Asian Business Research Journal
Vol. 10, No. 7, 92-104, 2025
ISSN: 2576-6759
DOI: 10.55220/2576-6759.503

Harnessing Fintech Innovations for Renewable Energy: Revolutionizing Investment Models to Achieve Sustainable Development Goal 7

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Abstract

In order to attain Sustainable Development Goal (SDG) 7 - Access to affordable, reliable, and modern energy for all, and the energy-related SDGs (SDGs 9 and 13), innovative financing mechanisms are needed to attract a range of actors and sources of finance at scale. This paper examines the disruptive potential of fintech on the renewable energy investment model. In particular, it explores how fintechs underpinned by blockchain, crowdfunding, artificial intelligence/machine learning (AI/ML), and decentralized finance (DeFi) can unlock capital access, streamline transactions, and build transparency in clean energy financing ecosystems. Drawing on an integrative review approach and complemented by country case studies from Nigeria, Kenya, and India, the article highlights patterns of how fintech apps facilitate access to inclusive, distributed, and ESG-compliant renewable energy solutions. Key findings indicate that fintech significantly widens access to energy finance and fosters local stakeholders, but regulation, cybersecurity, and digital exclusion present scaling challenges. The paper is rooted in Financial Intermediation Theory and Sustainable Investment Theory, providing a conceptual model to explore how digital innovations and policy environments interact with sustainable energy outcomes. It concludes with policy suggestions for developing enabling regulatory frameworks, strengthening digital infrastructure, and promoting cross-sector collaboration to scale up fintech-facilitated energy transitions. This study contributes to the growing body of literature on digital sustainability and offers practical guidance for policymakers and other stakeholders on connecting financial innovation with global clean energy objectives.

Keywords: AFintech Innovations, Renewable Energy Finance, Blockchain Technology, Sustainable development goal 7 (SDG 7), Peer-to-peer energy trading, Digital financial inclusion.

1. Introduction

FinancialGlobal energy markets are in a midst of a great transition away from reliance upon fossil fuels and toward increased deployment of renewable energy. Not only is this shift indispensable to reduce greenhouse gas emissions and improve energy access, but it is also pivotal to reaching Sustainable Development Goal 7 (SDG7), which targets universal access to affordable, reliable, sustainable, and modern energy by 2030 (United Nations, 2019). Financing this shift, however, is a formidable challenge, especially in emerging economies where energy poverty is the harshest. Renewable energy goals at the global level are projected to need trillions in cumulative investment to achieve (International Renewable Energy Agency (IRENA), 2020), however traditional finance is unlikely to be available to the extent needed, as characterized by high upfront costs, long time to approval, and risk-aversion—see (World Bank, 2019).

Within these limitations, fintech is coming to the fore as the disruptive and transformative voice of sustainable development. Deleware 4, O L Bremner and A Lennartz—Reforms ensured the high quality of their information-technology-essential economy, faster and more secure compared to traditional financial structures, Fintech innovations like blockchain, P2P (peer to peer) lending, and digital crowd-funding provide decentralized, transparent, and scalable alternatives, Zhang et al. Such technologies can help to democratize capital access, reduce transaction and operational costs and improve traceability and integrity in financial flows, which could lead to making renewable energy projects less risky and more attractive to financial institutions (Mendes & Soares, 2022).

When looking at new technologies that can do this, blockchain is being increasingly identified as a technology that can facilitate secure, immutable, and transparent transactions related to energy. For renewable energy investments, blockchain technology can guide decentralized energy market structure, online peer-to-peer energy trading, and green financial instrument issuance (such as green bond, carbon credit, etc.) (Saberi et al., 2021). Blockchain reduces dependence on financial intermediaries and substantially reduces transaction costs as well as speeding up capital extraction for clean energy investment (Pazaitis et al., 2022).

Likewise, P2P lending platforms present a viable option as an alternative source of capital to banks especially for small and medium renewable energy projects which always have constraints in securing funding from institutional sources. These intermediation services enable direct contact regarding loan or credit provision, and lend support to more inclusive and flexible financing products that incorporate social and environmental impact objectives (De la Hera et al., 2020). Thus P2Ps are positioned to fill the credit access holes through collaborative finance particularly at niche markets (Mansour, 2021) where rescue metrics are integrated into their investing decision (Hussain et al., 2023).

Crowdfunding stands as another disruptive fintech toolsthatinvolve in democratizing renewable energy finance. Online portals allow developers of renewable clean energy projects to solicit investments directly from individuals, communities and mission-aligned investors, avoiding reliance on conventional capital markets (Shneor et al., 2020). This process not only increases financial inclusion but also fosters a sense of community involvement and project ownership —both of which are vital for long-term sustainability and energy justice (Belleflamme et al., 2022; Hörisch, 2021).

Notwithstanding the great promise associated with these fintech applications, their application in renewable energy finance is relatively young and up against several structural challenges. However, regulatory ambiguity, cybersecurity challenges, poor digital infrastructure, and lack of uniform operational guidelines limits wider uptake (Boreiko & Massarotti, 2022). There is, furthermore, little robust empirical evidence on the impact, scale-up potential, and sustainability of these innovations, especially in low and lower middle income countries (LMICs) (Zhao et al., 2023).

Against this background, this paper examines the potential of financial innovations in the fintech sector to transform investment models in renewable energy for SDG 7. It examines how blockchain, P2P lending, and digital crowdfunding can close financing gaps and democratize access to capital and create transparent and inclusive energy financing systems. Drawing on financial technology, energy policy, sustainable development, and crossdiscipline topics, this research adds to a growing body of literature on digital finance for climate and energy. The results of the report provide useful guidance for policy makers, development finance institutions, investors, and project developers who want to use technology-based financial instruments to scale up investment in renewable energy.

2. Conceptual and Theoretical Review

2.1. *Conceptual Review*

The deployment of financial technology (fintech) in renewable energy finance is a game changer in how capital is raised, utilized, and managed for clean energy projects. The proposed nexus, which combines the intersection of the innovation diffusion theory and the sustainable investment architectures, is expected to offer a better understanding about how fintech mechanisms (i.e., blockchain technology, digital crowdfunding AI/ML, and DeFi) can reconfigure the conventional investment landscape to contribute to meeting the Sustainable Development Goal 7 (SDG 7).

Blockchain technology is the underlying infrastructure for transparency, security and disintermediation in renewable energy finance. Using decentralized ledgers and smart contracts, blockchain makes traceable, tamper-proof transactions which don't need intermediaries or central authorities. This enables decentralized power trading markets, tokenized green assets and, automated issuance of green bonds leading to an increased confidence for the investors and higher market liquidity (Saberi et al., 2021; Pazaitis et al., 2022). In the particular case of energy financing, blockchain enables transparent, on-the-fly verification of energy output, carbon credits, and financial flows, establishing tangible and credible links between impact and investment.

