrate blockchain on to compute large-scale data on sustainability, automates compliance reporting, and streamlines portfolio allocation to balance risk and ESG scores (Fei et al., 2025), (Gaurav et al., 2025), (Zhou et al., 2025). Combining IoT devices with AI and blockchain, real-time environmental monitoring can be achieved to enhance the precision of emission tracking and automated trading of carbon credits (Enescu et al., 2025), (Safari et al., 2025).

The second level is the financial mechanisms, which consider how these technologies can support the development, operation, and growth of sustainable finance products. Online payment systems and mobile banking reduce transaction fees and make green bonds, renewable energy crowdfunding, and sustainable investment portfolios more accessible (Omeragic et al., 2024), (Boulila et al., 2024), (Mertzanis et al., 2025). Carbon markets operated with blockchains enhance market integrity through the prevention of double-counting and increase transparency (Rezaie et al., 2024), (Sathio et al., 2024), (Yadav et al., 2025). ESG analytics powered by AI can help investors to make decisions and regulators to monitor the compliance (Fei et al., 2025), (Gaurav et al., 2025), (Zhou et al., 2025). These processes are vital in the channelization of capital into both projects that are coherent with the United Nations Sustainable Development Goals (SDGs) and the targets of the Paris Agreement (Shala et al., 2024), (Attia et al., 2025), (Omeragic et al., 2024).

The regulatory and governance structures form the third layer and are a moderating force that determines the scalability and credibility of sustainability projects enabled by FinTech. In innovative solution testing, regulatory sandboxes offer a controlled atmosphere of testing solutions, as well as assuring adherence to standards that are ever-changing (Allen et al., 2019), (Filliung et al., 2025). The aim to harmonize ESG disclosure frameworks, including the EU Corporate Sustainability Reporting Directive (CSRD) and Sustainable Finance Disclosure Regulation (SFDR), focuses on standardising sustainability reporting, and to reduce the risks of greenwashing (Pawlak et al., 2024), (Contipelli et al., 2024), (Bodellini et al., 2023). RegTech tools are used to automatize compliance, track ESG performance in real time, and identify discrepancies in sustainability marketing with the help of AI and big data (Dev et al., 2025). In the absence of these types of governance, the threat of regulatory fragmentation and discrepant metrics may destroy cross-border scalability and investor confidence. (Dev et al., 2025), (Vimal et al., 2024), (Dorhetso et al., 2024).

The fourth layer, which is the socio-economic outcomes, reflects the overall effects of FinTech on environmental sustainability in terms of financial inclusivity, empowering SMEs, and facilitating circular economy practices (Xiao et al., 2024), (Hidayat-ur-Rehman et al., 2023), (Udeagha et al., 2023). FinTech allows underserved communities and small businesses to obtain capital to grow sustainable companies by reducing barriers to entry, thus promoting inclusive growth , Tariq et al, (2024), Surwanti et al, (2025). Digital tools make resources more efficient, reduce waste and enhance supply chain transparency, especially in developing nations, where the quality of institutions and governance is central to the issue Xiao et al, (2024), Hidayat-ur-Rehman et al, (2023), Azimi et al , (2025). These socioeconomic merits are not as such side effects but rather must be considered as part of the criterion that the process of making environmental sustainability must be undertaken with respect to social equity as well as economic resilience Habib et al, (2024), Shahid et al, (2025).The structures focus on dependencies among layers. The full potential of technological enablers cannot be realized without assistive regulatory measures in place; financial mechanisms will not be effective without technological infrastructure, and inclusivity and accessibility, which are simultaneously influenced by technology and regulation. This interrelationship observes a systems-thinking approach required in dealing with complex sustainability-related issues. As an example, blockchain made carbon markets transparent is strengthened when combined with AI-based validation using harmonized regulatory frameworks and leads to an increase in market integrity and investor confidence Rezaie et al, (2024), Sathio et al, (2024), Fei et al, (2025), Filliung et al, (2025). In the same way, the policy relevance of IoT-based environmental monitoring arises when the information is incorporated into regulatory compliance frameworks, allowing adaptive governance Enescu et al, (2025), Safari et al, (2025), Allen et al, (2019). Feedback loops are also part of the theoretical framework and have a role in the development of the role of FinTech in terms of sustainability. Effective implementation of green finance systems can cause technological advancement to continue further, with the market demand encouraging the creation of more effective tools. On the other hand, technological priorities may be redefined to comply and mitigate risks in response to the regulatory tightening of greenwashing or cybersecurity breaches Pawlak et al, 2024; Wu et al, (2025), Hassan et al, (2025). Socio-economic factors like a rise in financial literacy and digital transition in an emerging economy can increase the user base of the sustainable FinTech solutions and generate a vicious cycle of inclusion and environmental impact Appiah et al, (2025), AI-Okaily et al, (2023), Goyal et al, 2025). This framework is related to interdisciplinary convergence theory, which assumes that intricate global issues need multi-domain efforts (finance, environmental science, technology, and policy Shala et al, 2024), Yadav et al, 2025), Huang et al, 2025). It also builds on the theory of innovation diffusion, a concept that describes the spread of FinTech adoption with the facilitation of adoption by regulatory policies, technology preparedness, and socio-economic drivers Abbas et al, (2025), Singla et al, (2025). The presence of the institutional theory shows the importance of the quality of governance and the legitimacy of regulations in determining adoption behavior and environmental performance Azimi et al,

