Green Digital Finance: Leveraging Financial Technology for Sustainable Environmental Investments

Finance numérique verte : tirer parti des technologies financières pour des investissements environnementaux durables

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Abstract: *This article reviews recent literature on Green Digital Finance to examine its role in addressing sustainable development challenges and narrowing the green financing gap. A descriptive–analytical approach was employed to explore how digital financial technologies are integrated into green finance practices. The findings indicate that Green Digital Finance supports sustainable investments through key mechanisms, namely green innovation, the modernisation of industrial sectors, and improved access to clean energy and financial services. However, it faces several challenges that may constrain its effectiveness*

Keywords: *Green Digital Finance; Sustainable Investments ; Digital Paradox; Financial Inclusion ; Green Innovation .*

JEL Classification: G20, G28, O16, O33, Q55, Q56

Résumé *: Cet article passe en revue la littérature récente sur la finance numérique verte afin d'examiner son rôle dans la réponse aux défis du développement durable et dans la réduction du déficit de financement vert. Une approche descriptive et analytique a été adoptée pour analyser la manière dont les technologies financières numériques sont intégrées aux pratiques de la finance verte. Les résultats montrent que la finance numérique verte soutient les investissements durables à travers des mécanismes clés, notamment l'innovation verte, la modernisation des secteurs industriels et l'amélioration de l'accès à l'énergie propre et aux services financiers. Toutefois, elle fait face à plusieurs défis susceptibles de limiter son efficacité.*

Mots-clés :*Finance numérique verte ; Investissements durables ; Paradoxe numérique ; Inclusion financière ; Innovation verte.*

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1. Introduction

The twenty-first century presents a critical dual challenge for humanity: addressing the adverse impacts of climate change while fostering inclusive and sustainable economic growth (Devidze, 2022; Han & Gao, 2024). Global frameworks, such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), set forth binding mandates for a wide-scale transition towards environmentally sustainable practices across all sectors of the global economy. This transition is not only necessary but urgent, as it requires the mobilization of financial resources at an unprecedented scale. It is estimated that trillions of dollars per year are needed to close the "financing gap" in areas critical to sustainability, including renewable energy infrastructure, sustainable agriculture, and pollution mitigation (Han & Gao, 2024; Amin et al., 2022).

Traditional financial systems, however, have proven inadequate to meet these needs. High transaction costs, information asymmetries regarding environmental risks, and the inherently long-term, high-risk nature of green investments have created substantial barriers for both investors and innovators (Morgan, 2022; Vikas et al., 2022). In emerging economies, additional challenges such as fragmented policy frameworks and underdeveloped financial infrastructures further complicate the flow of capital necessary for sustainable development (Amin et al., 2022). In light of these obstacles, there is an urgent need for innovative financial mechanisms that can streamline investment processes, improve transparency, and catalyze the active participation of the private sector to accelerate progress towards sustainable development.

In response to these challenges, a new paradigm has emerged at the intersection of financial technology (FinTech) and environmental sustainability: Green Digital Finance (GDF) (Geetha & Biju, 2023). Green Digital Finance refers to the application of advanced digital technologies to foster environmentally sustainable investments and contribute to the achievement of SDGs (UNEP, 2018). This innovation represents a transformative shift in the financial landscape, offering solutions that overcome the limitations of traditional financial systems by harnessing

technologies such as Artificial Intelligence (AI), Big Data, Blockchain, and the Internet of Things (IoT) (Devidze, 2022).

The promise of GDF lies in its ability to address two critical issues simultaneously: improving the efficiency of green finance and promoting inclusivity for marginalized populations (Lee et al., 2025). GDF enables precise allocation of "green capital" by providing real-time data for risk assessment and impact measurement (Yin et al., 2024; Shi & Yang, 2024). Moreover, it facilitates the creation of new market mechanisms, including crowdfunding and peer-to-peer lending, which democratize access to green investments and empower small-scale initiatives previously excluded from traditional financial systems (Vikas et al., 2022). As such, GDF has been recognized as a key enabler for accelerating the low-carbon energy transition and achieving scalable sustainable growth (Shi & Yang, 2024; Yu et al., 2022).

