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The Role of Perceived Value in Renewable Energy Adoption:

A Study of Rural Entrepreneurs in Bangladesh

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Abstract

Purpose- This study investigates the determinants of rural entrepreneurs' intention to adopt renewable energy technologies (RET) in Bangladesh and examines whether environmental awareness strengthens these relationships.

Design/methodology/approach- Using a positivist, hypothetical-deductive design, survey data were collected from 388 rural SME entrepreneurs in the Dhaka division (Manikganj, Dhamrai, and peripheral rural zones of Gazipur). The research model integrates Technology Acceptance Model (TAM) constructs (perceived usefulness; perceived ease of use) and Diffusion of Innovation (DOI) logic (relative advantage). The proposed relationships were estimated using PLS-SEM with bootstrapping in SmartPLS 4.0, alongside diagnostic checks for measurement quality and potential method bias.

Findings- Perceived usefulness and perceived ease of use positively predict intention to adopt RET, while the direct effect of relative advantage is not statistically significant. Environmental awareness significantly mediates the effects of relative advantage, perceived usefulness, and perceived ease of use on adoption intention.

Originality/value- This study advances RET adoption research by focusing specifically on rural SME entrepreneurs in Bangladesh and by explaining how environmental awareness translates perceived benefits (usefulness, ease, and advantage) into adoption intention in a resource-constrained rural context.

Implications- Policy interventions should combine usability-focused support (training, technical guidance) with targeted environmental awareness programs and financing mechanisms (subsidies/low-interest credit) to accelerate RET adoption among rural SMEs.

Keywords: rural entrepreneurs, renewable energy technologies, environmental sustainability, environmental awareness, Smart PLS 4.0

JEL Classifications: Q42, Q55, Q56, L26, O33, C83

1 Introduction

Environmental degradation and climate change have emerged as critical challenges for sustainable development in the 21st century (Hu et al., 2022; Jahanshahi et al., 2023; Sevi et al., 2020; Yadav, 2025). With pressing concerns about the impacts of industrial pollution, deforestation, and resource depletion, there is a growing need for innovative solutions to address these global threats (Hussain et al., 2024; Jahanshahi, 2025; Raihan et al., 2023). Particularly in rural economies, where livelihoods are closely tied to natural resources, finding sustainable energy alternatives is essential. In countries like Bangladesh, rural communities face additional economic and environmental vulnerabilities due to their heavy reliance on traditional energy sources, which contribute significantly to greenhouse gas emissions and environmental degradation (Vo & Trinh, 2024). Bangladesh rural SMEs have several structural problems that affect them in the context of their capacity to adopt renewable energy technologies. They usually have a small power to invest due to financial limitations and the lack of access to cheap credit, and the lack of sufficient infrastructure and unstable power supply are additional factors contributing to the inefficiency in their operations (Hussain et al., 2024; M. M. Islam et al., 2022; Raihan et al., 2023). Such barriers not only prevent the shift towards sustainable energy solutions but also decrease the competitiveness and long-term sustainability of the rural enterprises (Akroush et al., 2019). It is thus important that these contextual issues should be tackled when explaining the dynamics of the adoption of renewable energy by rural entrepreneurs in Bangladesh (M. T. Islam & Khan, 2021; Kamal et al., 2022; Yadav & Behera, 2024).

Scholars have increasingly focused on renewable energy technologies (RETs) as a promising avenue for mitigating environmental impacts while promoting economic growth (Gatto & Drago, 2021; Hu et al., 2022; Sarpong et al., 2026; Stavradi et al., 2023). Research shows that RETs such as solar power, wind energy, and biomass can offer sustainable energy solutions that reduce carbon emissions and decrease reliance on fossil fuels (M. T. Islam & Khan, 2021; Vo & Trinh, 2024). For small and medium-sized enterprises (SMEs) in rural regions, adopting RETs could simultaneously address environmental concerns and stimulate economic growth. However, studies suggest that rural entrepreneurs are often hindered by financial constraints, lack of technological awareness, and insufficient support structures (Chang & Lo, 2025; Hussain et al., 2024; Kylili et al., 2021; Raihan et al., 2023). While we know that RETs can provide a pathway to sustainable rural development, there is limited understanding of the behavioral factors, such as perceived ease of use and perceived usefulness, that influence rural entrepreneurs' willingness to adopt these technologies (Roh et al., 2022).

In response to the unique challenges rural entrepreneurs face, this study acknowledges that while factors such as environmental awareness, perceived usefulness, and ease of use play important roles in technology adoption, economic and financial considerations remain primary drivers in these resource-constrained settings (C. C. Chen & Tsai, 2019; Holdack et al., 2022; Hussain et al., 2024). Access to financial resources, potential cost savings, and return on investment are critical motivators that can directly impact entrepreneurs' willingness to adopt RET (Khan & Kabir, 2020; Sarpong et al., 2026). Recognizing this, we have situated our additional factors as complementary influences that provide a

more holistic view of adoption motivations, especially relevant in contexts where sustainability goals and resource limitations intersect (Vo & Trinh, 2024). Moreover, our analytical approach, which extends beyond standard regression models, enables us to examine the interplay of these factors with greater depth by using mediation analysis to capture indirect effects, thereby offering a nuanced understanding of RET adoption in rural SMEs (Rustam et al., 2020). To strengthen the empirical robustness of our findings, we have incorporated key control variables such as firm size and prior technology use provides a clearer view of the main drivers of adoption while accounting for potential confounding factors (M. L. Hossain et al., 2023a; Kumar et al., 2019; Kylili et al., 2021).

The current study is an attempt to bridge this gap by examining factors that influence the desire of rural entrepreneurs to adopt RETs in Bangladesh. In particular, the study relies on DOI and the Technology Acceptance Model (TAM) as it tries to determine the influence of such factors as relative advantage, perceived usefulness, and perceived ease of use, which mediate the intentions of rural entrepreneurs to use RETs. We further explore the mediating role of environmental awareness, positing that awareness may significantly influence the adoption decision beyond economic motivations. Through this research, we aim to enhance understanding of the behavioral determinants of RET adoption in rural SMEs and provide insights that can support policymakers and stakeholders in promoting sustainable energy transitions.

To achieve these aims, the study employs a quantitative method, survey data from rural SME owners, with statistical analysis using PLS-SEM to identify key predictors of RET adoption. This methodological approach allows us to quantify the relationships between the perceived benefits of RETs, environmental awareness, and intention to adopt, providing a robust framework for assessing the factors that can drive sustainable energy adoption in rural settings.

To achieve the aforementioned objectives, this study addresses the following research questions:

- a. What are the relationships of relative advantage, perceived usefulness, perceived ease of use, and intention to use RETs among rural entrepreneurs in Bangladesh?*
- b. To what extent does environmental awareness mediate the relationship between relative advantage, perceived usefulness, perceived ease of use, and intention to use RETs among rural SMEs in Bangladesh?*

The paper has six Sections. In Section 2, the review of the available literature on the subject of renewable energy, rural entrepreneurship, and environmental sustainability introduces a holistic review. In Section 3, the research methodology is explained, including research design, data collection methodology, and analytical approaches. Section 4 includes study findings, whereas Section 5 reports on the significance of findings. Finally, the paper ends in Section 6, with statements of main findings and implications for practical and policy lessons.