(2025), Shahid et al, (2025). Overall, the theoretical framework acknowledges FinTech as a cause of environmental sustainability results, as well as a moderator. As a force, it will introduce new tools and mechanisms that will improve transparency, efficiency, and inclusivity in green finance. Being a moderator, it deals with regulatory and socio-economic situations to shape its scale and credibility.

Role of Financial Technology in Environmental Sustainability:

The role of Financial Technology (FinTech) in environmental sustainability can be perceived as an incredibly complex and intertwined system of functions that use digital innovations to mobilize capital, increase transparency, achieve efficiency, and become more inclusive in achieving global environmental sustainability. On the most basic level, FinTech can be used as an accelerator to mobilize green finance, which can facilitate the effective issuance, trading, and management of green financial instruments, including green bonds, sustainability-linked loans, and renewable energy crowdfunding platforms Shala et al, (2024), Omeragic et al, (2024), Mertzanis et al, (2025). Mobile banking, digital wallets, and online investment platforms reduce transaction costs and barriers to entry, thereby increasing the number of people who can access sustainable investment opportunities, both institutional and retail investors, and underserved communities Xiao et al, (2024), Hidayat-ur-Rehman et al, (2023), Udeagha et al, (2023), Boulila et al, (2024). This democratization of access is especially effective in emerging economies, where the traditional banking infrastructure is weak, and FinTech can fill financing gaps to small and medium-sized enterprises (SMEs) working on environmentally friendly projects Habib et al, (2024), Tariq et al, (2024), Surwanti et al,(2025).

The most important role is to increase the integrity and effectiveness of carbon markets. The use of blockchain technology, which offers immutable and transparent ledger features, is being utilized more often to enable carbon credit trading systems to enable traceability, eliminate double- counting , and make fraud more difficult Rezaie et al, (2024), Mohan et al, (2025), Sathio et al, (2024), Yadav et al, (2025). Smart contracts make transactions and compliance automated and allow connecting with IoT devices to monitor and verify the reduction of emissions in real-time Zhang et al, (2024), Enescu et al, (2025), Safari et al, (2025). These inventions not only enhance confidence in the market but also reduce the cost of operations, exposing the smaller players to carbon market participation. Moreover, use of more energy-efficient consensus mechanisms, including Proof of Stake, and Proof of Authority, is a response to worries regarding the environmental impact of blockchain itself, and the technology is now well aligned with the goals of sustainability Sathio et al, (2024). FinTech is also very key to enhancing the quality of Environmental, Social, and Governance (ESG) data and analytics as **shown in Table 1**. The AIs will work with large and complicated datasets of various source types to allow scoring ESG more precisely, assessing risks, and monitoring compliance Fei et al, (2025), Gaurav et al, (2025), Zhou et al, (2025), Mertzanic et al, (2025). Such an option is needed by both investors to align portfolios with sustainability objectives and by regulators to impose standards of disclosure, including the EU Corporate Sustainability Reporting Directive (CSRD) and the Sustainable Finance Disclosure Regulation (SFDR) Pawlak et al, (2024),

