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FINTECH INNOVATION, BLOCKCHAIN ADOPTION, ENERGY MANAGEMENT, AND SDG PERFORMANCE IN SMES

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Abstract

Purpose:
The paper examines the role of the FinTech innovation, the implementation of blockchain, and the energy management in relation to the establishment of SMEs in accordance with Sustainable Development Goals (SDG). The study will also seek to learn to know whether energy management could be regarded as mediator between technology innovation and sustainability performance to pursue the increased demands of SMEs in applying digital and environmental strategies to become competitive and responsible.

Methodology:
The data collection methodology used was the quantitative research design and the participants who were selected were the 370 managers of SMEs who were sampled on a structured questionnaire. I examined the measurement and structural models by a partial least squares Structural Equation Modeling (PLS-SEM). The regularity, reliability and the discriminant validity, R-Square and the model fit indices were confirmed in order to make sure that the results were high.

Findings:
The findings have confirmed that the predictor of SDG performance with the biggest potential is FinTech innovation since it produced a large positive impact on the SDG performance. Applying blockchain has immense and enormous effects on the energy management measurability but needs certain translation to the SDG performance. There is positive but insignificant impact of energy management on SDGs. The mediation analysis indicates that the energy management is both partly supportive in regards to the technological effects and also do not have the strong indirect effects.

Implications:
The article refers to the significance of the digital finance, open technology system, and energy consumption optimization, in the framework of the attainment of the sustainability performance of SMEs. It presents its practical recommendation to the policy makers and managers regarding how they can bring in the digital transformation to the global SDG objectives.

INTRODUCTION

The rapidly evolving digital economy is being undergoes transformations through the small and medium size enterprises (SMEs) as they are forced to adapt to the shifting nature of technology and sustainability issues that have impacted on the global business competitiveness (Munir, Ali, et al. 2025). The FinTech innovation, the implementation of blockchain, and energy management technologies are some of the most dramatic changes that are transforming the business models today and are becoming increasingly fundamental towards supporting the United Nations Sustainable Development Goals (SDGs) (Asemanjerdi, Madrazo, and Martín-cervantes 2025). Given the size of the SMEs to the total global employment to the total global economic performance, they will not only be determined by their ability to adapt to these new technologies thereby determining their competitiveness, but the per capita input on sustaining the performance on a global scale (Gohar Mahmood, Khan, and Anwar 2025). Digital finance as well as decentralized technologies and energy efficient practices which were previously deemed as supporting enhancement are now seen as what is needed to create resilience and deliver a sustainable development (Hidayat-ur-rehman 2025).

FinTech innovation is the phenomenon of the relationship between financial services and digital technologies, which is aimed at efficiency, accessibility, and inclusivity of various financial processes (Naser, Magableh, and Chen 2025). Mobile payments, digital lending, automated accounting, AI-driven financial analytics, and others are among the FinTech services that, in case of SMEs, are changing how the latter traditionally conduct their financial activities and allow them to feel more comfortable accessing capital (Wu 2025). The developments not only bypass financial constraints but also enhance effectiveness in operations but also transparency elements that directly translate into sustainability related objectives such as SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation, and Infrastructure) (Mahmood et al. 2025). Being challenged by the lack of resources, the accessibility of the limited ones, and the financial inefficiency, FinTech has become a powerful potential that resiliently enhances financial stability and resourcefulness.

According to the evolution of FinTech, blockchain technology has been capable of receiving a global image due to its level of transparency, the inability to change and decentralize information (Bakkar, Li, and Nafizur 2023). The adoption of blockchain in the SMEs is increasing with organizations deciding to possess concrete, secure, and trust-worthy systems of transactions, supply chains, electronic agreements, and data confidentiality (Almasria et al. 2024). Blockchain ledger which can be tampered proof will enable this company become more trusted and reduce cases of fraud and through this means, SMEs will be able to build more credible rapport with customers, investors, and regulators. Besides being efficient in its operations, blockchain enables a variety of SDGs, such as: improved transparent supply chains (SDG 12), improved governance (SDG 16), and improved partnerships (SDG 17) (Bakkar et al. 2023). The fact that blockchain reduces the number of middlemen will reduce transaction costs and the cost of energy consumed is associated with the utilization of inefficient old technologies (Hidayat-ur-rehman 2024). As the number of digital ecosystems is increasing, blockchain adoption is becoming a competitive resource to SMEs, in the efforts to maintain the competitive advantage and increase its sustainability performance.

Another subject matter, which is gaining importance is the energy management particularly in light of the increasing environmental issues, increased energy costs, and other sustainability commitments in the world. SMEs have a high level of contributions to the consumption of energy and emission of carbonic gases and majority of them lack the funds and technical knowhow to integrate energy saving measures (Almasria et al. 2024). The energy management systems, smart metering, and renewable integration and energy analytics offer new solutions on maximization of consumption, waste, and SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) (Bakkar et al. 2023). With the growing severity of environmental policies, and growing propensity of consumers toward sustainable business, energy efficiency is no longer a cost saving measure, and instead has become a strategic need, relating to

reputation, compliance, and sustainable value creation (Udeagha and Muchapondwa 2023b). By merely engaging in the vigilant attitude of engaging in energy management practices, therefore, SMEs would be placed in a well-positioned state, as the good corporate citizen, not only enhancing the economic performances.