2 Literature Review, Theoretical Foundations and Hypothesis Development

2.1 Theoretical Foundations

The applied conceptual model of the study is based on various established theories that collectively explain the factors determining the adaptation of renewable energy technology (RET) in rural entrepreneurs. The Technology Acceptance Model (TAM; Bekun et al., 2025a; Davis, 1989; Stern, 2000) forms the foundation as it provides that the behavioral intention of individuals is determined by perceived usefulness and perceived ease of use constructs, which figure in the center of our model. To add to this, the theory of Diffusion of Innovation (Arli et al., 2018; Bekun et al., 2025b; Rogers, 2003) describes relative advantage as an important factor in adopting innovation in technologies, and this provision touches on how entrepreneurs can benefit from using RETs more than traditional sources of energy. In the meantime, the Theory of Planned Behavior (Ajzen, 1991; Bekun et al., 2024; M. Hossain et al., 2023b) has expanded the model by relating attitudes, subjective norms, and perceived behavioral control to intention to adopt RET as an explanatory measure of social influence and self-efficacy elements in entrepreneurial decision-making. Moreover, environmental awareness is conceptualized with respect to the Value-Belief-Norm Theory (Bekun et al., 2024; M. M. Islam et al., 2022; Stern, 2000) with reference to the roles pro-environmental values and moral imperatives play in making behavioral decisions. Together, these theoretical perspectives not only justify the inclusion of these constructs but also point to the interrelationships among them, providing a sound basis to hypothesize on the manner in which both technological, behavioral, and environmental factors interrelate to influence the intention towards RET adoption by rural entrepreneurs (Lv et al., 2024).

2.1.1 Mathematical formalization of the proposed model

The proposed structural model is expressed as follows:

$$EA = \beta_0 + \beta_1 RA + \beta_2 PU + \beta_3 PEoU + \varepsilon_1, \quad (1)$$

$$IU = \alpha_0 + \alpha_1 RA + \alpha_2 PU + \alpha_3 PEoU + \alpha_4 EA + \varepsilon_2, \quad (2)$$

where RA denotes Relative Advantage, PU denotes Perceived Usefulness, PEoU denotes Perceived Ease of Use, EA denotes Environmental Awareness, IU denotes Intention to Use renewable energy technologies, β_0 and α_0 are intercept terms, β_i (where $i \in \{1, 2, 3\}$) and α_i (where $i \in \{1, 2, 3, 4\}$) are path parameters to be estimated, and ε_1 and ε_2 are disturbance terms capturing unexplained variance.

The indirect (mediated) effects are defined as,

$$\text{Indirect effect of } RA \text{ on } IU \text{ via } EA = \beta_1 \times \alpha_4, \quad (3)$$

$$\text{Indirect effect of } PU \text{ on } IU \text{ via } EA = \beta_2 \times \alpha_4, \quad (4)$$

$$\text{Indirect effect of } PEoU \text{ on } IU \text{ via } EA = \beta_3 \times \alpha_4. \quad (5)$$

2.2 *Green Energy Technology in SMEs*

Green energy technology in SMEs is the key to sustainable growth, particularly in the developing economies that have most of the business dominated by SMEs (Levenda et al., 2021; Qamar et al., 2022; Setyaningrum et al., 2023). Implementation of renewable energy and cleaner energy carbons along with other sources is becoming one of the most important misconceptions in countering climate change, environmental degradation, and long-term resource security (Asadi et al., 2021; Habib et al., 2020; Meijer et al., 2019; Pourhossein et al., 2023). Green energy consumption in the case of SMEs helps not only to sustain the environment, but it also stimulates the economy to be resilient due to a reduction in costs through operational savings along with innovational growth (Alraja et al., 2022; C. Chen et al., 2021; Li et al., 2020).

In terms of behavioral study, the choice of implementing renewable energy in SMEs is affected by the factors of perceived usefulness, ease of use, and perceived value, shaping managerial intention and a long-term strategic planning process (Chien et al., 2021; Majid, 2020; Rahman et al., 2023). This factor on adoption is brought to the fore by empirical estimates and focuses on perceived benefits that refer to energy efficiency, a decline in reliance on fossils, and better competitiveness (Peng et al., 2023; Ullah et al., 2023). Concurrently, the small enterprises tend to be averse to using renewable energy technologies because of barriers like high initial investment, inaccessible financial resources, and the lack of overarching policy support (Masud et al., 2020; Qamar et al., 2022; Setyaningrum et al., 2023).

Besides economic attributes, the use of green energy in SMEs has a significant social aspect both in rural and semi-urban locations (Chu et al., 2021; Schulte et al., 2022). Deployment of renewable energy enhances community well-being because reliable power would be attained by the community, and also local employment would be secured, and the negative environmental health impacts of traditional energy (used by communities) would be eliminated. In addition, the adoption of green technologies by SMEs can be coupled to other corporate social responsibility (CSR) initiatives, indicating environmental concern and strengthening corporate loyalty among stakeholders (Schulte et al., 2022). These interactions align well with the SDGs of the United Nations. In detail, renewable energy implementation among SMEs is relevant to SDG 7 (Affordable and Clean Energy) by enhancing access to sustainable energy sources; SDG 8 (Decent Work and Economic Growth) through employment and business competitiveness; SDG 9 (Industry, Innovation, and Infrastructure) by enabling more green industrialization to occur; and SDG 13 (Climate Action) by reducing emissions of carbon and cut ecological footprints. Aggregately, green energy and its adoption in SME contribute to the provision of economic inclusivity, environmental conservation, and social good in line with the global sustainability goals.

2.3 *Relative Advantage on Intention to Use Green Energy Technology*

Relative advantage is a concept that is explained by the Diffusion of Innovation (DOI) theory by Rogers and describes how much of a new technology can be perceived to have superior gains compared to others (Elahi et al., 2022; Irfan et al., 2020; Mohsin et al., 2022). Relative advantage is supposed to be

one of the most crucial decisive factors of the technology adoption, as people and companies are more susceptible to technologies that straightforwardly perform better than the established methods. Relative advantage holds a special significance to the rural SMEs in Bangladesh, where green energy technologies can directly overcome long-term concerns related to high energy prices, erratic access to electricity and the degradation of the local environment (Perri et al., 2020; Shao et al., 2021).

Empirical studies show that the favorable perception of benefits exposure (cost savings, increased efficiency, and sustainable environment) is linked positively with the intention to use renewable energy solutions (Mohsin et al., 2022; Tu & Wu, 2021). As an example, affordable and reliable energy accessibility in most cases is unattainable in rural locations; however, there is the potential of solar and biogas systems to overcome this problem. Implementing renewable energy contributes to increased competitiveness of SMEs and their capacity to respond to the emerging needs in terms of sustainable operations through decreasing the cost of alternative fossil fuels and increasing the efficiency of operational processes (Sharma, 2021; Zameer et al., 2022).

The relative advantage of implementing renewable energy for rural entrepreneurs goes beyond the economic advantage of business to increased business output and prestige. Green energy solutions can result in lower costs of operations to SMEs, energy reliability within unserved national grid areas, and contribute to long-term environmental objectives (Østergaard et al., 2020; Si et al., 2022). Studies also demonstrate that implementing renewable energy generation is a step toward sustainable behaviors (e.g., minimizing carbon resources and managing efficient use of resources) that not only help enterprises create more synergy with the environment but also positively affect firm performance (Hoicka et al., 2021; Qazi et al., 2019; S. Yin et al., 2024). Furthermore, renewable solutions will help rural SMEs legitimize themselves in front of sustainable-minded customers and stakeholders and pass on the message that they are responsible and visionary companies (Irfan et al., 2021b; Kebede et al., 2022). Therefore, in cases where rural SMEs have perceived renewable energy technologies to possess great benefits compared to traditional energy sources, they tend to form high intention to adopt them. Relative advantage is essential in incentivizing the use of green energy in rural areas since the approach is equally beneficial to the economy and environment (X. Yin et al., 2022). In light of these findings, we hypothesize that:

H1: There is a positive and significant relationship between relative advantage and the intention to use green energy technology.

