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Solar energy adoption in business environment: How does it affect small firms in Nigerian rural settlement?

Akeem Tunde Nafiu[1]
Williams Okpebenyo[2+]
Godwin Wonah Ogar[3]

[1]*Prince Abubakar Audu University, Nigeria.*
[1]*Email: tundenafiu01@gmail.com*
[2]*Department of Business Administration/Management, Delta State Polytechnic, Otefe-Oghara, Nigeria.*
[2]*Email: williamokpebenyo01@gmail.com*
[3]*Department of Business Management, University of Calabar, Nigeria.*
[3]*Email: gwonahogar@unical.edu.ng*

(+ Corresponding author)

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ABSTRACT

This study focused on solar energy adoption in the business environment. The study examined the effect of solar energy adoption on competitiveness and resource preservation, the effect of solar energy investment on innovativeness, and the effect of ESG compliance on ecosystem protection, sustainable production, and environmental responsibility. The study applied a survey research design. Purposive sampling techniques were adopted. The study covered nine clusters illustrating the rural areas of the Niger Delta, with a sample size of 250 participants using a snowball sampling technique. The study used regression analysis to perform hypothesis testing. Findings showed that adoption of solar energy has a positive effect on competitiveness and resource preservation, and that solar energy investment has a strong, positive, and significant effect on innovativeness. Findings indicated that ESG compliance has a strong, positive, and significant effect on ecosystem protection, sustainable production, and environmental responsibility. The study recommended that policymakers and development institutions should focus on increasing the popularity of solar energy projects among small business enterprises, especially in rural areas.

Contribution/ Originality: The study used a detailed scientific approach to gather data and analyze it. This study is the first to unveil the role that ESG-driven renewable energy models can play in enhancing ecosystem protection, sustainable production, and environmental responsibility.

1. INTRODUCTION

Rural small businesses, particularly solar power businesses, use simplified perspectives on management and resources in their decision-making. These simplified management perspectives increasingly adopt Environmental, Social, and Governance (ESG) factors that affect small businesses in terms of competitiveness, preservation of resources, and sustainability. ESG factors affect management decisions in terms of investing, risk management, and engaging with society, which can be at variance with financial decisions (Elkington, 1997; Küfeoğlu, 2024). For example, a small business organization can adopt solar power to cut expenses, increase sustainability, and maintain consistency within the backdrop of protecting ecosystems (Abbas et al., 2023; Ahmad et al., 2020).

The conceptual underpinnings of ESG and sustainable energy-related decision-making can be found in the concept of triple bottom line, with a focus on the linkage between business performance and environmental and social accountability (Elkington, 1997). This approach has since been perfected into a defined model and approach to ESG in relation to sustainability actions and company performance and management (Eccles & Krzus, 2018; Friede et al., 2015). While most authors highlight innovative sustainable energy-related decisions particularly in large companies and in a developed country regime, most recent scholarly works suggest that using ESG initiatives in sustainable energy can especially in small and rural businesses improve innovativeness and resource use efficiency with a concerted push for green capital, energy independence, and sustainable manufacturing processes (Adebiyi et al., 2025; Qing et al., 2024). But in most instances, implementing an ESG model in a small and rural business community can be impeded by a lack of technical knowledge and poor regulatory compliance (Avwioroko, 2023; Dahlman et al., 2019).

Despite the universal evidence that solar energy investment improves competitiveness and resource conservation by virtue of decreased emissions and resource efficiency (Bhuiyan, 2022; Olabi & Abdelkareem, 2022), there is a lack of understanding of rural-specific dynamics for rural enterprises. For example, in rural settlement areas of Nigeria, one can witness small business enterprises operating in an environment fraught with energy insecurity, unavailability of infrastructure, as well as socio-economic conditions (Benni, 2023; Elisha & Gbaranbiri, 2024). Notably, there has been a focus on policy vacuums, social impacts, as well as solar renewable potential (Adeyanju et al., 2020; Ajayi, 2019), but little emphasis has been placed upon ESG considerations as a moderating factor between solar energy investment, innovation, and sustainable performance for rural enterprises at a local scale. ESG considerations with respect to protecting ecosystems, sustainable production mechanisms, or embracing responsible behavior in relation to the environment remain unclear.