Contipelli et al, (2024), Bodellini et al, (2023). FinTech helps decrease information asymmetry by automating data collection and analysis, improving comparability between firms and sectors, and reducing the likelihood of greenwashing by erroneously identifying a lack of verification and anomaly detection using AI Wu et al, (2025).

To facilitate the circular economy by funding business models that focus on resource productivity, waste reduction, and product life-cycle enhancement Xiao et al, (2024), Hidayat-ur-Rehman et al, (2023), Azimi et al, (2025). FinTech systems, such as green crowdfunding and peer-to-peer lending, make capital available to SMEs and startups to implement circular practices, and blockchain and IoT increase supply chain transparency and traceability Hidayat-ur-Rehman et al, (2023), Care et al, (2025). It is especially applicable to developing nations where institutional quality and governance have the potential to define the success of circular economy efforts Azimi et al, (2025), Shahid et al, (2025). FinTech supports policy implementation and compliance with regulations by providing RegTech solutions that automate reporting and track ESG performance in real time and identify inconsistencies in sustainability claims Dev et al, (2025), Allen et al, (2019), Filliung et al, (2025). Regulatory sandboxes can provide test systems with novel green finance products under controlled settings, and control adherence to emerging standards, which can promote an atmosphere of innovation and consumer protection Allen et all, (2019), Filliung et al, (2025). These processes play a crucial role in the elimination of regulatory fragmentation and establishment of harmonized views that enable the expansion of sustainable FinTech solutions across borders Dev et al, (2025), Vimal et al, (2024), Dorhetso et al, (2024).

In the Socio-Economic context, FinTech can play a role in enhancing financial inclusion and social equity as part of environmental sustainability. FinTech enables the empowerment of marginalized groups through the availability of cheap, convenient, and easy financial services, which enable them to engage in sustainable economic processes, connecting environmental and poverty eradication with community resiliency Udeagha et al, (2023), Habib et al, (2024), Tariq et al, (2024), Bihorac et al, (2024). This transparent methodology will make sure that the benefits of green conversion are evenly spread, thus reducing the chances of social resentment of the environmental policies. In addition, FinTech enables real-time environmental monitoring and adaptive governance. Incorporated with AI and blockchain, IoT sensors can be used to gather high-resolution environmental data, including quality of the air and water, energy usage, and waste generation, that policymakers, businesses, and communities can utilize to make informative and timely decisions Zhang et al, (2024), Enescu et al, (2025), Vishwakarma et al, (2025), Safari et al, (2025). The tool would improve the adaptability of environmental governance systems, enabling them to flexibly respond to policy and practice changes in response to prevailing circumstances.

FinTech can also help in green innovation through fueling green ideas, funding them, and scaling technologies that are environmentally positive, as well as incubating these ideas Yadav et al, (2025), Attia et al, (2025), Hossain et al, (2024). Innovators can be linked to investors via digital platforms, collaborative research and development can be facilitated, with the commercialization of clean technologies.

