ORIGINAL ARTICLE

OPEN ACCESS

Dual Impact of Green Financing and Financial Technology on Energy Efficiency

Sadaf Ambreen [1], **Tahira Awan** [2]

Author's Affiliation:

[1]PhD Scholar, Faculty of Management Sciences, International Islamic University, Islamabad, Pakistan
[2]Assistant Professor, Faculty of Management Sciences, International Islamic University, Islamabad Pakistan

Article History:

Submitted: July 16, 2024
Revised: September 21, 2024
Accepted: September 29, 2024
Published online: September 30, 2024

Corresponding author(s):

Sadaf Ambreen
Email: sadaf.ambreen@iiu.edu.pk

Co-author(s)Email:

Tahira Awan
tahira.awan@iiu.edu.pk

A B S T R A C T

Purpose - The analysis evaluates financial technology (Fin-Tech) and green financing effects on energy efficiency in Pakistan while emphasizing their role in developing sustainable growth. The research investigates digital inclusion in finance as well as green bonds and climate-oriented financial tools because of their growing importance in sustainable investments and technological advancements.

Study Design/methodology/approach - The analysis relies on time-series data spanning from 2001 until 2023, which researchers obtained from World Development Indicators (WDI). A combination of unit root analysis and correlation analysis together with ordinary least squares (OLS) regression serves to evaluate the relationship between Fin-Tech adoption and green financing mechanisms with their effects on energy efficiency. Research data indicates that technological innovations in the financial sector, along with digital payments and blockchain systems, produce major improvements in energy efficiency. The energy-efficient infrastructure and clean energy projects benefit from green financing tools which include green bonds and sustainable investment funds.

Findings - Results from regression analysis show that financial technology development creates positive changes in energy efficiency levels. The energy-efficient financing market has expanded because of financial technology innovations, which include electronic banking systems blockchain transaction mechanisms, and peer-to-peer credit services. The research supports the Innovation Diffusion Theory because innovation adoption drives financial behavioral changes across all sectors.

Research Practical Implications - The analysis faces restrictiveness due to the availability of definitive indicators tailored for Fin-Tech, which hampers potential wide-scale explanation. The research includes only Pakistan, therefore additional studies must focus on various emerging market contexts. Assessing the Role of Digital Currencies in Green Finance Granting central bank digital currencies (CBDCs) and green cryptocurrencies has increased, so research must evaluate their capacity to support low-carbon investments and enhance energy efficiency projects.

Originality/value - The existing literature gains new empirical evidence regarding how Fin-Tech functions together with green financing to enhance energy efficiency through this research. The research connects financial innovation with environmental sustainability while supplying significant directions for developing future sustainable development plans.

Keywords: Green financing, financial technology, Energy efficiency

JEL Classification Codes: O13, Q56,

1 | INTRODUCTION

The combination of financial technology (fin-tech) and green financing is central to improving energy efficiency and sustainable economic growth in Pakistan. With the growing global energy reality, the financial industry has started to use fintech to deploy greenfield financing actively (Sineviciene et al., 2017). The introduction of innovations in financial technology, including digital payments, blockchain, and online lending to individuals, has changed the competitiveness of financial services, which in turn stimulated investments into energy-saving and renewable energy technologies (Zhang, 2023). This study considers the influence of fin-tech and green financing on energy efficiency through multiple lenses. The Innovation Diffusion Theory (Rogers, 2003) explains how financial innovations circulate within and across societies and the investment patterns they generate. Sustainable Finance Theory also supports the need for integrating ESG elements into finance. Stakeholder Theory (Freeman, 1984) calls for embracing the interests of a wider range of constituents, namely, investors and regulators, but also the general public among the targets of a business or financial institution. Ultimately, the Resource Based View (RBV) Theory (Barney, 1991) highlights how digital financial resources enhance energy efficiency and how competing financial technology firms gain benefits.

1.1 | The Contribution of Fintech in Energy Efficiency

Innovation Diffusion and Fintech Adoption: The Analysis of New Technology Adoption explains how new technologies such as fintech are adopted and impact the market (Rogers, 2003). Fintech makes it possible to conduct Digital Banking, Mobile payment, and Blockchain payment transactions, which helps in green financing (Song & Han, 2022). These technologies lessen reliance on traditional financial intermediaries, leading to greater enablement of funding for energy efficiency projects by small businesses and individuals (Chen et al., 2023). In addition, turbine crowd financing for renewable energy projects made decentralized financing possible and rapid participation in sustainability initiatives (Taghizadeh-Hesary et al., 2019). The application of digital services in Pakistan is a good example of the application of IDT as it shows how the financial technology spread among different sectors of the economy, resulting in increased funding for green projects (Hussain & Zhang, 2023).

1.2 | Blockchain and Transparency in Green Investments

Financing strategies aimed at enhancing environmental protection, like green finance, have been bolstered by the use of blockchain technology. As per the current Sustainable Finance Theory, ESG factors have to be integrated into financial decisions to ensure sustainability in the long-run (UNEP, 2023). Blockchain's features guarantee that transactions involving green bonds and carbon credits are linked to real biogenic energy-efficient projects by recording the fraud-proof monetary transactions (Wang et al., 2023).

1.3 | Green Financing and Its Impact on Energy Efficiency

Sustainable Finance Theory and Green Bonds, the use of green bonds as a tool for financing is an example of green financing implementation, which is consistent with the Sustainable Finance Theory that seeks environmental integration into finance (Alquliti, 2022). Green bonds are a type of debt security that is issued to raise capital solely for financing renewable energy initiatives, energy-efficient construction, and low-carbon public transportation systems (Anh Tu & Rasoulinezhad, 2022; Tolliver et al., 2021). To align Pakistan's financial policies with international sustainability objectives, the SECP) has introduced policies to streamline the processes for issuing green bonds (SECP, 2023). Empirical evidence suggests that the issuance of green bonds increases energy efficiency by allocating resources to renewable energy projects (Khan et al., 2024).