Based on the principles of sustainability, the significance of the study essentially derives from the gap that it tries to fill concerning the impact solar energy adoption has on competitiveness and the preservation of resources, the role of solar energy investments and innovativeness, and the impact ESG compliance exerts on sustainability for small businesses located in rural settlements. By examining these enterprises, the research aims to make a significant input into understanding the role that ESG-driven renewable energy models can play.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Solar Energy Adoption, Competitiveness, and Resource Preservation

The use of solar energy has emerged as an investment strategy for small business entities in rural areas to enhance business competitiveness while making efficient use of resources. Empirical evidence shows that firms using solar energy tend to have low business costs, which makes them efficient and profitable (Ahmad et al., 2020; Chanchangi et al., 2023). Besides, the use of solar energy makes firms in rural areas responsible organizations in an effort to curb carbon emissions, which makes them contribute significantly to environmental sustainability (Bhuiyan, 2022; Olabi & Abdelkareem, 2022).

Research has emphasized the significance of a thorough assessment of the available options in solar technology in deriving such advantages. Those firms that embark on detailed analyses regarding technical functionality, installability, and available power conservation will be more likely to harvest the benefits and avert resource loss and degradation (Akinwale, 2020; Avwioroko, 2023). Businesses, on the other hand, that fail to commit to the adoption of solar technology solutions appropriately, stand the risk of witnessing inefficiencies, potential installation costs, and ineffective energy production (Anku, 2025; Sen & Ganguly, 2017). Effective forecasting on energy demand and environmental performance is key in making these adoption strategies in line with economic and environmental needs (Adebisi et al., 2023).

Apart from enhancing operational effectiveness, the use of solar energy also improves the positioning and perception in the market and society for businesses. It is evident that the firm's commitment to utilizing sustainable sources and practicing effective and responsible approaches wins the aid and trust of the stakeholders in the business, including the customers and the community, and this is reflected in the firm's enhanced business opportunities and social license to operate (Adebiyi et al., 2025; Ajayi, 2019). In rural regions where resources and infrastructure are limited and unreliable, the dependability and independence offered by solar energy would be a competitive advantage for the business to ensure continuity even when the power is erratic in the grid (Abbas et al., 2023; Olabi & Abdelkareem, 2022).

H_1: Solar energy adoption has an effect on competitiveness.

H_2: Solar energy adoption has an effect on resource preservation.

2.2. Solar Energy Investment and Innovativeness

Studies have established that investment in solar energy, which means the financial, technological, and human resource commitment to solar technologies, has the potential to boost significantly the innovative capability of organizations through exploration and knowledge development opportunities (Ahmad et al., 2020; Akinwale, 2020). Firms that invest more actively in solar energy are in a better position to apply new technologies, operational practices, and innovative solutions to their energy-related problems (Abbas et al., 2023; Obada et al., 2024). Business and community projects on solar energy increase the technical and managerial options they can consider, hence help organizations respond effectively to a lack of energy, infrastructural constraints, and unmet demands for sustainable operations (Arowolo, 2019; Chanchangi et al., 2023). Regarding the Niger Delta area, which finds itself in a critical situation in terms of energy supply and environmental pollution, solar energy investments open an opportunity for co-innovation in a way that would cover social requirements as well as serve economic and environmental purposes.

Research has suggested that although frameworks of regulation, financial support, and community factors frame the intensity of technological possibilities, solar energy investment has an effect that moderates the way these possibilities are actually pursued in innovation (Adebiyi et al., 2025; Ajayi et al., 2022). Akinwale (2020) and Obada et al. (2024) mention that solar energy investment as a strategic enabler can facilitate exploration activities, cooperation between sectors, and the use of hybrid resource energy and digital resource monitoring platforms. It is also suggested in research that solar energy investment accelerates adaptive learning as organizations are introduced to technological risks and environmental uncertainties that, when coped with in an effective manner, help to improve the ability to foster innovative processes as well as innovative solutions to problems (Abbas et al., 2023; Deinne & Ajayi, 2021). It is also an assumption of this research that solar energy investment positively focuses on the innovativeness of firms, which is an extremely essential element in understanding technological creativity in energy-scarce sectors that are sustainability-driven.

H_3: Solar energy investment has a positive effect on innovativeness.