Crowdfunding gets clean energy finance to the people Today, however, an increasing number of platforms are relying on digital technology and social connections to bring renewable energy investment to the masses. These platforms allow people, communities, and impact investors to finance energy projects—particularly small-scale community-government projects—without the need for major institutional financing. Crowdfunding further supports financial inclusion and local ownership, by enabling retail investors to invest according to their values and sustainability preferences (Shneor et al., 2020; Belleflamme et al., 2022). In addition, the participatory aspect of crowdfunding often triggers increased stakeholder involvement and ongoing commitment to the transition to renewables.

AI/ML provide with sophisticated data analytic tools to increase the accuracy, speed and safety of financing decision-making for RE. AI models can analyze a borrower's credit history by using nontraditional data sources, thus allowing for more inclusive credit scoring, particularly in markets where no credit history exists (Mansour 2021). It can also leverage predictive analytics to Fewer Costs of Compliance, More Funds for Innovation 2014 CA and the CA logo As mentioned earlier, providers can cut costs in compliance and utilize the savings in new areas service infrastructure, such as energy pricing models, detection of fraud in finance organizations and demand forecasting for grid planning. Both of them can thus improve the reliability and responsiveness of clean energy financing mechanism as well as reduces transaction costs and human errors.

Decentralized Finance (DeFi) is the next frontier of fintech disruption and enables the execution of programmable, permissioned and composable services that leverage blockchain protocols. By leveraging smart contracts, the DeFi platforms can help to automate lending, borrowing and yield farming activities for renewable energy projects, which eliminate the centralization of financial intermediaries or gatekeepers (Schär, 2021). These distributed architectures not only speed and improve the flexibility of capital allocation, but also reduce operational costs and reduce costs to entry for small energy producers, enabling a more inclusive, agile energy finance community.

These fintech mechanisms are conceptually related to clean energy finance through a few primary mechanisms: access to capital, transaction efficiency, and investment transparency. Fintech does two things in the first instance: it broadens access to capital by providing alternative and disintermediated pools of capital that are accessible even to underserved or completely un-banked users. Second, it improves efficiency by simplifying the flow of work and optimizing the costs and time needed for classical finance. Third, it increased transparency and accountability through the integration of transparency-technologies as well as data/integrity technologies in financial transactions and project results.

As a whole, these advances fundamentally redesign the ecosystem of finance underpinning SDG 7. The framework argues that, through the appropriate pairing with enabling regulatory environments and institutional capabilities – fintech can reduce financial obstacles, mitigate investments risks in renewables, and support broader access to the worldwide clean energy transition. This construct establishes the basis for unpacking the operative paths by which fintech applications are facilitating sustainable and scalable energy solutions in different economic contexts.

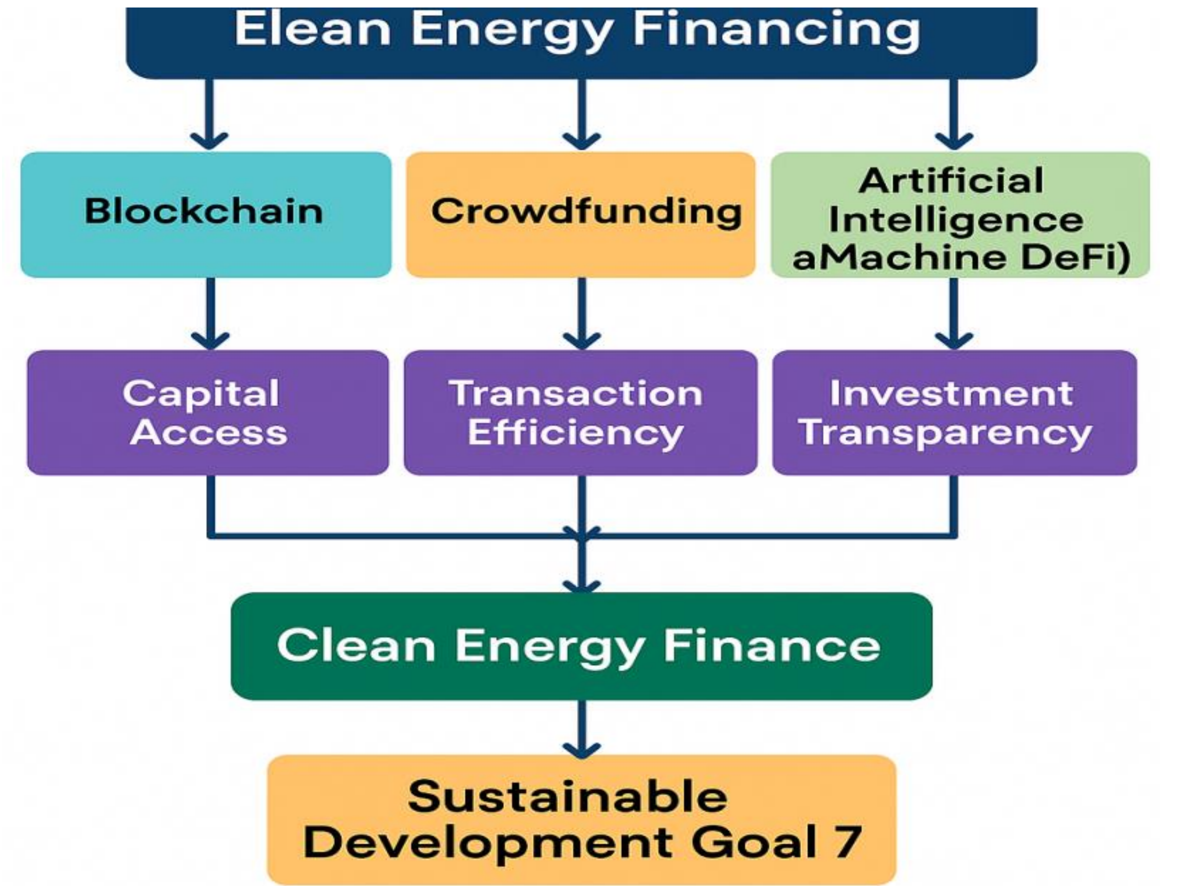

Figure 1. Conceptual Framework: Fintech Innovations for Clean Energy Financing toward Achieving SDG 7.

This conceptual framework illustrates how fintech mechanisms—blockchain, crowdfunding, AI/ML, and DeFi—collectively enhance capital access, transaction efficiency, and investment transparency. These elements converge to strengthen clean energy financing systems, addressing critical barriers in renewable energy investment. By streamlining financial flows and democratizing access, fintech innovations significantly contribute to accelerating progress toward Sustainable Development Goal 7 (SDG 7).