The adoption of robust green financing frameworks has led to notable improvement in energy conservation and decrease in carbon emissions in other countries (Chen et al., 2023). The issuance of green bonds in Pakistan illustrates the country's willingness to improve energy efficiency and maintain economic growth.

1.4 | Research Problem

The country deals persistently with attaining sustainable economic expansion and energy efficiency enhancement simultaneously. Non-renewable energy dependence by the country produces both environmental harm and creates energy vulnerability. The advancements in financial technology (fintech) and green financing around the world have not been effectively incorporated by Pakistan to tackle energy efficiency problems. Green financing solutions through financial technology struggle to maximize energy efficiency because the country faces three major issues: restricted funding opportunities, inadequate regulatory controls, and delayed technological implementation. Studies about fintech adoption and green financing exist independently, but no substantial research exists on their combined effects on maximizing energy efficiency within Pakistan. Among the obstacles preventing fintech applications from effectively mobilizing sustainable energy project financing are regulatory, along with institutional restrictions. This study investigates the relationship between fintech and green finance with energy efficiency to establish sustainable energy transition policies.

1.5 | Research Objectives

The research evaluates the relationship between fintech solutions and green financial instruments for enhancing energy efficiency throughout Pakistan. The key research objectives include: This research evaluates how fintech acceptance affects green financial support availability as well as operational efficiency in Pakistan's energy system. This analysis examines the influence that green financing mechanisms which include green bonds and sustainable investments have upon promoting better energy efficiency. This research examines the institutional as well as regulatory barriers which affect fintech and green financing integration throughout Pakistan. We need to detect principal obstacles together with advantageous conditions when it comes to using fintech tools within sustainable energy financing frameworks. The author proposes policy recommendations that will improve the energy transition in Pakistan through enhanced fintech and green financing systems.

By addressing this gap, this research suggests fresh insights and policy recommendations to improve environmental sustainability through green finance, and Financial Technology. The research establishes its importance through its focus on examining developing third country connections between fintech systems with green financial support for maximizing energy efficiency levels. Through an empirical study, researchers can provide practical recommendations to Pakistani policymakers who aim to improve energy sustainability. This dissertation consists of a complete literature survey, a detailed research approach section followed by empirical findings together with policy recommendations.

2 | LITERATURE REVIEW

The convergence of financial technology (fintech) and green financing has become pivotal in enhancing energy efficiency and promoting sustainable economic growth globally (Anh Tu & Rasoulinezhad, 2022). In Pakistan, these innovations are particularly significant due to the country's pressing energy challenges and environmental concerns. This literature review explores recent advancements in fintech and green financing, emphasizing their impact on energy efficiency within the Pakistani context. The discussion is framed through relevant theoretical lenses, including Innovation Diffusion Theory, Sustainable Finance Theory, Stakeholder Theory, and the Resource- Based View. The advancement of energy efficiency receives emphasis in recent

research because of fintech and green finance systems. The deployment of digital financial services has proven to increase renewable energy projects funding, according to Alquliti (2022). Research by Arner et al. (2020) proved that fintech platforms provide better green financing access through fees reduction and enhanced market transparency. Multiple research studies across China and ASEAN countries established that rising green bond issuance directly coincides with better energy performance and lower carbon pollution numbers (Udeagha & Ngepah, 2022). The financial sector of Pakistan shows slow progression towards implementing green finance solutions that are enabled by fintech technology (Kashif et al., 2025). Sustainable finance instruments have faced this set of hurdles because of regulatory difficulties and insufficient awareness from the general public (Ahlström & Monciardini, 2022). The research contributes evidence-based information about the effectiveness of Pakistani fintech and green finance implementations.

2.1 | Stakeholder Theory and Services of Financial Institutions

The Stakeholders Theory (Freeman, 1984) suggests that financial institutions must adjust their activities to ensure that social and environmental factors are given as much importance as business profit. About green financing, banks and investment companies have an important responsibility in channeling capital toward energy-saving endeavors (Smith, 2023). The alignment of strategy with sustainability objectives by financial institutions is exemplified in the recent investment by the Green Climate Fund in Pakistan to the tune of $15 million (Wijeweera & Rashid, 2023). To make green financing initiatives work effectively, stakeholders must take part in the process. The achievement of sustainable investments needs a regulatory framework, which policymakers, along with businesses and financial institutions, should establish together (Wang & Wang, 2020). The partnership between public and private entities proves successful at raising funds for major renewable energy initiatives, thus strengthening the role of green financing in enhancing energy efficiency (Ali et al., 2023).

2.2 | The Intersection of Fintech and Green Financing

Resource-Based View and Fintech's Competitive Advantage Firms use their distinctive financial and technological resources according to the Resource-Based View Theory (Barney, 1991) to compete successfully in the market. Through blockchain technology along with artificial intelligence (AI) and machine learning systems, Fintech green finance companies evaluate sustainable project risks and optimize sustainable investment choices (Huang & Yang, 2023). The innovative financial systems ensure transparent deals at reduced costs which help make energy-efficient investments more attainable (Chen et al., 2024). Robotically managed renewable energy project loan disbursements become possible through the combination of fintech and green financing technologies. The technology decreases the requirement of middle agents and optimizes transaction expenses and makes sure that sustainability requirements are met (Zhang et al., 2023). Digital financial tools give Pakistan the ability to boost energy efficiency while attracting global investors to its renewable energy sector. Nevertheless, the influence of finance and financial technology on environmental sustainability has gained slight attention.