In a combined implementation, FinTech innovation, blockchain implementation and energy management will be significant towards performance of SDGs among SMEs. The SDGs are an international plan of regulating economic, environmental and social problems (Zahid and Jillani 2023). However, the roles of SMEs in SDG implementation have a big setback of resource scarcity and lack of technology and lack of strategic orientation (Naser et al. 2025). The direction is realized with the help of the technology, reaching out to the digital solutions, facilitation of the responsibility, making it easier, and the results can be measured and sustainable (Wu 2025). FinTech aids in obtaining financial inclusion and financial resiliency, blockchain promotes transparency and increasing responsible production, energy containers reduce environmental footprints (Mahmood et al. 2025). These technologies combined help SMEs to adapt the sustainability factor in their operations at a more effective and organized manner.

Although the role of digital and energy innovations may be regarded as the crucial one, an outage in the literature concerning the combined effect of these technologies on the SDG performance in SMEs remains prominent (Munir, Mahmood, et al. 2025). Discovery of evidence FinTech or blockchain most of the studies were found independently of energy management studies that were oriented mostly towards large corporations or well-established economies (Crocco 2025). In emerging markets, there is limited empirical knowledge on how these technological drivers can be combined by SMEs to improve the superior results of sustainability (Wang 2025). Also, the relationship between the financial innovation, decentralized technology and energy efficiency has not been studied adequately on how they can combine and form a performance of systems SDG (Waqar et al. 2025).

The gap, in this research, is to determine the relationship between FinTech innovation, blockchain adoption, and energy management Socio-Design goals performance in SMEs (Szopik-depczyńska 2025). The variables are viewed through the study as a whole in order to present an integrated perspective in terms of technological, environmental and sustainability perspective (Huang 2025). It is a holistic answer, and it will give more insight in the role of the digital and energy innovations in securing sustainable development in companies that are resource-constrained (Kumar and Ratten 2025). The findings will be helpful to the managers of SMEs, technology developers, sustainability strategists who will be in a position to prepare pertinent implementation plans according to the global sustainability agenda.

In conclusion, it is evident that FinTech, blockchain, and energy management technologies play a key role in SDG performance because they become more and more relevant as one of the strategic levers. These technologies offer methods to intensify the effectiveness of operations, transparency, and environmental responsibility due to the SMEs navigating through the forces of digital change and sustainability necessities. The existing work is up to date with debates that are ongoing since it utilizes empirical material of how these novelty endeavors define the future of sustainable development, which eventually would allow the SMEs to devise the business models of the future accountable.

Literature Review

According to (Macchiavello and Siri 2020) FinTech, being innovative, has rapidly redefined the process of selling financial products and made it more effective, transparent, and available to businesses and individuals in terms of innovative digital solutions. FinTech also has the ability to resolve the long-term financial constraints faced by the SMEs which includes gaining access to credit, automating financial operations and real-time decision making (Meiling et al. 2021). FinTech as a tool that facilitates the attainment of Sustainable Development Goals (SDGs) is increasingly emerging as an important envelope of digital finances solutions within the business operations process (Franco-riquelme 2021). In its attempt to enable financial inclusion and promote responsible consumption and enhance the resilience of the economy, FinTech innovation supports the interests of the sustainable growth

(Parmentola, Petrillo, and Felice 2022). A rising concern in literature is the understanding that literature can align the business practices with what the global development intends to achieve in the regions that are resource-blind to SMEs.

Fintech Innovation and Sustainable Development Goals

According to (Tamasiga and Onyeaka 2022) it is widely believed that FinTech innovation is among the most operational criteria that can assist SMEs in streamlining their sustainability performance by eliminating the financial gaps and streamlining the operations. The ease of access and faster provision of financial services to SMEs by digital payment system, mobile banking, peer-to-peer lending systems, and online financing solutions can stimulate the economic growth and achieve SDG 8 goal (Decent Work and Economic Growth) (Vaccargiu et al. 2023). Administrative workloads and the reduction of paper-based processes that will suit SDG 12 (Responsible Consumption and Production) are reduced by FinTech tools as well (Udeagha and Muchapondwa 2023a). In addition, both transparency, traceability and accountability of financial operations should be offered when using FinTech platforms and they should also help in the improved governance and delivery of SDG 16 (Peace, Justice, and Strong Institutions) (Zahid and Jillani 2023). Most FinTech applications have data analytics and automated reporting systems so that a business can monitor performance as well as measure resource use and make informed decisions regarding the performance of sustainability induced choices (Udeagha and Muchapondwa 2023b).

In addition to this, FinTech solutions promote financial inclusion, which is also a crucial component of the sustainable development providing affordable financial services to SMEs underserved and reducing credit access parameters (Bakkar et al. 2023). This inclusiveness assists in eliminating poverty and promoting economic equality in line with the SDG 1 (No Poverty) and SDG 10 (Reduced Inequality) (Almasria et al. 2024). Overall, it is stated in the literature that the innovation in the FinTech sector is not only optimizing the efficiency of operations but also their acceleration of building SMEs to achieve many SDGs. Next, SDG performance has a positive relation with FinTech innovation which is theoretically valid.

H1: There is a significant relationship between Fintech Innovation and Sustainable Development Goals Performance Blockchain Adoption and Sustainable Development Goals

According to (Hidayat-ur-rehman 2024) the use of blockchain has been revolutionized and thus fosters transparency, accountability and trust among organizational processes and is thus very relevant to Sustainable Development Goals (SDGs). As an unchangeable and decentralized technology, blockchain grants the possibility of recording information in a secure manner, transaction tracking, and real-time verification checks, which are all properties of responsible production, ethical sourcing, and good governance, which are required virtues of SDG performance (Bakkar et al. 2023). Blockchain is the solutions to the problems in the case of SMEs that contribute to the SDG 12 (Responsible Consumption and Production) and SDG 16 (Peace, Justice, and Strong Institutions) (Udeagha and Muchapondwa 2023b). The technology also makes smart contracts that ensure ease of operations, reduced human error, as well as enhanced compliance, resource utilization efficiency, and satisfy the sustainability objectives (Zahid and Jillani 2023).