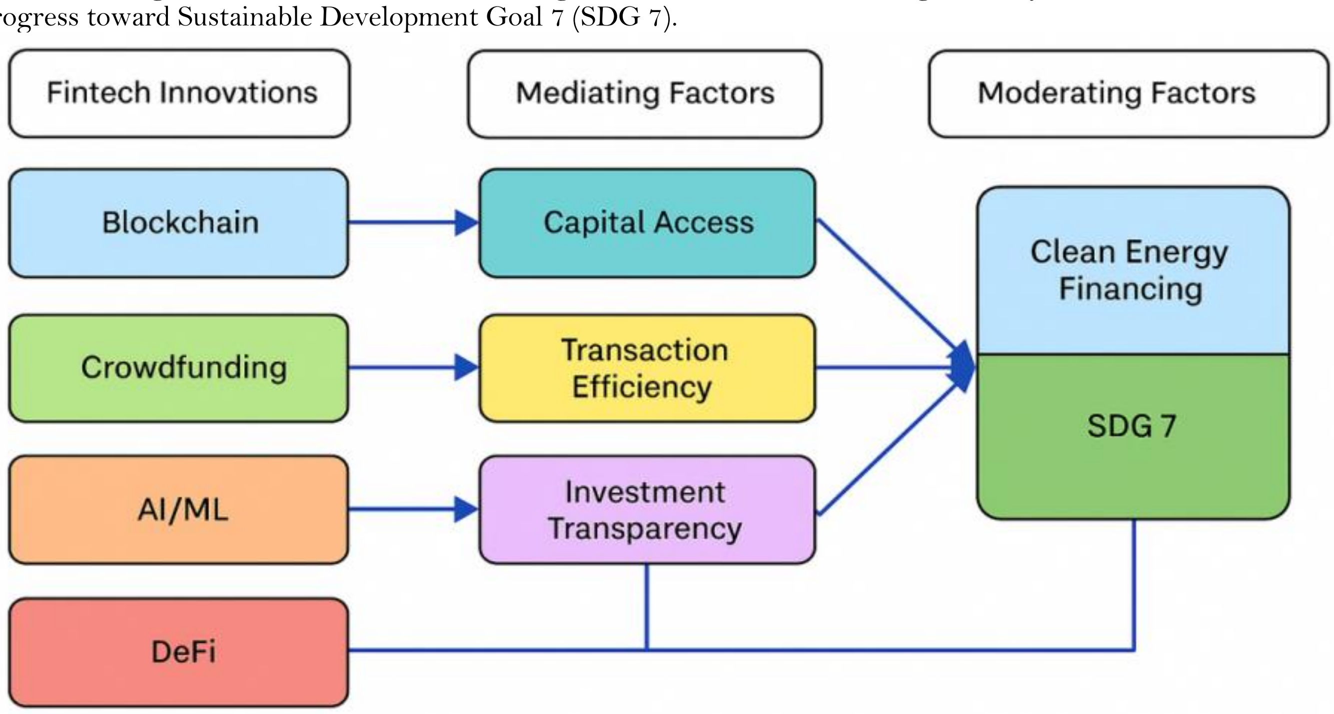

Figure 2. Extended Conceptual Framework: Fintech Innovations, Mediating and Moderating Factors in Clean Energy Financing for SDG 7.

This extended conceptual framework highlights how fintech innovations—blockchain, crowdfunding, AI/ML, and DeFi—impact clean energy financing through key mediating factors: capital access, transaction efficiency, and investment transparency. These mechanisms are influenced by moderating conditions such as institutional readiness and regulatory environment, ultimately shaping clean energy outcomes and advancing Sustainable Development Goal 7 (SDG 7) in both developed and emerging economies.

2..2. Theoretical Framework

ThThe study of financial technology (fintech) as an enabler in fast-tracking investment in renewable energy and the attainment of Sustainable Development Goal 7 (SDG 7) needs a solid theory investment. A multi-dimensional lens that draws from Financial Intermediation Theory, Diffusion of Innovation Theory and Sustainable Investment Theory is used in this paper. Specifically, these theories together present a multi-faceted framework for interpreting processes of how fintech innovations— including blockchain, crowdfunding, artificial intelligence and machine learning (AI/ML), and decentralized finance (DeFi)— reshape conventional financing models and facilitate clean energy development.

Financial Intermediation Theory, as developed by Gurley and Shaw (1960), suggests that intermediaries are necessary to lower the real costs of engaging in both the production and exchange of information and to provide efficient means through which savings and borrowers can be matched. Conventional financial intermediaries, like banks and development finance institutions, have generally been the dominant channels for clean energy finance. But, such organizations are often found to be relatively shackled by regulation, they have only a modest access and their investment behaviour quite conservative, and in particular as regards the funding of decentralized or small scale renewable projects (Allen & Santomero, 1997). It is in this backdrop that innovations (fintech) are chipping this landscape by cutting through financial intermediation. On the other hand, blockchain can assert peer-to-peer trustless transactions, crowdfinding platforms democratize capital raising, and directly match with investment, energy developers over investors with no need to go through traditional credit intermediaries lending channels (Zhang et al., 2021; Pazaitis et al., 2022). These solutions accelerate financing and lower the barriers to entry by increasing the number of players who can invest in clean energy, which in turn achieves greater efficiency of capital flows and greater access to finance.

This is complemented by a macro-structural view, incorporating the famous theory progression of diffusion of innovation (Rogers, 2003), which describes how innovations are adopted and spread in societies throughout time. The adoption of fintech in RE is influenced by the perceived innovation attributes: relative advantage, compatibility, complexity, trialablity and observability. The transparency, immutability and decentralization of the blockchain, for example, renders it especially appropriate for trust-building in energy transactions and verification of green assets (Saberi et al., 2021). Crowdfunding platforms appeal to socially responsible investors interested in handson involvement in meaningful projects (Shneor et al., 2020). AI also fosters more comprehensive and data based risk profiling as it allows for newfangled credit models to reach unbanked segments (Mansour, 2021). The penetration of these technologies is shaped by forces, however, that moderate and reshape the adoption and implementation of these technologies, such as the readiness of institutions to support them, regulatory regimes, digital infrastructure, and cultural acceptance, that in turn shapes the speed, scale, and equity of adoption in various contexts.

Value Based- Value Based :This theory posits that investment decisions should not be made based on the financial data alone, but also consider other factors such as "the economic and societal cost of connecting" the ESG factors. Philosophically solidly based on long-termism and stakeholder theory, it acknowledges that the use of capital must be consistent with societal aims more broadly, such as climate mitigation, energy justice and inclusive development (Sullivan & Mackenzie, 2017). Fintech solutions support these guidelines through the provision of platforms and protocols enabling impact measurement, transparency and accountability. For instance, blockchain makes traceable green bond issuance and carbon credit verification (Boreiko and Massarotti, 2022); artificial intelligence powers ESG scoring and sustainability risk assessment; DeFi protocols enable programmable investments against environmental thresholds; and crowd-funding nurtures contested locally owned and civic-participant energy transition (Belleflamme et al.2022. These fintech apps translate the message in sustainable finance by integrating ESG in the very foundation of investments.

Combined, these three theories offer a dynamic and comprehensive perspective on how and why fintech innovation and clean energy financing intersect. Understandably the structural shift in financial markets is informed by Smith-Mencka's Financial Intermediation Theory; the adoption and scaling of fintecs by Drucker's Time, Talent and Knowledge Society through the lens of Diffusion of Innovation Theory; and their alignment with long-term environmental and social objectives through Governance on Digital Finance by using Sustainable Investment Theory.