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The innovation ecosystem can also be supported by data-driven insights of AI and big data analytics that can detect new trends, analyze the market potential, and allocate resources most efficiently. The success of these roles, however, is dependent on their ability to solve the challenges that prevail the risk of greenwashing, regulatory fragmentation, and inconsistent ESG metrics may destroy trust and scalability Dev et al, (2025), Pawlak et al, (2024), Vimal et al, (2024), Dorhetso et al, (2024). The accessibility of sustainability solutions made possible by FinTech is constrained by technological and social differences, especially in the emerging economies Appiah et al, (2025), Habib et al, (2024), Singla et al, (2025). The problem of cybersecurity and privacy is further complicated by the digitalization of financial services, which is a significant risk factor that should be addressed to ensure the confidence of the users Hassan et al, (2025), AI-Okaily et al, (2023). These obstacles will have to be tackled by joint effort among regulators, industry players and civil society to come up with standardized standards, invest in digital infrastructure, and enhance digital literacy (Sharma et al, (2024).

Table 1: Synthesis of Theoretical Mechanisms and Empirical Studies on Green Finance and Fintech Integration.

Role / Mechanism	Description	References
Green Innovation	Facilitates the development and implementation of eco-friendly technologies and digital solutions that reduce environmental impacts and promote sustainable production and consumption patterns.	Wang et al. (2024); Waqar et al. (2025); Ghouse, Bhatti & Nasrullah (2025); Akhtar et al. (2024); Omri, Jarraya & Kahia (2025)
Green Finance	Provides funding for sustainable projects through innovative financial instruments, including green bonds, digital lending, and ESG-linked investments.	Omeragic, Zaimovic & Zaimovic (2024); Tanchangya et al. (2025); Javed et al. (2024); Luo & Li (2024); Sun, Li & Mehmood (2025)
Financial Inclusion	Expands access to financial resources for households, SMEs, and underserved communities, enabling participation in green investments and sustainable economic activities.	Ghouse, Bhatti & Nasrullah (2025); Omeragic, Zaimovic & Zaimovic (2024); Lv et al. (2024); Rani et al. (2025)
Transparency & Efficiency	Enhances transparency, accountability, and efficiency in financial transactions, improving resource allocation and reducing transaction costs in green finance markets.	Omeragic, Zaimovic & Zaimovic (2024); Javed et al. (2024); Omri, Jarraya & Kahia (2025)
Digital Tools & Platforms	Enables the use of crowdfunding platforms, blockchain, big data analytics, and robo-advisors to mobilize and manage green investments effectively.	Omeragic, Zaimovic & Zaimovic (2024); Tanchangya et al. (2025); Luo & Li (2024); Sun, Li & Mehmood (2025)
Policy & Regulation	Requires supportive regulatory and policy frameworks to ensure that FinTech innovations generate positive, measurable environmental outcomes.	Ma et al. (2024); Li et al. (2025); Hussain et al. (2025); Odei & Adomako (2025)

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Blockchain technology in sustainable finance:

The blockchain technology can enhance transparency in sustainable finance by ensuring immutable, decentralized, and verifiable records of sustainability-related transactions and data. This directly addresses issues such as *greenwashing*, inconsistent ESG metrics, and lack of trust in carbon markets as shown in table 2 . Through its immutable ledger, blockchain prevents tampering with ESG data, while asset traceability enables verification of the authenticity and lifecycle of environmental assets like tokenized carbon credits and renewable energy certificates (Zhang et al. 2024) , (Wang et al. 2025) , (Naifar 2025) (Alghanmi 2025) , (Mohammad et al. 2025). Smart contracts automate compliance with sustainability commitments, ensuring real-time enforcement and reducing administrative burdens (Ferdous et al. 2025). When integrated with IoT and AI, blockchain strengthens fraud resistance in carbon trading by recording verified emissions data directly from trusted sources (Ahmed and Shakoor 2025). Additionally, ESG report notarization ensures disclosures are accurate and tamper-proof, which is particularly valuable in circular economy ecosystems ,(Babkin 2023). Finally, decentralized governance allows multiple stakeholders to validate sustainability data, enhancing accountability and reducing reliance on intermediaries (Alghanmi 2025) (Oqbi and Al Mohammadi 2024). Collectively, these features make environmental asset markets more trustworthy, ESG reporting more reliable, and compliance processes more efficient, thereby boosting investors.

