Online Journal Modelling the New Europe
No. 48 / September 2025
https://neweurope.centre.ubbcluj.ro/

DOI: 10.24193/OJMNE.2025.48.05

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INNOVATIVE APPROACHES TO GREEN INVESTMENT: A DECENTRALIZED FINANCIAL MODEL FOR THE EUROPEAN

ABSTRACT: *The increasing fragmentation of the global economy, driven by disparities in governance, trade policies, and economic priorities, poses significant risks to multilateral efforts to combat climate change. In the current economic landscape, a paradigm shift is required - from traditional models focused primarily on efficiency and profitability toward resilience-driven approaches in both policy and corporate strategy. This study examines the role of DeFi and digital financial platforms in financing green technologies through blockchain mechanisms and tokenization, which enable lower capital mobilization costs and improved financial accessibility.*

The paper proposes an integrated digital finance model for sustainable investment, addressing key challenges in the European market, such as accelerating capital flows into green projects, expanding small and medium-sized enterprises' (SMEs) access to financing, and enhancing transparency through dynamic ESG metrics. The methodological framework is based on a quantitative model that predicts the impact of digital innovations on investment attraction for sustainable projects, reducing transaction costs, and eliminating access barriers for private investors. By leveraging blockchain, DeFi, and artificial intelligence (AI), the proposed model fosters an efficient, transparent, and inclusive financial ecosystem for sustainable investment. Additionally, this paper outlines the necessary regulatory steps for adapting the proposed model, emphasizing policy harmonization, digital infrastructure development, and financial literacy initiatives. The findings conclude that integrating digital finance into sustainable financial systems is a critical driver in achieving EU climate goals, while also unlocking new financing avenues for green projects in European countries and Ukraine. Future research will focus on empirically testing the model across different EU regions, considering levels of digitalization, regulatory frameworks, and socio-economic conditions, with particular attention to developing economies.

KEYWORDS: sustainable finance; decentralized finance; asset tokenization; blockchain; Green FinTech.

1. Introduction

The global economic landscape is increasingly shaped by fragmentation driven by differences in governance, trade policies, and economic priorities. This fragmentation poses significant risks to multilateral efforts aimed at combating climate change. The European Union (EU) has committed to achieving carbon neutrality by 2050, a goal that necessitates investments in sustainable projects projected to reach \$275 trillion. Traditional financial mechanisms struggle to meet these requirements due to high transaction costs, a lack of transparency, and risks of misuse. Leveraging digital financial platforms and decentralized finance (DeFi) solutions offers the potential to scale investments in green technologies and reduce the cost of capital mobilization.

While traditional economic paradigms in relatively stable global systems have focused on maximizing efficiency and profit, the current reality demands that resilience becomes a cornerstone of economic policy and corporate strategy both in Europe and worldwide. Integrating digital finance into sustainable financing requires a comprehensive approach that considers key aspects of digital transformation, financial innovation, and global challenges related to environmental sustainability. The proposed integration model aims to address existing barriers preventing businesses from actively investing in sustainable projects.

2. Literature Review

Recent years have seen sustainability and digitalization take center stage in academic discussions. Numerous studies focus on the macroeconomic impact of green financing and its implementation consequences (Shkodina I. et al., 2023; Alsharif, M.H. 2023). Financial innovations enable the integration of circular economy principles and Environmental, Social, and Governance (ESG) criteria into strategic decision-making (Kumar, B. et al., 2024). Green financing not only fosters economic growth, particularly in developing countries, but also addresses major economic challenges such as unemployment, poverty, inequality, and social issues (Fredj Jawadi et al., 2024).

A considerable body of research explores the microeconomic implications of green financing, including the integration of ESG factors into corporate strategies, which can enhance firm valuation (Passas I. 2024). Given that ESG factors may vary significantly at different stages of a corporation's lifecycle, understanding their role and how companies can effectively utilize financial technologies and green financing to improve ESG performance is crucial (Hu, H., Jia, Z., & Yang, S.,2024).

Van der Waal and Thijssens (2020) emphasize that while many corporations publicly commit to SDGs, the depth of their involvement varies significantly, often influenced by industry characteristics, regulatory environments, and stakeholder pressures. Moreover, the study underscores the role of institutional mechanisms in shaping corporate sustainability strategies. Firms operating in highly regulated markets or under strong stakeholder scrutiny are more likely to exhibit substantive commitment to SDGs. The authors also highlight that voluntary sustainability reporting and corporate disclosures serve as essential tools for assessing the authenticity and effectiveness of corporate SDG initiatives (Johannes W.H. van der Waal, & Thijssens, T., 2020). Research emphasizes the need to expand and enhance the green finance market to address sustainability challenges. Recommended strategies include advancing green finance through digitalization and promoting sustainability education (Nie, P. et al., 2024)

The analysis of the literature reveals that decentralized finance (DeFi) enhances the accessibility of financial services, reduces transaction costs, and ensures transparency in operations, which is critical for financing environmentally sustainable projects. The importance of integrating fintech tools, including artificial intelligence (AI), machine learning, big data analytics, and blockchain, is emphasized as these technologies improve the efficiency of financial services and open new avenues for sustainable development initiatives (Shkodina, 2024). The transformative potential of DeFi for international business is considered, particularly in creating accessible financial services without traditional intermediaries, thus promoting financial inclusivity (Harvey, C.R., & Rabetti, D., 2024). Notably, practitioners and regulatory representatives are actively participating in these discussions alongside academic researchers. Patschke (2024) explores the transformative role of AI in ESG reporting, emphasizing three key areas: data collection and processing, risk assessment, and regulatory compliance. The study highlights that AI-driven solutions can significantly enhance the accuracy and efficiency of ESG disclosures by automating the aggregation of sustainability-related data from diverse sources, such as corporate reports, regulatory filings, and real-time market information. Morgan Stanley (2024) highlights the increasing investor interest in ESG-focused financial instruments, driven by regulatory developments, evolving corporate sustainability commitments, and the growing recognition of ESG factors as critical determinants of long-term financial performance.