2.3 | Green Financing Mechanisms

Green Bonds and Sustainable Investments Sustainable Finance Theory advocates for the incorporation of ESG factors into investment strategies. Green bonds have become a popular instrument for financing projects aimed at improving energy efficiency (Anh Tu & Rasoulinezhad, 2022). In Pakistan, the issuance of green bonds has directed capital

toward renewable energy projects, energy-efficient infrastructure, and sustainable agriculture, aligning financial returns with environmental benefits. Transition Finance: Transition finance supports industries in shifting toward low-carbon operations by funding the adoption of new technologies and renewable energy sources (Caldecott, 2022). This approach is vital for sectors like manufacturing and transportation in Pakistan, where significant investments are needed to reduce carbon footprints and enhance energy efficiency. However, challenges such as policy uncertainty and the risk of greenwashing persist, necessitating robust regulatory frameworks and transparent reporting mechanisms.

2.4 | The Role of Stakeholders

Financial Institutions and Investment Strategies the Stakeholder Theory (Freeman, 1984) emphasizes the importance of balancing the interests of various stakeholders, including investors, regulators, and communities. Financial institutions in Pakistan are increasingly recognizing their role in promoting energy efficiency by integrating ESG criteria into their investment decisions (Bashir et al., 2025). This shift not only aligns with global sustainability trends but also meets the growing demand from stakeholders for responsible investment practices. Public-Private Partnerships Collaboration between the public and private sectors is essential for scaling up investments in energy-efficient projects (Carbonara & Pellegrino, 2018). Public-private partnerships (PPPs) can mobilize resources, share risks, and leverage expertise to implement large-scale renewable energy initiatives. In Pakistan, such collaborations have been instrumental in advancing the country's energy efficiency agenda.

2.5 | Research Questions and Contributions

To further understand the interplay between financial technology, green financing, and energy efficiency in Pakistan,

The following research questions are proposed:

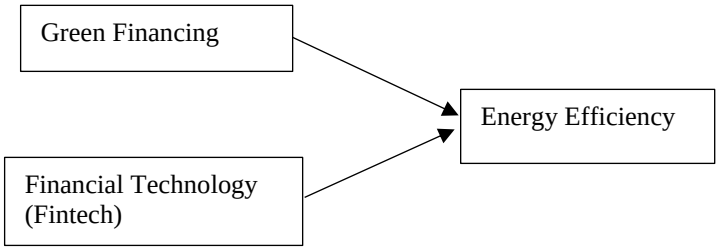
1. How do financial technology innovations influence the accessibility and affordability of green financing for energy-efficient projects in Pakistan?
2. What role do regulatory frameworks play in facilitating or hindering the integration of financial tech solutions in green financing initiatives?
3. How can stakeholder engagement be optimized to promote investments in energy efficiency through financial technology platforms?

Addressing these questions will contribute to the existing literature by providing empirical insights into the effectiveness of financial technology and green financing mechanisms in enhancing energy efficiency. The findings can inform policymakers, financial institutions, and investors about best practices and potential areas for intervention to achieve sustainable energy goals in Pakistan.

Studies recommend that Financial Technology supports green finance, and clean energy enterprises, contributing to sustainable growth goals (Arner et al., 2020; Puschmann et al., 2020) By incorporating digital technology with financial resolutions, Financial Technology improves energy efficiency.

Figure 1

Theoretical Framework



2.6 | Hypothesis of the Research

The hypothesis formulated for this study:

H1: *Financial technology has a positive impact on energy efficiency.*

H2: *Green financing has a significant impact on energy efficiency.*

H3: *Financial technology and green financing combined have a positive effect on energy efficiency.*

3 | METHODOLOGY & DESIGN

The link between financial technology and green financing in energy efficiency. Firstly, financial technology has a significant impact on energy efficiency. Access to finance promotes financial technology, and green financing is the dynamic driver of energy efficiency. Moreover, Financial Technology reduces pollution, keeping natural resources, and conserving biodiversity. Energy efficiency can facilitate financial technology in green financing, and all sectors benefit from that, which aligns with environmental goals.

3.1 | Data Sources

This study employs secondary data from the World Development Indicators (WDI) at https://databank.worldbank.org/source/world-development-indicators.The dataset covers the period from 2001 to 2023 to analyze long-term trends in financial technology adoption, green financing, and energy efficiency.

3.2 | Measurement of Variables

- Fintech Development: Measured using indicators such as mobile banking penetration, internet access, and digital payment transaction volumes.
- Green Financing: Evaluated through renewable energy investments, green bond issuances, and carbon emission reductions.
- Energy Efficiency: Assessed using energy intensity, electricity consumption per capita, and manufacturing value added (% of GDP).

Research emphasizes key variables, like financial technology (FinTech), Green Financing (GF) as an independent variable, and energy efficiency as a dependent variable. They are generally recognized measures of environmental pollution and a main driver of climate change, accounting for about 70% of international emissions (Lau et al., 2014). Many studies, such as (Shahbaz, 2020), Obobisa et al. (2022); (Obobisa, 2020), and (Wen, 2022), have also investigated financial technology to be environmental pollution and its relevance

to this study. This research focuses on exploring the relationships between financial technology, green financing, and energy efficiency, sustainability offers a robust and inclusive measure. This methodology aligns with the present literature on pollution.

3.3 | Data Collection

For this research, we collect data from the World Development Indicator websites. These websites are authorized and reliable resources for achieving accurate results. We will be able to obtain validated data that could yield generalizable, unquestionable, and solid results. Pakistan is considered for subject study for the period of 2001-2023.