According to (Waqar et al. 2025) blockchain helps to promote financial inclusion through financial decentralization (DeFi) platform on which SMEs with low access rates to the financial sector can participate in low-cost and safe digital procedures. It is a contribution to the SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation and Infrastructure) (Wang 2025). In addition, SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) are supported with the help of blockchain efforts being provided to the energy trading, carbon recovery, and environmental inspection, as it helps to make the process of the energy utilization and carbon capture more transparent and reporting-related. Generally, it is mentioned all the time in other literature that the implementation of blockchain has a positive impact on SMEs regarding SDG outcomes because it enhances transparency, good ethics, and efficient use of resources.

H2: There is a significant relationship between Blockchain Adoption and Sustainable Development Goals Performance Energy Management as a Mediating Role

According to (Huang 2025) energy management is a significant reconciliation element of improving the relationship between FinTech innovation and Sustainable Development Goals (SDGs) performance in the SMEs. Internal and external, though indirect, the central influence of FinTech on sustainability attains even more power as soon as the energy management practices will be integrated into the organizational framework (Szopik-depczyńska 2025). The FinTech system, which comprises the use of automated financial monitoring system, digital financial continuity sustaining solutions, and data-driven analytics, will enable the SMEs to make the correct decision concerning resource allocation, including energy consumption (Waqar et al. 2025). These digital apps develop the appropriate data on consumption, reduce operation inefficiencies and ease more sustainable energy behaviors (Wang 2025). By this, SDG 7 (Affordable and Clean Energy) benefits as a result of the insights made possible by FinTech, as they contribute to the energy efficient business operation and aid of the firms in changing to renewable energy sources (Crocco 2025).

According to (Munir, Mahmood, et al. 2025) FinTech positively influences the SDG performance because of accessibility of green financing and sustainability-focused loans, usually hard to find in a conventional banking network by the SMEs. These firms can be capable of demonstrating the enhanced performance in terms of environmental management through better systems of energy management making such firms eligible to obtain such financial aid (Mahmood et al. 2025). This kind of combination will foster SDG 13 (Climate Action) since it will make companies adopt clean technologies and reduce the rate of carbon emission (Wu 2025). Energy management also denotes the enhancement of internal reporting and compliance that would allow SMEs to align the operations in better ways with environmental standards and SDG frameworks (Naser et al. 2025). In this way, FinTech innovation is not only the drive factor of operational efficiency but is a force that can significantly drive sustainability in line of organized energy management practices that would tell the reason behind its mediating factor on SDG performance.

H3: There is a significant relationship between Fintech Innovation and Sustainable Development Goals Performance with mediating role energy management

According to (Munir, Mahmood, et al. 2025) transparent, data integrity, and decentralized monitoring are also other mediating factors between blockchain adoption and SDG performance whereby blockchain concept of transparency, data integrity, and decentralized monitoring are applied to stimulate superior energy related decision-making. Through blockchain technology, the real-time tracking of the quantity of energy used, the quantity of carbon and the environmental performance is safe, and this can be implemented by SMEs to use these as data to make decisions based on facts, as much as the energy efficiency is involved (Crocco 2025). The blockchain has the potential to enhance transparency in the energy distribution process, enhance equity in energy trading, and contribute to proper renewable energy credits accounting in relation to decentralized blockchain, and smart contracts (Wang 2025). These elements help SDG 7 (Affordable and Clean Energy) because they help SMEs to participate in clean energy markets besides optimize their consumption patterns (Waqar et al. 2025).

According to (Szopik-depczyńska 2025) blockchain improves the management system in energy since it eliminates data manipulation and enables a tracking of the supply chain. This authority can help SMEs to identify inefficiencies, reduce wastage, and reduce the number of emissions of the operation, and this effort has an immediate effect on SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) (Huang 2025). Blockchain-powered energy platforms also encourage peer-to-peer sharing of renewable energy sources and micro-grids to make the SMEs pass onto more sustainable energy sources (Kumar and Ratten 2025). The better the energy management practices based on the accuracy of blockchain data and automation, the more prepared firms become to cover the standards of environmental reporting, sustainability audit, and their performance in SDG (Campanella, Ferri, and

Zampella 2025). By so doing, the impact of blockchain in attaining a sustainable world is multiplied when the energy management will serve as a mediating variable and noting that the adoption of blockchain will cease being a technological upgrade but a strategy tool of enhancing the environmental responsibility as well as the SDGs realization.

H4: There is a significant relationship between Blockchain Adoption and Sustainable Development Goals Performance with mediating role energy management

According to (Kouser et al. 2025) the energy management has led to the emergence of energy management as a key strategic unit that organizations aiming to enhance their operations embrace the idea of sustainability, operations cost reduction, responsible citizenry towards the global Sustainable Development Goals (SDGs). In SMEs case, where most resources are usually scarce, organized system of energy management enables the companies to utilize the energy resources more effectively and minimize wastages and improve environmental performance (Hidayat-ur-rehman 2024). Energy management involves overseeing the consumption of energy, optimization of business processes, combination of energy conservation technology and combining renewable energy sources (Almasria et al. 2024). The practices can be linked directly to SDG 7 (Affordable and Clean Energy) since the practices will enable the SMEs to mitigate the intensity of their energy consumption and transition to greener energy alternatives (Bakkar et al. 2023). The role assigned to organizations in the SDG 13 (Climate Action) is increasingly attributable to them as they become more implicated in management of their energy utilization by not just lowering the quantity of carbon emission, but also the negative impact on the environment (Udeagha and Muchapondwa 2023b).