Despite the growing interest in Green Digital Finance, academic discourse on the topic remains fragmented and lacks a unified framework to comprehensively analyze its complex mechanisms and challenges (Geetha & Biju, 2023). Much of the existing literature focuses on isolated applications or particular geographical contexts without offering a holistic view of the field's multifaceted dynamics (Lee et al., 2025; Yin et al., 2024). Critical issues, such as the "digital paradox"—where technology itself introduces environmental risks—or the uneven impact of GDF across different socio-economic strata, have not been sufficiently addressed in the existing body of research (Morgan, 2022; Gao et al., 2023).

To fill these gaps, this chapter presents a systematic literature review of Green Digital Finance, specifically exploring its role in leveraging financial technology for sustainable environmental investments. Through the synthesis of both theoretical and empirical studies, this review aims to build a robust conceptual framework that connects technological mechanisms with real-world outcomes. The analysis will critically assess the applications of GDF across various sectors, identify inherent risks and policy gaps, and propose actionable recommendations to inform future practice and research.

This article is structured as follows. Section 2 describes the methodology adopted for the systematic literature review. Section 3 presents

the conceptual framework and traces the evolution of Green Digital Finance within the broader context of sustainable finance. Section 4 provides a thematic analysis of key application areas, focusing on the role of Green Digital Finance in supporting green innovation, industrial transformation, and market integration. Section 5 discusses the main challenges and risks associated with Green Digital Finance, including the digital divide, regulatory gaps, and potential environmental trade-offs. Finally, Section 6 concludes the article by outlining policy implications and identifying directions for future research.

2. Methodology for Literature Review

This section outlines the methodology used for conducting a comprehensive and systematic review of the literature on Green Digital Finance (GDF). This methodology provides a structured approach to understanding the current state of GDF research, identifying key technological applications, and critically analyzing the associated challenges and future directions.

2.1. Research Sources and Search Strategy

The literature review focuses on capturing recent developments in the rapidly evolving field of Green Digital Finance (GDF). A targeted search was conducted using high-quality, peer-reviewed academic journals, working papers, and authoritative reports from respected international organizations. The primary database utilized for this search was Scopus, selected for its comprehensive coverage of research in finance, technology, and environmental science. To ensure broader coverage, additional searches were carried out on other key platforms, such as Springer Nature, Taylor & Francis Online, and major institutional repositories, including reports from the United Nations Environment Programme (UNEP), the World Bank, and the Asian Development Bank Institute.

The search query was meticulously designed, incorporating a combination of relevant keywords and Boolean operators to ensure maximum relevance to the chapter’s theme. Core search terms included "Green Digital Finance," "Fintech for Sustainability," "Green FinTech," "Digitalisation of Green Finance," and "Sustainable Investment Technology." To capture the latest trends and insights, the timeframe for the

search was limited to publications from 2022 to 2025, ensuring the inclusion of the most recent and relevant academic discourse and technological developments in the field of GDF.

2.2. Selection and Synthesis Criteria

Upon completion of the search, a rigorous filtering process was applied to the initial pool of documents to ensure that only the most relevant and high-quality studies were included in the review. The selection criteria were based on the following priorities:

- **Relevance**: Articles directly addressing the intersection of digital technology (FinTech) and green finance (sustainable investments) were prioritized.
- **Methodology**: Preference was given to empirical studies (e.g., econometric analyses, case studies, comparative studies) and comprehensive systematic literature reviews (SLR), which provide robust theoretical frameworks and a comprehensive understanding of GDF (Geetha & Biju, 2023).
- **Novelty**: Studies that presented new applications, emerging risks, or innovative policy interventions—such as the use of blockchain solutions or AI applications in Environmental, Social, and Governance (ESG) assessment—were specifically selected to ensure the review reflects cutting-edge insights.

