Journal of Frontiers in Multidisciplinary Research

Designing a Data-Driven Sustainable Finance Model: A Pathway for Small and Medium Enterprises to Transition to Clean Energy

Verlinda Attipoe [1*], Ezinne C. Chukwuma-Eke [2], Comfort Iyabode Lawal [3], Solomon Christopher Friday [4], Ngozi Joan Isibor [5], Abiola Oyeronke Akintobi [6]

[1] Independent Researcher, United States of America
[2] TotalEnergies Nigeria Limited
[3] Independent Researcher, Abuja Nigeria
[4] PwC Nigeria
[5] Deloitte LLP, United States of America
[6] Independent Researcher, Lagos Nigeria

* Corresponding Author: **Verlinda Attipoe**

Article Info

E-ISSN: 3050-9726
P-ISSN: 3050-9718
Volume: 04
Issue: 01
January-June 2023
Received: 11-12-2022
Accepted: 18-01-2023
Published: 21-02-2023
Page No: 210-218

Abstract

The transition to clean energy is a critical global priority, yet small and medium enterprises (SMEs) face significant financial barriers that hinder their adoption of sustainable energy solutions. This study explores the development of a data-driven sustainable finance model as a strategic pathway for SMEs to access affordable capital, mitigate investment risks, and enhance financial inclusion in the clean energy sector. Grounded in stakeholder theory and sustainable development theory, the study examines how financial technology (FinTech), big data analytics, artificial intelligence (AI), blockchain, and alternative investment structures can optimize capital allocation and improve credit accessibility for SMEs. The findings reveal that while traditional financing mechanisms often exclude SMEs due to perceived risks and limited credit histories, data-driven credit scoring, blended finance, and sustainability-linked instruments can bridge financing gaps and promote investment in clean energy. However, technological limitations, regulatory inconsistencies, and financial constraints persist. The study proposes policy recommendations, including the harmonization of green finance regulations, public-private partnerships, and international cooperation, to create an enabling environment for SME participation in sustainable finance. Future research should explore the role of decentralized finance and AI-driven investment strategies in scaling clean energy transitions. This study contributes to the ongoing discourse on sustainable finance, emphasizing the importance of financial innovation in achieving global climate goals.

DOI: https://doi.org/10.54660/.IJFMR.2021.2.1.87-94

Keywords: Sustainable Finance, Clean Energy Transition, SMEs and Green Investment. Climate Finance Mechanisms, Financial Technology (FinTech)

1. Introduction

1.1 Background on sustainable finance and clean energy transition

Sustainable finance has emerged as a critical enabler of the global transition to clean energy, ensuring that financial resources are directed toward environmentally responsible and socially inclusive projects. It encompasses financial services and investment strategies that integrate environmental, social, and governance (ESG) considerations into decision-making processes (Bhatnagar & Sharma, 2022). With climate change becoming a pressing global concern, financial institutions, investors, and policymakers

increasingly prioritize green finance initiatives to support the shift from fossil fuels to renewable energy sources. The clean energy transition involves replacing carbon-intensive energy systems with renewable alternatives such as solar, wind, and hydropower. However, achieving this transformation requires substantial capital investment, innovative financing mechanisms, and supportive regulatory frameworks (Ma, Li, Aslam, Ali, & Alamri, 2023).

The role of sustainable finance in this transition is multifaceted. It not only provides funding for renewable energy projects but also ensures that financial instruments such as green bonds, sustainability-linked loans, and carbon credits drive responsible investment (Yeboah & Boateng Prempeh, 2023). Moreover, data-driven financial models are revolutionizing the sector by enhancing risk assessment, optimizing capital allocation, and improving transparency in climate-related investments. The growing integration of financial technology (FinTech) and big data analytics in sustainable finance enables investors to make informed decisions, thus accelerating the adoption of clean energy solutions (Karelberg, 2018). As governments worldwide commit to net-zero emissions targets, the alignment of financial systems with sustainability goals has become imperative. This alignment is particularly crucial for small and medium enterprises, which often lack access to traditional financing but play a vital role in energy sector innovation (Karelberg, 2018).

1.2 Importance of SMEs in the energy transition

SMEs are fundamental to the global clean energy transition due to their innovative capacity, agility, and significant economic contributions. These enterprises account for a substantial share of employment and economic activity worldwide, making them essential players in achieving sustainability goals (Ragazou, Passas, Garefalakis, & Dimou, 2022). Their ability to adapt to emerging technologies and market shifts allows them to pioneer decentralized energy solutions, energy efficiency innovations, and local renewable energy projects. Unlike large corporations, which often have the resources to undertake large-scale renewable energy projects, SMEs focus on niche areas, such as off-grid energy systems, smart grids, and community-based clean energy solutions (Yikilmaz & Cekmecelioglu, 2023).