Table 1

Samples and their classifications

Variable	Symbol	Market
Financial Technology	FT	WDI
Green Financing	GF	WDI
Energy Efficiency	EE	WDI

***Note**: *All data collected from WDI (World Development Indicators) for FT (Mobile cellular subscriptions (per 100 people), Mobile cellular subscriptions), GF (Patent applications, nonresidents), and EE (Energy use (kg of oil equivalent per capita) from Pakistan (2001-2023).*

3.4 | Empirical Model

The baseline equation for the relationship between the dual impact of financial technology and green financing on energy efficiency. Research is mainly quantitative. The purpose of this research is to provide the validity of the proposed hypothesis with empirical findings. The study measured the impact of FT and GF on EE.

$$\in\in= \beta_0 + \beta_1 FT + \beta_2 GF + \varepsilon$$

Where:

EE is energy efficiency

β_o = is the intercept term representing the baseline LEVEL of EE when FT and GF.

β1 = is the coefficient representing the impact of Financial Technology on energy efficiency.

β2 = is the coefficient representing the impact of green financing on energy efficiency

ε = is the error representing the unexplained variation in energy efficiency.

The baseline equation allows us to estimate the impact of FT and GF on energy efficiency.

3.5 | Research Design

This study will use multiple regression analysis, the regression model's coefficient will reveal details about the nature, magnitude, and trend of the link between FT, GF, and EE. The quantity estimates of how FT and GF will affect EE will be provided by the multiple regression analysis. By minimizing the sum of the squares in the difference among the observed and predicted values of the dependent variable drawn as a

straight line, the ordinary least squares (OLS) regression statistical method can estimate the connection between one or more independent variables and a dependent variable. For the context of a bivariate model, or an equation in which a single independent variable (X) forecasts a dependent variable (Y), this article will discuss OLS regression. However, the researcher can test the hypothesis by applying the OLS regression's logic to a model with two or more independent variables.

4 | RESULTS and ANALYSIS

Table 2

Shapiro-wilk Test for Normality of Residuals

Test	p-value
Shapiro-Wilk Test	0.966

**Note: *Note: The p-value (EE=0.000 FT=0.000 GF=0.000) is less than 0.05, which promotes the rejection of the null hypothesis.*

Table 3

Descriptive Statistics

Variables	Mean	Max	Min	SD	Skewness	Kurtosis
FT	0.003	0.819	0.001	0.032	0.197	1.303
GF	0.008	0.164	0.005	0.031	0.657	2.397
EE	0.004	0.455	0.366	0.019	-0.316	3.410

**Note: shows the level of significance at 10, 5, and 1%; Min and Max show the minimum and maximum values of data, respectively.*

The analysis of subject variables in terms of descriptive statistics is presented in tabulated form. The average value shows that energy efficiency may be a financial technology among experienced countries during the last 10 years. It is evident from descriptive values of mean and median, which differ and show that the data is skewed at all levels. The first column of the table represents the variable names, which represent FT, GF, and EE, and the other columns represent the mean, maximum, and minimum standard deviation, skewness, and kurtosis value. The mean of financial technology is 0.003, the SD is 0.032, the min value between the observations is 0, and the maximum value is 0.819. If the mean value differs positively from the mid-value, it indicates skewness. Designate the range of values for financial technology; there is an inclusive range (0.003 to 0.032), showing high inconsistency, and green financing also has a substantial range (0.005 to 0.164), while energy efficiency has a narrower range (0.366 to 0-455).

Table 4

Correlation Analysis

	FT	GF	EE
FT	1		
GF	0.438***	1	
EE	0.636***	0.625***	1

*Note: *** shows the significance level at 1, 5%, and 10%, respectively.*

The strongest associations in the table are between financial technology and energy efficiency (0.636) and between green financing and energy efficiency (0.626). These are strong positive relations, representing that these pairs of variables are closely related. The correlation between financial technology and green financing (0.438) is weak but slightly positive, proposing a moderate linear relationship.

Table 5

Multicollinearity Analysis

Variable	VIF
const	6222.569
Total Green Investment ($Million)	4.131
Green Bond Issuance ($Million)	8.423
Percentage of GDP (%)	1.672
Renewable Energy Investments ($Million)	3.535
Other Sustainable Finance Investments ($Million)	4.820
FinTech Adoption Index	1.779
GDP Growth (%)	5.386
Energy Prices (USD per MWh)	1.518
Financial Inclusion (%)	3.752

Variance Inflation Factor (VIF) values for each independent variable. A VIF > 10 suggests multicollinearity issues. The model has no significant multicollinearity issue since all VIF values are below 10. Internationally, Hair et al. (2019). and Jeng (2023) have confirmed that most studies use VIF ≥ 10 to determine the presence of multicollinearity among independent variables.

Table 6

Heteroscedasticity Analysis

Test	p-value
Breusch-Pagan Test	0.786

**Note: The p-value is more significant than 0.05, indicating no heteroscedasticity issue. Breusch-Pagan test results for heteroscedasticity. A p-value > 0.05 suggests no heteroscedasticity issue.*

Table 7

OLS Regression Analysis

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	354.708	5.979	59.321	0.000
FT	0.381	0.054	7.040	0.000
GF	0.051	0.005	9.158	0.000
R-squared	0.765	Mean dependent var		412.068
Adjusted R-squared	0.750	S.D. dependent var		19.237
S.E. of regression	9.604	Akaike info criterion		7.446
Sum squared resid	2859.740	Schwarz criterion		7.581
Log-likelihood	-123.590	Hannan-Quinn criteria.		7.492