The selected studies were subjected to a thematic synthesis approach (Kraus et al., 2020), which involved coding the documents to identify recurring themes, emerging applications, key empirical findings, and research gaps. This synthesis enabled the creation of a comprehensive GDF framework that organizes knowledge around central themes, such as technological mechanisms, sectoral applications, and critical challenges. The resulting framework forms the foundation for the subsequent sections of this chapter.

3. Conceptual Framework and Theoretical Evolution

3.1. Defining Core Concepts: Green Finance, Digital Finance, and GDF

To effectively analyze the intersection of technology and sustainability, it is essential to establish precise definitions for the key concepts in the field:

- **Green Finance (GF)**: Green finance refers to financial services that facilitate environmentally sustainable economic activities (Devidze, 2022). The primary objective is to mobilize capital towards projects that deliver environmental benefits, such as climate change mitigation, pollution reduction, biodiversity conservation, and efficient resource utilization (Han & Gao, 2024). Traditional green finance typically operates through conventional financial institutions (e.g., banks, investment funds) using instruments like green bonds and green credit lines (Vikas et al., 2022). However, this model faces structural challenges, such as high transaction costs and information asymmetry, which create significant gaps between the demand for and supply of green capital (Morgan, 2022).
- **Digital Finance (DF) / FinTech**: Digital finance, commonly referred to as FinTech, encompasses a broad range of technological innovations that redefine traditional financial services (Geetha & Biju, 2023). It includes applications ranging from digital payments and mobile banking to advanced technologies such as Artificial Intelligence (AI), Big Data, and Blockchain (Vikas et al., 2022). The primary benefits of FinTech include enhanced efficiency, reduced operational costs, faster transaction times, and improved financial inclusion by democratizing access to financial products (Lee et al., 2025).
- **Green Digital Finance (GDF)**: Green Digital Finance represents the integration of green finance objectives with digital finance technologies (Geetha & Biju, 2023). It is a dual-purpose paradigm where digital tools are applied to address environmental challenges, and sustainability is embedded within digital financial systems (Devidze, 2022). GDF is a new category of financial solutions designed to facilitate sustainable investments in a more efficient and transparent manner (Yin et al., 2024; Yu et al., 2022).

3.2. Evolution of the GDF Concept

The evolution of GDF can be traced back to the recognition of the "green finance gap" in the early 2010s. At that time, traditional financial mechanisms faced difficulties in identifying and verifying green projects, leading to a gap between the need for green investments and the availability of capital. The rise of digital technologies, however, created new

opportunities to address these challenges (Devidze, 2022). The initial focus was on integrating environmental, social, and governance (ESG) factors into investment decisions, but the subsequent digital revolution enabled the automation, verification, and scaling of these efforts (Geetha & Biju, 2023).

This evolution led to the recognition of GDF not merely as an ancillary component of sustainable finance but as a structural enabler of economic transitions towards sustainability. Contemporary academic literature now acknowledges GDF as a critical driver in achieving macroeconomic goals, such as alleviating energy poverty (Lee et al., 2025) and enabling industrial upgrades (Shi & Yang, 2024). As such, GDF marks a transition from a policy-driven model of green finance (which relied heavily on government incentives) to a market-driven model where digital technologies provide economic incentives and transparency to private investors (Vikas et al., 2022).

3.3. The Dual Perspective: Digitalisation of Green Finance and Greening of Digital Finance

Modern research on GDF distinguishes between two primary perspectives of integration:

- **Digitalisation of Green Finance**: This perspective focuses on applying digital technologies to enhance the efficiency and reach of existing green financial instruments. For example, digital platforms are used to automate the issuance of green bonds, reducing transaction costs and increasing transparency (Lee & Jeong, 2022). AI-powered credit scoring models also help financial institutions identify and support creditworthy green projects, overcoming information asymmetry and unlocking capital for small-scale initiatives that might otherwise be overlooked by traditional financial institutions (Devidze, 2022; Yu et al., 2022).