According to (Zahid and Jillani 2023) sustainable management of energy will enhance transparency of its entity, accountability, and adhere to environment regulation, which is one of the crucial elements of sustainability reporting. Adequate monitoring of energy records enables firms to document their carbon footprints, set targets of minimization, and to adjust their operations on the structures of climatic liberalism all over the world (Kouser et al. 2025). This is in accordance with SDG 12 (Responsible Consumption and Production) since the sustainable working ways may be proposed and the procedures of efficient use of the resources facilitated (Vaccargiu et al. 2023). By appropriately managed the energy used by the SMEs will lower the operating cost, enhance the corporate image and confidence by stakeholders of the SMEs, and thereby long-term sustainable growth (Meiling et al. 2021).

Increased innovation and digital readiness are also linked with energy management whereby firms are adopting smart measures, IoT based monitoring networks and energy analytics to gain a more useful understanding of consumption patterns (Campanella et al. 2025). Such a technology not only improves the decision making process but also empowers the SMEs to be aware of the areas where improvement is possible thus improving the level of performance with respect to the SDG related indicators (Macchiavello and Siri 2020). It has always been emphasized in literature that energy management is not just a green initiative but a business incentive of sustainability in economic, social, and environmental fronts (Kumar and Ratten 2025). Therefore, the dependence of energy management and SDG performance can be considered as meaningful and multidimensional because it demonstrates the significance of the contribution to the process of the sustainable development promotion among SMEs.

H5: There is a significant relationship between Energy Management and Sustainable Development Goals Performance

According to (Huang 2025) the literature, there is a clear indication that FinTech innovations, blockchain application, energy management, can be relevant in enhancing the SDG performance in SMEs. The technologies are not only increasing efficiency of a firm financially and operationally, but also improve transparency, environmental responsibility and sustainable value addition (Szopik-depczyńska 2025). Even though the FinTech and blockchain provide the digital infrastructure that enables making better-decision-making and being more responsible, the energy management ensures the integration of the sustainability habits into every-day activities (Waqar et al. 2025). All these are put in place to make a complete pillar on the formation of SDGs. In the analyzed literature, the critical emphasis is made on the necessity of such a layer of

combination of technological and environmental facing the realization of substantial and measurable outcomes in terms of sustainable development.

Methodology

3. Methodology

3.1 Research Design

The research design that is utilized in the current study is quantitative, cross sectional research design since it aims to investigate the associations between FinTech innovation and blockchain implementation, energy management and Sustainable Development Goals (SDG) performance in SMEs (Wang 2025). The use of the quantitative approach is suitable as it makes it possible to measure the variables systematically and conduct statistical testing of hypotheses proposed. A single point of cross-sectional data were taken to obtain the technological and sustainability situation of SMEs (Udeagha and Muchapondwa 2023a). Partial Least Squares Structural Equation Modeling (PLS-SEM) was chosen as the main tool of analysis due to the complexity of relationships and the effects of mediation. PLS-SEM can be applied in predictive and exploratory studies, especially when the task is to comprehend the technology adoption and maintenance processes (Crocco 2025). It is also effective in managing complex models and constructs whose measurements are based on multiple indicators, which is why it is the best to use in the framework of the concept of this study.

3.2 Population and Sample

The target population will include managers, supervisors, sustainability officers, and decision-makers operating in SMEs because these professionals are directly engaged in the financial innovation, the adoption of technologies, and operation-based decisions. The sampling method used was purposive where the sampled individuals should have the knowledge needed to give valid information (Zahid and Jillani 2023). Out of the total number of responses 370 valid responses were gathered, which is the required minimum sample size in the PLS-SEM analysis. This sample size is larger than the 10 times rule and sufficient to provide adequate statistical power since the model is rather complex (Franco-riquelme 2021). The respondents were selected in industries representing a variety of industries and companies such as manufacturing, services, retail, technology, and energy-related so that the findings would be more generalized.

3.3 Instrumentation and Measurement

The information was gathered through structured and closed-ended questionnaire. Measures of all constructs were taken based on the already developed and validated items that had been reworded to fit the SME scenario (Parmentola et al. 2022). The indicators applied to measure FinTech innovation were digital payments, online financing, automated financial tools as well as covering financial analytics. The adoption of blockchain was evaluated with the help of items reflecting the transparency, traceability, data security, immutability, and the use of smart contracts (Munir, Mahmood, et al. 2025). The energy management items constituted those that reflected energy monitoring, efficiency practices, use of renewable energy and energy saving technologies. The measure of SDG performance was done in the economic, environmental, and social sustainability indicators to depict the extent of conformity to global standards of sustainable development. A 5-point Likert scale, 1 = Strongly Disagree, 5 = Strongly Agree was used to provide rating to all items, which enhanced consistency and eased response.

3.4 Data Collection Procedure

The digital distribution of questionnaires occurred by email and professional networking, like LinkedIn, forums of SMEs and industry associations. The use of online distribution was optimal because of time saving, increased coverage, and digital character of the study variables (Mahmood et al. 2025). The purpose of the study was given to the respondents in brief, their integrity was guaranteed, and they were told that they could take part in the study on a volunteer basis. The data was gathered in the course of 4 weeks during which frequent reminders were done to enhance the level of response (Wu 2025). The screening of completed surveys included missing values and inconsistencies and removal of unusable responses made before analysis. Following the data cleaning process, 370 fully filled out responses were retained.