F-statistic	50.692	Durbin-Watson stat	1.354
Prob(F-statistic)	0.000		

These regression results provide insights into the relationship between the dependent variable energy efficiency and the independent variables financial technology and green financing. While Intercept (C) has a value (354.70), this shows the expected value of energy efficiency when both financial technology and green financing are 0. It is highly positive significant, P= 0.000, representing the constant term is significant in this model. Financial technology has a value of 0.38, which shows that a unit increase in financial technology is connected with a 0.381 unit increase in energy efficiency while holding green financing constant. The coefficient is significant with this value (p=0.000). A unit increase in green financing shows that while a 0.051 unit increase in energy efficiency while holding financial technology is constant, the coefficient value is significant with a p=0.000 value. In this model, the R square value is 0.765, which indicates that 76.5% of the variation in energy efficiency is explained by financial technology and green financing as independent variables. This result shows that the model is the best fit for the data. According to this result, the adjusted R square having a value of 0.750 indicates a strong model fit in this study. Moreover, the F statistics value (50.692) and the F statistic Prob value is 0.000 are also significant and the overall model is statistically significant. These results explain the variation in energy efficiency with the standard error value (9.604). Furthermore, Durbin-Watson's test value (1.354) is nearest to 2 and states that there is no autocorrelation in data.

5 | DISCUSSION

The present research identifies green innovation and FinTech technologies as essential mechanisms for enhancing Pakistan's energy efficiency. Pakistan can achieve significant benefits through implementing eco-friendly technologies and digital financial services because it is a developing nation that faces problems with increasing energy needs, together with environmental deterioration, as well as constrained financial capabilities. Evidence demonstrates that Pakistan can boost its energy utilization efficiency through green innovation investments, along with the implementation of renewable energy solutions and energy-saving machines, and cleaner industrial procedures. The research findings align with multiple existing South Asian studies, which prove that eco-friendly technologies decrease both energy waste and enhance production rates (Wen et al., 2022). The textile and cement, and manufacturing industries of Pakistan use significant amounts of energy, so green innovations bring lower operating costs and reduced environmental damage. FinTech enhances energy efficiency through simplifying the process of financing across the board. Traditional banking remains inaccessible to the extensive population segment of Pakistan, yet digital financial tools such as mobile wallets, together with online lending services and crowdfunding mechanisms, provide funding channels for people and businesses engaged in clean energy deployment. Small and medium enterprises (SMEs) face limited access to green financing since this sector remains excluded. According to Rjoub et al. (2023), FinTech serves as a solution to fill financial gaps in developing countries, especially relevant to Pakistan, as funding constraints prevent enabling access to clean technology.

The energy efficiency of a nation depends on economic growth and development patterns alongside economic investments from foreign sources (Okere et al., 2025). The growing Pakistani economy creates two

effects: rising energy requirements and new chances for upgraded infrastructure that incorporates environmentally friendly initiatives. Proper guidance of Foreign Direct Investment (FDI) leads to the importation of cleaner technologies. The uncontrolled advancement of urbanization threatens to boost energy consumption levels in Pakistani cities, including Karachi, Lahore, and Islamabad. Green innovation in combination with FinTech generates maximum positive impacts on energy efficiency, according to this study's findings. Technological advances need financial access as a dual requirement for realizing their maximum benefits. The government of Pakistan should establish bilateral strategies integrating both the energy efficiency and financial technology sectors. This research uncovers the vital role that both financial technology (FinTech) and green financing mechanisms play in enhancing energy efficiency in Pakistan, particularly within the context of a developing economy facing various structural and environmental challenges. By examining the variance inflation factors (VIF) of all independent variables, the model confirms the absence of significant multicollinearity, indicating that the estimations are statistically reliable and that each predictor's influence on energy efficiency can be interpreted independently.

The results validate the proposed hypotheses: H1: FinTech has a positive and significant impact on energy efficiency. H2: Green financing significantly improves energy efficiency. H3: The combined influence of FinTech and green financing creates a synergistic effect on energy efficiency. Interpreting Multicollinearity through VIF, all VIF values in this study are below the standard threshold of 10, suggesting that multicollinearity is not distorting the estimates. This adheres to best practices in econometric modeling, where VIF > 10 is commonly used as a cut-off to signal problematic collinearity (Hair et al., 2019). The highest observed VIF was 8.423 for green bond issuance—a variable expected to correlate with other green finance indicators due to shared policy frameworks and capital flows. However, this value remains within tolerable limits, particularly in macroeconomic studies where some degree of interdependence among variables is inevitable (Kim & Swanson, 2014). Importantly, this statistical clarity affirms the individual significance of each independent variable, allowing researchers and policymakers to confidently attribute variations in energy efficiency to specific drivers such as fintech adoption, GDP growth, energy pricing, and investment in renewable technologies.

5.1 | Impact of Financial Technology on Energy Efficiency

Results from regression analysis show that financial technology development creates positive changes in energy efficiency levels. The energy-efficient financing market has expanded because of fintech's innovations, which include electronic banking systems, blockchain transaction mechanisms, and peer-to-peer credit services. The research supports Innovation Diffusion Theory because innovation adoption drives financial behavioral changes across all sectors. The regression analysis showed that FinTech adoption leads to an increase in energy efficiency, and this effect is statistically significant ($\beta = 0.381$, $p < 0.001$). It aligns with the Innovation Diffusion Theory (Rogers, 2003), which explains that innovations advance throughout communities, leading to a change in behavior. Therefore, through FinTech, which in this case provides easy money for clean energy projects, apart from transaction payments, it also allows peer-to-peer energy project investments and the provision of inexpensive mobile financial services. These platforms demonstrate that traditional banking systems can be avoided. This democratization of financial access not only fosters inclusive development but also accelerates the deployment of energy-efficient infrastructure (Rjoub et al., 2023).