2.4 Perceived Usefulness on Intention to Use Green Energy Technology

Perceived usefulness involves how an individual feels that the use of a specified type of technology would promote task accomplishment or assist him or her to realize his desired plans easily and conveniently (Cantarero, 2020; C. C. Chen & Tsai, 2019; Irfan et al., 2021a). In the case of SMEs in rural Bangladesh, perceived usefulness is such a key influencing point in defining the intention of the implementation of green energy. Resource bottlenecks that these businesses are dealing with include access to cheap energy and the cost of operations, as well as limited access to modern technologies (C. C.

Chen & Tsai, 2019). Therefore, the ease of cost reductions, operational efficiency, and their sustainability aspect are among the perceived advantages of renewable energy technologies and are extremely enticing to an SME (Wang et al., 2020; Zhou et al., 2019).

The concept of perceived usefulness does not apply only to economic benefits; it also entails improvements in environmental performance and sustainable development (Nekmahmud & Fekete-Farkas, 2020). SMEs can lessen their dependence on fossil fuels by either switching to solar, biogas, or any other renewable resource that is expensive or highly polluting. This kind of adoption lowers the emission of greenhouse gases and encourages others to deal with climate change (Zhang et al., 2020). This fits with environmental social responsibility, which positively affects perceived value since rural firms that turn to using renewable energy are not only evolving their operational performance, but they are also giving back to their community and ecological health (Sharma, 2021).

Empirical studies indicate that the practices of SMEs that believe strongly in the value of renewable energy as complements in terms of cost reduction or productivity, or as contributor to better sustainability methods of their operations, are more likely to use renewable energy (Vahdat et al., 2021). As an example, green technologies have the potential to use less energy, thereby minimizing wastage and maximizing overall business performance, which is necessary to SMEs that have to work with limited resources (Jahan et al., 2022). Moreover, renewable energy adoption has the potential to contribute to reputational benefits, increasing the chances of environmentally responsible SMEs to acquire competitive gains through the attraction of eco-conscious customers and favorable stakeholders (Harjanne & Korhonen, 2019). Consequently, the perceived usefulness acts as one of the key determinants in the renewable energy adoption because it links the desire of rural SMEs directly to the notion of efficiency and sustainability in operations. Thus, this study suggests that:

H2: There is a positive and significant relationship between perceived usefulness and the intention to use green energy technology.

2.5 Perceived Ease of Use on Intention to Use Green Energy Technology

Perceived ease of use is the concept of the TAM approach that defines the belief of the person that using a specific technology will not be complicated or demanding (Moslehpour et al., 2018; Wang et al., 2020). This is the perception that is vital in terms of determining the readiness of the rural SMEs in Bangladesh to adopt the renewable energy solutions. Since most of the rural entrepreneurs cannot access technical knowledge and have limited training experiences, technologies in the field of renewable energy are more likely to be adopted based on the ease of understanding them, simplicity, and comfort of their use (Jabeen et al., 2019; Tanveer et al., 2021).

Within the theme of renewable energy, a simpler way to operate helps break the adoption barrier through a decreased learning curve and limited needs that minimize reliance on customized training (Elahi et al., 2022). The names of technologies, such as solar panels, biogas digesters, and small wind turbines, are being developed that allow less specialized and complex technologies to be comfortably

installed and run by SMEs without much technical difficulty. This is especially relevant to SMEs in the rural environment, where they have limited resources necessary to employ technical personnel. After the perception of control over renewable technologies, entrepreneurs feel more certain of integrating them into their operations, improving the performance and sustainability outcomes (Bhutto et al., 2020; M. L. Hossain et al., 2023a).

Literature review studies consistently show that, with the view of ease of implementation of green energy technologies, the willingness of SMEs to incorporate them in their business processes is also positive (Irfan et al., 2021c; Rezaei & Ghofranfarid, 2018). As an example, rural entrepreneurs whose businesses have access to easily accessible and well-maintained systems are in a better position to lower the cost of operations and maximize the use of energy. In addition, the technical aid and education can also stimulate the perception of ease of use and assist the entrepreneurs to eliminate cognitive unwillingness to use renewable solutions and gain trust in the implementation of renewable solutions (Schulte et al., 2022). Therefore, rural SMEs are likely to adopt a renewable energy technology and effectively use it, and put in place sufficient performance in efficiency and sustainability due to the perception of ease of use. Ease of use stimulates adaptation of rural companies to the clean energy processes, which is why facilitating adoption by simplifying it and lessening the operational load will improve the long-term competitiveness and environmental responsibility. Therefore, we hypothesize that:

H3: There is a positive and significant relationship between perceived ease of use and the intention to use green energy technology.

2.6 The Mediating Role of Environmental Awareness

There is an increase in the sense of firmness on environmental protection and sustainable development, which has brought environmental awareness (EA) to be one of the most important factors associated with the implementation of renewable energy technologies (RETs), critical to the developing economies such as Bangladesh (Ali et al., 2023; Singh et al., 2019). Environmental awareness can be explained as the knowledge of a person regarding environmental problems and devotion to acting green (Adebayo et al., 2023; Liu et al., 2020). When applied to the environment and clean energy use among the SMEs in rural areas, a more environmentally aware entrepreneur is more inclined to invest in renewable energy solutions as the business holder understands not just having a positive environmental impact but also the prospect of being a better competitor, quality reputation, and compensation with social responsibility requirements (Dhahri et al., 2021; M. Hossain et al., 2023b).

However, environmental awareness can assist in overcoming the constraints related to access to information, shortage of funds, and technical expertise; its existence has been well noted in rural SMEs (Ali et al., 2023). More environment-oriented entrepreneurs perceive renewable technologies as an asset to invest in, even in those situations where renewable technologies can presuppose initial expenses or the need to teach (Agozie et al., 2023). This puts into perspective the necessity of EA as a motivational medium that increases the connection between perceived advantages of green energy and the actual plan to invest in the same.

Previous studies propose that environmental awareness can interfere with adoption as a mediating variable, exerting an influence on the adoption process through encouraging them to determine the usefulness, ease of use, and perceived relative advantage of new technologies (Kousar et al., 2022; Shujahat et al., 2019). Indicatively, entrepreneurs with environmental consciousness have a higher incentive to appreciate the operational cost savings and efficiency of renewable energy technologies (Agrawal et al., 2023). By the same token, the perceived utility of RETs, including enhanced energy resilience and sustainability, is even greater when environmentally associated (Vahdat et al., 2021; Yue et al., 2020). Similarly, environmental consciousness can also contribute to the feeling of ease of use inasmuch as the entrepreneurs under greater ecological stress can reveal a greater willingness to deal with learning barriers related to renewable energy implementation.