The literature review indicates that integrating digital finance into sustainable financing is a promising direction that can significantly enhance the efficiency and accessibility of environmentally-oriented investments. However, no existing studies have combined sustainable financing and digital innovation into a unified model to address the challenges of a fragmented economy.

3. Purpose of the Study

The purpose of this study is to develop and validate a model for green investment that integrates decentralized financial technologies (DeFi), tokenization, and blockchain to address the challenges of sustainable finance in the European market. The study aims to explore how the proposed model can enhance capital flows to green projects, foster financial inclusion for small and medium-sized enterprises (SMEs), and harmonize ESG metrics to improve transparency and accountability.

4. Methodology

The methodological framework for developing the model for integrating digital finance into sustainable financing is structured to ensure both theoretical rigor and empirical validity. This approach draws upon established methodologies applied in previous studies that have examined digital financial ecosystems, DeFi applications, and ESG-driven investment strategies (Jawadi, F. et al., 2024; Nie, P. et al., 2024). The first stage consists of an extensive systematic literature review, synthesizing key findings from leading peer-reviewed journals and reports from international financial institutions. This review focuses on studies that explore the role of decentralized finance, asset tokenization, ESG compliance, and sustainable investment mechanisms.

The content analysis method is employed to identify prevailing challenges and opportunities in digital financial ecosystems, drawing upon research methodologies on blockchain-based financial innovations and DeFi's role in sustainable finance. Additionally, this stage integrates comparative case analysis of ESG compliance trends to evaluate their effectiveness in mobilizing capital for green investments. The outcome of this stage is the formation of a conceptual framework for the model, incorporating three key components: transparency through asset tokenization, decentralized financial platforms, and dynamic ESG data monitoring.

To empirically validate the proposed model, quantitative econometric techniques are utilized. Multiple regression analysis is implemented to examine the relationships between key financial variables - Ainvest, Csaved and ESGscore - and the overall model efficiency (Efficiencymodel). The regression model enables an assessment of statistical significance, ensuring robustness in measuring the contributions of each variable. Furthermore, linear optimization methods are applied to calibrate the weight coefficients (w1, w2, w3) of key determinants within the efficiency function, thereby optimizing capital allocation in sustainable investments. Stochastic modeling is applied to account for uncertainties in financial flows and transaction costs, allowing for the assessment of model stability under volatile market conditions, such as tokenized asset fluctuations and variable ESG metrics. Similar methods have been employed in recent works on risk management in tokenized finance (Zhang et al., 2024). To enhance model interpretability while preserving critical insights, Principal Component Analysis (PCA) is applied. PCA facilitates the dimensionality reduction of ESG indicators, ensuring that the model remains analytically robust without oversimplification. The validation of the model is based on real-world data from sustainable investment markets and DeFi platforms. Key sources include financial reports from the OECD, World Bank, and European Investment Bank, as well as analytical insights from DeFi Pulse, DappRadar, and institutional ESG rating agencies. These datasets ensure empirical consistency with prior research and contribute to the generalizability of the findings.

The final stage includes recommendations for the regulatory adaptation of the model in EU countries, encompassing policy harmonization, digital infrastructure development, and improving investors' financial literacy. By integrating these methodological refinements and aligning with past research in the field, this study ensures theoretical rigor, empirical reliability, and practical applicability in the evolving landscape of digital sustainable finance.

5. Results and Discussion

Traditional financial systems, predominantly based on centralized institutions, have demonstrated significant limitations in their ability to adapt to contemporary global challenges and crises. Centralized financial institutions often face a range of structural deficiencies that hinder their efficiency. First, complex bureaucratic procedures and high transaction costs slow down decision-making and the implementation of financial programs. Second, the centralized management of financial flows renders the system vulnerable to corruption, abuse, and a lack of transparency. Third, existing risk management mechanisms frequently fail to account for the systemic nature of modern global crises, such as the 2008 financial crisis and the economic repercussions of the COVID-19 pandemic.

Moreover, traditional financial systems do not always meet the demands of sustainable development. Their high dependence on fossil fuels, inefficiencies in financing green initiatives and limited access to investment resources for small and medium-sized enterprises (particularly in developing countries) further highlight their restricted capabilities.

In 2020, the volume of sustainable investments reached $35.3 trillion, increasing to $37.8 trillion in 2022, reflecting a 7% growth. However, addressing climate change and environmental challenges requires significantly larger investments - ranging from $125 trillion to $275 trillion by 2050 (Investing in the Green Economy, 2022). Policymakers worldwide must encourage sustainable investment practices by creating financial incentives and establishing the necessary regulatory frameworks to facilitate the flow of investments into sustainable projects.