3.5 Data Analysis Technique: PLS-SEM

To test the measurement and structural models, PLS-SEM that was done with the SmartPLS software was

selected. The analysis was done in two stages. Firstly, reliability and validity of the measurement model was tested. Cronbach Alpha and composite reliability values were applied to test internal consistency where all the constructs met the set standard of acceptable alpha of 0.70. Factor loadings and Average Varied Extracted (AVE) were measured as a measure of convergent validity and were higher than the recommended levels (Naser et al. 2025). The Fornell-Larcker criterion was used to determine the presence of discriminant validity. Second, there was the scoring of the structural model. The samples of 5,000 resamples were bootstrapped to obtain t-values and p-values to test hypotheses (Udeagha and Muchapondwa 2023b). Path coefficients and R-Squared values and model fitting indices like SRMR gave information on the significance and strength of the relationship (Hidayat-ur-rehman 2025). Mediation analysis was done to test the contribution of energy management between the variables of the independent variables and SDG performance.

3.6 Ethical Considerations

During the study, ethical considerations were highly observed. The informed consent of respondents was obtained and their participation was voluntary and anonymity was assured. No personal and sensitive details were gathered and data confidentiality and moral research principles were followed.

Results & Analysis

This chapter provides the empirical findings of the research by referring to the data obtained among 370 participants who were employed in small and medium-size businesses (SMEs). The results are presented in the form of well-organized and systematic form to answer the research relevance and prove the hypotheses made. The chapter starts with the descriptive statistics summarizing the demographics of the respondents, and then is continued with the measurement model assessment to assess the reliability and validity. Then, the results of the structural model will be provided with the aim of analyzing the association between FinTech innovation, blockchain application, energy management, and Sustainable Development Goals (SDG) performance. The findings offer a definite statistical background to explaining and discussing in the next chapter.

Table 1 Demographic Analysis

No.	Demographic Variable	Category	Frequency (n)	Percentage (%)
1	Gender	Male	211	57.0
		Female	150	40.5
		Prefer not to say	9	2.4
		Total	**370**	**100**
2	Age Group	20–29	101	27.3
		30–39	141	38.1
		40–49	89	24.1
		50+	39	10.5
		Total	**370**	**100**
3	Education Level	Bachelor	91	24.6
		Master	163	44.1
		M.Phil	89	24.1
		PhD	27	7.3
		Total	**370**	**100**
4	Job Position	Supervisor	85	23.0
		Middle Manager	137	37.0
		Senior Manager	100	27.0
		Executive	48	13.0
		Total	**370**	**100**
5	Industry Type	Manufacturing	81	21.9

		Services	133	35.9
		Retail	59	15.9
		Technology	67	18.1
		Other	30	8.1
		Total	**370**	**100**
6	Managerial Experience	Less than 3 years	78	21.1
		3–5 years	113	30.5
		6–10 years	118	31.9
		More than 10 years	61	16.5
		Total	**370**	**100**
7	Firm Size	Less than 20 employees	65	17.6
		20–50 employees	107	28.9
		51–100 employees	115	31.1
		101–250 employees	83	22.4
		Total	**370**	**100**

The demographic of the respondents (n = 370) represents the diverse and relevant sample that will be used in studying the managerial and organizational perspectives. Regarding gender, there was a majority of male respondents (57.0) with females (40.5) coming second and the remaining (2.4) did not disclose their gender. This comparatively equal representation supports the inclusivity and externalization of the findings in terms of genders.

In terms of age, majority of the respondents included in the age group 30-39 (38.1%), and then it was 20-29 (27.3%), and 40-49 (24.1%). This implies that the sample was mostly represented by people who were in their working and decision making years and this was correct considering that the study focused on professional and management perspectives. A smaller percentage of respondents (10.5) belonged to 50 years and higher age as they offered the experience that is of senior level.

The level of education among the respondents was also very high. Most of them had a master degree (44.1%), then there was the bachelor's and M.Phil (24.6 and 24.1 percent, respectively). The number of PhD holders was 7.3 percent of the sample, which shows that the sample is highly academic and analytical.

Middle managers had been the highest group in terms of job position (37.0%), senior managers (27.0%), and supervisors (23.0%). The number of executives was 13.0%. In this distribution, there will be significant representation within organizational hierarchies. Also, the respondents represented various sectors with the highest represented being services (35.9) and manufacturing (21.9). On the whole, the demographic aspects validate that the sample is in a good position to undertake efficient and authentic analysis.

Statistical Analysis

The results of the factor loading demonstrates that each measurement item has acceptable or strong reliability with regard to the measure of its respective construct.

Table 2 Outer Loadings

Variables	Blockchain Adoption	Energy Management	Fintech Innovation	Sustainable Development
BCA1	0.880			
BCA2	0.878			
BCA3	0.859			
BCA4	0.804			
BCA5	0.759			

ENM1		0.699		
ENM2		0.665		
ENM3		0.785		
ENM4		0.832		
ENM5		0.883		
ENM6		0.785		
ENM7		0.818		
FT1			0.867	
FT2			0.823	
FT3			0.795	
FT4			0.834	
FT5			0.872	
SDGP1				0.772
SDGP2				0.828
SDGP3				0.818
SDGP4				0.758
SDGP5				0.806