2.3. ESG Compliance and Sustainability Performance

Literature indicates that ESG compliance is a pivotal factor affecting the outcomes of sustainability as it helps organizations incorporate environmental protection, social responsibility, and good corporate management into their operational and strategic process decisions (Alamillos & De Mariz, 2022; Ayyoob & Sajeev, 2024). Firms that comply with ESG metrics tend to make more effective decisions regarding the preservation of ecosystems and the use of resources and implement sustainable production methods (Küfeoğlu, 2024; Leong, 2024). For example, a compliant organization operating within the energy sector will make effective decisions regarding the preservation of ecosystems and the application of sustainable energy production systems, such as the reduction of carbon emissions and oil spills (Akani et al., 2022; Benni, 2023; Nnadi et al., 2022). This will directly contribute to the preservation of ecosystems. For a place like the Niger Delta region, environmental degradation caused by the production of oil constitutes a significant challenge. It has been found that ESG metrics can aid in the restoration of the environment and increase the ecological sustainability of the environment (Elisha & Gbaranbiri, 2024; Nriagu, 2021).

However, some of these studies have pointed out that ESG compliance also contributes to sustainable production in terms of optimizing resource efficiency, utilising renewable energy technology, and embracing circular economy practices (Abbas et al., 2023; Adebisi et al., 2023; Kandpal et al., 2024). Firms embracing ESG practices have a better chance to fully incorporate sustainable production practices that will minimize waste generation, improve energy efficiency, and mitigate potential threats to a cleaner environment (Ahmad et al., 2020; Chanchangi et al., 2023). Moreover, some governance aspects in ESG that address clear accounting and accountability regarding publicly-oriented transparency and engagement practices also enable effective monitoring and evaluation processes for environmental and social practices (Bais et al., 2024; Maione, 2023; Van Wyk & Els, 2023). These processes not only encourage more attention to be paid to environmental concerns and responsibilities but also raise the levels of credibility and legitimacy of the organization (Kulova & Nikolova-Alexieva, 2023; Sonko & Sonko, 2023).

Moreover, it has been identified that ESG integration for improvement in adaptability regarding changes in regulations, social expectations, and sustainability matters helps an organization be proactive regarding preparations for changes in ESG matters (Tarczynska-Luniewska et al., 2024; Uzoigwe, 2023). Furthermore, through strategic planning, the integration of ESG criteria in firms leads to a better balance between sustainability needs regarding the protection of nature and societal well-being, in addition to financial sustainability in firms (Li et al., 2025; Njokuji, 2019). Moreover, case studies related to renewable energy indicate ESG-focused investments in this domain result in innovation, easy transition to clean energy production and use, and environmentally sustainable industrial practices in firms and companies (Mupa et al., 2024; Ngobeh et al., 2023; Qing et al., 2024).

H_4: ESG compliance has a positive effect on ecosystem protection.

H_5: ESG compliance has a positive effect on sustainable production.

H_6: ESG compliance has a positive effect on environmental responsibility.

3. METHODOLOGY

3.1. Research Design

The study applied a survey research design that aimed at gathering data on the implementation of ESG principles among small firms located in rural settlements of the Niger Delta region of Nigeria. The survey was conducted on the owners/managers who were asked to respond to a pre-prepared format of questions. To first engage the selected firms, an invitation letter followed by telephone calls and emails was used as a means of communication, at a time that is convenient to the participants, so as not to interfere with their normal operations. To obtain quality data, personal administration of the questionnaires was done. Additionally, the participants had all been fully informed of the reasons why the investigation was being conducted prior to taking part in the survey.

3.2. Sampling

The participants in this study were owners and managers of small-scale firms operating in rural settlements in the Niger Delta zone. The Niger Delta rural settlements are defined by a shortfall in access to established energy supply chains and, therefore, are critical areas for interventions with renewable energy (Ajayi, 2019; Akinwale, 2020; Avwioroko, 2023). Purposive sampling techniques were adopted in this study to ensure that only business entities actively engaged in renewable energy product and distribution or renewable energy project management were selected. The study covered nine clusters illustrating the rural areas of the Niger Delta, with a sample size of 250 participants using a snowball sampling technique to cover a representative sample of the population of interest.