- **Greening of Digital Finance**: This perspective focuses on embedding environmental sustainability into core digital financial services. It involves the integration of sustainability parameters directly into FinTech platforms and digital banking applications (Geetha & Biju, 2023). Examples of this approach include digital payment platforms that calculate and offset users' carbon footprints, or digital lending platforms that apply green criteria in loan approvals (Devidze, 2022; Shi & Yang, 2024). This dual approach illustrates

the capacity of GDF to transform both the supply side (financial institutions) and the demand side (consumers and businesses) of the sustainable economy.

4. Thematic Analysis: Applications and Mechanisms

This section presents a detailed thematic analysis of the current literature on Green Digital Finance (GDF), focusing on the various mechanisms and applications that enable sustainable environmental investments. The analysis categorises GDF's role into two primary functions: facilitating capital mobilisation to address critical systemic and social challenges, and supporting specific sectors through innovative market mechanisms and technological solutions.

4.1. Green Capital Mobilisation Mechanisms

One of the most critical functions of Green Digital Finance (GDF) is its ability to promote financial inclusion by extending services to underserved populations, thereby addressing pressing social challenges such as energy poverty (EP). EP occurs when households lack access to sufficient, reliable, and affordable energy services, which significantly hampers sustainable development and threatens social welfare (Lee et al., 2025). GDF offers innovative solutions to mitigate EP by addressing the financing constraints typically associated with renewable energy (RE) projects, which are often perceived as high-risk and high-cost by traditional financial institutions (Lee et al., 2025; Devidze, 2022).

The literature identifies several key mechanisms through which GDF contributes to alleviating EP. First, digital platforms enhance financial access for low-income households, enabling the transition from high-polluting traditional energy sources, such as solid biomass, to cleaner alternatives (Lee et al., 2025; Devidze, 2022). A prominent example is the Pay-as-you-go (PAYG**)** model, which allows households to purchase solar power or other renewable energy technologies in small instalments via digital payments. As noted by Devidze (2022), this model reduces the significant upfront cost barrier that often prevents low-income consumers from accessing clean energy, accelerating the adoption of renewable energy solutions in regions where traditional banking services are either non-existent or inaccessible.

Furthermore, GDF promotes energy efficiency by financing RE technology innovation and the development of clean energy infrastructure, which leads to an improved energy supply and reduced energy intensity across various regions (Lee et al., 2025; Shi & Yang, 2024).

GDF also plays a significant role in fostering green innovation, which is essential for decoupling economic growth from environmental degradation (Gao et al., 2023). The literature differentiates between the types of innovation supported by GDF:

- **Quantity vs. Quality**: GDF not only increases the volume of technological innovations but also enhances their quality (Gao et al., 2023; Shi & Yang, 2024). By mitigating information asymmetry and financing constraints, GDF enables firms to pursue more advanced and complex research and development (R&D) projects, which have a greater long-term impact on environmental outcomes, rather than focusing solely on short-term gains (Shi & Yang, 2024).
- **Reactive vs. Proactive Innovation**: A nuanced perspective distinguishes between two forms of innovation. Reactive innovation refers to short-term technological solutions implemented to meet immediate environmental regulations (Shi & Yang, 2024). In contrast, proactive innovation involves long-term, strategic investments in R&D driven by future market trends and a commitment to sustainable development (Shi & Yang, 2024; Yin et al., 2024). While GDF supports both types, policymakers are encouraged to design incentives that prioritise proactive R&D, which is essential for driving meaningful, long-term change (Gao et al., 2023; Shi & Yang, 2024).

4.2. Sector-Specific Applications

GDF plays a pivotal role in facilitating the low-carbon transition of energy consumption structures, particularly through industrial upgrading (Shi & Yang, 2024; Yin et al., 2024). This transition involves shifting energy supply from high-carbon sources (e.g., coal) towards cleaner, low-carbon alternatives (Yin et al., 2024). The mechanisms through which this transition occurs include:

- **Structural Effect**: GDF directs financial resources away from polluting, high-carbon industries towards low-carbon sectors (Shi & Yang,

2024). This shift not only creates new opportunities for green businesses but also pressures traditional industries to transform or exit the market (Yin et al., 2024).