Despite their potential, these enterprises face significant barriers to scaling their clean energy initiatives. Many operate in emerging markets where access to reliable financing, regulatory support, and technical expertise is limited. Additionally, high initial capital costs for renewable energy adoption deter many SMEs from transitioning to sustainable practices. Nevertheless, their role in energy innovation cannot be overlooked (Pinkse & Groot, 2015). They contribute to reducing greenhouse gas emissions by developing energy-efficient technologies, engaging in circular economy practices, and providing localized solutions for energy distribution. Policymakers and financial institutions must therefore design targeted support mechanisms, ensuring that SMEs can access the resources needed to integrate clean energy solutions into their business models (Kaygusuz, 2012).

1.3 Challenges SMEs face in accessing sustainable finance

Despite their importance, SMEs often struggle to secure financing for clean energy projects due to several structural and financial constraints. Traditional financial institutions perceive them as high-risk borrowers, primarily due to their limited collateral, inconsistent revenue streams, and shorter business lifecycles (Shinozaki, 2012). Moreover, the long payback periods associated with renewable energy investments discourage banks from extending credit to SMEs. Even when financing options exist, complex application processes, high interest rates, and stringent eligibility criteria make it difficult for smaller enterprises to access these funds (Henriques & Catarino, 2016).

Another significant challenge is the lack of awareness and expertise in navigating the landscape of sustainable finance. Many SMEs are unfamiliar with green financing instruments such as climate bonds, blended finance, and carbon trading, limiting their ability to leverage these opportunities. Furthermore, regulatory uncertainties and inconsistencies in climate finance policies across different jurisdictions create additional obstacles. In developing economies, where SMEs constitute a large share of businesses, the absence of well-structured public-private partnerships further exacerbates the financing gap (Bakhtiari, Breunig, Magnani, & Zhang, 2020). Addressing these barriers requires innovative financial models that leverage data-driven insights, risk-sharing mechanisms, and tailored financial products to enhance SME participation in the clean energy transition.

1.4 Objectives and scope of the study

This study aims to develop a comprehensive, data-driven sustainable finance model that facilitates SME participation in the clean energy transition. By exploring innovative financing mechanisms, technological advancements, and regulatory frameworks, it seeks to provide actionable insights for financial institutions, policymakers, and business leaders. The study will investigate how data analytics, artificial intelligence, and digital financial platforms can be harnessed to improve credit risk assessment, optimize capital allocation, and increase transparency in sustainable financing.

The scope of this research extends beyond theoretical discussions, incorporating empirical case studies of successful sustainable finance models that have enabled SMEs to scale clean energy solutions. Additionally, it will examine the role of financial institutions, government policies, and international climate finance initiatives in addressing SME financing barriers. By identifying best practices and policy recommendations, this study aims to bridge the financing gap and accelerate the transition to a low-carbon economy. Ultimately, the findings will contribute to the broader discourse on financial inclusion, economic resilience, and climate action, reinforcing the critical role of SMEs in shaping a sustainable energy future.

2. Theoretical and conceptual framework

2.1 Key theories underpinning sustainable finance

Sustainable finance is grounded in several theoretical frameworks that explain the interplay between financial decision-making, environmental sustainability, and economic development. Among the most relevant are stakeholder theory and sustainable development theory.

Stakeholder theory posits that businesses and financial institutions should consider the interests of all stakeholders—including investors, customers, employees, regulators, and the broader society—rather than focusing solely on shareholder profits (Myllynen, Kamau, Mustapha, Babatunde, & Adeleye, 2023). In the context of sustainable finance, this theory highlights the responsibility of financial

actors to promote long-term value creation that benefits both economic and environmental stakeholders. By integrating sustainability considerations into investment decisions, financial institutions can foster inclusive economic growth while mitigating risks associated with climate change (Onukwulu, Fiemotongha, Igwe, & Ewim, 2023).

Sustainable development theory further reinforces the need for financial strategies that balance economic growth with environmental preservation and social equity. It emphasizes the importance of ensuring that present financial and economic activities do not compromise the ability of future generations to meet their needs. In sustainable finance, this translates into prioritizing long-term investments in renewable energy, resource efficiency, and climate resilience over short-term financial gains. These theoretical perspectives provide a foundation for designing financial models that align capital flows with sustainability objectives, particularly in supporting small enterprises engaged in clean energy initiatives (Ogundeji, Omowole, Adaga, & Sam-Bulya, 2023).