3.3. Data Collection Instrument

This survey used a structured questionnaire to elicit data on ESG issue adoption and implementation practices in small firms. Some dimensions on this questionnaire include solar energy adoption, solar energy investment, ESG compliance, competitiveness, resource preservation, innovativeness, ecosystem protection, sustainable production, and environmental responsibility. These variables were further operationalized into a range of questionnaire items developed based on previous established scales in ESG and renewable energy studies (Adebiyi et al., 2025; Lu & Li, 2024; Olaleye, 2021). All questionnaire items were scored using a five-point Likert scale comprising 1 ("strongly disagree") to 5 ("strongly agree"). The study conducted construct validity. Cronbach's Alpha was then used for the instrument's reliability, all of which surpassed the suggested value of 0.70. The pilot test resulted in clarification and relevance (see Table 1).

3.4. Data Analysis

The study used descriptive statistics and inferential statistics in data analysis, with the use of Regression Analysis to perform hypothesis testing at a level of significance of 5% (0.05). The measure of construct reliability used $\alpha \geq 0.70$, while the measures of convergent validity included Average Variance Extracted (AVE) of greater than 0.50, as well as a minimum item factor loading of a value of 0.70 (Hair et al., 2017). The measure of discriminant validity was performed by checking the Fornell-Larcker criterion, requiring the square root of the AVE of each construct to be greater than the correlation between the constructs. The following models are specified for the regression.

$$COM = \beta_0 + \beta_1 SEA + \varepsilon \quad (1)$$

$$REP = \beta_0 + \beta_1 SEA + \varepsilon \quad (2)$$

$$INN = \beta_0 + \beta_1 SEI + \varepsilon \quad (3)$$

$$ECP = \beta_0 + \beta_1 ESC + \varepsilon \quad (4)$$

$$SUP = \beta_0 + \beta_1 ESC + \varepsilon \quad (5)$$

$$ENR = \beta_0 + \beta_1 ESC + \varepsilon \quad (6)$$

Where;

Solar Energy Adoption = SEA.

Solar Energy Investment=SEI.

ESG Compliance=ESC.

Competitiveness = COM.

Resource Preservation = REP.

Innovativeness = INN.

Ecosystem Protection = ECP.

Sustainable Production = SUP.

Environmental Responsibility = ENR.

β= Coefficient.

ε = Error Term.

4. DATA ANALYSES AND RESULTS

This section presents results from the analyses of data. The results are presented in tables and interpreted accordingly.

Table 1. Validity and reliability results.

Indicator variables	Loading	AVE	CR	Chron (α)
SEA1	0.811	0.602	0.754	0.776
SEA2	0.784			
SEA3	0.736			
SEA4	0.752			
SEA5	0.795			
SEI1	0.841	0.650	0.781	0.807
SEI2	0.804			
SEI3	0.798			
SEI4	0.719			
SEI5	0.863			
ESC1	0.821	0.583	0.767	0.764
ESC2	0.789			

Indicator variables	Loading	AVE	CR	Chron (α)
ESC3	0.764			
ESC4	0.718			
ESC5	0.721			
COM1	0.756	0.600	0.753	0.775
COM2	0.771			
COM3	0.741			
COM4	0.792			
COM5	0.811			
REP1	0.782	0.614	0.783	0.784
REP2	0.835			
REP3	0.738			
REP4	0.743			
REP5	0.815			
INN1	0.826	0.636	0.775	0.798
INN2	0.796			
INN3	0.822			
INN4	0.758			
INN5	0.784			
ECP1	0.722	0.569	0.762	0.755
ECP2	0.746			
ECP3	0.842			
ECP4	0.724			
ECP5	0.732			
SUP1	0.813	0.578	0.783	0.760
SUP2	0.765			
SUP3	0.712			
SUP4	0.803			
SUP5	0.702			
ENR1	0.785	0.614		0.784
ENR2	0.814			
ENR3	0.728			
ENR4	0.762			
ENR5	0.825			

Table 1 shows the robust evidence of the reliability of measurement and the convergent validity of all constructs. All of the loadings of the indicators have exceeded the minimum required value of 0.70. This further shows that there is satisfactory representation of the latent constructs by their indicators. The Average Variance Extracted (AVE) value varies from 0.569 to 0.650, having exceeded the minimum required standard of 0.50. This shows that all constructs account for variance in their indicators in excess of 50%. The constructs have all exceeded 0.75 in construct reliability (CR). All of the Cronbach alphas have exceeded 0.70. These results have collectively confirmed that the measurement model is reliable for further analysis.