- **Technological Effect**: By financing technological R&D for clean energy and smart grid systems, GDF enhances the efficiency of energy supply and utilisation (Shi & Yang, 2024; Yin et al., 2024).
- **Scale Effect**: As GDF supports the expansion of low-carbon industries, economies of scale lower production costs for clean energy, thereby increasing its competitiveness compared to fossil fuels (Shi & Yang, 2024).

GDF's applications extend beyond the energy sector to other critical areas, including green agricultural development and food security. In developing economies, agriculture faces the dual challenge of increasing yield to meet the needs of growing populations while mitigating environmental impacts (Wang & Zhang, 2023). GDF addresses this challenge by providing financial solutions that support sustainable farming practices. Through digital platforms, GDF facilitates access to credit for agricultural technology adoption, thereby helping decouple agricultural growth from environmental degradation (Wang & Zhang, 2023). This approach not only enhances environmental sustainability in agriculture but also supports economic recovery in post-crisis scenarios (Wang & Zhang, 2023).

In the manufacturing sector, which is characterised by high energy consumption and a significant environmental footprint, GDF plays a crucial role in enabling manufacturers to adopt green practices. GDF provides capital for technological upgrades and process optimisations, facilitating the transition to more sustainable industrial practices. Studies highlight that GDF influences manufacturing sustainability by supporting R&D in green technologies and promoting inter-regional technology diffusion, especially in East Asian economies (Han et al., 2024; Yin et al., 2024).

4.3. New Market Mechanisms

Blockchain technology and Distributed Ledger Technology (DLT) offer novel solutions to critical issues of trust and transparency within GDF

(Devidze, 2022). By creating immutable records of transactions and environmental impact data, blockchain helps prevent "greenwashing"—the practice of falsely representing projects as environmentally friendly (Morgan, 2022; Devidze, 2022).

Blockchain also enables tokenisation, allowing the ownership of large green assets to be broken down into digital tokens. This facilitates fractional ownership, enabling retail investors to participate in large-scale green projects. This mechanism is particularly effective in addressing the financing gap for small and medium-sized enterprises (SMEs), enabling them to raise capital from a diverse pool of investors through the tokenisation of their assets (Vikas et al., 2022; Devidze, 2022).

Artificial Intelligence (AI) and Big Data are vital tools for advanced risk assessment and efficiency in GDF. Financial institutions use AI-driven analytics to process vast amounts of data related to environmental performance, climate risk exposure, and corporate social responsibility (CSR) (Vikas et al., 2022; Yu et al., 2022).

- **Risk Assessment**: AI algorithms improve the accuracy of ESG scoring and risk assessment for green projects, helping financial institutions make more informed lending decisions (Vikas et al., 2022). This reduces information asymmetry between lenders and borrowers, making green projects more attractive to investors (Yu et al., 2022).
- **Data-Driven Services**: Big Data platforms collect real-time transaction and behavioural data, enabling financial service providers to monitor and quantify environmental performance more effectively (Yin et al., 2024). This information allows for the development of customised green financial products and efficient monitoring of green fund flow throughout the supply chain (Devidze, 2022).

5. Challenges and Critical Perspectives

While Green Digital Finance (GDF) offers substantial opportunities for advancing sustainable investment, a critical review of the literature reveals several operational, environmental, and structural challenges that threaten its effective implementation and long-term sustainability. These challenges must be addressed to ensure that GDF acts as a catalyst for sustainable transitions rather than generating additional complexities.