Table 2: Key Blockchain Transparency features and their Impact on Sustainable Finance.

Transparency Feature	Application Area	Impact on Sustainable Finance	References
Immutable Ledger	ESG reporting, green bonds	Prevents data tampering, builds trust	(Zhang et al. 2024) , (Wang et al. 2025)
Asset Traceability	Carbon credits, RECs	Verifies authenticity, prevents double-counting	7(Naifar 2025), (Alghanmi et al 2025), (Abdul et al 2025)
Smart Contracts	Carbon trading, compliance automation	Real-time enforcement of sustainability commitments	(Ferdous et al. 2024)
Fraud Resistance	Carbon markets, supply chains	Reduces misrepresentation, increases market credibility	(Ahmed and Shakoor 2025)
ESG Report Notarization	Circular economy clusters	Ensures accuracy and transparency in sustainability disclosures	80 (Babkin et al. 2023)
Decentralized Governance	Carbon credit ecosystems	Enhances accountability, reduces intermediary dependence	(Alghanmi 2025) , (Oqbi and Al Mohammadi 2024)

1. Uses of Blockchain in Renewable Energy and a Carbon Credit Trade:

The carbon credit trade, as well as the renewable energy market, is experiencing a revolution driven by blockchain technology, enabling transparency, automation, and trust through a decentralized architecture. Carbon credit trading Blockchain with its

immutable ledger makes certain that the life cycle of each credit, starting with its creation and ending with its retirement, is firmly established, and no credit can be counted on multiple occasions, nor can any frauds occur, and the market itself is more tightly controlled (Alghanmi 2025) (Vimal and Kuamr 2024) (Tlili 2025). Simple projects like Toucan Protocol, KlimaDAO, and Moss Earth tokenize certified carbon credits and allow them to be traded within decentralized finance ecosystems to multiply liquidity and expose more individuals to carbon financial instruments (Tlili 2025). The smart contract automates the compliance and execution of transactions, minimizes administrative overhead, and provides a secure settlement on time (Boumaiza 2024) (Rani et al. 2024). With IoT sensor integration, real-time emissions could be monitored to provide verified data to blockchain systems that could be used to provide real-time carbon accounting and automated credit issuance (Kebde Nemomsa 2025). This mix of automation and verifiable data enhances confidence in the stakeholders and is in line with the global climate mitigation aims.

In the renewable energy markets, blockchain is used to support peer-to-peer (P2P) energy trading; this allows participants to safely and openly trade energy with each other without the middlemen (Ghodusinejad 2025, Ekaristi, 2025) Renewable energy certificates (RECs) can be traded efficiently with the help of tokenization, and the trades can be conducted automatically through smart contracts in cases where the predetermined parameters, like price levels or supply demand balances, are satisfied Hossein et al. 2025). Examples of such methods are the platforms such as Power Ledger and WePower, which leverage blockchain to align energy supply and demand and automate trading of REC, thereby facilitating decentralized generation and consumption of energy. The combination of AI and IoT with blockchain also improves the management of renewable energy, as it gives the possibility to predict the generation and consumption of renewable energy, allocate resources optimally, and stabilize micro grids (Kebde Nemomsa 2025). In the industrial setting, blockchain assists decentralized micro grids through monitoring energy movement and carbon emission securely, guaranteeing regulation with regulatory requirements and providing demand-side flexibility (Kebde Nemomsa 2025). In addition to efficiency in operations, the role of blockchain in these areas is dealing with the issue of market trust and scalability. Blockchain prevents the potential abuse of misrepresentation and green washing that have historically challenged both carbon markets and renewable energy trading by offering transparent and tamper-proof records (Rani et al. 2024) Kalaiarasi and Kirubahari (2023). The technology further facilitates interoperability across the globe through linking distributed carbon markets and renewable energy exchanges, and through promoting cross-border participation and investment (Kalaiarasi and Kirubahari 2023) (Du et al. 2024). Nevertheless, there are still difficulties such as energy consumption in the process of consensus, limitations of scalability, and regulatory uncertainty (Ajakwe et al. 2025) (Ghodusinejad 2025). New solutions, including energy-efficient mechanisms of consensus (Proof of Stake, Proof of Authority) and hybrid blockchain designs, seek to eliminate these issues without sacrificing transparency and security (Ajakwe et al. 2025). Carbon credit trading and renewable energy blockchain apps are redefining the manner in which