As indicated in Table 2, the Fornell-Larcker criterion can be used further to determine the adequacy of the measurement model in terms of discriminant validity. The square root of the highest inter-construct correlation for each construct (shown in Table 1) is smaller than the square root of the AVE for each construct. Even though the correlation between constructs, for instance, ESG compliance and ecosystem protection, sustainable production, as well as environmental responsibility, can be considerable, the values obtained are still lower than the square root of the AVE, implying a set of related but non-overlapping constructs, which are statistically valid in terms of concept differentiation.

Table 2. Correlations of constructs.

Variables	SEA	SEI	ESC	COM	REP	INN	ECP	SUP	ENR
SEA	-	0.413	0.348	0.537	0.532	0.367	0.402	0.380	0.369
SEI	0.432	-	0.424	0.329	0.445	0.545	0.418	0.398	0.385
ESC	0.348	0.429	-	0.372	0.383	0.411	0.572	0.546	0.566
COM	0.531	0.388	0.363	-	0.492	0.356	0.370	0.362	0.352
REP	0.520	0.403	0.385	0.498	-	0.360	0.394	0.384	0.366
INN	0.375	0.563	0.412	0.342	0.371	-	0.411	0.423	0.388
ECP	0.423	0.412	0.560	0.345	0.355	0.412	-	0.545	0.559
SUP	0.367	0.394	0.543	0.327	0.383	0.407	0.545	-	0.345
ENR	0.364	0.387	0.569	0.343	0.388	0.391	0.458	0.537	-

Table 3. Demographics of participants.

Demography	Frequency	Percent
Gender		
Male	125	50.0
Female	125	50.0
Age		
18 – 22 years	55	22
23 – 27 years	67	26.8
28 – 32 years	42	16.8
33 – 37 years	82	32.8
38 years and above	4	1.6
Education		
OND/Equivalence	88	35.2
HND/B.Sc	101	40.4
MBA/M.Sc	20	8
PhD	41	16.4
Experience		
Less than 1 year	47	18.8
1 – 3 years	50	20
4 – 6 years	104	41.6
7 – 9 years	19	7.6
Above 10 years	30	12

Source: Field survey, 2025.

From Table 3, it is evident that there is a 50:50 split in terms of gender among those who participated in this study. This shows that this research has managed to get a good representation from both sides of the gender divide to achieve inclusivity in this research. In terms of age distribution, the majority of those who responded to this survey are in the actively employed age bracket. These include those who fall between 33 and 37 years (32.8%), those between 23 and 27 years (26.8%), and those between 18 and 22 years (22%). These three groups sum up over four-fifths of this sample and therefore present a true picture of those in this field who are actively engaged in decision-making and running this field in question. Also, very few respondents fall in the above 38 years in this field to some small extent.

Concerning their level of educational attainment, participants are fairly educated because a large number possess HND/B.Sc (40.4%) and OND/equivalent (35.2%) certificates, although a large number also hold postgraduate certificates in MBA/M.Sc (8%) and PhD (16.4%). This sample implies a level of intellectual acumen that can grasp notions of sustainability, ESG concepts, and renewable energy approaches. Moving to their level of work experience, more participants possess 4-6 years of work experience (41.6), followed by 1-3 years (20%), and less than a year (18.8%). This indicates that many participants are comprised of those in their middle level of work experience, thus increasing the validity of their perceptions toward ESG practices and solar energy approaches among small firms in rural areas.

Table 4. Regression result on solar energy adoption, resource preservation, and competitiveness.

SEA	Column I	Column II
	COM	REP
Coefficient (P-value <0.05)	0.959*	0.891*
R-squared	0.927	0.812
Adjusted R-squared	0.926347	0.811
S.E. of regression	0.379	0.603
Sum squared resid	35.674	90.272
Log likelihood	-111.354	-227.406
F-statistic	3132.731	1071.873
Mean dependent var	3.528	3.484
S.D. dependent var	1.398	1.389
Akaike info criterion	0.907	1.835
Schwarz criterion	0.935	1.863
Hannan-Quinn criterion.	0.918	1.847
Durbin-Watson stat	1.999	2.027

Note: * = P-value <0.05.
Source; Field Survey (2025).