The majority of sustainable funds are registered in Europe, accounting for 88% of their total value, with active operations also observed in North America. However, due to stricter standards (e.g., in the US and EU), growth rates slowed down during 2023 - 2024 (Global Sustainable Investment Alliance, 2022).

According to the Morgan Stanley Institute for Sustainable Investing's report, Sustainable Reality, as of the first half of 2024, global sustainable investment funds reached $3.5 trillion in assets, constituting 7% of the total assets of global funds. Growth compared to the end of 2023 amounted to 3.9%. During the first half of 2024, the net inflow into these funds totaled $20 billion, comprising $22 billion in the first quarter, followed by a $2 billion outflow in the second quarter - the first decline since 2022 (Morgan Stanley, 2024).

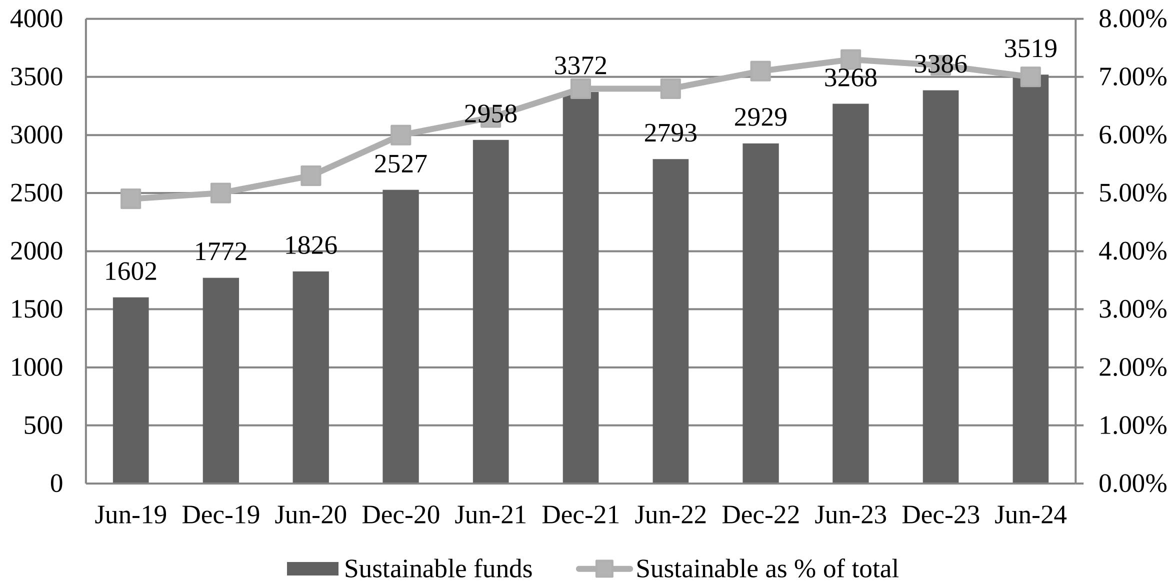

Fig 1. Assets of Sustainable Funds, USD Billion

Traditional financial systems encourage businesses to focus on financial reporting that overlooks environmental, social, and governance (ESG) factors in financial models. This often directs funds into industries harmful to the environment, undermining long-term sustainable growth. Businesses typically expect rapid financial returns, while industries reliant on fossil fuels or non-ecological technologies continue to dominate many economies, offering more comprehensible and lucrative opportunities for investors.

Sustainable investments often have a longer payback period, which reduces the appeal for companies seeking to maximize short-term profits amidst global uncertainty. Many companies lack access to quality ESG data or standardized methodologies for assessing the performance of environmental projects. This complicates the evaluation of risks and benefits associated with such investments. In an era of global instability, companies may avoid investing in new or riskier sectors, including sustainable financing. Military conflicts, political instability, or economic recessions further decrease businesses' willingness to invest.

One of the key components of transforming modern financial systems is decentralization, which enables the creation of more transparent, inclusive, and efficient economic models. Blockchain and distributed ledger technologies (DLT) are revolutionizing traditional financial operations by eliminating the need for centralized institutions, thereby significantly reducing transaction costs.

In recent years, the DeFi market has been growing steadily, with a compound annual growth rate (CAGR) of 45.36% (InsightAce Analytics, 2024). By the end of 2024, the total value of assets in DeFi reached $146 billion (TradingView, 2024).

Fig 2. Total DeFi Market Cap, $

DeFi platforms, such as Aave and Compound, provide users with the opportunity to obtain loans without intermediaries. The primary advantage of these platforms lies in process automation through smart contracts, enabling rapid and secure transactions. In the trading sphere, decentralized exchanges (Uniswap and SushiSwap) facilitate direct asset exchanges between users without the need for a centralized intermediary. This mechanism not only reduces costs but also minimizes the risk of manipulation by exchanges. DeFi has also transformed the insurance sector, with platforms like Nexus Mutual and Etherisc offering decentralized insurance services. These platforms utilize smart contracts to automate compensation processes, thereby enhancing transparency and efficiency (LinkedIn Pulse, 2024). Thus, DeFi increases the inclusivity of the financial system, serving populations previously excluded due to geographical, economic, or social constraints.

DeFi integrates with traditional finance (TradFi) by leveraging hybrid financial products that combine the strengths of both systems. These products include tokenized securities and decentralized trading platforms offering traditional financial instruments. Such integration ensures easy access for all participants to these financial systems, enabling companies to attract more financial resources for their projects. This synergy also boosts investor confidence by combining the reliability of traditional finance with the innovation of decentralized finance.