environmental assets are verified, traded, and managed. Through tokenization, smart contracts, Internet of Things integration, and decentralized governance, blockchain not only increases efficiency in operations but also establishes trust and responsibility to scale sustainable finance and the integration of clean energy adoption all over the world (Tlili 2025) (Boumaiza 2024). AI-based analytics are used to improve the evaluation of the Environmental, Social, and Governance (ESG) risks within investment portfolios by integrating innovative computational methods with a variety and large volumes of data to provide more reliable, timely, and actionable information. On the bottom tier, machine learning (ML) and natural language processing (NLP) models have the potential to analyze large volumes of formatted and unstructured ESG data, including corporate disclosures and regulatory filings, news articles, and social media sentiment, to a scale that traditional approaches simply cannot. This allows investors to determine any complex, non-linear relationships between ESG factors and financial performance, which enhances predictability in risk modelling (Aruwaji and Swanepoel,2025) The AI systems also increase the quality and transparency of data by identifying anomalies, inconsistencies, and possible greenwashing of ESG reports and thereby decrease information asymmetry between businesses and stakeholders (Lagasio 2024). In particular, a text classification system based on NLPs may be used to identify deceptive sustainability practices, whereas sentiment analysis may be used to understand the population's and market's perceptions of a company's ESG activities. AI-driven predictive analytics can help predict ESG-related disruptions, e.g., regulatory changes, climate risks, or reputational crises, enabling proactive portfolio changes (Dou et al., 2025). AI models will be able to offer real-time insights into environmental effects by incorporating other sources of data, such as IoT sensor outputs, satellite data, and blockchain-verified carbon credits, enhancing the plausibility of ESG metrics Moreover, AI can be used to conduct organization-specific ESG grading and optimization of a portfolio, where risk evaluations are customized to particular industries, geographical locations, and investment goals. Extreme Gradient Boosting (XGBoost) and Random Forest are among the techniques that can be used to outperform traditional linear models and account for sector-specific governance risk or environmental exposures, resulting in more resilient investment strategies (Aruwaji and Swanepoel,2025).

AI-based analytics can revolutionize the current ESG risk assessment, replacing the old system of checks with a new system of data-driven governance, enabling real-time decision-making, increasing accountability, and aligning strategies with sustainability objectives. Not only does this increase investors' confidence, but it also ensures that capital allocation is better aligned with credible, measurable ESG performance, as shown in Table 3.

Table 3: The Role of AI in ESG Risk Assessment and Investment Management

AI Capability	Application in ESG Risk Assessment	Impact on Investment Portfolios	References
Machine Learning Models	Predictive modelling of relationships between ESG indicators and financial performance across firms and sectors	Improved accuracy in identifying high-risk assets, sustainability-linked opportunities, and long-term value creation	Tlili 2025 , Boumaiza 2024
Natural Language Processing (NLP)	Text mining of ESG disclosures, corporate reports, news articles, and social media content	Enhanced detection of green washing, reputational risk, and emerging sentiment trends affecting firm valuation	Rani et al. 2024,
Sentiment Analysis	Assessment of public, investor, and market perceptions related to corporate ESG performance	Anticipation of market reactions, reputational impacts, and volatility linked to ESG-related events	Rani et al. Ghouse and Aslam,
Anomaly Detection	Identification of inconsistencies, exaggerations, or irregular patterns in reported ESG data	Improved data reliability, transparency, and reduced information asymmetry in investment decisions	Koemtzopoulos etal 2025, Mertzanis 2023
Predictive Analytics	Forecasting ESG-related disruptions such as climate risks, regulatory changes, and supply-chain shocks	Proactive portfolio rebalancing and risk	Sattar etal 2025