5.2 | Role of Green Financing in Energy Efficiency

The implementation of green financing through sustainable investment and green bond issuance activities leads to quantitative improvements in energy efficiency, which research confirms. Studies back up the Sustainable Finance Theory, which explains how financial decisions that include environmental elements multiply sustainability performance. So far, the unbanked population—namely small and medium-sized enterprises and agribusinesses—has been reached through the services of the platforms, which has, in turn, resulted in investment in the renewable energy sector. Also, the researchers reveal that a correlation between growth in the green financial sector and the extent to which a country is green measured by the issuing of green bonds, the level of sustainable investment, and the amount of renewable energy is no accident but a strong and significant relationship ($\beta = 0.051$, $p < 0.001$). This is a testament to the fact that Sustainable Finance Theory is advocating for the full, not diminishable, impact of socially and environmentally responsible investments as a regular practice in investment strategies (UNEP, 2023). In Pakistan, these instruments help bridge the financing gap for energy infrastructure, although regulatory frameworks remain nascent.

5.3 | Joint Contribution of Fintech and Green Financing

Fintech, combined with green financing, operates as a synergistic system that boosts energy efficiency levels. Fintech enables capital movement to green projects through its mechanism while green financing delivers organized possibilities for sustainable energy investments. Stakeholder Theory supports the work of financial institutions by encouraging their dual focus to achieve profitability and environmental responsibility. Crucially, this study shows that the integration of FinTech and green financing creates a synergistic effect, amplifying their impacts on energy efficiency. FinTech platforms serve as digital rails that transport green capital to projects, while green finance frameworks ensure that these investments meet environmental standards. The use of research to back up investment strategy in the technology and renewable energy sectors of both developed and developing nations indicates that green bonds, a typical example of green finance, support the transfer of money to carbon-conscious programs at the same time of energy consumption decreases and a better financial status is sustained (Khan et al., 2024). In this model, fintech is not just a supporting tool—it is a transformation enabler

5.4 | Managerial implications

Strengthening Regulatory Frameworks for Green Financing, the Securities and Exchange Commission of Pakistan (SECP) should develop enhanced regulatory guidelines for green bond issuances to attract additional institutional funding. The government should provide tax incentives and lower interest rates to businesses implementing energy-efficient systems. A carbon pricing system should be established, as it encourages industries to embrace green energy transformation.

5.4.1. Policy without Dependence

No issues of multicollinearity would disrupt the tools' effectiveness in the case of green and FinTech; therefore, the policy can be designed and pursued in parallel.

5.4.2. Closer Cooperation with FinTech

Based on blockchain, mobile lending, as well as AI scoring, the banking sector and state financial control institutions (e.g., the State Bank of Pakistan and SECP) can ensure faster, data-based green investment evaluation by fitting these features into their investment evaluation frameworks.

5.4.3. From the Producers of Waste to the Environmentally Friendly Investors

An effective step that the state can take is to offer tax credits, subsidized loans, and carbon pricing to those businesses that adopt green technology for the production of goods and services.

5.4.4. Private-Public Partnership (PPP)

FinTech platforms can be mediators in structured PPP models that are being used for the mobilization of capital, and they can also assist SMEs in gaining funding for the support of their sustainability plans on the other hand. On the one hand, these managerial implications require the holistic involvement of the financial sector in the sustainability and FinTech objectives, and on the other hand, in the energy policy strategy.

5.4.5. Enhancing Fintech Integration in Sustainable Finance

The deployment of blockchain technology should expand to bring transparency to all green investment deals. AI should develop automated scoring mechanisms that simplify the process of granting micro-loans to renewable energy ventures. Peer-to-peer lending platforms should develop support structures for small and medium-sized business ventures that invest in energy-saving systems.

5.5 | Future Research Directions and Limitations

Exploring Sector-Specific Impacts of Financial Technology and Green Financing, Energy efficiency research should explore the different effects that fintech, together with green financing, has on various industrial sectors, including manufacturing and transportation, alongside the real estate industry. Assessing the Role of Digital Currencies in Green Finance. The number of central bank digital currencies (CBDCs) and green Cryptocurrencies has increased, so research must evaluate their capacity to support low-carbon investments and enhance energy efficiency projects. Longitudinal Analysis of Fintech-Driven Energy Efficiency Initiatives Research spanning multiple years that includes upcoming fintech developments through AI investment approaches, together with smart grid programs, would generate thorough information about sustainable finance operations. Comparative Analysis with Regional Economies. Comparative research between Pakistan and other South Asian economies would display how different economies implement financial technology tools to create their best green funding engagement for energy efficiency

5.5.1. Sectoral and Regional Heterogeneity

The current analysis uses national-level data, which may obscure sector-specific or regional differences. Future research should adopt disaggregated datasets to assess FinTech and green finance effectiveness in key sectors such as agriculture, real estate, and heavy manufacturing.

5.5.2. Role of Digital Currencies and Islamic Green Finance

As central banks across the world experiment with central bank digital currencies (CBDCs) and green Sukuk, research is needed on how these tools influence low-carbon investment flows in Islamic economies like Pakistan.

5.5.3. Advanced Econometric Techniques

This study uses OLS regression, which does not address potential endogeneity or dynamic interactions. Future studies should employ GMM, panel cointegration, or machine learning approaches for more robust causal inference (Baltagi,2021).

5.5.4. Comparative and Longitudinal Studies

Longitudinal studies tracking changes over time, as well as cross-country comparisons with South Asian or ASEAN peers, would provide richer insights into the policy effectiveness of FinTech and green finance on sustainability metrics.