In summary, this study also relies on a dual theoretical framework: Financial Intermediation Theory is mobilized to examine how fintech mechanisms reshape the acce ss to and efficiency of capital flows, while Sustainable Investment Theory informs the analysis of the alignment of these mechanisms with sustainability and climate goal s at large. The Diffusion of Innovation Theory indeed is a complementary approach to understand the adoption behaviour and contextual triggers or obstacles. This combined theoretical basis is the analytic scaffolding 9 10 to investigate how fintech innovations can disrupt investment models and accelerate towards achieving SDG 7.

2.3. Empirical Review

The intersection of financial technology (fintech) and renewable energy investment has received academic and policy attention in recent years, largely as a response to the financing constraints of Sustainable Development Goal 7 (SDG 7)—universal access to affordable, reliable, sustainable and modern energy. An emerging literature delves into the prospects for new fintech business models to transform direct investments into financing solutions, and work to create more inclusive, efficient, transparent energy systems. This article provides a review and synthesis of the existing literature on four major fintech innovations—blockchain, crowdfunding, artificial intelligence (AI) and machine learning (ML), and decentralized finance (DeFi)—and their uses within the renewable energy domain.

2.3.1. Fintech and Financing of Renewable Energy

Conventional financial systems have found it difficult to adapt to the decentralized, capital-intensive and risk-embracing dimension of investments in renewable energy, especially in developing countries (IRENA, 2020; World Bank, 2019). In return, fintech has become a disruptive catalyst in connecting capital voids while driving down economic walls. According to Zhang et al. (2021), through fintech, money and information can flow through new channels without traditional intermediaries, which contribute to financial inclusion and green investment. Fostering investments consistent with ESG principles Devices for robo advice in the fintech sense model investing decisions in an ESG-compliant way as underlined by Boreiko and Massarotti (2022).

2.3.2. Applications of Blockchian in Clean Energy

The focus and attention of the power community on blockchain technology has the same logic of being driven by the utility of the technology to improve transparency, lower transaction costs, and to enable decentralized trading systems. Saberi et al. (2021), blockchain supports direct P2P energy trade, instantaneous transaction payment, and renewable energy asset tokenization, leading to energy democratization. Pazaitis et al. (2022) illustrate how blockchain can be employed to verify carbon credits and support green bond issuance, as a trust-enabling infrastructure around ESG-linked finance. However, adoption is limited due to regulatory ambiguity, complex technology, scaling in the developing world (Zhao et al., 2023).

2.3.3. Crowdfunding & Community Finance

Such platforms have emerged as key facilitators in driving grass-roots investment in local renewable projects. Shneor et al. (2020) explain that crowdfunding enables participatory finance with individuals and communities co-financing solar mini-grids and bioenergy systems. Belleflamme et al. (2022)) underscore how equity- and reward-based crowdfunding models have succeeded in engaging retail investors with green energy startups, in particular through the value-based connection to sustainability. Yet some doubts still arise about investors protection, due diligence for ensuring that small projects are not already collapsed and non-institutionally funded crowdfunding projects will survive in the long time (De la Hera et al., 2020).

2.3.4. Risk Assessment and Optimization Using AI and Machine Learning

Credit scoring, fraud detection, and financial forecasting in energy finance are increasingly becoming augmented by AI and ML technologies. Mansour (2021) shows how AI-driven alternative credit scoring can improve financial inclusion of underbanked renewable energy (RE) entrepreneurs. AI also supports dynamic pricing, load prediction and predictive analytics for energy demand, thus improving project feasibility and financial planning (Wang et al., 2021). However, the dependence on high-quality data and concerns of algorithmic bias make equitable implementation challenging (Hussain et al., 2023).

2.3.5. DeFi and Programmable Investments

DeFi is a budding subsect of fintech that uses blockchain technology to provide decentralized lending, borrowing, and asset management without the need for traditional intermediaries. Schär (2021) [Informal Comments, 5] describes DeFi protocols as providing programmable finance – smart contracts that automatically implement investment criteria like sustainability thresholds or emission limits. This feature is especially applicable for green finance where performance-based investment models are gaining significant importance. But the volatility of DeFi markets and lack of established regulatory structures pose risks for large investors (Aramonte et al., 2022).

2.4. Gaps in the Literature

Although the literature demonstrates the transformative role of fintech in green finance, there are still some gaps. First, many articles are merely about the functionality of the technology without a fair assessment of the project success, social equity, or environmental performance. Second, evidence from empirical studies on the fintech-enabled energy finance are primarily focused on developed markets, with a dearth of studies in Sub- Saharan Africa, where access to finance is most problematic (Mendes & Soares, 2022). Third, no integrative study on the composite impact of multiple fintech tools—blockchain, crowdfunding, AI, and DeFi together—on one financing mode. Finally, little is known about mediating or moderating variables: i.e., the readiness of regulation (Susskind, 2013) or the willingness of agents in the renewable energy field (hdr) and omnibus law, 2020).

3. Methodology

This piece is designed as a qualitative, multi-method study appropriate for an interdisciplinary examination at the intertwined nodes of fintech, renewables and sustainable development. Because fintech applications in renewable energy finance are still developing and are contextually embedded, the methodology combines desk research, integrative literature review and multi-case study approach to provide conceptual rigour and empirical applicability. This architecture allows for testing of new financial architectures and their effects on SDG 7 (in particular in developing and transitional economies).

3.1. Research Design and Approach

The research is explorative in nature and the methods of interpretation and analysis occupy a more important place than those of testing hypothesises. The justification for this is that there is a requirement to comprehend the complicated concepts that are associated with how fintech innovations, such as blockchain, crowdfunding, AI/ML, and decentralized finance (DeFi), alter the investment patterns for renewables. Because of the novelty of fintech apps in this domain and the limited amount of empirical evidence from across regions, qualitative studies provide rich contextualization, thematic exploration, and theory-generative research.

3.2. Data Sources

The research is based on secondary data from academic studies, policy papers, regulatory reports, fintech white papers, and international institutions' databases. Fintech and green finance trends you can learn from Fintech and green finance trends you can learn from No-header article Text published 2017-10-03 Reference to Fintech in the scientific papers also reads with a pixel weight (http://www.50partners.com/wpcontent/uploads/2016/05/fintech_colorspace.pdf) In this edited volume, For instance, Scopus-indexed journals, such as ScienceDirect, SpringerLink, Wiley, and Emerald Insight to name a few, offer academic perspectives on fintech and green finance trends. Institutional sources constitute reports, papers and documents from IRENA, UNSDG, World Bank, AfDB and IEA. Moreover, reports and working papers from major fintech platforms and blockchain consortia are referred to for practical applications within energy finance ecosystems.

3.3. Literature Selection and Review Process

The review is conducted using an integrative review approach to integrate knowledge across inter-discipline fields and learn from a range of literatures. This focus makes sense in terms of theorising about the convergence of finance, technology, and sustainability in relation to energy access. The search strategy is in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline for qualitative syntheses. The following keywords have been used: fintech AND renewable energy, blockchain AND energy finance, AI AND sustainable investment, crowdfunding AND SDG 7, DeFi AND energy access, green digital finance. Eligibility criteria Peer-reviewed published studies between 2018 and 2024 focussing on fintech in clean energy or ESG-aligned finance. Excluded are editorials, speculative opinion pieces and publications lacking an appropriate methodological description.