Despite stringent regulatory measures and legal uncertainties in many countries, particularly in the U.S. and EU (e.g., compliance with KYC/AML requirements), as well as issues like fraud and hacking (with estimated losses in the DeFi sector exceeding $1.5 billion in 2024), the market is expected to grow. According to MilkRoadPRO experts, the total value of assets in DeFi could reach $700 billion by the end of 2025 (Milkroad, 2025). This highlights the rapid adoption of decentralized solutions addressing contemporary challenges in fragmented economies and fostering global economic integration.

Blockchain, as the foundation of decentralized financial systems, ensures the reliability and transparency of transactions. The use of distributed ledgers allows data to be stored across multiple network nodes, eliminating risks inherent in centralized systems. The absence of centralized intermediaries enables small and medium-sized enterprises (SMEs) to secure funding without significant transaction costs. All operations within the system are recorded and available for real-time verification, minimizing fraud and abuse risks.

On the global market, blockchain technology demonstrates unprecedented growth rates. By 2027, the blockchain market is projected to reach $99.37 billion, with a compound annual growth rate (CAGR) of 55.0%, nearly tenfold the 2022 figures (Research and Markets, 2022). This growth is attributed not only to the adoption of blockchain in finance but also to its integration into sectors such as logistics, healthcare, energy, and public administration. The implementation of blockchain technologies in these sectors enhances efficiency, security, and transparency, representing a significant step in the digital transformation of the EU economy.

The use of blockchain and asset tokenization opens unique opportunities for attracting investments in green projects. It is well-known that blockchain, especially Proof-of-Work (PoW) protocols, consumes substantial energy, which contradicts sustainable development goals. However, the Proof-of-Stake (PoS) protocol, which is more energy-efficient, is gradually being adopted despite slow implementation. These technologies not only make environmentally oriented assets accessible to investors but also create a foundation for transparent, efficient, and sustainable financial systems. For instance, the Islamic Development Bank in Saudi Arabia employs blockchain for instant clearing, which enhances the speed of financial transactions and reduces risks (Reuters, 2017).

Asset tokenization enables the fragmentation of traditional financial instruments. Initially focused on real estate and art, tokenization now encompasses commodities, corporate bonds, intellectual property, and infrastructure projects. This diversity not only demonstrates the versatility of tokenization but also expands the pool of potential investors and markets, enriches the ecosystem, and enhances liquidity. It allows investments through peer-to-peer (P2P) transactions, eliminating intermediaries and reducing transaction costs. As of early 2024, the market value of tokenized assets reached $2.77 billion (LinkedIn Pulse, 2024). According to a report by Boston Consulting Group (BCG) and ADDX, asset tokenization is projected to reach $16 trillion, or 10% of global GDP, by 2030 (Boston Consulting Group, 2024).

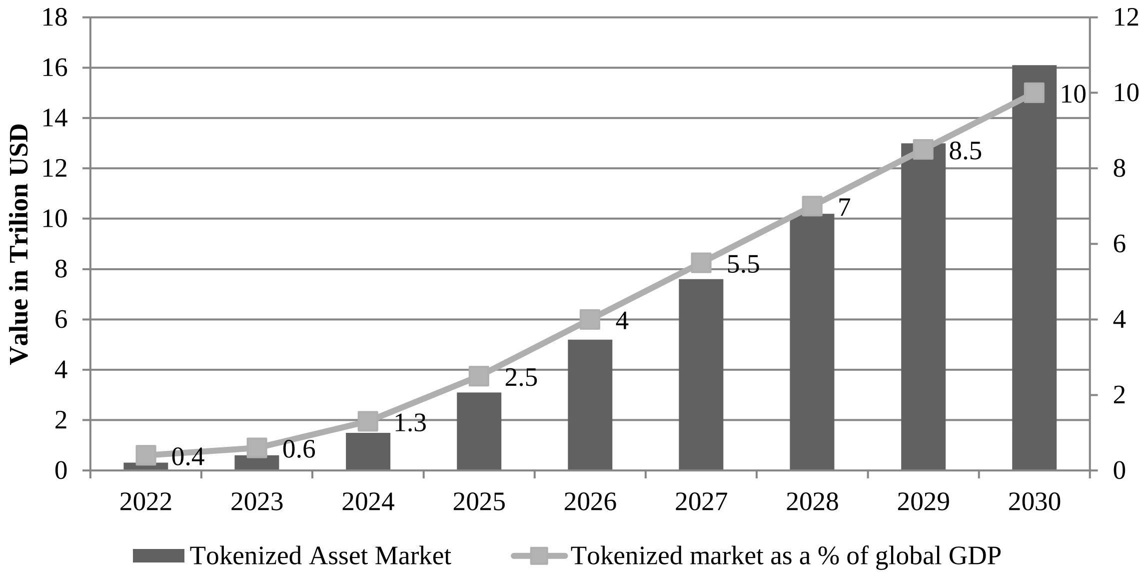

Fig 3– Tokenized Asset Market as a Share of Global GDP

In the context of sustainable finance, tokenization facilitates investment accessibility for small-scale investors. Green asset tokens ensure a clear link between financial investments and environmental outcomes, enhancing investor trust. FeverTokens uses blockchain to track every stage in the lifecycle of tokenized green bonds. This guarantees investors that their funds are directed towards achieving specified environmental goals.