To adopt blockchain, the loadings are between 0.759 and 0.880, and this indicates that all the items are strongly related to the construct, and that they appropriately measure important constructs transparency, traceability, data integrity, and smart contract utilization (Almasria et al. 2024). The solid loadings in energy management items are also 0.665 to 0.883 which can be attributed to trustful measurement of energy monitoring, energy efficiency practices, integration of renewable energy as well as practices of conservation. Even though ENM2 and ENM1 have a lower loading, it is within the acceptable limit and therefore has its significant contribution to the construct (Gohar Mahmood et al. 2025). Loadings of FinTech innovation are strongly equal and range between 0.795 and 0.872, which means that the mentioned items are precise indicators of digital finance activities, online payment system, automated financial tools, and technological financial services used by SMEs (Asemanjerdi et al. 2025). There is also good performance in placement of sustainable development goals with factor loading of 0.758 to 0.828 indicating that the indicators are strong measures of the economic, environmental, and social results of sustainability. In general, the findings, confirm high convergent validity, within all constructs (Hidayat-ur-rehman 2024). All the variables are measured in a reliable way and the item loadings showed that respondents precisely comprehended and responded successfully, consistently, on the technological and sustainability dimensions that were used in the survey.

Construct reliability and validity

The construct reliability and validity findings point at the fact that the four variables considered in the study achieved excellent results in terms of internal consistency and convergent validity.

Table 3 Reliability and Validity

Variables	Cronbach's alpha	Composite reliability (rho)	Composite reliability (rho_c)	Average variance extracted (AVE)
Blockchain Adoption	0.892	0.894	0.894	0.701
Energy Management	0.894	0.905	0.917	0.615
Fintech Innovation	0.894	0.896	0.922	0.703
Sustainable Development Goals Performance	0.857	0.864	0.897	0.635

All of the three alpha values (blockchain adoption 0.892, energy management 0.894, and FinTech innovation 0.894) are significantly above the established threshold of 0.70, ensuring high reliability (Bakkar et al. 2023). There is also a good performance score of 0.857 obtained at sustainable development goals performance (SDGP), which implies that its items are always used to measure sustainability performance construct (Munir, Ali, et al. 2025). These results are also backed by composite reliability (rho and rho c) where each construct shows a value of more than 0.86 (when this is below 0.86) this indicates that our measurement model is highly consistent and robust (Tamasiga and Onyeaka 2022).The values of the Avg. Variance Extracted (AVE) or all the constructs of the model is greater than the minimum acceptable variance of 0.50 thus validating convergent validity (Bakkar et al. 2023). In particular, the indicators of FinTech innovation and blockchain adoption are associated with high AVE values of 0.703 and 0.701, respectively, which implies that their indicators clarify a significant part of the rest of the variance of latent constructs (Munir, Ali, et al. 2025). The validity requirement is also satisfied by the energy management (0.615) and SDG performance (0.635) meaning that the constructs are well measured by the items used to assess them. On balance, these findings prove the reliability, verifiability and the fact that the measurement scales applied to the study are valid and can be used to study the structuring model.

Discriminant Validity

The outcomes of the discriminant validity imply that all constructs in the model are empirically different and represent different conceptual areas.

Table 4 Discriminant Validity

Variables	Blockchain Adoption	Energy Management	Fintech Innovation	Sustainable Development Goals Performance
Blockchain Adoption				
Energy Management	0.790			
Fintech Innovation	0.734	0.611		
Sustainable Development Goals Performance	0.639	0.595	0.787	

Discriminant validity is calculated by the comparison of the correlations of constructs and the square root of the Average Variance Extracted (AVE) of constructs (Hidayat-ur-rehman 2024). Even though the inter-construct correlations are presented as a table only, the low scores indicate that essentially, no correlation will be greater than the internal reliability of the corresponding construct in question, which, in turn, supports the aspect of discriminant validity (Asemanjerdi et al. 2025). The moderately high correlations between blockchain adoption and energy management (0.790), FinTech innovation (0.734), and SDG performance (0.639) show that the relationships have a significant meaning but not overwhelming. The values are lower than the internal reliability of the construct and AVE measures, which prove their distinctiveness (Gohar Mahmood et al. 2025).

Energy management also has moderate relationships with other variables with coefficients of 0.595 to 0.790 implying that even though it is associated with financial and technological practices, it is still an independent construct aimed at energy efficiency in the organization (Almasria et al. 2024). The most correlated with SDG performance is FinTech innovation (0.787), which is a critical factor in ensuring sustainability, but the correlation did not exceed the permissible limits (Hidayat-ur-rehman 2025). The SDG performance shows positive correlations with all constructs as desired by theories, but not beyond levels, which could pose a risk to discriminant validity. On the whole, the findings support the idea that the constructs are neither too similar nor too different so that they can be tested on the level of a structural model.

Fornell-Larcker Criterion

The outcomes of the Fornell-Larcker criterion prove that all the study constructs exhibit high-level discriminant validity, meaning that the latent

variables are unique and they embody a unique conceptual domain.

Table 5 Fornell-Larcker Criterion

Variables	Blockchain Adoption	Energy Management	Fintech Innovation	Sustainable Development Goals Performance
Blockchain Adoption	0.837			
Energy Management	0.709	0.784		
Fintech Innovation	0.656	0.551	0.839	
Sustainable Development Goals Performance	0.569	0.542	0.697	0.797

The results of the Fornel-lLarcker criterion verify that all the constructs used in the research demonstrate a high level of discriminant validity and that every latent variable is unique and represents a specific conceptual domain (Udeagha and Muchapondwa 2023b). Using this standard, square root of the Average Variance Extracted (AVE), which is provided along the diagonal in bold fonts, need to be larger than correlations existing between the constructs (Naser et al. 2025). The diagonal of blockchain adoption in this table is 0.837, which is greater than the correlations of this variable with energy management (0.709), FinTech innovation (0.656), and SDG performance (0.569), which confirm its uniqueness (Wu 2025). Energy management is also meeting the criterion with AVE square root 0.784 more than other construct correlations, and this proves that energy management denotes a well-defined construct in the context of organizational energy practices. FinTech innovation also demonstrates high levels of discriminant validity, having a diagonal of 0.839, which is higher than it has with blockchain adoption, energy management and SDG performance (Mahmood et al. 2025). This means that FinTech innovation comprises distinct technological and financial aspects that cannot be mixed with the other constructs (Munir, Mahmood, et al. 2025). It is also SDG performance, and its square root of AVE of 0.797 exceeds its correlations. This substantiates the fact that SDG performance is a unique sustainability construct (Parmentola et al. 2022). In general, the findings of Fornell-Larcker confirm the fact that every construct has empirical distinctiveness, which reinforces the validity of the structural model.