2.2 Concept of data-driven finance in sustainability

Data-driven finance is transforming sustainable investment by enhancing decision-making through real-time analytics, predictive modeling, and risk assessment. This approach relies on the systematic collection, processing, and analysis of financial, environmental, and operational data to improve capital allocation efficiency and transparency. In the context of sustainability, data-driven finance enables investors and financial institutions to evaluate the environmental impact of investments, measure carbon footprints, and assess climate-related risks (E. K. Jessa, 2023).

For SMEs, data-driven financial models offer significant advantages by improving access to credit, reducing financing costs, and streamlining investment processes. Advanced analytics can assess the creditworthiness of small enterprises based on alternative data sources, such as transaction histories, energy consumption patterns, and market trends (Hassan, Collins, Babatunde, Alabi, & Mustapha, 2023). Additionally, machine learning algorithms can identify investment opportunities with high sustainability potential while minimizing exposure to financial and environmental risks. The growing integration of big data in finance is also driving the development of new financial instruments, such as sustainability-linked loans and performance-based green bonds, which incentivize businesses to meet specific environmental targets (Fiemotongha, Igwe, Ewim, & Onukwulu, 2023b).

2.3 The Role of financial technology and big data in sme financing

FinTech is playing an increasingly vital role in expanding SME access to sustainable finance by offering innovative solutions that streamline lending processes, enhance risk assessment, and improve financial inclusion. Digital lending platforms, blockchain-based financing models, and AI-driven credit scoring are revolutionizing how small enterprises secure funding for clean energy projects. By leveraging alternative data sources, such as utility bills, supply chain transactions, and social media activity, FinTech companies can provide SMEs with tailored financial products that align with their sustainability goals (Fiemotongha, Igwe, Ewim, & Onukwulu, 2023a).

Big data analytics further enhances SME financing by enabling more accurate risk assessments and investment tracking. Financial institutions and investors can utilize big data to evaluate the environmental, social, and governance performance of SMEs, ensuring that funds are allocated to businesses with strong sustainability credentials (J. O. Basiru, L. Ejiofor, C. Onukwulu, & R. U. Attah, 2023). Additionally, blockchain technology offers transparency and security in green finance transactions, reducing fraud risks and improving trust among stakeholders. These technological advancements are instrumental in bridging the financing gap for SMEs, enabling them to participate more effectively in the clean energy transition (Daramola, Apeh, Basiru, Onukwulu, & Paul, 2023).

2.4 Policy frameworks supporting SME transition to clean energy

A supportive policy environment is essential for facilitating SME access to sustainable finance and accelerating their adoption of clean energy solutions. Governments and international organizations have introduced various policy frameworks aimed at promoting green investment, reducing financing barriers, and incentivizing SMEs to integrate sustainable practices into their operations.

One of the key policy instruments is green taxonomy, which provides a standardized classification system for identifying environmentally sustainable economic activities. By defining clear criteria for green investments, taxonomies help financial institutions direct capital toward clean energy projects while reducing the risk of greenwashing. Additionally, regulatory frameworks such as the Task Force on Climate-related Financial Disclosures (TCFD) and the European Union's Sustainable Finance Disclosure Regulation (SFDR) enhance transparency in climate-related financial reporting, enabling investors to make informed decisions (J. O. Basiru, C. L. Ejiofor, E. C. Onukwulu, & R. U. Attah, 2023a).

Public-private partnerships also play a crucial role in supporting SMEs through blended finance models, which combine public and private capital to de-risk investments in renewable energy. Government-backed loan guarantees, tax incentives, and grants further enhance SME access to affordable financing for sustainability projects. By aligning financial regulations with clean energy objectives, policymakers can create an enabling environment that fosters innovation, reduces financing costs, and drives inclusive economic growth (Adewale, Olorunyomi, & Odonkor, 2023).

3. Designing a data-driven sustainable finance model

3.1 Core components of the model

A data-driven sustainable finance model is built on three fundamental components: data analytics, risk assessment, and investment structures. These elements work together to optimize capital allocation, enhance financial transparency, and mitigate risks associated with clean energy investments.

Data analytics plays a crucial role in sustainable finance by enabling financial institutions and investors to make informed decisions based on real-time insights. By leveraging big data, financial entities can assess the financial health of SMEs, track sustainability performance, and evaluate environmental impacts. Predictive analytics, driven by historical data, helps identify investment opportunities with high returns while ensuring alignment with sustainability goals. Moreover, data-driven credit scoring models can assess SME creditworthiness more accurately

than traditional methods, making financing more accessible to businesses with limited collateral (Adefila, Ajayi, Toromade, & Sam-Bulya, 2023).