Regression equations in Table 4 (column I) reveal that Solar Energy Adoption (SEA) has a strongly positive and significant effect on competitiveness (COM). The regression coefficient of SEA (β=0.959, p < 0.001) illustrates that improved adoption of solar energy has nearly torn-the-corner impacts on firm competitiveness, alongside the positive and significant constant. The model has an extremely high goodness of fit, evidenced by an R-Squared of 0.927 and an Adjusted R-Squared of 0.926. The model is an accurate description of the data, supported by the strongly significant F-statistic of 3132.731 (p < 0.001). The Durbin Watson Statistic of 1.999 illustrates an absence of autocorrelation in the error terms. It can be inferred that the results have provided conclusive evidence that solar energy adoption has been one of the primary drivers of firm competitiveness among the sample.

The result from the regression analysis in column II also depicts that solar energy adoption has a positive and significant impact on resource preservation (REP). The coefficient value of solar energy adoption (β = 0.892; p < 0.001) depicts that a higher rate of solar energy adoption makes a significant contribution to higher resource preservation, and simultaneously, the positive and significant value of the constant term also depicts that there exists a certain level of resource preservation independent of solar energy adoption. The result also depicts that the model fits perfectly and explains a large percentage (81.2%) of variation in resource preservation with respect to solar energy adoption because the R-squared and adjusted R-squared values are 0.812 and 0.811, respectively. Additionally, because the F-statistic value (1071.873) is significant at p = 0.0001, and the Durbin-Watson Statistic (2.027) indicates that there are no serial correlations in the residuals.

Table 5. Regression result on solar energy investment and innovativeness.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.347	0.084	4.160	0.000
SEI	0.910	0.023	39.626	0.000
R-squared	0.864	Mean dependent var		3.388
Adjusted R-squared	0.863	S.D. dependent var		1.408
S.E. of regression	0.521	Akaike info criterion		1.541
Sum squared resid	67.294	Schwarz criterion		1.570
Log likelihood	-190.685	Hannan-Quinn criterion.		1.553
F-statistic	1570.212	Durbin-Watson stat		1.817
Prob(F-statistic)	0.000			

Source: Field Survey (2025).

The results of the regression analysis presented in Table 5 show that there is a positive relationship between the solar energy investment (SEI) and innovativeness. The coefficient of solar energy investment (β=0.910, p<0.001) shows that investment in solar energy has really made a positive impact on the innovativeness of the firm. There is a positive constant term; this shows that there is some amount of innovativeness that has been created regardless of the amount of investment in the solar energy sector. The explanatory power of the model is very high, with an R-squared of 0.864 and an adjusted R-squared of 0.863. This means that more than 86 percent of the variance in innovativeness can be accounted for by the investment in the solar sector. The overall model is significant, evidenced by the significance of the F-statistic (1570.212, p<0.001), but there is no evidence of autocorrelation in the data, evidenced by the Durbin Watson Statistic of 1.8171. This evidence offers conclusive proof that investment in the solar sector is an important determinant of innovativeness.

Table 6. Regression result on ESG compliance, ecosystem protection, sustainable production, and environmental responsibility.

ESC	Column I	Column II	Column III
	ECP	SUP	ENR
Coefficient (P-value <0.05	0.935*	0.962*	0.919*
R-squared	0.857	0.912	0.818
Adjusted R-squared	0.856	0.912	0.817
S.E. of regression	0.531	0.416	0.605
Sum squared resid	69.971	42.288	89.405
Log likelihood	-195.563	-132.476	-224.564
F-statistic	1482.887	2541.194	1096.477
Mean dependent var	3.524	3.443	3.463
S.D. dependent var	1.400	1.404	1.416
Akaike info criterion	1.581	1.093	1.842
Schwarz criterion	1.609	1.122	1.870
Hannan-Quinn criterion.	1.592	1.105	1.853
Durbin-Watson stat	1.924	2.093	1.958

Note: * = P-value <0.05.
Source; Field Survey (2025).