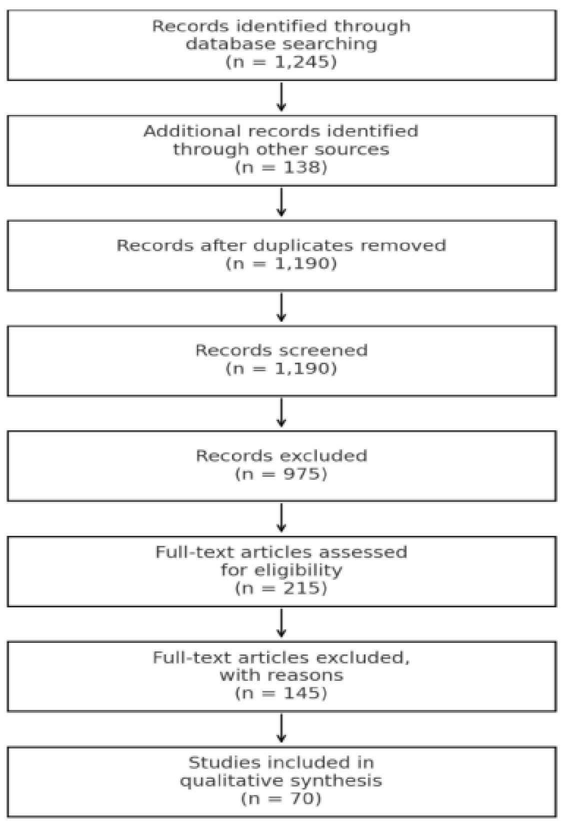

Figure 3. PRISMA 2020 Flow Diagram.

3.4. Case Study Selection and Framework

To contextualize the conceptual insights, multiple case studies are incorporated, focusing on countries where fintech innovations are actively supporting renewable energy deployment. These include:

Nigeria: Crowdfunded solar mini-grids and mobile payment integration.

Kenya: M-PESA-based financing of off-grid clean energy systems.

India: Blockchain-enabled peer-to-peer energy trading platforms.

Germany/Estonia: Tokenized green bonds and DeFi-based green finance pilots.

The case selection criteria include geographical diversity, innovation maturity, and demonstrable impact on energy access or financing mechanisms. Each case is examined using a thematic framework comprising innovation type, regulatory environment, capital mobilization model, ESG alignment, and outcome effectiveness.

3.5. Analytical Strategy

The data is analyzed using thematic content analysis, organized around four analytical dimensions:

Mechanism of fintech innovation (e.g., blockchain architecture, AI algorithm, DeFi protocol),

Financing model (e.g., P2P lending, crowdfunding, tokenization)

Outcomes (e.g., improved access to capital, enhanced transparency, ESG compliance),

Enabling or moderating factors (e.g., regulatory frameworks, institutional capacity, technological infrastructure).

NVivo or ATLAS.ti software tools are optionally applied for coding literature and policy texts where needed, ensuring a consistent coding scheme for pattern identification.

3.6. Trustworthiness and Rigor

For rigor, the study follows Lincoln and Guba (1985) qualitative research trustworthiness criteria of credibility, transferability, dependability, and confirmability. Credibility is established using various sources of data triangulation. Detailed contextualization aids in transferability. Dependability is established by documenting the analysis process, and confirmability is achieved by citing publicly available data sources and published evidence.

3.7. Ethical Considerations

Since the research is purely based on secondary data and published literatures, a research of this nature confirms its non-human subject benefit and not involving the ethical issues related to primary research. However, I am careful to cite sources, because that of course is part of getting the data right and abiding by the ethical practices of academic research.

4. Case Study and Comparison of Alignment

The use of fintech advances in financing renewable energy is more and more apparent in emerging and transitional economies. This chapter focuses on three country-level examples Nigeria, Kenya, and India to discuss how different types of digital tools, namely blockchain, crowdfund, and mobile fintech solutions are transforming access to clean energy finance. Each case is analyzed according to fintech modality, financing architecture and synergy with Sustainable Development Goal 7 (SDG 7), and compared in relation to lessons and scalability factors.

4.1. Nigeria: Crowdfunded Solar Mini-Grids

Energy access still presents an enormous challenge for over 85 million Nigerians who are without access to sustainable power (IEA, 2021). The conventional grid expansion is still not economically and practically viable for isolated regions, which has led to the emergence of off-grid renewable energy solutions like solar mini-grids. Crowdfunding networks such as Havenhill Synergy, AllOn and the Renewable Energy Performance Platform (REPP) have also enlisted small-scale private financing to fund solar mini-grids in rural areas. Via online platforms, they combine investment from individual and institutional investors (reward and debt-based models).

These platforms have succeeded thanks to their transparency, low investment thresholds and social impact narratives, all catering to impact-oriented investors and diaspora communities (Shneor et al., 2020; Belleflamme et al., 2022). For instance, Havenhill's crowdfunding provided for the installation of Solar Microgrids to underserved villages in Abuja and Nasarawa states, marrying technology access with community participation (REPP, 2021). These interventions use digital monitoring instruments for performance monitoring and mobile-based repayment structures that increase financial accountability and user affordability.

4.2. Kenya: M-Power Integration in Off-Grid Renewable Projects

Kenya is a global leader in harnessing mobile fintech for inclusive energy access. Over 70% of adults are using mobile money platforms (mainly M-PESA), and the country has built a strong eco- system for pay-asyou-go (PAYG) solar systems. Firms such as M-KOPA Solar, Azuri Technologies and d.light, operate in a similar manner—these companies employ mobile fintech platforms to supply off-grid households with solar lighting, mobile charging and efficient appliances on pay-as-you-go terms (Kudo et al., 2021).

The fintech service in Kenya leverages mobile payments, ID systems, and AI- driven credit scoring to enable real-time, risk-mitigated energy lending. These new technologies enable unbanked communities to apply for clean energy without the need for any collateral or investment up front (Hussain et al., 2023). The convergence of mobile fintech with energy service delivery contributes not just to SDG 7 but also intersects with SDG 1 (No Poverty) and SDG 9 (Industry, Innovation and Infrastructure) by promoting entrepreneurship and digital inclusion.

4.3. India: Blockchain-Enabled Peer Energy Trading

India is integrating Blockchain-powered peer-to-peer (P2P) energy trading to increase grid flexibility and decetralize energy access. The Uttar Pradesh Power Corporation Ltd. and Bihar State Power Holding Company have worked with Power Ledger (an Australian blockchain company) to trial decentralized energy markets in parts of their urban and peri-urban areas (Power Ledger, 2020). These markets enable households with rooftop solar power (prosumers) to sell electricity to their neighbors directly using smart contracts and blockchain ledgers.