In February 2023, the world's first tokenized green bonds were issued in Hong Kong, amounting to HK$800 million. These bonds were part of Hong Kong's financial technology development strategy. The use of blockchain for registration, settlement, and clearing enabled high transaction transparency, reduced costs, and expedited operations (HKMA, 2023). This project marked a critical milestone in the adoption of blockchain technologies in green finance and underscored the potential of tokenization for sustainable development. In November 2023, Societe Generale issued a digital green bond registered on the Ethereum blockchain via the SG-FORGE platform, ensuring transparency of ESG data as all environmental and social characteristics of the bond are accessible to investors (SG Forge, 2023).

Platforms such as Nori and CarbonX utilize tokenization to transform carbon credits into digital assets. This approach creates a transparent and decentralized ecosystem for trading carbon credits on a global scale. Nori specializes in converting carbon sequestration credits into digital assets available for purchase via peer-to-peer transactions (Carbon Herald, 2023). CarbonX employs blockchain to track the lifecycle of carbon credits. In 2024, the platform actively developed the market for climate solutions, focusing on accessibility for both private and public sectors. Their solutions aim to optimize credit costs and expand participation in global emission reduction initiatives. These platforms not only promote financial sustainability but also demonstrate new opportunities for integrating digital assets into environmental investments, contributing to the establishment of an efficient carbon credit market aligned with global ESG standards.

It is essential to note that the adoption of blockchain and tokenization depends on technological infrastructure, which is not always available in developing countries. For instance, some regions face limited internet access and financial illiteracy among the population, hindering the integration of such solutions. Moreover, tokenization of green assets encounters legal constraints and regulatory gaps. Many countries lack legislation governing token management, posing legal risks for investors.

Approximately 60% of DeFi platforms focused on sustainable projects leverage AI solutions for project analysis and verification. AI in sustainable investing is a critical tool for analyzing large volumes of environmental, social, and governance (ESG) data, enhancing decision-making efficiency and investment transparency. DeFi platforms with AI capabilities can create tokenized green assets. Platforms such as Nori and CarbonX utilize AI to transform carbon credits into digital assets. AI tools assist in verifying projects for ESG compliance before tokenization. AI improves the efficiency of ESG data verification by 30%-40% compared to traditional methods (Patschke, M., 2024).

AI also predicts how projects will impact the environment and society. For instance, it can model the effects of green energy implementation in a specific region or assess the prospects of investments in carbon credits. AI can monitor in real-time how financed projects align with stated goals (e.g., carbon emission reduction), reducing the likelihood of manipulation and enhancing transparency.

At the same time, it is important to acknowledge the challenges associated with integrating AI into DeFi. These challenges primarily include issues of data quality, privacy, transparency, high computational requirements, and regulatory barriers. For instance, automated contract execution without considering social contexts may lead to adverse consequences for local communities. Additionally, unreliable sensors for monitoring environmental, social, and governance (ESG) metrics or incorrect data interpretation can result in misinformation. Such issues undermine trust among stakeholders and may lead to conflicts between parties.

Nevertheless, the decentralization of financial systems represents a promising development avenue that requires an integrated approach, encompassing innovation, regulatory support, and increased educational efforts for all participants in the process. With the growing global demand for sustainable investments, DeFi and blockchain systems are transforming traditional financial markets, promoting decentralization, efficiency, transparency, and trust. It is anticipated that these technologies will become pivotal in reshaping the global financial system in the coming years, enabling it to address the challenges of sustainable development.

To accelerate the adoption of green asset tokenization, regulatory support for digital technologies, the involvement of traditional financial institutions in blockchain utilization, and the development of ESG standards to enhance data transparency and reliability are essential. These measures will foster the creation of financial systems that meet future challenges and stimulate growth in sustainable investment.

To transition sustainable finance from a theoretical concept to a practical mechanism capable of mobilizing resources for creating an ecologically, socially, and economically sustainable future, the establishment of a Model for the Integration of Digital Finance into Sustainable Finance is deemed necessary. This model aims to address key shortcomings of traditional sustainable finance systems through the use of modern digital technologies. It integrates advanced technologies such as blockchain, DeFi, and AI to create an efficient, transparent, and inclusive financial environment.

6. Proposed Model and Mathematical Framework

The model is based on three interconnected components:

1. Green Asset Tokenization. The use of blockchain to create digital assets representing green projects (e.g., renewable energy sources, carbon credits) ensures accessibility and transparency. Tokenization lowers barriers for small investors and broadens access to investments for various population groups. To enhance the security of tokenized assets, quantum-resistant cryptographic methods can be applied, safeguarding the system against potential future threats. This approach allows real-time tracking of fund flows to specific projects and enhances their transparency.

For calculating the accessibility of tokenized assets for investors, we propose a formula that considers risk factors, liquidity, and the investment time horizon:

$$Ainvest = \frac{(Vtoken \times Sfractions}{\mathrm{P}entry \times \mathrm{R}risk \times \mathrm{L}liquidity \times \mathrm{H}time} \tag{1}$$

Where:

A_{invest} - The volume of the available asset for an individual investor;

V_{token} - The total value of the tokenized asset;

$S_{fractions}$ - The number of tokenized fractions (fractional ownership);

P_{entry} - The entry-level investment amount;

R_{risk} - The asset risk coefficient (from 0 to 1, where 1 represents the lowest risk);

$L_{liquidity}$ - The liquidity coefficient (from 0 to 1, where 1 represents full liquidity);

H_{time} - The time coefficient (e.g., discounting associated with the investment horizon).