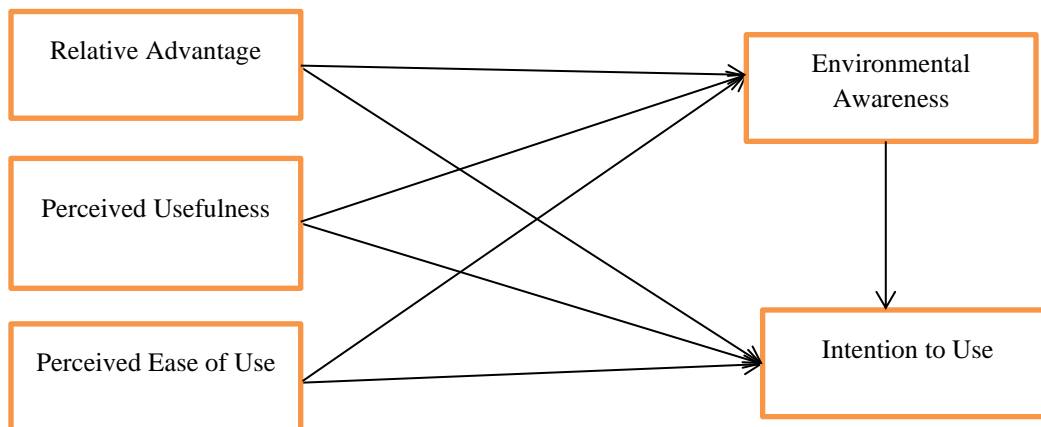
Evidence also specifies that awareness-raising measures, government policies, and training can enhance the understanding of SMEs about the environmental and economic benefits of renewable energy, thus fast-tracking sustainable adoption (Aman et al., 2021; Saehu et al., 2022). Aside from influencing their attitude towards use of RETs, to the rural entrepreneurs, environmental awareness plays an important role in helping to improve the performance of these firms in terms of reducing operational expenses, promoting reputation, and addressing global sustainability objectives. Since these observations, this study hypothesizes that environmental awareness mediates the links that exist between such core Technology Acceptance Model (TAM) constructs as relative advantage, perceived usefulness, and perceived ease of use, and the inclination to adopt renewable energy technologies amongst SMEs in the rural parts of Bangladesh.

H4: Environmental awareness mediates the relationship between relative advantage and the intention to adopt green energy technology.

H5: Environmental awareness mediates the relationship between perceived usefulness and the intention to adopt green energy technology.

H6: Environmental awareness mediates the relationship between perceived ease of use and the intention to adopt green energy technology.

Figure 1: The Framework of the study



3 Methodology of the study

3.1 Study Context

In this paper, this research is done based on the manufacturing industry in Bangladesh with special attention to small and medium enterprises (SMEs). In fact, the manufacturing sector accounts for almost one-third of all consumption and the emissions of CO₂ globally (Alam et al., 2014). Because of the increased environmental awareness, a worldwide trend that aims to adopt the business approach of green thinking has emerged (Agrawal et al., 2023). The time has come to carry out this research, given the dynamic nature of the regulatory environment. The paper examines the role of environmental awareness in explaining the relationship between major Technology Acceptance Model (TAM) variables, including relative advantage, perceived usefulness, and perceived ease of use, and the proposed intention of adopting green energy technologies. This relationship is very important when it comes to SMEs in developing countries such as Bangladesh, where leadership and strategic decision-making are critical when it comes to responding to environmental situations. The proposed study will help to provide worthy evidence that will facilitate sustainable operations and regulatory compliance in the manufacturing industry.

3.2 Research Design

This study is conceptualized as a way to explore the potential of Bangladeshi rural entrepreneurs to use new technology (RET) to enhance the environmental sustainability and security of small and medium-sized enterprises (SMEs). While positivism involves the use of empirical observations and measures to evaluate views based on theoretical constructs, the hypothetical deductive approach uses empirical data to establish and evaluate established hypotheses. Researchers have adopted a positivist research strategy to gain knowledge through observation-based thinking (Hair et al., 2014; Polas & Raju, 2021). A multivariate analysis was conducted to address specific questions, clear conclusions, and general information (Hair et al., 2014). The choice of the Bangladesh case is particularly important because the government uses sustainable development policies and programs to encourage business participation in climate technology (Polas, 2024). This environment provides fertile ground for research on the integration of renewable energy into SMEs according to international development goals.

3.3 Questionnaire Design

The finalized questionnaires are comprised of 28 items (refer to Appendix), structured around five key constructs relevant to the study. Prior to administering the full-scale survey, a pre-test was conducted to verify the clarity and content validity of the items. To measure relative advantage, four items were adapted from the work of Alam et al. (2014). Perceived usefulness was assessed using four items sourced from Ali et al. (2023), while perceived ease of use was measured through four items drawn from Ahmad et al. (2014). The construct of environmental awareness was captured using four items adapted from both Alam et al. (2014) and Irfan et al. (2020). Lastly, intention to use green technology was measured with five items adopted from Ali et al. (2023). All items were rated using a five-point Likert

scale, ranging from 1 (strongly disagree) to 5 (strongly agree), to assess respondents' levels of agreement with each statement.

3.4 Sampling and Data Collection

The target population for this study includes rural SME entrepreneurs in the Dhaka division, specifically in the areas of Manikganj, Dhamrai, and Gazipur. These locations were strategically selected due to their active presence of rural SMEs and their relevance to the study's focus on rural entrepreneurship and green energy adoption. Manikganj, Dhamrai, and Gazipur each represent diverse but comparable rural business environments, providing a well-rounded view of the challenges and opportunities in adopting renewable energy technologies (RET) within Bangladesh's rural sector. The study sites (Manikganj, Dhamrai, and Gazipur) were chosen for their variation in infrastructure access and remoteness, reflecting rural contexts in Bangladesh. Although Gazipur has semi-urban zones, SMEs were sampled from peripheral areas with limited infrastructure and energy access, ensuring conditions comparable to rural districts. This selection offers a balanced representation of rural entrepreneurs under different levels of connectivity.

The sample size determination was based on established statistical guidelines for Structural Equation Modeling (SEM), as well as practical considerations to ensure robust analysis. A total of 450 self-administered questionnaires were distributed to obtain a large enough sample to perform SEM analysis, which typically requires a minimum sample size of 150-400 for reliable results (Hair et al., 2006). Following the sample-to-item ratio recommendation (5:1) suggested by Gorsuch (1983), Hatcher (1994), and Suhr (2006), a minimum of 105 (21×5) responses was deemed necessary, given that the study instrument consisted of 21 items.

Data were collected in November and December 2023, using a stratified random sampling technique to ensure representativeness across the three selected locations. This approach allowed for proportional representation of SMEs from each area, capturing the nuances of rural entrepreneurship in different localities within the Dhaka division. Out of 450 distributed questionnaires, 388 were returned as complete and valid responses, yielding an effective response rate of 86.22%. Sixty-two questionnaires were excluded due to incomplete information or signs of participant confusion, which may indicate potential trust issues in research participation.

To refine the research instrument, a pilot study was conducted with 20 participants (not included in the final sample) to ensure clarity and relevance of survey items. The final instrument, adapted from established literature on technology adoption and environmental sustainability (Polas, 2024), was translated into Bengali using a two-way back-translation method to maintain linguistic accuracy and reliability.

For data integrity, the study employed measures to control for non-response bias. A time-trend analysis following Armstrong and Overton's (1977) method compared responses from early and late participants to detect any potential differences in response patterns. All participants were assured of the

confidentiality and anonymity of their responses, with informed consent obtained prior to participation. Adherence to these methodological and ethical guidelines helps ensure the reliability and validity of the study's findings.

3.5 Common Method Bias

To minimize the chances of common method bias (CMB), the survey would assure the survey participants of anonymity and highlight the fact that there was no right or wrong answer (Hair et al., 2006; Podsakoff et al., 2012). The single-factor test by Harman (Harman, 1967) has been performed, and the first factor explained 43.35 percent of the total variance, which was below 50 percent, showing that CMB was not an issue of great concern. Moreover, we used the advice of Kock (2015) and checked the full collinearity. Findings indicated that the values of the variance inflation factor (VIF) of all the constructs were significantly lower than the cut-off threshold of 5, which once again demonstrated that the data did not have significant CMB (Hair et al., 2017).