Risk assessment is another vital component, as clean energy investments are often perceived as high-risk due to market volatility, regulatory uncertainties, and long payback periods. A data-driven approach enhances risk mitigation by analyzing external factors such as energy price trends, policy shifts, and climate-related risks. Advanced risk modeling techniques, including scenario analysis and stress testing, help financial institutions and investors assess potential vulnerabilities in clean energy projects. Additionally, integrating ESG criteria into risk assessment frameworks ensures that investments contribute to long-term sustainability rather than short-term financial gains (Olanrewaju Awoyemi, Attah, Basiru, Leghemo, & Onwuzulike, 2023; J. O. Basiru, C. L. Ejiofor, E. C. Onukwulu, & R. U. Attah, 2023b).

Investment structures within a data-driven model must be designed to accommodate the unique financial needs of SMEs. Traditional financing mechanisms, such as bank loans, often fail to meet the requirements of small enterprises due to stringent eligibility criteria and high-interest rates. Alternative structures, including sustainability-linked loans, green bonds, and revenue-based financing, provide SMEs with flexible funding options (Odio *et al*., 2021). Crowdfunding platforms and peer-to-peer lending networks further democratize access to capital, allowing SMEs to attract investment from diverse sources. By incorporating data-driven insights into investment structures, financial institutions can tailor financial products that align with the specific growth trajectories of clean energy SMEs (Abbey, Olaleye, Mokogwu, & Queen, 2023a).

3.2 Integration of ai, blockchain, and machine learning in sustainable finance

The integration of artificial intelligence, blockchain, and machine learning is transforming sustainable finance by enhancing efficiency, security, and decision-making processes. These technologies improve financial transparency, reduce transaction costs, and enable more precise risk assessments, making them essential for scaling SME participation in clean energy financing.

AI-driven analytics enhances financial decision-making by automating credit risk assessments, fraud detection, and investment evaluations. Through natural language processing, AI can analyze sustainability reports, regulatory filings, and market trends to identify high-potential clean energy projects. AI-powered robo-advisors also assist SMEs in navigating financing options by recommending tailored investment strategies based on financial and operational data (Otokiti, Igwe, Ewim, Ibeh, & Sikhakhane-Nwokediegwu, 2022).

Blockchain technology improves transparency and security in financial transactions by providing an immutable ledger of transactions. In the context of sustainable finance, blockchain ensures that green investments are traceable, reducing the risk of greenwashing and fraudulent claims. Smart contracts—self-executing agreements coded on blockchain—automate financial transactions based on predefined sustainability criteria, ensuring that funds are disbursed only when clean energy projects meet specific performance benchmarks. This level of accountability builds investor confidence and streamlines funding processes for SMEs (Abbey, Olaleye, Mokogwu, & Queen, 2023b).

Machine learning algorithms enhance predictive modeling and risk analysis by identifying patterns in vast datasets. These algorithms can assess SME creditworthiness based on non-traditional data points, such as energy consumption patterns, supply chain efficiency, and carbon footprint metrics. Additionally, machine learning-powered climate risk models help financial institutions evaluate how environmental factors might impact investment returns, allowing them to adjust financing terms accordingly. The integration of these technologies not only enhances financial inclusion for SMEs but also ensures that capital is allocated efficiently to support the clean energy transition (Mustapha & Ibitoye, 2022; Onukwulu, Fiemotongha, Igwe, & Ewim, 2022).

3.3 Role of financial institutions, investors, and policymakers

The successful implementation of a data-driven sustainable finance model requires active collaboration among financial institutions, investors, and policymakers. Each stakeholder plays a critical role in shaping the financial ecosystem that supports SME participation in clean energy.

Financial institutions, including banks, impact investors, and venture capital firms, serve as the primary providers of capital for SMEs. They must integrate data analytics and digital finance solutions to improve credit accessibility and streamline investment processes. By offering tailored financial products, such as pay-as-you-save models for energy efficiency upgrades, banks can incentivize SMEs to adopt clean energy solutions. Additionally, financial institutions should enhance ESG reporting requirements to ensure that sustainability performance is factored into lending decisions (O Awoyemi, Attah, Basiru, & Leghemo, 2023; J. O. Basiru, C. L. Ejiofor, E. C. Onukwulu, & R. U. Attah, 2023c).

Investors, particularly those focused on impact investing and green finance, play a crucial role in directing capital toward SMEs engaged in clean energy. Institutional investors, such as pension funds and sovereign wealth funds, can allocate resources to sustainable finance initiatives that support SME growth. Additionally, venture capitalists and private equity firms should leverage data-driven investment strategies to identify high-growth SMEs that contribute to decarbonization efforts. By prioritizing long-term sustainability over short-term profitability, investors can drive meaningful change in the clean energy sector (Basiru, Ejiofor, Onukwulu, & Attah, 2022).