The results obtained from the regression analysis, as presented in Table 6 (Column I), reveal that ESG compliance (ESC) positively and significantly affects ecosystem protection. The coefficient value of ESC (β=0.935, p <0.001) suggests that a high degree of ESG compliance makes a significant difference in improving ecosystem protection performance, signifying effective protection and conservation of the environment. The positive value and significance of the constant term reveal that a certain degree of ecosystem protection exists independently, despite low performance in ESG compliance. The model fits very well, with an R-squared value of 0.857 and an adjusted R-squared value of 0.856, signifying that ESG compliance explains around 86% of the variation in ecosystem protection performance. The F-statistic (1482.887) and 'p' value (< 0.001) suggest that the model is highly significant, and the Durbin-Watson Statistic (1.924) suggests that there are no problems with autocorrelation in the model.

The outcome from the regression analysis in column II shows that the effect of ESG compliance is significantly and directly related to sustainable production (SUP). The result indicated by the coefficient for ESC (β = 0.962, p < 0.001) indicates that the level of sustainable production in the company increases significantly when there is a higher level of ESG compliance. The result indicates that the constant is not statistically significant. The result implies that the factor sustainable production is significantly explained by the impact of ESG compliance and is less influenced by the constant. The result has a very high level of explanatory power, with an R-squared and an adjusted R-squared at 0.912 and 0.912, respectively, meaning that over 91% of the variation in sustainable production is explained by the impact of ESG compliance. The F-statistic for the result is 2541.194 and is statistically significant at p = 0.000, meaning that the result is statistically valid. The result indicates that the Durbin-Watson statistic is 2.093, meaning that the result is valid and is less influenced by the possibility of autocorrelation.

These regression results in column III reveal that ESG compliance is strongly and positively significant in influencing ENR. The coefficient of ESC (β = 0.919, p < 0.001) infers that a higher level of compliance with ESG substantially improves the commitment to environmentally responsible practices, like pollution control, resource conservation, and environmental stewardship. The constant term is also highly significant to indicate a level of environmental responsibility that may exist outside of ESG compliance. The model exhibits very high explanatory power, as the R-squared stands at 0.818 while the adjusted R-squared is at 0.817, which informs us that about 82 percent of the variation in environmental responsibility is explained by ESG compliance. It also follows that the overall model is statistically robust, as the F-statistic comes to be significant with 1096.477, $p < 0.001$, whereas the Durbin-Watson statistic is 1.958, suggesting no serious autocorrelation; therefore, an estimated relationship will be reliable.

5. DISCUSSION

Findings show that the adoption of solar energy has a positive and significant effect on competitiveness and resource preservation among small firms in rural settlements. To clarify, this suggests that firms adopting solar energy strategies are better equipped to address their reduced operational expenses, which would, in effect, improve their competitiveness in the challenging rural business setup, besides ensuring the conservation of resources through reduced reliance on fossil fuels, which, on the other hand, cause negative effects on the environment. The stance of the present research is, therefore, that firms adopting solar energy view the same not as an investment directed at conserving the planet but as an investment aimed at improving their competitiveness, thus playing a crucial role in determining organizational success, especially located in rural settings, which not only remain deprived of constant electricity but are extremely fragile from an environmental perspective as well. It is evident that the findings are in line with previous research studies that focus on the significance of renewable energy to the business performance of organizations. For example, Adeyanju et al. (2020) and Chanchangi et al. (2023) find strong potential for solar energy in addressing energy deficits in Nigeria, with full support for sustainable development goals. Likewise, the study by Abbas et al. (2023) and Ajayi et al. (2022) establishes the magnitude to which investments in renewable sources of energy contribute to efficiency and sustainable competitiveness. From an environmental perspective, the findings are supportive of Akinwale (2020) and Bhuiyan (2022), who note that the adoption of renewable energy sources has a crucial role in ecosystem conservation and the mitigation of resource depletion. Their importance lies in the fact that there is empirical evidence at the firm level that the adoption of solar energy may serve as a functional avenue to achieving competitive advantage and resource preservation in rural economies.