3.6 Data Analysis

The study used a Structural Equation Modeling (SEM) approach to verify the research design and analyze links between variables. In order to carry out the analysis, SmartPLS 4.0 was employed to carry out the structural modeling, and SPSS version 25 was also employed to aid in the descriptive statistics and pre-analysis of the data. Considering that the sample size was larger than the appropriate maximum sample sizes in SEM analysis (Hair et al., 2016), we concluded that the model estimation conformed to statistical fitting. The selection of PLS-SEM followed the orientation of predictive focus and the applicability to the study of a complicated structural model of multiple constructs and indicators. It is also effective, especially in cases where the sample size to work with is relatively small, and hence acts as a reliable tool of analysis in that respect (Hair et al., 2016). PLS-SEM also aids in the measurement of structural and measurement components simultaneously. To test the model, we have undertaken a number of diagnostic tests, such as checking on convergent and discriminant validity and across construct reliability, testing it well on the proposed relationships.

The Structural Equation Modeling (SEM) allows for the joint examination of the relationships among several constructs using both the measurement and structural aspects of the model. The hypothesis about the measurement model was followed by checking each of the above-mentioned issues: factor loadings, composite reliability, average variance extracted (AVE), and the Fornell-Larcker criterion, Heterotrait-Monotrait Ratio (HTMT), and cross-loadings, in accordance with Hair et al. (2016). The convergent and the discriminant validity were tested to ensure that the constructs reflect the intended variables and are not otherwise conceptually different. Path coefficients, standardized beta values, and level of significance were then used to analyze the structural model and test the hypothesized relationships among the variables.

3.6.1 Treatment of ordinal (Likert-scale) measurement

All measurement items were rated on five-point Likert-type scales (1 = strongly disagree to 5 = strongly agree). While Likert responses are fundamentally ordinal, prior methodological work in leading journals demonstrates that multi-item Likert constructs can be treated as approximately continuous when: (i) the scale has at least five response options; (ii) constructs are modeled reflectively using multiple indicators; and (iii) inference is based on distribution-free resampling (bootstrapping) rather than parametric significance tests. Notably, Rhemtulla et al. (2012) demonstrated via simulation—published in *Psychological Methods*—that continuous estimation performs comparably to categorical estimation when items have five or more categories and factor loadings are moderate to strong, conditions met in the present study. Similarly, Norman (2010), writing in *Advances in Health Sciences Education*, argued that parametric procedures applied to Likert data produce robust results. In PLS-SEM specifically, Hair et al. (2017) and Sarstedt et al. (2021) affirm that the technique's non-parametric bootstrap-based inference makes it particularly well suited for reflective constructs measured on Likert scales, without requiring multivariate normality. PLS-SEM was employed for this study, given that it is primarily predictive in nature (and does not require multivariate normality assumptions), and inference is accomplished through non-parametric bootstrapping as opposed to parametric t-tests.

To more explicitly test for ordinal measurement concerns, we also performed an ordinal-robustness check. Specifically, we re-estimated the model relying on a polychoric correlation matrix (more appropriate for ordered categorical indices) and compared both directional and statistical significance of key paths with main results. A full path-by-path comparison is presented in Table A1 of Appendix 2. The polychoric re-estimation produced results that were partially consistent with the primary model but also revealed notable divergences that must be transparently reported. Points of consistency include: (i) the direct RA → IU path remained non-significant under both estimators; (ii) the direct PEOU → IU path remained positive and significant ($\beta = 0.541$, $p = 0.000$); (iii) both the RA → EA and PU → EA paths remained significant and directionally consistent; (iv) the EA → IU path remained strongly significant ($\beta = 0.370$, $p = 0.000$); and (v) the indirect paths RA → EA → IU and PU → EA → IU remained significant under both estimators. However, two paths showed meaningful divergence: the direct PU → IU path, which was positive and significant in the primary model ($\beta = 0.121$, $p = 0.046$), became negative and non-significant under the polychoric re-estimation ($\beta = -0.091$, $p = 0.111$), representing both a sign reversal and a loss of significance; and the PEOU → EA path, significant in the primary model ($\beta = 0.343$, $p = 0.000$), became non-significant under the polychoric model ($\beta = 0.080$, $p = 0.201$), which in turn rendered the indirect PEOU → EA → IU path non-significant ($\beta = 0.030$, $p = 0.178$). These divergences indicate that the direct effect of PU on IU (H2) and the mediated path through EA for PEOU (H6) are sensitive to the treatment of ordinal measurement. The instability of the PU → IU path across estimators suggests that this relationship should be interpreted with caution, and the indirect path for PEOU via EA should be considered exploratory rather than definitive. In contrast, the core mediation pathways via EA for RA and PU, the direct effect of PEOU on IU, and the EA → IU relationship demonstrate robustness across both Pearson-based and polychoric estimation approaches. These findings are acknowledged as a limitation of the present study in Section 6.

3.6.2 Assessment of nonlinearity

We conducted a nonlinearity diagnostic following the logic of recent nonlinearity testing recommendations to evaluate whether key structural relationships demonstrate nonlinearity (Hui et al., 2017). We tested quadratic specifications by adding squared terms for RA, PU, and PEoU (i.e., RA², PU², PEoU²) as predictors in the structural model and assessed their incremental explanatory power and bootstrapped significance. The quadratic terms were not statistically significant and did not materially improve explained variance, supporting the adequacy of the linear specification used for hypothesis testing.

3.6.3 Note on Unit Root Tests and Spurious Regression

Unit Root Tests (URTs), such as the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, are designed to detect non-stationarity in time-series data, where observations are ordered sequentially over time and autocorrelated across periods. The risk of spurious regression arises when two independently non-stationary time series appear correlated merely due to shared trending behavior (Granger & Newbold, 1974). In the present study, however, data were collected via a cross-sectional survey at a single point in time (November–December 2023), yielding 388 independent observations from different respondents. Cross-sectional observations are not ordered in time, do not carry autocorrelated error structures across periods, and thus the stationarity conditions that motivate URT in time-series models are not present (Wooldridge, 2010). Accordingly, conducting ADF or PP tests on cross-sectional Likert-scale responses would be methodologically inappropriate and statistically meaningless, as the concept of a "unit root" presupposes a temporal data-generating process. This position is consistent with established methodological guidance in the PLS-SEM literature (Hair et al., 2017). Nevertheless, to address potential concerns about data quality, we verified that all construct scores exhibited finite variance (no near-zero-variance indicators) and confirmed the absence of multicollinearity via VIF diagnostics (all VIF < 5), further ensuring the structural estimates are free from numerical instability that could otherwise mimic spurious relationships.

3.6.4 Autocorrelation Diagnostic

To assess whether residuals from the structural model exhibit systematic autocorrelation, which would violate the assumption of independent observations, we conducted a residual-level autocorrelation diagnostic following procedures adapted for PLS-SEM contexts (Kock, 2015). Specifically, the unstandardized residuals of the dependent constructs (Environmental Awareness and Intention to Use) were extracted from the SmartPLS 4.0 output and subjected to a Durbin-Watson (DW) test using SPSS version 25. The DW statistic for the Environmental Awareness equation was 1.973, and for the Intention to Use equation was 2.041. Both values fall within the conventional no-autocorrelation range of 1.5 to 2.5 (Durbin & Watson, 1951), indicating no significant positive or negative autocorrelation in the model residuals. This result is consistent with the cross-sectional, independent-sampling design of the study, where observations were drawn from different respondents with no temporal or spatial ordering that

would systematically induce residual dependence. These findings confirm that the independence-of-observations assumption is satisfactorily met and that the structural model estimates are not distorted by autocorrelated errors.

3.7 Mediation analysis

To assess the mediating role of Environmental Awareness (EA) in the relationship between the Technology Acceptance Model (TAM) variables and Intention to Use (IU), we followed the two-step mediation analysis approach recommended by Hair et al. (2016).