Using this formula, it is possible to assess the attractiveness of tokenized assets for different investor segments based on their preferences and financial capabilities. The smaller the value of Pentry, the wider the range of investors able to participate in the project, increasing the financial accessibility of the project (minimum investment of $1 (low threshold) makes the project accessible even to small private investors). However, if the total asset value Vtoken is too high, it may limit accessibility for small investors even with a low Pentry. A larger number of Sfractions increases flexibility for investors and allows them to purchase a small fraction of the asset.

Institutional investors with a high tolerance for risk may find greater accessibility to assets with a high Rrisk, while retail investors are more likely to focus on Pentry and Lliquidity. Thus, to enhance asset accessibility, it is necessary to reduce the entry-level investment amount (Pentry) to attract small investors, ensure transparency in the valuation of tokenized assets (Vtoken) to build trust, and increase the number of tokenized fractions (Sfractions) to enable small investors to acquire them.

2. Decentralized financial platforms (DeFi) that use smart contracts to attract investments into green projects without traditional financial intermediaries lower transaction costs and speed up financial operations. Utilizing blockchain protocols based on Proof-of-Stake (PoS) or other energy-efficient methods reduces energy consumption, which is crucial for sustainable projects.

The optimization of costs within a decentralized finance (DeFi) system can be represented using the following formula:

$$\mathrm{C}opt = \frac{\sum_{i=1}^{n}(Ti \times Ri)}{Egas \times G} \tag{2}$$

Where

C_{opt} - Optimized transaction costs;

T_i - Transaction volume (in tokens or fiat equivalent);

R_i - The level of commission for a particular transaction *i*;

E_{gas} - The average efficiency of gas use (used to calculate commissions in blockchains);

G - The average cost of gas at the time of the transaction;

n - The total number of transactions in the system.

The formula considers factors such as transaction volume, fee levels, and the efficiency of gas resource utilization, making it more precise and relevant in modern DeFi protocols. It enables assessing how reducing fees or selecting optimal timing for transactions (when the value of G is minimal) can help lower overall costs. The transaction volume and associated fees determine the transaction's costliness, depending on its size and the fee structure, which may vary across different DeFi protocols. Gas is a critical cost indicator in blockchain transactions, especially in ecosystems like Ethereum. Enhancing gas efficiency (Egas) helps reduce expenses. This formula can be employed in analyzing financial flows in DeFi to evaluate the economic feasibility of specific protocols, identify the most efficient times for transactions, or transition to protocols with more favorable conditions.

3. Dynamic ESG Monitoring. Leveraging AI and IoT, the model ensures real-time ESG compliance monitoring. AI enhances the efficiency of ESG data processing and mitigates the risks of greenwashing through data verification. IoT sensors enable precise tracking of environmental impact indicators, such as CO_2 emissions.

The evaluation of a project's compliance with ESG standards through the integration of IoT and AI can be expressed using a formula that accounts for both basic ESG metrics and dynamic changes over time, incorporating weight coefficients, external factor influences, and random components:

$$ESG_{score}(t) = \alpha \cdot E(t) + \beta \cdot S(t) + \gamma \cdot G(t) + \delta \cdot X(t) + \epsilon(t) \quad (3)$$

where:

$ESG_{score(t)}$ - Integrated ESG assessment at time *t*.

E(t), S(t), G(t) - Indicators of environmental, social, and governance factors, respectively, at time *t*.

α, β, γ - Weight coefficients reflecting the relative influence of ESG components (adjustable depending on the industry or region).

X(t) - Aggregate impact of external factors (e.g., macroeconomic conditions, regulatory policies, market volatility) at time *t*.

δ - Weight coefficient for external factors.

ϵ(t) - Random component accounting for measurement errors, uncertainties, or other irregular influences.

This approach emphasizes time dependency (t), enabling the dynamic representation of ESG data, which is crucial for real-time monitoring. Incorporating variables such as macroeconomic conditions or market risks X(t) makes the formula relevant to complex financial and regulatory environments. The inclusion of weighting coefficients (α, β, γ, δ) allows parameter calibration based on the industry, region, or strategic priorities, thus adapting the formula to specific conditions. Random components address measurement inaccuracies or unforeseen market events.

Summary Formula for Overall Model Efficiency.

The integrated formula evaluates economic, social, environmental, and technological dimensions to assess the overall model efficiency:

$$\text{Efficiency}_{model} = w_1 \cdot A_{invest} + w_2 \cdot C_{saved} + w_3 \cdot ESG_{score} + w_4 \cdot R_{tech} + w_5 \cdot S_{soc} \quad (4)$$

Where:

$\text{Efficiency}_{model}$ - Overall model efficiency.

w_1, w_2, w_3, w_4, w_5 - Weights of each component, reflecting their significance in the overall strategy.

A_{invest} - Accessibility of tokenized assets for investors.

C_{saved} - Cost savings on transactions.

ESG_{score} - ESG compliance index of projects.

R_{tech} - Technological adaptation coefficient, reflecting the integration of advanced technologies (e.g., IoT, blockchain, AI).

S_{soc} - Social impact of the model, including improvements in financial literacy, investor trust, and social acceptance of innovations.