Finding shows that solar energy investment has a strong, positive, and significant effect on innovativeness. This means that solar energy investment not only acts as a solution to energy issues in organizations but also acts as a driving force for innovation, learning, and adaptation in organizations. Regarding small organizations in rural settlements, solar energy investment may trigger problem-solving activities in terms of energy storage and efficiency, which may act as a stimulant for innovation and creativity in those organizations. This finding strongly supports previous research papers on innovation and sustainable growth facilitated by the contribution of investments in renewable energy to innovation in organizations. Abbas et al. (2023) and Qing et al. (2024) were able to establish the fact that spending on renewable sources increases technological ability and productivity within an optimal monetary and policy mix. Ahmad et al. (2020) and Obada et al. (2024) further demonstrated that innovation in solar photovoltaic technology acts as a stimulant for perpetual innovation in terms of system efficiency and application in developing countries. From the Nigerian and Niger Delta perspective, Adeyanju et al. (2020) and Chanchangi et al. (2023) suggest that renewable energy development opens innovation opportunities within the region to fill the gap of access to energy, thereby opening new innovation avenues. The significance of this finding is based on its ability to give empirical support to the suggestion that solar energy investment influences innovativeness within a firm, thereby supporting the suggestion for developing renewable energy to fill the gap of innovation.

Findings indicate that ESG compliance has a strong, positive, and significant effect on ecosystem protection, sustainable production, and environmental responsibility. This means that firms committed to ESG practices will be in a better position to address ecological degradation challenges while using cleaner production methods and maintaining environmentally responsible practices. From this perspective, ESG compliance goes beyond mere signatory practices to cover practical operational methods in purified emissions protection practices, biodiversity preservation, and environmentally responsible practices in decision-making processes. This study believes that ESG compliance acts as a flexible governing mechanism that makes firm-level practices synchronize with overall sustainability efforts, especially when environmental integrity is a concern, a fact well proven in the case of environments such as that in the Niger Delta region. This finding corresponds entirely with previous scholarly analyses on ESG and sustainability aspects. Likewise, Lim et al. (2022) and Popescu et al. (2022) describe how the best ESG practices also have a profound efficacy on the environmental aspect and green operation processes that are made more holistic and comprehensive by incorporating environmental elements and controls with quality and governance processes. Specifically focusing on Africa and Nigeria regions, Olaleye (2021) and Uzoigwe (2023) also highlight how the adaptation and compliance of ESG processes result in greater environmental stewardship and have the efficacy to reduce the perennial concerns and issues associated with the environment and ecological degradation witnessed for many years. The efficacy of ESG compliance on the protection of the ecosystem also supports the views of Akani et al. (2022) and Ogunkan (2022). In addition, the nexus between ESG compliance and sustainable production reinforces the arguments presented in the work of Kandpal et al. (2024) and Leong (2024), in which ESG frameworks are presented as facilitators of clean production technology and the adoption of a circular economy. The relevance of such a link is based on its potential to create empirical verification that ESG compliance leads to a positive outcome in terms of environmental and production advantages, thereby providing a justification for the complementary use of ESG (Carroll & Shabana, 2010).

6. CONCLUSION

The conclusion drawn from the study is that the implementation of solar energy is a revolutionary strategy for firms operating in rural areas since it exerts a positive impact from an innovative and environmental perspective. The study firmly shows that the adoption of solar energy has a strong positive impact on the innovativeness of businesses, meaning that firms that strategically invest in solar energy are more likely to adopt new products, processes, and ways of doing business. Furthermore, the study also shows the strong positive influence of ESG adoption on the protection of the ecosystem, environmentally responsible business practices beyond introducing business processes focused on sustainability; outside of the economic performance of firms, the adoption of ESG has a positive impact because it promotes the conservation of the ecosystem, environmentally responsible business practices, meaning a strong positive impact on the results of the research.

6.1. Recommendations

The study recommends that:

i. Policymakers and development institutions should focus on increasing the popularity of solar energy projects among small business enterprises, especially in rural areas. Governments should put in place initiatives such as tax breaks, subsidies, and favorable financing programs aimed at lowering the cost of investment associated with the use of solar energy. Small business owners should take an initiative and incorporate solar energy into their business operations as a means of reducing their energy costs, improving business efficiency, and preserving natural resources.

ii. Solar energy investment for firms should be actively promoted and financed by governments, financial institutions, and other business support agencies, as such investments significantly enhance innovativeness through cost savings, technological upgrading, and the development of new products and processes.

iii. Businesses and other regulatory bodies should emphasize and enforce compliance with ESG matters. It is hereby established that ESG standards contribute to the protection of the ecosystem, sustainable production practices, and overall environmental responsibility.

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