Policymakers have a responsibility to create an enabling regulatory environment that facilitates SME access to sustainable finance. This includes implementing tax incentives for clean energy investments, establishing carbon pricing mechanisms, and enforcing sustainability disclosure regulations. Additionally, governments should support the development of digital financial infrastructure, such as open banking platforms and blockchain-based registries, to improve financial transparency and efficiency (Hassan, Collins, Babatunde, Alabi, & Mustapha, 2021).

Public-private partnerships are also essential in mobilizing blended finance, where public funds de-risk private investments in clean energy projects. By aligning the interests of financial institutions, investors, and policymakers, a data-driven sustainable finance model can unlock new opportunities for SMEs, accelerating their transition to clean

energy. This integrated approach ensures that financial resources are allocated efficiently while fostering innovation, economic growth, and environmental sustainability (Paul, Abbey, Onukwulu, Agho, & Louis, 2021).

4. Implementation challenges and strategic solutions

4.1 Barriers to adopting a data-driven finance model

The adoption of a data-driven sustainable finance model for SMEs in the clean energy sector is hindered by several barriers, categorized into technological, financial, and regulatory challenges. Technological barriers stem from the limited digital infrastructure and data accessibility in many regions, particularly in emerging markets (Psara *et al*., 2022). SMEs often lack the necessary technological tools to collect, analyze, and leverage financial and sustainability data. Many small enterprises still rely on manual accounting and reporting systems, making it difficult to integrate advanced analytics, AI-driven risk assessments, and blockchain-based financing models. Additionally, cybersecurity risks pose a challenge to digital finance adoption, as data-driven platforms require robust security frameworks to prevent fraud and data breaches (E. Jessa, 2017).

Financial barriers include the high cost of implementing data-driven financial technologies and the reluctance of financial institutions to invest in SMEs with unproven track records. Many banks and investors perceive clean energy projects as high-risk due to long payback periods, market volatility, and policy uncertainties. Furthermore, the lack of standardized sustainability reporting metrics makes it challenging for financial institutions to assess the viability of SME projects. Many small enterprises also face difficulties in securing collateral, leading to credit restrictions and high-interest loan structures that hinder their ability to invest in clean energy solutions (Anyanwu, Dawodu, Omotosho, Akindote, & Ewuga, 2023; J. O. Basiru, C. L. Ejiofor, E. C. Onukwulu, & R. Attah, 2023).

Regulatory barriers include inconsistent policy frameworks, lack of clear guidelines on green finance, and variations in sustainability disclosure requirements across different regions. Many countries do not have well-defined taxonomies for sustainable investments, creating ambiguity for financial institutions and investors (Boschmans & Pissareva, 2018). Additionally, complex bureaucratic procedures and regulatory hurdles discourage SMEs from accessing public funds and incentives designed to support clean energy initiatives. Without a harmonized regulatory environment, financial institutions struggle to integrate sustainability considerations into lending and investment decisions.

4.2 Solutions for overcoming financing gaps and risk perception

Addressing financing gaps and changing risk perceptions requires innovative financial mechanisms, risk-sharing strategies, and improved financial literacy among SMEs. Blended finance is a key solution for reducing investment risks and encouraging private sector participation. This approach combines public funds, concessional loans, and private capital to de-risk SME clean energy projects. By leveraging guarantees from development banks, government-backed credit enhancements, and green bonds, financial institutions can improve the attractiveness of SME investments (Havemann, Negra, & Werneck, 2022).

Alternative credit scoring models powered by big data and AI can enhance SME access to finance. Traditional credit assessments rely on collateral and financial history, which many small businesses lack. Instead, data-driven models can evaluate creditworthiness based on transactional data, energy usage patterns, and supply chain metrics. This approach allows lenders to extend financing to SMEs with strong sustainability credentials but limited conventional credit histories (Papantoniou, 2022).

Sustainability-linked financial instruments, such as green bonds and pay-as-you-save models, offer SMEs flexible financing solutions. Green bonds provide long-term capital at favorable rates for enterprises that meet specific sustainability targets, while pay-as-you-save schemes allow businesses to implement clean energy solutions with repayment structures linked to energy savings. These models lower upfront investment barriers and make clean energy transitions more feasible for SMEs (Gonçalves, Goes, D'Agosto, & La Rovere, 2022).

Financial literacy programs targeting SMEs can bridge knowledge gaps and empower business owners to navigate sustainable finance options. Many small enterprises lack awareness of available financial instruments, sustainability reporting requirements, and risk mitigation strategies. Governments, financial institutions, and industry associations should collaborate to provide training programs that enhance SME capacity to engage in green finance (Fazekas, Bataille, & Vogt-Schilb, 2022).