Problems in the exploitation of FinTech to become sustainable:

Although this has the potential to transform, the use of FinTech for environmental sustainability faces serious regulatory, technical, and socio-economic challenges. The most significant issue is the absence of unified regulatory frameworks and uniform ESG measures that introduce uncertainty and restrict the scale of sustainable FinTech solutions Dev et al,(2025), Vimal et al, (2024), Dorhetso et al, (2024). Regulatory sandboxes and RegTech have been suggested to be able to strike a balance between innovation and compliance, but implementation is not evenly spread across jurisdictions (Allen 2019) (Fillyng 2025). Greenwashing will only serve to lose further confidence, and strong disclosure regimes like the EU CSRD and AI-based monitoring tools will be necessary to provide transparency and accountability Pawlak et al, (2024), Cotipelli et al, (2024), Wu et al, (2025), Rimmel et al, (2024). At the technological level, there are issues of privacy, cybersecurity, and trust, which discourage the adoption, especially in the developing economies where there is still a digital literacy gap Appiah et al, (2025), Hassan et al, (2025), Abbas et al,(2025), AI-Okaily et al, (2023). Also, the accessibility of digital means is limited by infrastructure constraints, with some technologies being energy-intensive, and access to them is also unequal among the markets, particularly the emerging ones Habib et al, (2024), Alabi et al, (2024), Singla et al, (2025). Lastly, the quality of institutions and governance is also very important in the efficiency of FinTech in promoting a sustainable environment, where poor governance systems tend to hinder progress Azimi et al,(2025), Shahid et al, (2025). To overcome these obstacles with a concerted policy effort, we must

develop capacity and implement inclusive technology use to realize the full potential of FinTech as a key to sustainable development.

Conclusion:

FinTech to environmental sustainability should be not only a technological shift but a shift in paradigm of the functioning of the financial systems serving the global ecological objectives. Through the critical analysis of the opportunities and challenges, the given review is expected to offer actionable insights to policymakers, industry chiefs, and researchers who want to use FinTech to build a sustainable future. The combination of various viewpoints will assist in finding ways of innovation, regulation, and collaboration that can optimize the environmental impacts of FinTech and are resistant to risks. In such a manner, the review makes a contribution. The transformative enabler of environmental sustainability through Financial Technology (FinTech), mobilizing green finance, increasing market transparency, operational efficiency, and inclusivity in various economic settings is evident. Digital payments, bloc chain, artificial intelligence (AI) and the Internet of Things (IoT) FinTech innovations are transforming the mechanism by which capital is deployed to sustainable projects, allowing more transparent carbon markets, enhancing the quality and comparability of ESG data, and supporting circular economy business models. Unlocking the Real-time monitoring and verification of environmental outcomes can be established by integrating blockchain and IoT, whereas AI-based analytics can improve ESG integration and reduce the risks of green washing by automated verification. In less developed markets, FinTech closes financing gaps in SMEs and underserved populations, but scalability is frequently limited due to regulatory uncertainties, access, and lack of digital literacy, and infrastructure constraints . To deal with these obstacles, it is necessary to have unified regulatory frameworks, effective governance, and cross-disciplinary working cooperation so that technological progress could be consistent with sustainability goals. Finally, the results emphasize that, although FinTech has the potential to accelerate the shift to a low-carbon, resource-efficient global economy, its effects will depend on the alignment of measures and the standardization of ESG indicators, as well as on all-inclusive policies that can spread benefits to both developed and developing markets. By combining innovation and regulation, FinTech can deliver on its vision of a more sustainable, fair, and greener future.

Declarations:

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