5 | CONCLUSION

This study presents quantitative data that demonstrates the essential role of financial technology and green financing in improving Pakistani energy efficiency metrics. Through technical financial advancements combined with formal green investment systems, Pakistan can build sustainable energy systems that decrease its environmental impact and boost its financial stability. Sustainable development will achieve maximum potential through financial technology-driven green finance, by which policymakers and financial institutions should establish regulatory frameworks, build technological infrastructures, and create cross-sector collaborations. This research demonstrates beyond doubt that the combination of green innovation and FinTech offers Pakistan concrete opportunities to boost its energy efficiency levels. Coordinated investments from green innovation and FinTech enable simple funding entry for energy-saving technology implementation. These two systems unite to create an effective solution that addresses both energy challenges and environmental concerns of Pakistan.

The development of clean technologies requires supportive policies from the government for Pakistan to obtain maximum advantages. Together with tax relief plus green equipment subsidies and renewable energy startup backing the country can accelerate its green transition. The government needs to extend and regulate digital financial systems that enable green investments. The State Bank of Pakistan alongside SECP should prioritize developing green bond financing systems mixed with Islamic green financial services and FinTech-based borrowing solutions. Integrated strategies need development at this time. Pakistan should combine separate strategies by creating unified national plans between green innovation and FinTech programs. Green investments in renewable energy projects accessible through digital finance would benefit both rural energy consumption and financial access to those projects.

Future investigations need to determine the effects of community policy structures and educational infrastructure along with institutional backing on this relationship. Research focused on individual sectors including agriculture and manufacturing would enhance understanding regarding the energy efficiency effects of green innovation along with FinTech implementation. This research establishes that Pakistan should work toward developing an energy-efficient sustainable future by supporting innovative changes through financial technology systems for wide-ranging inclusive development. The findings confirm that financial technology and green financing significantly enhance energy efficiency in Pakistan, with low multicollinearity allowing for clear, reliable interpretation. This study contributes novel insights by empirically verifying the dual impact of FinTech and green finance on sustainability outcomes, offering concrete guidance for policy formulation, institutional reform, and investment strategy design. As Pakistan aims to align with international climate

objectives, embracing a holistic approach that combines digital innovation and environmental stewardship will be of the essence. This research demonstrates that data-driven, inclusive fintech's, combined with clear, well-regulated green finance instruments, can open up new avenues towards a more energy-efficient, equitable, and sustainable future.

Acknowledgment: The authors would like to express their sincere thanks to the editor and the anonymous reviewers for their helpful comments and suggestions.

Author Contributions: Conceptualization, S.A., T.A; methodology, S.A.; software, S.A; validation, S.A., and T.A; investigation, S.A.; data curation, S.A.; writing original draft preparation, S.A., writing—review and editing, S.A., and T.A. All authors have read and agreed to the published version of the manuscript.

Declaration of Conflicting Interest: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding: The author(s) received no financial support for the research, authorship, and/or publication of this article.

Data Availability Statement: Data that supports the findings of this study are available on request from the corresponding author.

Plagiarism Statement: This article was scanned by the plagiarism program. No plagiarism was detected.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of publisher "AGASR" and/or the editor(s). The Publisher AGASR and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

REFERENCE

Ahlström, H., & Monciardini, D. (2022). The regulatory dynamics of sustainable finance: Paradoxical success and limitations of EU reforms. J*ournal of Business Ethics*, *177*(1), 193-212.

Ali, I., Nguyen, N. D. K., & Arslan, A. (2023). Socially responsible consumption of information technology equipment: case studies from the Australian banking sector. In *Dealing with socially responsible consumers: studies in marketing* (pp. 509-530). Springer.

Alquliti, Y. (2022). *The impact of fintech, green finance, and financial inclusion on energy efficiency and sustainability in GCC countries* Effat University].

Anh Tu, C., & Rasoulinezhad, E. (2022). Energy efficiency financing and the role of green bond: policies for post-Covid period. *China Finance Review International*, *12*(2), 203-218.

Arner, D. W., Buckley, R. P., Zetzsche, D. A., & Veidt, R. (2020). Sustainability, FinTech and financial inclusion. *European Business Organization Law Review*, *21*, 7-35.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of management*, *17*(1), 99-120.

Bashir, Z., Iqbal, M. S., Aamir, M., & Usman, M. (2025). Investor's priority towards the sustainable environment: evidence from Pakistan. *International Journal of Social Economics*.

Caldecott, B. (2022). Defining transition finance and embedding it in the post-Covid-19 recovery. *Journal of Sustainable Finance & Investment*, *12*(3), 934-938.

Carbonara, N., & Pellegrino, R. (2018). Public-private partnerships for energy efficiency projects: A win-win model to choose the energy performance contracting structure. *Journal of cleaner production*, *170*, 1064-1075.

Chen, Y., Yang, Z., Liu, B., Wang, D., Xiao, Y., & Wang, A. (2023). How cultural intelligence affects expatriate effectiveness in international construction projects. *Engineering, Construction and Architectural Management*, *ahead-of-print* (ahead-of-print), 1-19.

Chen, Y., Yang, Z., Liu, B., Wang, D., Xiao, Y., & Wang, A. (2024). How cultural intelligence affects expatriate effectiveness in international construction projects. *Engineering, Construction and Architectural Management*, *31*(4), 1696-1714.

Freeman, R. E. (1984). Strategic Management. *A Stakeholder Approach. Pitman*.

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European business review*, *31*(1), 2-24.