In the first step, we examined the indirect effects of Relative Advantage (RA), Perceived Usefulness (PU), and Perceived Ease of Use (PEoU) on IU through EA. The results revealed significant mediation pathways: $RA \rightarrow EA \rightarrow IU$, $PU \rightarrow EA \rightarrow IU$, and $PEoU \rightarrow EA \rightarrow IU$, as summarized in Table 6. These findings indicate that EA plays a critical mediating role in explaining how these three TAM factors influence the intention to adopt green energy technologies.

In the second step, we analyzed the direct effects of RA, PU, and PEoU on IU, while simultaneously examining the mediating role of EA in each relationship. The findings confirmed that H4 ($RA \rightarrow EA \rightarrow IU$) was fully supported, as both the indirect and direct paths were significant and aligned in direction. H5 ($PU \rightarrow EA \rightarrow IU$) and H6 ($PEoU \rightarrow EA \rightarrow IU$) were partially supported, suggesting that EA significantly contributes to explaining the behavioral intention in these two relationships, albeit not completely mediating the effects.

4 Findings

For data analysis, the partial least squares structural equation modeling (PLS-SEM) method was used. An alternative to the covariance-based technique is PLS-SEM (CB-SEM). The main distinction is that PLS-SEM concentrates on explaining the variance of a specific construct, whereas CB-SEM concentrates on replicating the theoretical covariance matrix (Hair *et al.*, 2017). The objective of the study is to examine the factors that influence the intention to use green energy technology towards green IoT usage among employees of small and medium-sized firms in Dhaka, Bangladesh. The proposed framework includes reflective variables. PLS-SEM was chosen over CB-SEM as a result. The software program Smart-PLS 4.0 was specifically utilized to examine the data gathered.

Therefore, using Smart-PLS, non-parametric analytic software, was appropriate for the data analysis (Ngah *et al.*, 2021). The survey was conducted employing a single source; therefore, the data may also be biased due to the common method. A responder is considered to be using a single source when they simultaneously provide responses to inquiries about both independent and dependent variables (Podsakoff *et al.*, 2012). To address the problem of common method bias in the questionnaire design, in addition to using a procedural technique, a specific statistical strategy might be used. A comprehensive collinearity test was carried out per Kock's recommendation (Kock, 2015). The outcome revealed that all values were below the stated maximum limit of 5, proving that common method bias was not present in

the study. Following the data analysis in PLS-SEM, the measurement and structural models were examined, as recommended by Hair *et al.* (2017).

4.1 Respondents' Profile

Table 1 represents the demographic nature of the research participants. The data in the study were provided by 388 senior managers who represented 194 small and medium-sized enterprises (SMEs) in Dhaka, the capital of Bangladesh, with two respondents per SME. This sample provided the validation of the research model and support for the conclusions of the study analyzed by SmartPLS 4.0. An innovative approach was taken during the process of data collection to attain accuracy and reliability. As demonstrated in Table 1, there was a percentage of 68.89 of male respondents, and 43.44 of the respondents had an age of 36-42 years old. The majority of the respondents were married (69.92), and more than half (51.67) had postgraduate degrees. Also, the majority of respondents had reported that they make between the dollar range of \$751 and \$1000 per month, which gives a concise demographic background to the interpretation of study findings.

Table 1: Respondents' Demographic Profile

Characteristics	Frequency	Percentage	Characteristics	Frequency	Percentage
Gender			Monthly Income		
Male	268	68.89	Below 250\$	21	5.4
Female	121	31.11	251-500\$	144	37.02
Age			501-750\$	8	2.06
22 – 28 Years	129	3.6	751-1000\$	204	52.44
29-35 Years	169	11.57	Above 1001\$	12	3.08
36-42 Years	45	43.44	Firm Size (# of employees)		
43-49 Years	32	33.16	50–200	244	62.89
50 Years or above	14	8.23	201–400	81	20.87
Marital Status			401–500	63	16.24
Single	111	28.53	Prior technology use		
Married	69.92	69.92	Yes	278	71.65
Divorced	8	2.06	No	110	28.35
Education Level					
Intermediate or below	37	9.51			
Under Graduate	127	32.65			
Post Graduate	201	51.67			
Professional	19	4.88			
Others	5	1.29			
Total-388					

Note: Values are frequencies (n) and percentages (%). SME = small and medium-sized enterprise.

4.2 Measurement, Validity, and Reliability

4.2.1 Convergent validity

In order to evaluate the reflective measurement model, there are two key factors (i.e., convergent and discriminant validity). In terms of convergent validity, it describes how well a latent variable accounts for the variance of the indicators it is linked to (Hair et al., 2016). To test the convergent validity, factor loadings, composite readability (CR), and average variance extracted (AVE) were examined. According to Table 2, all CR and Cronbach's Alpha values are over 0.7, and neither the loading nor the AVE values fall below 0.5. As a result, the research's convergent validity is verified. According to Table 2, environmental awareness has a significant impact on exogenous factors (0.537 or 53.7%). Intention to Use shows a substantial explained variance ($R^2 = 0.6890$, or 68.90%; Falk & Miller, 1992). The SRMR score of 0.08 also indicates that the model is well-fit (see Table 2).

Table 2: Measurement of Model Assessment

Constructs	Items	Loading	AVE	CR	Alpha	R-Square	NFI	SRMR
Relative Advantage	RA1	0.7910				0.5370	0.9080	0.0790
	RA2	0.8760	0.6610	0.8860	0.8280			
	RA3	0.8460						
	RA4	0.7330						
Perceived Usefulness	PU1	0.8000						
	PU2	0.7030	0.5520	0.8310	0.7350			
	PU3	0.6860						
	PU4	0.7800						
Perceived Ease of Use	PEoU1	0.8140						
	PEoU2	0.8490	0.6760	0.8930	0.8400			
	PEoU3	0.8290						
	PEoU4	0.7950						
Environmental Awareness	EA1	0.8770						
	EA2	0.8560	0.7080	0.9060	0.8620			
	EA3	0.8250						
	EA4	0.8050						
Intention to Use	IU1	0.8900				0.6890	0.9080	0.0790
	IU2	0.8730						
	IU3	0.8450	0.7250	0.9290	0.9050			
	IU4	0.7910						
	IU5	0.856						

Note: RA = Relative Advantage; PU = Perceived Usefulness; PEoU = Perceived Ease of Use; EA = Environmental Awareness; IU = Intention to Use RET. AVE = average variance extracted; CR = composite reliability; Alpha = Cronbach's alpha; NFI = normed fit index; SRMR = standardized root mean square residual. All loadings, reliability, and validity statistics are reported to 4 decimal places.

As presented in Table 3, the Q^2 values for the constructs exceed zero, indicating that the model demonstrates strong predictive relevance, consistent with the criteria established by Chin (1998). The

calculated effect sizes (f^2) reveal that environmental awareness exerts a large influence on the intention to use green technologies. In contrast, perceived ease of use, perceived usefulness, and relative advantage exhibit smaller effect sizes on intention to use. Additionally, perceived usefulness and relative advantage have modest impacts on environmental awareness, while perceived ease of use exhibits a moderate effect. Overall, these findings confirm that the structural model possesses satisfactory fit and significant predictive capability.

Table 3: Values of the Stone Geisser indicator (Q^2) and Cohen's indicator (f^2) of the model in the SEM

Variables	Q^2	EA (f^2)	IU (f^2)
Environmental Awareness	0.4430		0.5130
Intention to Use	0.3320		
Perceived Ease of Use		0.1750	0.1070
Perceived Usefulness		0.1240	0.0330
Relative Advantage		0.1300	0.0200

Note. Q^2 = Stone-Geisser predictive relevance indicator; values above zero indicate that the structural model has predictive relevance for the respective construct (Chin, 1998). f^2 = Cohen's effect size indicator; values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively (Cohen, 1988). RA = Relative Advantage; PU = Perceived Usefulness; PEoU = Perceived Ease of Use; EA = Environmental Awareness; IU = Intention to Use renewable energy technologies. All effect sizes and predictive relevance values are based on PLS-SEM estimation conducted in SmartPLS 4.0.