4.3 Policy recommendations for governments and financial institutions

To facilitate the adoption of a data-driven finance model, policymakers and financial institutions must implement strategic reforms that create a conducive environment for SME financing in the clean energy sector. Governments should establish clear and standardized green finance regulations to reduce ambiguity in sustainable investment. Developing a national green taxonomy aligned with global standards, such as the EU Sustainable Finance Taxonomy or the International Financial Reporting Standards (IFRS) for sustainability disclosures, would provide clarity for financial institutions and investors. Additionally, tax incentives, such as deductions for renewable energy investments and carbon pricing mechanisms, can further encourage SMEs to adopt clean energy solutions.

Financial institutions should integrate sustainability considerations into their credit risk assessment frameworks. By adopting ESG-linked lending criteria and requiring sustainability disclosures, banks and investors can ensure that capital is allocated to SMEs with strong environmental commitments. Furthermore, financial institutions should collaborate with technology providers to develop digital finance platforms that simplify SME access to green financing. Open banking systems, powered by blockchain and AI, can enhance transparency and efficiency in financial transactions.

Public-private partnerships should be expanded to drive clean energy financing for SMEs. Governments can collaborate with financial institutions and impact investors to create blended finance programs, providing risk guarantees and concessional capital to de-risk SME investments. Additionally, establishing green finance hubs—centers of excellence that provide advisory services, funding support, and technical assistance—can help SMEs navigate the complexities of sustainable finance.

4.4 Role of international cooperation and climate finance mechanisms

International collaboration is crucial in scaling sustainable finance solutions and ensuring that SMEs worldwide have access to the resources needed for clean energy transitions. Multilateral climate finance institutions, such as the Green Climate Fund (GCF) and the Global Environment Facility (GEF), play a pivotal role in providing financial support for SME clean energy projects. These organizations offer grants, concessional loans, and risk-sharing mechanisms that reduce investment barriers. Strengthening partnerships between local financial institutions and international climate funds can enhance capital availability for SMEs.

Cross-border investment frameworks should be strengthened to facilitate foreign direct investment (FDI) in clean energy SMEs. International financial institutions, including the World Bank and regional development banks, can support SME financing through guarantees and co-financing arrangements. Additionally, global sustainability reporting standards should be harmonized to ensure transparency and consistency in sustainable finance practices.

Technology transfer agreements can further enable SMEs to access innovative financing solutions. Advanced economies can support clean energy adoption in developing markets by facilitating knowledge exchange on digital finance, blockchain applications, and AI-driven credit models. Through international cooperation, SMEs in emerging markets can benefit from technological advancements and best practices in sustainable finance.

5. Conclusion

This study has highlighted the critical role of a data-driven sustainable finance model in facilitating the clean energy transition for SMEs. Key theoretical frameworks, including stakeholder theory and sustainable development theory, provide the foundation for aligning financial decision-making with sustainability objectives. The integration of big data, AI, blockchain, and FinTech innovations has been identified as a transformative force in SME financing, enhancing credit accessibility, risk assessment, and investment efficiency. However, several barriers—including technological limitations, financial constraints, and regulatory challenges—hinder the widespread adoption of this model. Strategic solutions, such as blended finance, alternative credit scoring models, and sustainability-linked financial instruments, offer viable pathways to bridge financing gaps. Policy recommendations emphasize the need for standardized green finance regulations, public-private partnerships, and international cooperation to create an enabling environment for SME participation in the clean energy sector.

For SMEs, adopting a data-driven financial approach improves access to affordable financing, enhances operational efficiency, and strengthens competitiveness in the clean energy sector. Leveraging digital finance tools and sustainability reporting mechanisms can enhance their creditworthiness and attract investors. Investors, particularly impact investors and venture capitalists, can use data-driven insights to identify high-potential clean energy SMEs while managing investment risks effectively. The integration of ESG-linked investment frameworks ensures that capital flows toward businesses with measurable environmental impact. Policymakers play a crucial role in creating a regulatory landscape that supports sustainable finance by implementing green taxonomies, carbon pricing mechanisms, and financial incentives. Strengthening transparency in sustainability reporting and promoting digital financial infrastructure can further facilitate SME access to green finance.

Further research is needed to explore the scalability of data-driven finance models across different economic contexts, particularly in developing economies with limited financial infrastructure. Examining the long-term impact of AI-driven credit assessment on SME financing patterns could provide valuable insights into improving financial inclusion. Additionally, future studies should investigate the role of decentralized finance (DeFi) and tokenized assets in expanding SME access to sustainable capital. Research on policy harmonization at the global level is also essential to address inconsistencies in sustainable finance regulations and reporting standards. As digital finance and clean energy markets continue to evolve, interdisciplinary research integrating financial economics, data science, and environmental studies will be crucial in advancing knowledge and shaping policies that drive a sustainable energy transition for SMEs.