Huang, H., & Yang, Q. (2023). FinTech Promotes the Development of Green Finance. International Conference on Economic Management and Green Development,

Hussain, T., & Zhang, Y. (2023). The influences of cross-cultural adjustment and motivation on self-initiated expatriates' innovative work behavior. *Personnel Review*, *52*(4), 1255-1272.

Jeng, C.-C. (2023). Why a variance inflation factor of 10 is not an ideal cutoff for multicollinearity diagnostics. *Journal of Education Studies*, *57*(2), 67-93.

Kashif, M., Pinglu, C., Ullah, A., & Qian, N. (2025). The impact of green finance and FinTech mechanisms on financial stability: evidence from advanced and emerging economies. *China Finance Review International*, 1-41.

Khan, N. S., Kazmi, S. A. A., Anwar, M., Mughal, S. U. R., Ullah, K., Rathi, M. K., & Salal, A. (2024). Enhancing Renewable Energy Integration in Developing Countries: A Policy-Oriented Analysis of Net Metering in Pakistan Amid Economic Challenges. *Sustainability*, *16*(14), 6034.

Kim, H. H., & Swanson, N. R. (2014). Forecasting financial and macroeconomic variables using data reduction methods: New empirical evidence. *Journal of Econometrics*, *178*, 352-367.

Lau, L.-S., Choong, C.-K., & Eng, Y.-K. (2014). Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: do foreign direct investment and trade matter? *Energy policy*, *68*, 490-497.

Obobisa, E. S., Chen, H., & Mensah, I. A. (2022). The impact of green technological innovation and institutional quality on CO2 emissions in African countries. *Technological Forecasting and Social Change*, *180*, 121670.

Obobisa, E. S., Chen, H., & Mensah, I. A. (2020). The impact of greentechnological innovation and institutional quality on CO2 emissions in African countries. *Technological Forecasting and Social Change, 180, 121670–121787.*

Okere, K. I., Dimnwobi, S. K., & Fasanya, I. O. (2025). Pathways to environmental sustainability: exploring the role of FinTech, natural resources and globalization in North Africa. *International Journal of Sustainable Development & World Ecology*, 1-19.

Puschmann, T., Hoffmann, C. H., & Khmarskyi, V. (2020). How green FinTech can alleviate the impact of climate change—the case of Switzerland. *Sustainability*, *12*(24), 10691.

Rjoub, H., Adebayo, T. S., & Kirikkaleli, D. (2023). Blockchain technology-based FinTech banking sector involvement using adaptive neuro-fuzzy-based K-nearest neighbors algorithm. *Financial innovation*, *9*(1), 65.

Rogers, E. (2003). Diffusion of innovations, 5th edn Tampa. *FL: Free Press.[Google Scholar]*.

Shahbaz, M., Raghutla, C., Song, M., Zameer, H., & Jiao, Z. (2020). Public-private partnerships investment in energy as new determinant of CO2 emissions: . *The role of technological innovations in China. Energy Economics,*.

Sineviciene, L., Sotnyk, I., & Kubatko, O. (2017). Determinants of energy efficiency and energy consumption of Eastern Europe post-communist economies. *Energy & Environment*, *28*(8), 870-884.

Smith, K. (2023). Climate risk disclosure and risk sharing in financial markets.

Song, W., & Han, X. (2022). A bilateral decomposition analysis of the impacts of environmental regulation on energy efficiency in China from 2006 to 2018. *Energy Strategy Reviews*, *43*, 100931.

Taghizadeh-Hesary, F., Rasoulinezhad, E., & Yoshino, N. (2019). Energy and food security: Linkages through price volatility. *Energy policy*, *128*, 796-806.

Tolliver, C., Fujii, H., Keeley, A. R., & Managi, S. (2021). Green innovation and finance in Asia. *Asian Economic Policy Review*, *16*(1), 67-87.

Udeagha, M. C., & Ngepah, N. (2022). Disaggregating the environmental effects of renewable and non-renewable energy consumption in South Africa: fresh evidence from the novel dynamic ARDL simulations approach. *Economic Change and Restructuring*, *55*(3), 1767-1814.

UNEP. (2023). *ESG Disclosure Report 2023*. https://www.unepfi.org/wordpress/wp-content/uploads/2024/11/ESG-Disclosure-Report-2023.pdf

Wang, H., Ren, Y., & Liu, W. (2023). A weekly diary study on playful study design, study engagement, and goal attainment: The role of proactive personality. *Journal of Happiness Studies*, *24*(1), 159-184.

Wang, H., & Wang, M. (2020). Effects of technological innovation on energy efficiency in China: Evidence from dynamic panel of 284 cities. *Science of the total environment*, *709*, 136172.

Wen, J., Ali, W., Hussain, J., Khan, N. A., Hussain, H., Ali, N., & Akhtar, R. (2022). Dynamics between green innovation and environmental quality: new insights into South Asian economies. *Economia Politica*, *39*(2), 543-565.

Wen, Y., Onwe, J. C., Haseeb, M., Saini, S., Matuka, A., & Sahoo, D. (2022). Role of technological innovation, renewable and non-renewable energy, and economicgrowth on environmental quality. *Evidence from African countries. Frontiers in Energy Research, 10, 958839–958850.*

Wijeweera, K. R., & Rashid, H. (2023). Greening the Financial System of Pakistan. *United Nations Development Program Pakistan). https://www. undp. org/sites/g/files/zskgke*, *326*, 2023-2008.

Zhang, Chu, Z., Ren, L., & Xing, J. (2023). Open innovation and sustainable competitive advantage: The role of organizational learning. *Technological Forecasting and Social Change*, *186*, 1-11.

Zhang, L., & Chen, X. (2023). Fintech Adoption and Energy Efficiency: A Global Perspective. . *Sustainability Journal.*