The blockchain-based infrastructure allows secure, transparent, and real-time energy settlement to minimize the transaction costs and inefficiencies of centralized utilities (Saberi et al., 2021; Pazaitis et al., 2022). Energy tokens are transferred to customers when they get surplus power back and can either be cashed or used as reinvestment into the circular energy economy etc. The regulatory sandbox and digital utility reforms of the Indian government, on the other hand, have enabled these pilots, effectively making India one of the first of the emerging economies to be experimenting with scalable blockchain solutions in the retail energy market (Zhao et al., 2025).

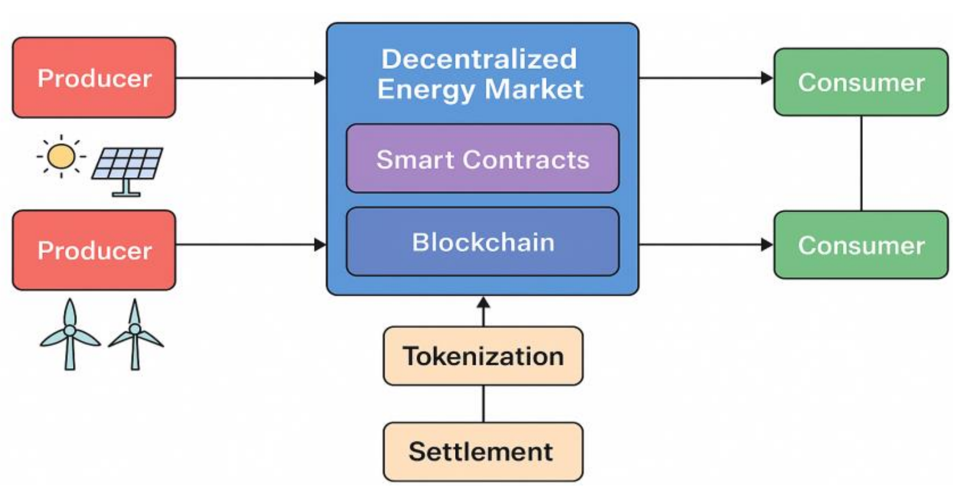

Figure 4. Blockchain-Based Peer-to-Peer Energy Trading Model.

This comprehensive diagram illustrates a blockchain-based peer-to-peer (P2P) energy trading model, where energy prosumers with solar or wind generation trade excess power directly with consumers through a decentralized ledger system. Smart contracts automate payments, and tokenized energy units facilitate secure, transparent, and real-time settlements. The model promotes efficiency, reduces intermediaries, and supports localized, low-carbon energy economies.Saberi et al.,

4.4. Lessons Learnt and Scalability across Comparisons

These three cases bring out the themes of how fintech is fast tracking the deployment of renewable energy. First, the technology aligns with user behavior, driving strong adoption rates; witness mobile money in Kenya or social media-based crowdfunding in Nigeria. Second, the digital financial inclusion is strategic in achieving penetration to the underbanked segments, and it permits small-ticket investments as well as micro-repayments, which the traditional bankers cannot support (Mansour, 2021).

But disparate levels in regulatory preparedness, infrastructure development and digital literacy mean different paths to scalability. The success of India's blockchain is supported by the proactive energy regulation and the sophisticated ICT infrastructure cycle, and Nigeria's crowd funding models, which are very reliant on diaspora and philanthropic capital, are not completely institutionally embedded in the support structures. Kenya's mobile-first ecosystem, supported by the ubiquity of M-PESA, demonstrates how fintech has been integrated into service delivery models to achieve larger social impact.

Scalability, in turn, depends on several convergent elements: (i) regulatory environment, including regulatory support in the form of sandboxes and licensing regimes; (ii) institutional capacity, chiefly, but not exclusively, among utilities and start-ups; (iii) access to infrastructures (in particular mobile and digital connectivity); and (iv) collaboration with the ecosystem including government, donor and investment partners. All of these variables will influence the extent to which fintech-driven energy models can evolve from tests to system-wide applications, which are significant contributors to the SDG 7 targets.

Table 1. Comparative Table: Fintech Applications in Renewable Energy Finance.

Country	Fintech Application	Technology Used	Key Actors	Regulatory Support	Outcomes	Challenges
Nigeria	Crowdfunding for solar mini-grids	Crowdfunding platforms, mobile payments, digital monitoring	Havenhill Synergy, REPP, AllOn	Limited; evolving regulatory framework for crowdfunding	Expanded rural energy access, community engagement, diaspora investment	Low regulatory clarity, reliance on donor and diaspora capital
Kenya	Mobile Pay-as-you-go (PAYG) solar systems	M-PESA, AI-driven credit scoring, mobile platforms	M-KOPA, d.light, Azuri Technologies	Strong; well-established mobile finance ecosystem	Inclusive access for unbanked populations, improved payment flexibility	Affordability at scale, cybersecurity vulnerabilities
India	Blockchain-enabled peer-to-peer energy trading	Blockchain, smart contracts, IoT integration	Power Ledger, Uttar Pradesh and Bihar utilities	Supportive pilot programs via regulatory sandboxes	Transparent energy trading, reduced transaction costs	Scalability, integration with national grid, legal ambiguity

5. Policy and Regulatory: Implications

The successful incorporation of fintech solutions in renewable energy finance are inherently contingent on a supporting policy and regulatory framework that juxtaposes the digital financial systems with sustainability goals. Central banks, financial regulators, and energy commissions, and so on, are all involved in (perhaps unconsciously) shaping the institutional architecture which dictates the patterns of capital flow, operation of financial technologies and progression of energy markets. Their interventions influence the uptake of technologies including blockchain, peer-to-peer lending and DeFi, and their supervision is instrumental in maintaining a balance between innovation and systemic stability (Arner et al., 2016). Central banks, in particular, play a crucial role in framing the regulatory environment for digital payments, mobile money platforms, and open banking systems—technologies that underpin fintech-enabled energy access, especially in 'off-grid' rural populations (Ozili, 2018).

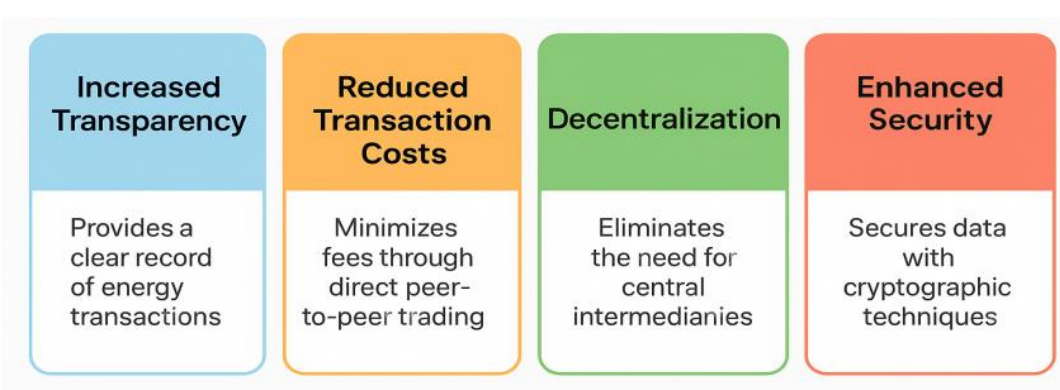

Figure 5. Benefits of Blockchain in Renewable Energy Markets.