6. References

1. Abbey ABN, Olaleye IA, Mokogwu C, Queen A. Building econometric models for evaluating cost efficiency in healthcare procurement systems. International Journal of Economics and Finance Studies. 2023.
2. Abbey ABN, Olaleye IA, Mokogwu C, Queen A. Developing economic frameworks for optimizing procurement strategies in public and private sectors. Journal of Business and Finance Research. 2023.
3. Adefila AO, Ajayi OO, Toromade AS, Sam-Bulya NJ. A sociological review of gender equity in agricultural development: Global trends and lessons for US policy. Agricultural Policy Review. 2023;(pending publication).
4. Adewale TT, Olorunyomi TD, Odonkor TN. Big data-driven financial analysis: A new paradigm for strategic insights and decision-making. 2023.
5. Anyanwu A, Dawodu SO, Omotosho A, Akindote OJ, Ewuga SK. Review of blockchain technology in government systems: Applications and impacts in the USA. World Journal of Advanced Research and Reviews. 2023;20(3):863-875.
6. Awoyemi O, Attah R, Basiru J, Leghemo I. A technology integration blueprint for overcoming digital literacy barriers in developing world educational systems. Iconic Research and Engineering Journals. 2023;7(3):722-730.
7. Awoyemi O, Attah RU, Basiru JO, Leghemo IM, Onwuzulike OC. Revolutionizing corporate governance: A framework for solving leadership inefficiencies in entrepreneurial and small business organizations. International Journal of Multidisciplinary Research Updates. 2023;6(1):45-52.
8. Bakhtiari S, Breunig R, Magnani L, Zhang J. Financial constraints and small and medium enterprises: A review. Economic Record. 2020;96(315):506-523.
9. Basiru JO, Ejiofor CL, Onukwulu EC, Attah R. Enhancing financial reporting systems: A conceptual framework for integrating data analytics in business decision-making. IRE Journals. 2023;7(4):587-606.
10. Basiru JO, Ejiofor CL, Onukwulu EC, Attah RU.