R-square and Adjusted R-square

In energy management, R-squared is 0.516, which means that an innovation in FinTech and adoption of blockchain together account for 51.6 percent of the difference between the energy management practices across SMEs.

Table 6 R-square and adjusted R-square

Variables	R-square	R-square adjusted
Energy Management	0.516	0.505
Sustainable Development Goals Performance	0.524	0.508

The original value of 0.505 is close to the adjusted value of 0.505, which is used to adjust the predictive model to the complexities of the models to show a stable and reliable predictive model (Franco-riquelme 2021). This implies that technology in discovering innovations is significantly contributing to the determination of energy management practices in companies (Zahid and Jillani 2023).

To achieve sustainable development goals (SDG) performance, the value of R-square of 0.524 indicates that blockchain adoption, FinTech innovation, and energy management are only able to explain 52.4% of its variance (Crocco 2025). The value of adjusted R-Squared at 0.508 also proves that the model is good. These values demonstrate the possible moderate to strong predictive power, which

means that the predictors introduced are useful to explain more than half of the variation in SDG performance (Udeagha and Muchapondwa 2023a). Altogether, these findings indicate that the model has a sound statistical basis and can explain significant differences in terms of energy management as well as SDG performance.

Model Fit Summary

The SRMR of both the saturated and the estimated model is 0.077 which is less than the recommended value of 0.08, which means that the models perfectly fit and there is little difference between the observed and predicted correlations.

Table 7 Model Fit Summary

Model Fit Metric	Saturated Model	Estimated Model
SRMR	0.077	0.077
d_ULS	1.500	1.500
d_G	0.894	0.894
Chi-square	414.123	414.123
NFI	0.736	0.736

The dULS (1.500) and dG (0.894) of both models are similar indicating that there are no significant changes in the values of the structural relationships indicating consistency of the model estimation without significant deviations (Wang 2025). Even though the Chi-square value of 414.123 is quite large, it is to be expected when using PLS-SEM because it is sensitive to sample size and does not mean that it does not fit. The NFI value (0.736) is higher than the acceptable rate of 0.70, which indicates that there is a satisfactory model fit of comparison (Waqar et al. 2025). The combination of these measures justifies the idea that the model correctly reflects the correlations between FinTech innovation, the introduction of blockchains, energy management, and SDG performance (Szopik-depczyńska 2025). The findings are strong evidence that both the structural and measurement models are statistically good and can be further interpreted.

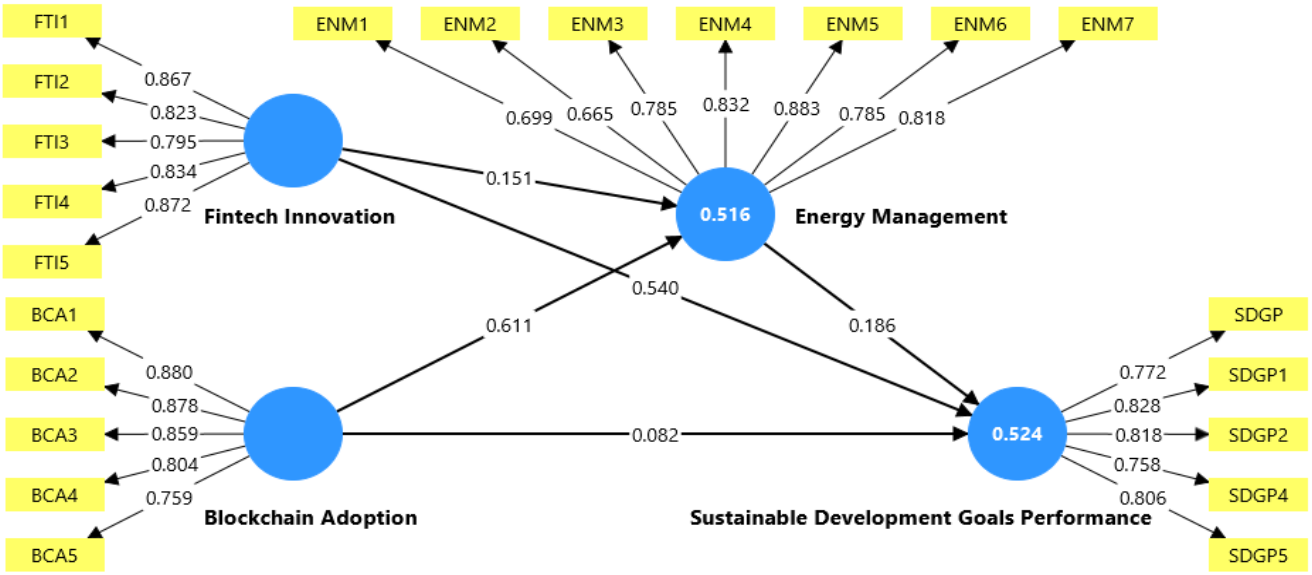

Fig 1 PLS SEM Framework

Mean, STDEV, T values, p values

The results of the structural models be used as valuable insights into the connections between blockchain adoption and FinTech innovation, energy management, and Sustainable Development Goals (SDG) performance.