This consolidated formula can be utilized for scenario modeling, forecasting the impact of various variables on model efficiency, and evaluating the potential for integrating digital finance into global sustainability strategies. Its key strength lies in its comprehensive scope, addressing economic, environmental, technological, and social aspects of sustainable finance.

Weight coefficients (w_i) are adjustable depending on national priorities (e.g., the EU or Ukraine), and the inclusion of additional variables (e.g., legal or cultural constraints) enables adaptation to market-specific or regional characteristics. This formula also facilitates quantitative assessment given sufficient data, simplifying comparisons between different approaches.

The widespread implementation of the model in the global economy requires the development of an international regulatory framework for the tokenization of sustainable assets and the unification of ESG standards. For instance, the establishment of global standards for ESG tokens and smart contracts under the auspices of OECD or UN would reduce legal uncertainty and foster investor trust.

The model must also account for regional regulatory specifics in sustainable finance and climate change. For example, compliance with initiatives such as the European Green Deal or the Net Zero Initiative is essential. National regulatory institutions and market participants should actively develop and refine mechanisms that ensure investor protection and transaction transparency. Examples include mandatory auditing of tokenized green assets or developing ethical standards for using AI and smart contracts in sustainable finance.

Key development directions include introducing tax incentives for investors in sustainable projects and subsidies for projects implementing innovative technologies and promoting financial literacy among investors regarding green investment opportunities and deploying advanced technologies, such as blockchain, IoT, and tokenization. These efforts will encourage a broader range of investors, including small business representatives and private individuals, to participate actively in sustainable finance.

7. Conclusions

In the global turbulence, sustainable digital finance has emerged as a transformative solution capable of addressing the dual imperatives of environmental sustainability and economic integration. The integration of innovative sustainable digital finance strategies (Green FinTech) can significantly enhance multilateral economic cooperation and address key challenges of global fragmentation. The adoption of green finance innovations will facilitate increased cross-border capital flows for sustainable projects, reduce regional disparities, standardize ESG metrics to improve global comparability and accountability, and support small and medium-sized enterprises (SMEs) through accessible financing, fostering inclusive economic growth.

The developed model is promising both for the academic community and for practical application. Its novelty lies in the combination of digital finance tools (DeFi, tokenization, blockchain) with the requirements of sustainable development and ESG principles. This creates prerequisites for developing new approaches to capital mobilization in green investments, addressing practical issues such as barriers to investment access for small enterprises and individuals, transaction cost reduction, and combating greenwashing.

The model also reflects financial technology development trends and addresses the challenges of regulatory fragmentation, making it relevant for the EU and countries aspiring to European integration, such as Ukraine. The integration of digital finance into sustainable financing can ensure synergy between digital transformation, economic stability, and environmental responsibility. Leveraging blockchain and tokenization technologies enables SMEs, the backbone of the European economy, to access funding for green initiatives. This, in turn, fosters innovation in renewable energy, energy efficiency, and emissions reduction.

The application of digital finance reduces dependence on traditional financial intermediaries and supports financial stability even in times of crisis. For the EU, this accelerates the achievement of climate goals, while for Ukraine, it offers an opportunity to become an active participant in the European financial system and attract investments for post-war recovery in a sustainable manner. Ukrainian enterprises can access funding for sustainable projects through decentralized financial platforms, driving economic growth and increasing competitiveness in EU markets.

Future research will focus on empirically testing the model in different regions of the EU, including Ukraine, which aims to integrate into the European space. Nevertheless, the empirical validation of the model using real-world data remains an avenue for future research. Subsequent studies will focus on applying the proposed formulas to empirical datasets derived from Ukrainian and international investment projects. This will enable the estimation of model coefficients, the assessment of its predictive accuracy, and the enhancement of its applicability across various economic contexts. Particular attention will be given to adapting the model to the specific conditions of developing economies, considering levels of digitalization, technology accessibility, and regulatory constraints. It is also essential to explore how various socio-economic and regulatory conditions impact the model's effectiveness, specifically identifying factors that promote or hinder investor engagement with tokenized assets across countries.

Given that the integration of digital finance into sustainable financing requires active involvement of SMEs and small private investors, developing strategies to enhance digital literacy (awareness of tokenization, blockchain, DeFi) is a priority for government policy and educational institutions.

In summary, the proposed model is a multifunctional tool capable of delivering more transparent, accessible, and sustainable financing for the EU and countries integrating into the European economy. Its implementation could represent a significant step toward harmonizing digital and sustainable financial strategies on a global scale.