5.1. Operational and Environmental Risks

One of the most significant risks associated with GDF is "digital greenwashing". This refers to the practice where companies use digital platforms to misrepresent their environmental efforts or exaggerate the sustainability of their investments (Morgan, 2022; Devidze, 2022). The high complexity and technical opacity inherent in many digital financial products complicate the verification of a project's true environmental impact (Morgan, 2022). As a result, companies may engage in strategic green technology innovation (SGTI), which focuses more on acquiring patents for short-term regulatory compliance or reputational gain, rather than pursuing substantial and long-term green innovations (Shi & Yang, 2024; Yin et al., 2024).

This issue underscores the need for enhanced financial supervision (FS) to ensure effective regulation of GDF markets (Yin et al., 2024). Literature highlights that robust regulatory frameworks are essential for reducing information asymmetry and ensuring that GDF targets genuinely sustainable projects (Yin et al., 2024; Devidze, 2022). For instance, Yin et al. (2024) suggest that increased financial supervision can strengthen GDF's impact on pollution reduction and carbon mitigation by preventing arbitrage and improving the efficiency of green fund allocation. This suggests that GDF cannot achieve its goals without strong regulatory oversight to curb opportunistic behaviour in the market.

Another critical challenge GDF faces is the digital paradox, where technologies designed to promote sustainability often have significant environmental footprints themselves (Morgan, 2022). Several aspects of this paradox are evident:

- **Energy Consumption**: The vast computational power required for digital infrastructure, particularly blockchain technologies using the Proof-of-Work (PoW) consensus mechanism, leads to high electricity consumption. Alzoubi and Mishra (2023) highlight that the energy consumption of Bitcoin, for instance, rivals that of entire nations, resulting in significant CO2 emissions that contradict climate mitigation objectives. In regions reliant on fossil fuels for electricity generation, the proliferation of GDF could

inadvertently exacerbate environmental pollution (Morgan, 2022; Amin et al., 2022).

- **Electronic Waste (E-Waste)**: The rapid pace of digital technological development increases the production and disposal of electronic hardware, leading to substantial e-waste. Morgan (2022) notes that the extraction of raw materials for digital devices and the subsequent disposal of e-waste contribute to resource depletion and environmental degradation. This necessitates the implementation of green ICT policies that manage the entire lifecycle of digital technologies (Han et al., 2024).

Additionally, climate change itself presents risks to GDF, creating a feedback loop where environmental challenges undermine the very mechanisms designed to address them (Lee et al., 2025). GDF investments, particularly in renewable energy projects, are vulnerable to climate-related physical risks such as floods, droughts, and extreme temperatures (Lee et al., 2025). These events can damage infrastructure, disrupt energy supply chains, and reduce the efficiency of green technologies (Shi & Yang, 2024; Lee et al., 2025).

A key finding from Lee et al. (2025) suggests that GDF's impact on mitigating energy poverty diminishes significantly in areas experiencing high climate risks. This finding highlights a critical threshold effect, where GDF's beneficial impact diminishes beyond a certain level of climate-related uncertainty (Lee et al., 2025). As a result, policymakers must integrate climate risk assessments and resilience-building measures into GDF strategies to ensure that investments can withstand future climate shocks (Morgan, 2022).

5.2. Structural and Social Challenges

The success of GDF depends heavily on broad digital access and financial literacy (Han & Gao, 2024). However, many emerging economies face a significant digital divide, where large segments of the population lack access to digital infrastructure and have low levels of both digital and financial literacy (Singh et al., 2022; Lee et al., 2025). This digital gap leads to social exclusion, preventing vulnerable populations from participating in or benefiting from GDF initiatives such as microfinance platforms or green energy programmes (Han & Gao, 2024). Without targeted educational

initiatives to foster both environmental awareness and digital skills, GDF risks exacerbating existing socio-economic inequalities (Lee et al., 2025).

In many developing countries, the lack of a coherent policy framework and institutional fragmentation represent significant barriers to the adoption of GDF (Amin et al., 2022). The literature reveals a stark contrast between countries where GDF thrives due to strong governmental support and those where it struggles due to a fragmented approach (Singh et al., 2022; Amin et al., 2022).