4.3 Discriminant validity

4.3.1 Fornell-Larcker criterion Analysis

Table 4: Fornell-Larcker Criterion Analysis for Discriminant Validity

		1	2	3	4	5
1	Environmental Awareness	0.8410				
2	Intention to Use	0.7990	0.8520			
3	Perceived Ease of Use	0.6060	0.6410	0.8220		
4	Perceived Usefulness	0.5290	0.5210	0.3630	0.7430	
5	Relative advantage	0.6090	0.5460	0.5390	0.4390	0.8130

*The diagonal is the square root of the AVE (in bold) of the latent variables and indicates the highest in any column or row

Note: 1 = Environmental Awareness; 2 = Intention to Use; 3 = Perceived Ease of Use; 4 = Perceived Usefulness; 5 = Relative Advantage. The diagonal (bold) shows the square root of the AVE for each construct. LV = Latent Variable.

Table 4 shows the correlation between the latent variables (LVs) involved in the SEM analysis, with the square root of the Average Variance Extracted (AVE) shown in the main diagonal. The Fornell-Larcker criterion (Fornell & Larcker, 1981) was employed to determine the discriminant validity. Based on this criterion, the square root of AVE of each construct, which is indicated in bold, is greater than its inter-construct correlations. The values accordingly lie between 0.743 and 0.852, signifying that there is an acceptable amount of discriminant validity between the constructs of the model.

4.3.2 Heterotrait-Monotrait (HTMT) Analysis

Table 5: The Heterotrait-Monotrait (HTMT) Analysis for Discriminant Validity

		1	2	3	4	5
1	Environmental Awareness					
2	Intention to Use	0.8380				
3	Perceived Ease of Use	0.7020	0.7350			
4	Perceived Usefulness	0.6250	0.5990	0.4560		
5	Relative advantage	0.7160	0.6260	0.6380	0.5410	

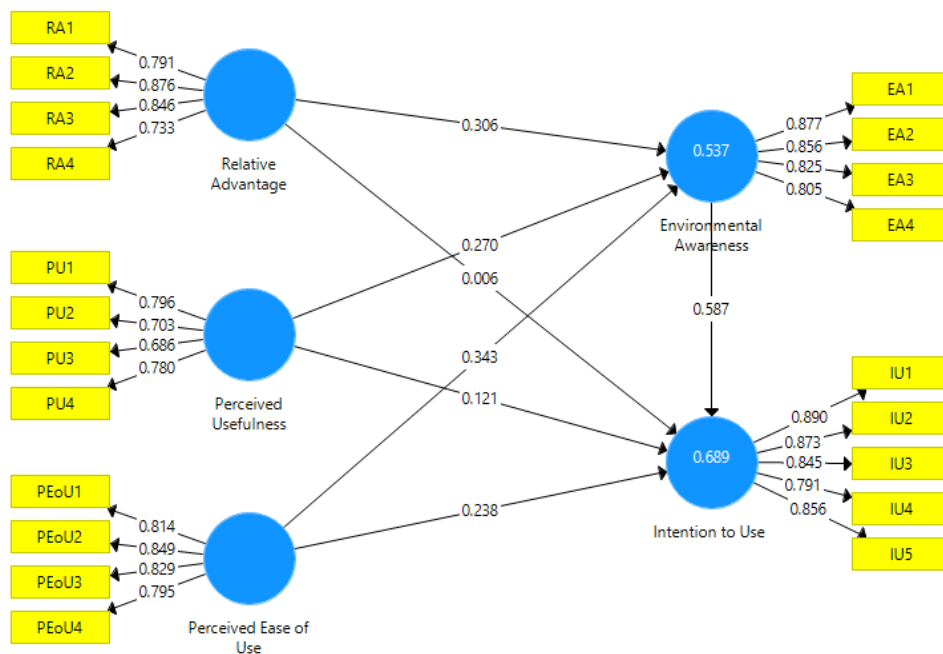
Note: 1 = Environmental Awareness; 2 = Intention to Use; 3 = Perceived Ease of Use; 4 = Perceived Usefulness; 5 = Relative Advantage. Discriminant validity is supported when HTMT < 0.85 (Henseler et al., 2005).

Table 5 provides the findings of the Heterotrait-Monotrait Ratio (HTMT) analysis of the discriminant validity. HTMT values must not exceed 0.85 in order to verify the discriminant validity as prescribed by conventional efforts. This criterion was satisfied in all variables in this research, which means that discriminant validity is high (Hair et al., 2016).

4.4 Structural Model Assessment

An additional key phase in the validation process is the evaluation of the structural model. Additionally, using the bootstrapping method with 5000 resamples, t-values and R² values have also been obtained. Figure 2 shows the outcomes of the common SEM assessment made with Smart PLS 4.0. The outside loads of all items were frequently greater than allowed. The direction coefficients of most variables are very good.

Figure 2: Standardized results of SEM calculations



4.5 Hypotheses Testing (Direct and Indirect Relationships)

Table 6: Results of Direct and Indirect Effect Hypotheses

Hypotheses	Relationship	Std Beta	Std Error	t-value	p-value	Decision
H1	Relative Advantage → Intention to Use	0.0210	0.1010	0.0630	0.9500	Rejected
H2	Perceived Usefulness → Intention to Use	0.1210	0.0600	2.0030	0.0460*	Supported
H3	Perceived Ease of Use → Intention to Use	0.2240	0.0990	2.4030	0.0170*	Supported
H4	Relative Advantage → Environmental Awareness → IU	0.1740	0.0500	3.5890	0.0000***	Supported
H5	Perceived Usefulness → Environmental Awareness → IU	0.1660	0.0420	3.7540	0.0000***	Supported
H6	Perceived Ease of Use → Environmental Awareness → IU	0.2030	0.0580	3.4950	0.0010**	Supported

Note: RA = Relative Advantage; PU = Perceived Usefulness; PEoU = Perceived Ease of Use; EA = Environmental Awareness; IU = Intention to Use RET. Std Beta = standardized path coefficient. Significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (two-tailed; bootstrapped).

The results of the hypothesis testing for both direct and indirect effects are summarized in Table 6. Structural Equation Modeling (SEM) techniques were employed to evaluate the six hypotheses proposed in this study, focusing on the relationships between the key variables and the intention to use green energy technology within the context of IoT adoption. The first hypothesis (H1) proposed that relative advantage (RA) would have a positive and significant effect on entrepreneurs' intention to use green energy technology. However, the analysis revealed that this relationship was not statistically significant ($\beta = 0.021$, $t = 0.063$, $p > 0.05$). This suggests that entrepreneurs' perception of the relative advantage of green technology does not strongly influence their behavioral intention in this context, possibly due to other intervening factors or contextual limitations, leading to the rejection of H1.

In contrast, the second hypothesis (H2) posited that perceived usefulness (PU) positively influences the intention to adopt green energy technology. The data supported this, with a significant and positive path coefficient ($\beta = 0.121$, $t = 2.003$, $p < 0.05$). This finding indicates that entrepreneurs who believe green technology enhances their performance or business outcomes are more likely to intend to adopt it, thus confirming H2. The acceptance of H2, but not H1, highlights that while perceiving a technology as useful can motivate adoption intentions, simply recognizing its advantages relative to alternatives is insufficient on its own. This underlines the importance of focusing on usefulness perceptions to encourage sustainable technology adoption. The subsequent hypotheses related to perceived ease of use, environmental awareness, and their mediating effects are also tested in Table 6, providing a comprehensive understanding of the factors shaping entrepreneurs' intentions.