This diagram highlights the comprehensive benefits of blockchain in renewable energy markets. It showcases how blockchain enhances transparency, reduces transaction costs, automates contract execution, facilitates decentralized energy trading, and improves traceability of green assets. By removing intermediaries and enabling real-time, tamper-proof data flows, blockchain fosters trust, scalability, and financial innovation in clean energy systems. Saberi et al., 2021.

An increasingly successful tool to foster innovation and safeguard regulation at the same time, are regulatory sandboxes. These are sandboxed domains where fintech enterprises can try out new models — they might include using artificial intelligence in credit assessments for off-grid energy projects, or using blockchain-based systems to trade energy — in restricted pilot areas under short-term waivers or limited licenses, under the watch of financial authorities. Regulatory sandboxes have been successfully implemented in countries including Nigeria, Kenya and India, in the latter case where financial innovation units within central banks have teamed up with energy agencies to test inclusive and green finance solutions (Zetzsche et al., 2017; Di Castri & Plaitakis, 2021). Regulators can use these frameworks to observe the evolution of risks and facilitate market experimentation. Alongside sandboxes, sustainability and financial inclusion objectives are gaining traction in national digital finance strategies. For example, in Kenya, the National Treasury Digital Finance Policy (2020) lists green finance and renewable energy investment as targeted areas for digital finance scale up. Governments could use fintechs to leverage private capital towards renewables more effectively by embedding ESG considerations into fintechs and providing incentives, such as tax relief or concessional finance, to help them steer finance towards sustainability-aligned projects (IFC, 2021).

Still, the potential of fintech for renewable energy finance remains limited by entrenched structural impediments. These include, but are not limited, to a digital divide expressed as the uneven access to internet infrastructure, digital equipment, and digital literacy, especially among rural areas, women, and the poor. This cleft impedes broad participation in fintech platforms and worsens inequalities of access to clean energy and financial inclusion (World Bank, 2022). Furthermore, fears over cyber security are mounting as fintech platforms manage more and more customer data and transactions. (2022) also argue that breaches in data, system, and fraud protections can lead to a loss of trust and investor confidence, and that this is especially the case where cyber security regulation is lacking or unevenly applied. There is also a legal uncertainty of smart contracts, tokenized energy assets as well as cross-border DeFi transactions that generate regulatory complications. Most developing nations do not yet have any comprehensive legal framework to facilitate the decentralized paradigm, which has given rise to ambiguous white spots and therefore to obstacles for institutional investors becoming involved and for the long term scalability (Ghosh & Ghosh, 2022).

Navigating these issues will require multi-stakeholder governance that involves financial, energy, and digital regulators. Collaboration between fintech developers, utilities, regulators, and civil society is critical and must be driven across the sector in order to co-create regulatory environments that promote innovation and protect the public. These frameworks must be developed with interoperability, digital inclusion and sustainability at their heart. The systemic impact of fintech to democratize renewable energy finance will be limited by infrastructure and incumbents' inertia unless policy integration is pursued deliberately. As such, a proactive, forward-looking approach to regulation is necessary to capture the complete potential of fintech policy to facilitate clean energy transitions and to hasten progress on SDG 7 (United Nations, 2019; Zhang et al., 2021).

6. Findings and Discussion

This article reviews literature, policy documents, and international cases and shows that financial technology (fintech) is gradually changing renewable financing by facilitating access to capital, improving investment efficiency, and promoting transparency. Such changes are of particular importance in developing and transition economies where energy access continues to be hindered by a lack of infrastructure and barriers related to traditional financing. The results highlight three key mechanisms by which fintech solutions—blockchain, crowdfunding, artificial intelligence and machine learning, (AI/ML) and decentralized finance (DeFi)—can help achieve Sustainable Development Goal 7 (SDG 7).

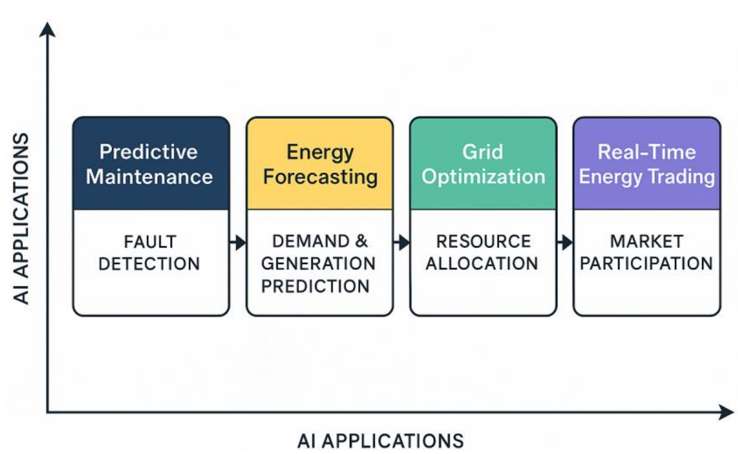

Figure 6. AI Integration in Renewable Energy Systems.

This diagram illustrates a comprehensive integration of Artificial Intelligence (AI) across the renewable energy system. It shows how AI supports energy forecasting, predictive maintenance, dynamic load management, grid optimization, and real-time trading. Through machine learning and smart sensors, the system improves efficiency, reduces downtime, and facilitates intelligent energy distribution aligned with sustainability goals.Wang et al., 2021

First, fintech significantly expands access to capital for renewable energy projects. Crowdfunding and peer-to-peer (P2P) lending platforms have emerged as effective alternatives to traditional financing, enabling small and medium-scale developers to raise funds from retail and impact investors. Evidence from Nigeria shows that crowdfunded solar mini-grids successfully mobilize diaspora capital and promote energy inclusion in underserved communities (REPP, 2021). Similarly, Kenya's use of mobile-money platforms like M-PESA to support pay-as-you-go (PAYG) solar systems demonstrates how digital financial tools can empower previously unbanked populations to access clean energy (Kudo et al., 2021). These mechanisms decentralize financial decision-making, bypass credit gatekeepers, and foster localized ownership—features that are especially valuable in contexts where institutional finance is absent or risk-averse.