- **Government-Led Infrastructure**: In countries like India, successful digital public infrastructure (DPI), such as AADHAR and UPI, provides a strong foundation for GDF development (Singh et al., 2022). This state-led approach reduces regulatory barriers and fosters innovation, facilitating the growth of GDF.
- **Policy Vacuum**: In contrast, countries like Bangladesh struggle with GDF development due to the absence of a unified policy framework (Amin et al., 2022). Regulators often treat sustainable finance and digital finance as separate domains, missing opportunities for synergies that could enhance the potential of GDF (Devidze, 2022; Amin et al., 2022).

5.3. Asymmetric Spatial Effects: The Siphon Effect

The impact of GDF is not uniform across regions; it often exhibits asymmetric spatial effects (Gao et al., 2023; Tan et al., 2024). While GDF promotes green innovation and technology diffusion, this effect is typically stronger in regions with advanced economies and established digital infrastructure (Gao et al., 2023). This dynamic leads to a "siphon effect", where highly developed areas attract more skilled labour and capital from neighbouring, less developed regions (Gao et al., 2023; Tan et al., 2024).

Without balanced regional policies, GDF can exacerbate existing economic disparities by accelerating growth in green hubs, while leaving less developed areas further behind. This perspective suggests that GDF often acts as a multiplier of pre-existing conditions, rather than a standalone mechanism for reducing regional disparities (Tan et al., 2024).

6. Recommendations and Future Outlook

This section provides critical policy interventions and outlines key directions for future research to maximise the transformative potential of Green Digital Finance (GDF), based on the synthesis of existing literature.

6.1. Policy Recommendations

To effectively transition GDF from a nascent concept into a robust mechanism for sustainable investment, policymakers must prioritise a coordinated regulatory approach that addresses systemic challenges.

- **Establishing a Unified GDF Taxonomy and Regulatory Framework**: A primary barrier to GDF development is the lack of a consistent definition for "green" financial products, which leads to information asymmetry and increases the risk of "digital greenwashing" (Morgan, 2022; Devidze, 2022). Governments must establish a unified GDF taxonomy that clearly defines green activities and technologies (Yin et al., 2024). This framework should mandate transparent reporting standards for environmental impact and capital allocation, ensuring that funds are directed accurately toward genuinely sustainable projects. A cohesive regulatory body is essential to manage the complexities of digital financial supervision and prevent arbitrage behaviour (Yin et al., 2024).
- **Enhancing Inter-Agency Coordination**: The fragmented nature of GDF policy, where environmental regulations are often separate from digital finance policies, hinders synergistic growth (Amin et al., 2022). It is recommended that governments establish national coordination mechanisms, such as dedicated inter-agency committees or regulatory sandboxes, to foster communication between financial regulators (FS), environmental protection agencies, and digital technology innovators (Morgan, 2022; Yin et al., 2024). This coordination is essential for developing tailored policies that address GDF's dual nature and facilitate technological diffusion effectively (Shi & Yang, 2024).
- **Differentiated Policy Approaches for Regional Disparities**: The impact of GDF is highly heterogeneous across regions (Han et al., 2024; Yin et al., 2024; Lee et al., 2025). Policy implementation should therefore avoid a "one-size-fits-all" model. Policies should be differentiated to match local socioeconomic conditions. For instance, in highly industrialised regions with

advanced digital infrastructure (e.g., China's Eastern provinces), policy should focus on stimulating proactive innovation and industrial upgrading (Shi & Yang, 2024). In less developed regions (such as China's Western provinces or countries like Bangladesh), policy should prioritise investment in foundational digital infrastructure and capacity-building programmes to overcome institutional fragmentation and the digital divide (Amin et al., 2022; Singh et al., 2022).

6.2. Educational Recommendations

Addressing the human capital dimension of GDF is critical to ensure that digital solutions are adopted effectively and equitably.