References

1. Alsharif, M.H. (2023). Green IoT: A Review and Future Research Directions. *Symmetry*, 15(3), 757. Available at: https://www.researchgate.net/publication/369369399_Green_IoT_A_Review_and_Future_Research_Directions.
2. Boston Consulting Group. (2024). Relevance of on-chain asset tokenization in 'crypto winter'. Available at: https://web-assets.bcg.com/1e/a2/5b5f2b7e42dfad2cb3113a291222/on-chain-asset-tokenization.pdf.
3. Carbon Herald. (2023). Nori Launches Nori Net Zero Tonne™ – The First Hybrid Carbon Removal Credit. Available at: https://carbonherald.com/nori-launches-nori-net-zero-tonne-the-first-hybrid-carbon-removal-credit/.
4. Global Sustainable Investment Alliance. (2022). *Global sustainable investment review 2022*. Available at: https://www.gsi-alliance.org/wp-content/uploads/2023/12/GSIA-Report-2022.pdf.
5. Harvey, C.R., & Rabetti, D. (2024). International business and decentralized finance. *Journal of International Business Studies*, 55, 840–863. Available at: https://doi.org/10.1057/s41267-024-00705-7.
6. HKMA. (2023). HKSAR Government's Inaugural Tokenised Green Bond Offering. Available at: https://www.hkma.gov.hk/eng/news-and-media/press-releases/2023/02/20230216-3/.
7. Hu, H., Jia, Z., & Yang, S. (2024). Exploring FinTech, green finance, and ESG performance across corporate life-cycles. *International Review of Financial Analysis*. Available at: https://doi.org/10.1016/j.irfa.2024.103871.
8. InsightAce Analytics. (2024). Decentralized Finance (DeFi) Market. Available at: https://www.insightaceanalytic.com/request-sample/1607.
9. Investing in the Green Economy. (2022). Available at: http://surl.li/qgjsx.
10. Jawadi, F., Pondie, T.M., & Cheffou, A.I. (2024). New challenges for green finance and sustainable industrialization in developing countries: A panel data analysis. *Energy Economics*. Available at: https://doi.org/10.1016/j.eneco.2024.108120.
11. Johannes W.H. van der Waal, & Thijssens, T. (2020). Corporate involvement in Sustainable Development Goals: Exploring the territory. *Journal of Cleaner Production*, 252. Available at: http://surl.li/qgjoy.
12. Kumar, B., Kumar, A., Sassanelli, C., & Kumar, L. (2024). Exploring the Role of Finance in Driving Circular Economy and Sustainable Business Practices. *Journal of Cleaner Production*. Available at: https://doi.org/10.1016/j.jclepro.2024.144480.
13. LinkedIn Pulse. (2024). Real-World Asset Tokenization 2024: Transforming Investment Landscapes. Available at: https://www.linkedin.com/pulse/real-world-asset-tokenization-2024-transforming-investment-umwtf
14. LinkedIn Pulse. (2025). Top 11 Decentralized Finance Development Use Cases in 2025. Available at: https://www.linkedin.com/pulse/top-11-decentralized-finance-development-use-cases-2025-2sxee.
15. Milkroad. (2025). DeFi will hit $700B market cap by EOY 2025. Available at: https://milkroad.com/daily/defi-will-hit-700b-market-cap-by-eoy-2025/.
16. Morgan Stanley. (2024). *Global Sustainable Fund Report H1 2024*. Available at: https://www.todayesg.com/morgan-stanley-2024-global-sustainable-fund/.
17. Morgan Stanley. (2024). *Sustainable Reality: Modest Outperformance, But Flows Only Slightly Positive*. Available at: https://www.morganstanley.com/content/dam/msdotcom/en/assets/pdfs/RO3865603-Sustainable_Reality_1H_2024_Report-FINAL.pdf.
18. Nie, P., Zhong, J., Ren, Z., & Huang, J. (2024). Sustainable financing solutions for the growth of resource-driven economies in the digital economy age. *Resources Policy*, 98. Available at: https://doi.org/10.1016/j.resourpol.2024.105350.

19. Passas, I. (2024). The Evolution of ESG: From CSR to ESG 2.0. *Encyclopedia*, 4(4), 1711-1720. Available at: https://doi.org/10.3390/encyclopedia4040112.
20. Patschke, M. (2024). Three Ways AI Can Transform ESG Reporting. *ESG Today*. Available at: https://www.esgtoday.com/guest-post-three-ways-ai-can-transform-esg-reporting/.
21. Research and Markets. (2022). Blockchain In Banking And Financial Services Global Market Opportunities. Available at: https://www.researchandmarkets.com/reports.
22. Reuters. (2017). Saudi Arabia's IDB plans blockchain-based financial inclusion product. Available at: https://www.reuters.com/article/us-islamic-finance-fintech/saudi-arabias-idb-plans-blockchain-based-financial-inclusion-product-idUSKBN1CP08W?il=0
23. SG Forge. (2023). Societe Generale issues a first digital green bond on a public blockchain. Available at: https://www.sgforge.com/societe-generale-issues-a-first-digital-green-bond-on-a-public-blockchain/.
24. Shkodina, I. (2024). Green digital finance: Driving sustainable investments through decentralization and digitalization. *Global Scientific Trends: Economics and Public Administration*, 1(1), 90–105. Available at: https://gst-journal.net.ua/index.php/gst/issue/view/1.
25. Shkodina, I.V. (2024). The concept of sustainable digital finance: Integration of sustainable financing with digital innovations. *Business Inform*, 2, 237–243. Available at: https://www.business-inform.net/export_pdf/business-inform-2024-2_0-pages-237_243.pdf.
26. Shkodina, I.V., & Zelen′ko, O.O. (2023). Sustainable finance as a factor in the transformation of financial relations. *Business Inform*, 2, 204–209. (In Ukrainian).
27. TradingView. (2024). Total DeFi Market Cap. Available at: https://www.tradingview.com/symbols/TOTALDEFI/
28. Zhang, Y. Gao, X., Koedijk, K., and Ryu, S. (2024). Guest editorial: Non-fungible token (NFT) and alternative finance: digitalization, decentralization and tokenization. *China Finance Review International*, Vol. 14 No. 3, pp. 421-429. https://doi.org/10.1108/CFRI-09-2024-349