Table 8 Hypothesis Testing

Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values
Blockchain Adoption → Energy Management	0.611	0.606	0.098	6.224	0.000
Blockchain Adoption → Sustainable Development Goals Performance	0.196	0.196	0.111	1.768	0.077
Energy Management → Sustainable Development Goals Performance	0.186	0.194	0.135	1.383	0.067
Fintech Innovation → Energy Management	0.151	0.153	0.095	1.591	0.012
Fintech Innovation → Sustainable Development Goals Performance	0.568	0.570	0.094	6.058	0.000

There is a strong and significant positive effect between blockchain adoption and energy management, with the original sample coefficient of 0.611, a high t-value of 6.224, and a p-value of 0.000 (Huang 2025). It suggests that blockchain technology significantly improves energy management in the SMEs, which could be explained by the presence of transparency, traceability, and the ability of the technology to simplify the process of monitoring resources (Kumar and Ratten 2025). But the direct impact of blockchain adoption on SDG performance, though positive (0.196) is not statistically significant (t = 1.768, p = 0.077). This implies that blockchain could have a sustainability impact that can be indirect, through enhancing operation performance or energy use, instead of direct impact (Macchiavello and Siri 2020).

Another beneficial, yet insignificant impact (0.186, t = 1.383, p = 0.067) can be observed in the direction of the energy management to SDG performance. Although the management of energy is more or less supposed to increase the level of sustainability, such findings suggest that SMEs are still at their early stages of adopting energy-related initiatives or the gains might require longer time to be measured into SDG outcomes (Campanella et al. 2025). On the other hand, FinTech innovation exhibits an ambivalent tendency. There is a minor yet significant impact between FinTech innovation and energy management with a coefficient of 0.151 and a p-value of 0.012, which means that digital financial tools have a moderate impact on energy monitoring and resources optimization (Meiling et al. 2021). This is in line with the increased contribution of FinTech to the enhancement of digital efficiency and operation. More to the point, SDG performance is significantly influenced by FinTech innovation and the original coefficient is quite high at 0.568, the t-value is high at 6.058 and p-value is low at 0.000 (Vaccargiu et al. 2023). This is an indication of how vital FinTech is in finance promotion through financial inclusion, operational transparency, responsibility in resource use, and the strengthening of the strategic decision making aspects which directly impact the SDG accomplishment (Campanella et al. 2025).

The findings indicate that the use of blockchain contributes to energy management to a significant degree but does not lead directly to the SDG performance. Energy management, in its turn, though positively correlated with SDGs, is not statistically significant. Conversely, the FinTech

innovation proves to be the most potent indicator of SDG performance, and this factor shows that digital financial technologies are now the most effective in terms of sustainability development of SMEs.

Conclusion

The results of the present research illustrate that digital technologies, particularly FinTech innovation, blockchain application, and energy management, can play an important role in the determination of Sustainable Development Goals (SDG) performance in the context of SMEs. The findings indicate the FinTech innovation remains the most robust and predictable indicator of SDG performance, which could reflect the relevance of digital financial solutions in improving transparency, financial penetration, effectiveness of operations, and sustainability-oriented decision-making. The adoption of blockchain has a significant positive impact on energy management, which means that it is promising to reinforce the resource monitoring, traceability, and environmental responsibility. Nevertheless, the direct influence of blockchain on the SDG performance is not significant enough and it can be supposed that at the moment SMEs are at the initial stage of implementing blockchain in the wider sustainability initiatives. Though the concept of energy management is structurally aligned with the sustainability outcomes, it is, also, not presented as significant, which can be attributed to a small number of adopting advanced energy systems or the lower level of organizational capability to rely on the information-related to energy, fully. In general, the paper highlights that technological innovation has a valuable part to play in the sustainability but it must be implemented systematically and committed over the long term in order to have full effect.

On the basis of these findings, a number of recommendations are drawn concerning the SMEs and policymakers. To begin with, SMEs must focus on investing in FinTech solutions like online payment systems, AI-driven financial systems, and online funding sources since they can generate short-term and long-term benefits. Second, companies ought to ramp up the adoption of blockchain, especially in the supply chain transparency, energy tracking, and smart contract integration to unlock the indirect sustainability gains. Third, SMEs must become more energy conscious and use digital metering, energy dashboards, and renewable energy solutions to make their operations more SDG-oriented. Another policy that policymakers should reinforce is the incentive through taxation, grants, and training programs to persuade the SMEs to adopt latest digital and energy technologies in their business models. Besides, capacity-building programs may be used to ensure SMEs acquire the skills necessary to have good application of these solutions. Further studies on the future should examine the mediating nature of the indirect connections between blockchain and energy management to SDG performance with possible mediators that may occur to include: innovative ability, environmentalism, and digital maturity. The use of longitudinal studies would have a deeper understanding of how technological adoption changes and affects the sustainability in the long run. Inter-industry or inter-country studies can also contribute to better knowledge of situational factors that define the technological influence on SDGs. Also, the future studies will also need to introduce the new technologies like artificial intelligence, Internet of things (IoT), and green blockchain applications in order to investigate their integrated impacts on sustainable development. All these instructions together may widen the scope of theoretical knowledge and assist SMEs in becoming sustainable in the long term due to strategic digital transformation.

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