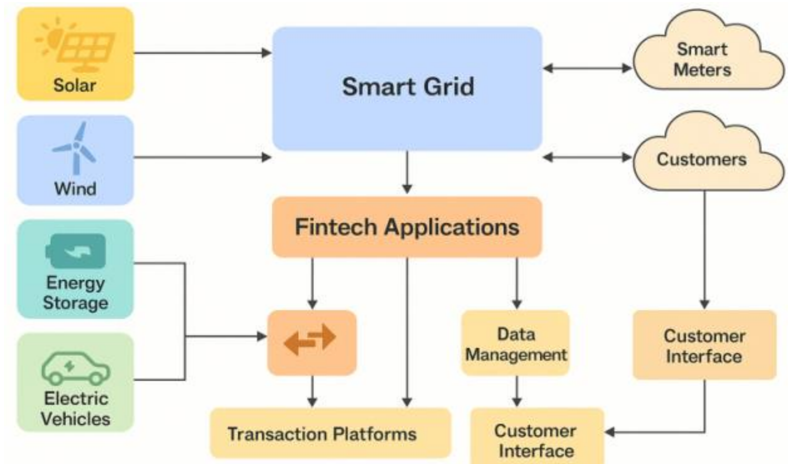

Figure 7. Smart Grid Architecture Incorporating Fintech Solutions.

This diagram presents a smart grid architecture integrated with fintech solutions, where renewable sources like solar and wind are connected to smart meters, storage systems, and decentralized markets. Fintech applications enable real-time payments, data analytics, and customer engagement through blockchain, mobile platforms, and AI. The system ensures efficient energy flow, transparency, and financial inclusivity across the energy value chain. Zhang et al., 2021

Second, fintech enhances the efficiency and scale of renewable energy financing by utilizing advanced analytics and digitalized infrastructure. Dynamic credit scoring, load forecasting and fraud detection leveraged by AI/ML tools have helped improve the accuracy and speed in delivery of financial and energy services (Mansour, 2021; Wang et al., 2021). In India, the introduction of blockchain-facilitated peer-to-peer energy trading platforms has shown promise in driving down transaction costs and enabling settlement to be made more speedily through smart contracts and distributed ledgers (Power Ledger 2020). These advancements decrease both the cost and cycle time of energy financing and open up new business models, which were not possible with traditional financing models.

Third, fin-tech-powered traceability and real-time monitoring tools have helped improve transparency & accountability in clean energy finance. Blockchain technologies can make it possible to verify that green assets perform as promised, and to issue digitalized financial instruments, such as green bonds and carbon credits (Saberi et al., 2021; Pazaitis et al., 2022). The suite of tools are especially powerful in attracting institutional and impact investors, who are increasingly asking for measurable environmental and social impacts. Fintech and the incorporation of ESG Metrics The incorporation of ESG metrics into digital finance ordinances brings investor expectations into deeper alignment with underlying project performance, thereby contributing toward a more sustainable future.

On the negative side, however, the results also present barriers and contextual limitations that prevent the exploitation of full potentials of fintech in the renewable energy finance. A key challenge is the digital divide, which limits the reach and impact of fintech platforms for marginalised groups, particularly in rural and low income areas (World Bank, 2022). Further, cybersecurity weaknesses and regulatory ambiguity, especially regarding DeFi protocols, smart contracts and cross-border deals, also present threats to trust and scalability (Ghosh & Ghosh, 2022; Boreiko & Massarotti, 2022). This suggests that while fintech can reduce inefficiencies in energy finance, its efficacy depends very much on facilitating policy contexts, digital infrastructures, and institutional capabilities.

The conversation confirms the theoretical foundations of the study as well. Under a Financial Intermediation Theory approach, fintech explains how financial intermediaries' role change by facilitating decentralized capital movements and lowering transactional issues (Allen & Santomero, 1997). Using Diffusion of Innovation Theory (Rogers, 2003), the adoption of fintech in renewable energy follows trends in innovation adoption, more so influenced by perceived value, trialability and contextual factors. Sustainable Investment Theory is also reinforced as ESG benchmarking and impact verification tools become more integrated in the design of fintech platforms, encouraging the long-term integration of values and responsible investment practices (Sullivan & Mackenzie, 2017).

The results of this study note that those fintech innovations are technologically transformative and structurally disruptive, meaning involving them democratize access, improve efficiency and reinforce accountability in the context of renewable energy finance. Nevertheless, these platforms' scale, and utility is contingent upon overcoming systemic obstacles such as legal uncertainty, cybersecurity infrastructure, and the digital competence of end-users. This informs the need for future research to incorporate these insights as elements of larger financial and energy policy frameworks that accommodate a fintech as an enabler—rather than just an efficiency driver— for just and sustainable energy transitions in the Global South.

7. Conclusion and Suggestions

This article aims to explore how fintechsolutions – in the form of blockchain, crowdfunding, artificial intelligence/machine learning (AI/ML), and decentralized finance (DeFi) – are disrupting renewable energy investments models and supporting the attainment of Sustainable Development Goal 7 (SDG 7). The research is primarily informed by integrative literature review, policy analysis and cross-national case studies, and has revealed that fintech shows great potential in transforming financing of clean energy by providing better access to capital, making transactions more efficient, and by improving transparency and traceability.

The results emphasize that fintech platforms are facilitating new types of decentralized, inclusive and scalable sustainable energy finance – especially in growth markets such as Nigeria, Kenya and India. In this way, fintech is not just tackling age-old challenges to financing, but also enabling communities locked out of funding sources to be part of the transition to clean energy. Innovations like mobile-enabled PAYG models, blockchain-powered energy trading, and digital crowdfunding are disrupting the geography of financial intermediation and driving lower-level investment streams.

Nevertheless, the study also highlights important constraints and contextual risks for attention. The digital divide still represents a significant barrier to the inclusiveness of fintech-enabled energy solutions. Cybersecurity exposure, uncertainty about DeFi and smart contract legalities, and the lack of harmonized regulations still present challenges to further scale and trust in fintech. Implications-These findings indicate that although fintech innovations are inherently transformative, their sustained transformational effects largely depend on enabling institutional contexts, effective governance frameworks and inclusive digital infrastructures.

In view of this awareness there are the following recommendations made by the study:

Policymakers and regulators need to develop flexible, innovation-friendly regulatory environments that encourage fintech experimentation, before safeguarding consumer protection and data security, for example through mechanisms such as regulatory sandboxes. The convergence of regulations among financial and energy fields is essential for the scaling of integrated solutions.

DFIs and multilateral institutions should finance digital infrastructure and capacity-building programs, especially in low-income and rural areas, in order to narrow the digital divide and improve access to fintech by renewable energy stakeholders.

Fintech and energy developers should focus on inclusive design by incorporating environmental, social and governance (ESG) metrics, affordability mechanisms and localized UI, to ensure that financial and technological innovation is integrated with social equity goals.

The intersection between fintech, energy access, and sustainability deserves more attention by scholars, nongovernmental organizations, think tanks, and the research community, especially in under studied regions. Given the paucity of evidence regarding the long-term (and perceived) developmental, risk and socio-environmental implications of fintech-driven clean energy projects, there is need for empirical research to guide real-time policies.

Cross-sector alliances between governments, fintech providers, utilities, civil society, and the private sector must be enhanced to develop collective innovation systems that can pool a range of financial resources towards universal energy access.

Fintech is, in sum, a key facilitator of the energy transition. When used in a thoughtful and transparent manner, it has the potential to unlock new paths to reach SDG 7 – to make universal and affordable, reliable, and modern energy services a global and common reality.

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