Streamlining procurement processes in engineering and construction companies: a comparative analysis of best practices. Magna Scientia Advanced Research and Reviews. 2022;6(1):118-135.
11. Basiru JO, Ejiofor CL, Onukwulu EC, Attah RU. Financial management strategies in emerging markets: a review of theoretical models and practical applications. Magna Scientia Advanced Research and Reviews. 2023;7(2):123-140.
12. Basiru JO, Ejiofor CL, Onukwulu EC, Attah RU. The impact of contract negotiations on supplier relationships: A review of key theories and frameworks for organizational efficiency. International Journal of Multidisciplinary Research and Growth Evaluation. 2023;4(1):788-802.
13. Basiru JO, Ejiofor CL, Onukwulu EC, Attah RU. Optimizing administrative operations: A conceptual framework for strategic resource management in corporate settings. International Journal of Multidisciplinary Research and Growth Evaluation. 2023;4(1):760-773.
14. Basiru JO, Ejiofor L, Onukwulu C, Attah RU. Corporate health and safety protocols: A conceptual model for ensuring sustainability in global operations. Iconic Research and Engineering Journals. 2023;6(8):324-343.
15. Bhatnagar S, Sharma D. Evolution of green finance and its enablers: A bibliometric analysis. Renewable and Sustainable Energy Reviews. 2022;162:112405.
16. Boschmans K, Pissareva L. Fostering markets for SME finance: Matching business and investor needs. 2018.
17. Daramola OM, Apeh CE, Basiru JO, Onukwulu EC, Paul PO. Optimizing reverse logistics for circular economy: Strategies for efficient material recovery and resource circularity. 2023.
18. Fazekas A, Bataille C, Vogt-Schilb A. Achieving net-zero prosperity: how governments can unlock 15 essential transformations. 2022.
19. Fiemotongha JE, Igwe AN, Ewim CP-M, Onukwulu EC. Innovative trading strategies for optimizing profitability and reducing risk in global oil and gas markets. Journal of Advance Multidisciplinary Research. 2023;2(1):48-65.
20. Fiemotongha JE, Igwe AN, Ewim CP-M, Onukwulu EC. International Journal of Management and Organizational Research. 2023.
21. Gonçalves DNS, Goes GV, D'Agosto MA, La Rovere EL. Development of policy-relevant dialogues on barriers and enablers for the transition to low-carbon mobility in Brazil. Sustainability. 2022;14(24):16405.
22. Hassan YG, Collins A, Babatunde GO, Alabi AA, Mustapha SD. AI-driven intrusion detection and threat modeling to prevent unauthorized access in smart manufacturing networks. Artificial Intelligence (AI). 2021;16.
23. Hassan YG, Collins A, Babatunde GO, Alabi AA, Mustapha SD. AI-powered cyber-physical security framework for critical industrial IoT systems. Machine Learning. 2023;27.
24. Havemann T, Negra C, Werneck F. Blended finance for agriculture: exploring the constraints and possibilities of combining financial instruments for sustainable transitions. In: Social Innovation and Sustainability Transition. Springer; 2022. p. 347-358.
25. Henriques J, Catarino J. Motivating towards energy efficiency in small and medium enterprises. Journal of Cleaner Production. 2016;139:42-50.
26. Jessa E. Soil stabilization using bio-enzymes: A sustainable alternative to traditional methods. Communication in Physical Sciences. 2017;2(1).
27. Jessa EK. The role of advanced diagnostic tools in historic building conservation. Communication in Physical Sciences. 2023;9(4):639-650.
28. Karelberg M. The future of responsible investments in the context of algorithm-based decisions. 2018.
29. Kaygusuz K. Energy for sustainable development: A case of developing countries. Renewable and Sustainable Energy Reviews. 2012;16(2):1116-1126.
30. Ma Q, Li S, Aslam M, Ali N, Alamri AM. Extraction of natural resources and sustainable renewable energy: COP26 target in the context of financial inclusion. Resources Policy. 2023;82:103466.
31. Mustapha SD, Ibitoye B. Comprehension analysis of traffic signs by drivers on urban roads in Ilorin, Kwara State. Journal of Engineering Research and Reports. 2022;23(6):53-63.
32. Myllynen T, Kamau E, Mustapha SD, Babatunde GO, Adeleye A. Developing a conceptual model for cross-domain microservices using event-driven and domain-driven design. 2023.
33. Odio PE, Kokogho E, Olorunfemi TA, Nwaozomudoh MO, Adeniji IE, Sobowale A. Innovative financial solutions: A conceptual framework for expanding SME portfolios in Nigeria's banking sector. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(1):495-507.
34. Ogundeji IA, Omowole BM, Adaga EM, Sam-Bulya NJ. International Journal of Management and Organizational Research. 2023.
35. Onukwulu EC, Fiemotongha JE, Igwe AN, Ewim CP-M. International Journal of Management and Organizational Research. 2022.
36. Onukwulu EC, Fiemotongha JE, Igwe AN, Ewim CP-M. Transforming supply chain logistics in oil and gas: best practices for optimizing efficiency and reducing operational costs. Journal of Advance Multidisciplinary Research. 2023;2(2):59-76.
37. Otokiti BO, Igwe AN, Ewim C, Ibeh AI, Sikhakhane-Nwokediegwu Z. A framework for developing resilient business models for Nigerian SMEs in response to economic disruptions. International Journal of Multidisciplinary Research and Growth Evaluation. 2022;3(1):647-659.
38. Papantoniou AA. Regtech: steering the regulatory spaceship in the right direction? Journal of Banking and Financial Technology. 2022;6(1):1-16.
39. Paul PO, Abbey ABN, Onukwulu EC, Agho MO, Louis N. Integrating procurement strategies for infectious disease control: Best practices from global programs. Prevention. 2021;7:9.
40. Pinkse J, Groot K. Sustainable entrepreneurship and corporate political activity: Overcoming market barriers in the clean energy sector. Entrepreneurship Theory and Practice. 2015;39(3):633-654.
41. Psara K, Papadimitriou C, Efstratiadi M, Tsakanikas S, Papadopoulos P, Tobin P. European energy regulatory, socioeconomic, and organizational aspects: An analysis of barriers related to data-driven services across electricity sectors. Energies. 2022;15(6):2197.

42. Ragazou K, Passas I, Garefalakis A, Dimou I. Investigating the research trends on strategic ambidexterity, agility, and open innovation in SMEs: Perceptions from bibliometric analysis. Journal of Open Innovation: Technology, Market, and Complexity. 2022;8(3):118.
43. Shinozaki S. A new regime of SME finance in emerging Asia: Empowering growth-oriented SMEs to build resilient national economies. 2012.
44. Yeboah S, Boateng Prempeh K. Greening the future: Mobilizing environmental finance for sustainable development in developing countries. 2023.
45. Yikilmaz I, Cekmecelioglu HG. Organizational agility as a key driver of innovation performance in SMEs and large enterprises. In: New Perspectives and Possibilities in Strategic Management in the 21st Century: Between Tradition and Modernity. IGI Global; 2023. p. 209-238.