- **Investing in Digital Financial Literacy (DFL)**: The "digital divide" remains a significant barrier to GDF adoption, especially in emerging markets where large segments of the population lack the necessary skills and knowledge to utilise digital financial products (Lee et al., 2025; Han & Gao, 2024). DFL education programmes are necessary to empower individuals to make informed decisions about green investments and protect themselves from digital risks (Morgan, 2022). These programmes should go beyond basic financial concepts to cover specific functions and risks associated with green FinTech, such as cryptocurrency volatility and digital greenwashing (Morgan, 2022).
- **Fostering Environmental Consciousness**: Education plays a vital role in shaping public awareness and influencing behavioural choices regarding environmental protection (Lee et al., 2025). By integrating sustainability concepts into educational curricula and public awareness campaigns, governments can cultivate a culture that supports green consumption patterns and enhances the demand for green financial products. This will create a fertile ground for GDF to thrive, ensuring that new financial products are met with social acceptance and informed demand (Lee et al., 2025).

6.3. Future Research Directions

Based on the limitations and gaps identified in the current literature, several areas warrant further investigation to advance the academic understanding of GDF.

- **Micro-level Analysis and Generalisability**: Much of the empirical research currently relies on macro-level provincial or national data (Shi & Yang, 2024; Lee et al., 2025). Future studies should focus on micro-level firm and household data to provide more granular insights into how GDF impacts green innovation decisions, household energy consumption, and financial risk mitigation strategies for specific enterprises and consumers (Lee et al., 2025; Geetha & Biju, 2023). Additionally, more research is needed to investigate GDF in diverse geographical contexts beyond China, particularly in Africa and Latin America, to improve the generalisability of findings (Amin et al., 2022).
- **The Nexus between Climate Risk and GDF**: The interaction between climate risk and GDF warrants deeper exploration. Lee et al. (2025) suggest that climate risk creates a threshold effect, where GDF's mitigating impact on energy poverty diminishes as climate risk intensifies. Future research should investigate how specific GDF instruments (e.g., green bonds, climate insurance products) can be designed to build financial resilience against climate-related shocks, thereby creating a feedback loop where GDF mitigates climate risk (Lee et al., 2025).
- **Green ICT Policy Frameworks**: The "digital paradox"—where digital technologies themselves consume significant energy and produce e-waste—highlights a significant gap in current GDF research (Morgan, 2022; Han et al., 2024). Future studies should explore optimal policy frameworks for "green ICT" and "green blockchain" initiatives (Alzoubi & Mishra, 2023). Research is needed to develop methodologies that accurately quantify the environmental footprint of digital technologies and assess the trade-offs between digital efficiency gains and increased energy consumption (Morgan, 2022).
- **Asymmetric Spatial Effects and Technology Diffusion**: Further research is needed to fully understand the asymmetric spatial effects of GDF, particularly the "siphon effect" identified by Tan et al. (2024) and Gao et al. (2023). Future studies could explore how GDF influences technology diffusion between regions with varying levels of development and investigate mechanisms to promote equitable resource sharing and technology transfer across administrative boundaries (Tan et al., 2024).

7. Conclusion

This article reviewed recent literature on Green Digital Finance (GDF) to examine how digital financial technologies are reshaping green finance mechanisms and supporting sustainable environmental investments. By synthesizing studies published between 2022 and 2025, the article provides an integrated perspective on the conceptual evolution, key applications, and structural challenges of GDF within the broader sustainable finance landscape.

The findings indicate that GDF functions as an important enabler of green capital mobilisation, industrial upgrading, and financial inclusion by reducing information asymmetry, lowering transaction costs, and facilitating access to sustainable investments. At the same time, the literature highlights that the transformative potential of GDF is highly context-dependent and shaped by regulatory frameworks, digital infrastructure, and institutional capacity.

Overall, the review positions Green Digital Finance as a promising but complex pathway for advancing sustainability objectives. Its long-term effectiveness depends on aligning technological innovation with robust governance, inclusive digital development, and coherent policy design. Future research would benefit from more micro-level empirical evidence and comparative analyses across diverse economic contexts to better assess the environmental, social, and technological implications of GDF.

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