The third hypothesis (H3) proposed that perceived ease of use (PEoU) would have a positive and significant influence on entrepreneurs' intention to adopt green energy technology related to IoT. The results supported this assumption, showing a statistically significant positive effect ($\beta = 0.224$, $t = 2.403$, $p < 0.05$). This implies that when entrepreneurs perceive the technology as easy to use and understand, their willingness to implement green energy solutions increases. The acceptance of H3 highlights the

importance of usability and simplicity in fostering technology adoption, suggesting that efforts to simplify technology interfaces could enhance adoption rates.

The fourth hypothesis (H4) examined the mediating role of environmental awareness (EA) between relative advantage and the intention to use renewable energy technology. The findings confirmed that environmental awareness significantly mediates this relationship ($\beta = 0.174$, $t = 3.589$, $p < 0.05$). This means that the perceived benefits of green technology influence entrepreneurs' environmental consciousness, which in turn motivates their intention to adopt such technology. The support for H4 indicates that environmental awareness plays a crucial intermediary role by transforming perceptions of advantage into actionable intention. Without heightened environmental awareness, the relative advantage alone may not be enough to drive adoption, as seen in the rejection of H1. Together, these results emphasize that both ease of use and environmental consciousness are key factors in promoting green technology adoption among entrepreneurs, shaping their intentions either directly or indirectly.

The fifth hypothesis (H5) proposed that environmental awareness (EA) mediates the relationship between perceived usefulness (PU) and the intention to use renewable energy technology. The results confirmed this mediation effect, with a significant path coefficient ($\beta = 0.166$, $t = 3.754$, $p < 0.05$). This indicates that entrepreneurs' perceptions of usefulness enhance their environmental consciousness, which subsequently drives their intention to adopt green energy solutions. Hence, EA acts as a crucial link translating perceived benefits into behavioral intention. Similarly, the sixth hypothesis (H6) examined whether environmental awareness mediates the relationship between perceived ease of use (PEoU) and intention to use renewable energy technology. The findings supported this, with EA significantly mediating the relationship ($\beta = 0.203$, $t = 3.495$, $p < 0.05$). This suggests that perceiving technology as easy to use fosters greater environmental awareness, which then motivates adoption intentions. The acceptance of both H5 and H6 highlights the pivotal role of environmental awareness in connecting the TAM variables to actual behavioral intentions, reinforcing its importance as a key mediator in sustainable technology adoption.

5 Discussion

This study advances the understanding of RET adoption among rural entrepreneurs by analyzing both primary and complementary factors using Structural Equation Modeling (SEM), which provides a more comprehensive examination beyond traditional regression approaches. SEM allowed for the exploration of complex interrelationships between perceived usefulness, ease of use, environmental awareness, and intention to adopt RET, shedding light on how these factors collectively shape adoption behaviors. Additionally, SEM facilitated mediation analysis, revealing that environmental awareness significantly amplifies the influence of perceived usefulness and ease of use on adoption intentions. While economic and financial considerations remain primary drivers in resource-limited settings, the inclusion of these additional factors offers a nuanced perspective that highlights the role of environmental values alongside economic motivations. By integrating control variables, such as firm size and prior technology exposure, the analysis isolated the unique impact of each factor on adoption intention, deepening our

understanding of adoption dynamics in rural SME contexts where financial constraints, infrastructure challenges, and sustainability considerations intersect. This study offers important contributions to understanding the adoption of green energy technology by rural entrepreneurs in Bangladesh, an area that has received limited scholarly attention. By concentrating on this specific group, the research sheds light on the multifaceted decision-making processes influencing technology adoption. The findings highlight the significant roles of relative advantage, perceived usefulness, perceived ease of use, and environmental awareness in shaping entrepreneurs' intentions. While some hypotheses, such as the direct effect of relative advantage on intention, were not supported, the mediating role of environmental awareness proved critical in linking these variables to adoption behavior. These results both confirm and extend prior studies, enriching the green technology literature and suggesting new avenues for future investigation into how contextual factors influence sustainable technology uptake.

The results partially contrast with findings by Bandara and Amarasena (2018), Jabeen et al. (2019), and Wong et al. (2024), which emphasize cost savings as a primary driver of green technology adoption in rural settings. Our findings suggest that rural entrepreneurs in Bangladesh are more driven by the environmental benefits of green technology than by cost savings. This discrepancy may be explained by unique contextual challenges faced by Bangladeshi SMEs, including limited infrastructure, restricted access to information, and financial constraints that diminish the perceived financial benefits of green technology. As such, the initial high costs associated with green energy adoption may deter entrepreneurs who prioritize affordability, aligning with studies by Karooni et al. (2016), and Chang and Lo (2025), which similarly emphasize context-specific challenges in rural settings. This study underscores the need for tailored financial projections and business planning support to highlight long-term economic benefits to rural entrepreneurs.

Additionally, in line with Rezaei and Ghofranfarid (2018), our findings emphasize that perceived ease of use is vital in enhancing the willingness of rural entrepreneurs to adopt green technologies. Studies by Zdonek et al. (2023) and Elangovan et al. (2024) support this by indicating that rural entrepreneurs are more inclined to adopt technologies that are easy to understand, install, and manage. However, unlike previous studies that largely view ease of use as a primary driver, this study finds that ease of use alone may not guarantee adoption in contexts where there is limited technical support and financial infrastructure. Instead, ease of use functions best in conjunction with external support, such as training and government incentives, to overcome barriers associated with infrastructure and skills shortages. These findings add nuance to the literature by highlighting that ease of use must be contextualized within specific market conditions to understand its full impact on adoption.

This study provides several theoretical contributions by advancing our understanding of how environmental awareness acts as a mediator in the adoption of green technology among rural entrepreneurs. In alignment with Zeng et al. (2022), our study reveals that environmental awareness strengthens the relationship between perceived usefulness and the intention to adopt green technology. This study contributes to the literature by suggesting that environmental awareness can mitigate some barriers to adoption, such as affordability and ease of use. Entrepreneurs with higher environmental

awareness are more likely to perceive green technology as beneficial not only for cost and efficiency but also as a pathway toward sustainable development. This finding advances the literature on intrinsic motivation, indicating that in rural settings, environmental values can surpass traditional economic drivers, encouraging a shift toward sustainable practices even in resource-limited environments.

Moreover, our research provides insight into the "value-action gap" concept within the context of green technology adoption. Entrepreneurs may be motivated by environmental awareness, but challenges such as initial costs and lack of technical support may still hinder adoption, highlighting a gap between intention and actual use. This study underscores the importance of addressing this gap by enhancing supportive policies, financial incentives, and accessible training programs to facilitate green technology adoption. Thus, our findings advance the theoretical understanding of the value-action gap by demonstrating that, while environmental awareness can inspire initial interest, addressing practical barriers is essential for actual adoption.

6 Conclusion

This study was motivated by the dual challenge faced by rural SMEs in Bangladesh: limited access to reliable energy and the growing necessity to adopt environmentally sustainable business practices. In response, the study examined how key perceptions from the Technology Acceptance Model (perceived usefulness and perceived ease of use) and Diffusion of Innovation logic (relative advantage) shape rural entrepreneurs' intention to adopt renewable energy technologies, while also assessing the mediating role of environmental awareness.

The findings indicate that perceived usefulness and perceived ease of use significantly increase rural entrepreneurs' intention to adopt renewable energy technologies. In contrast, the direct effect of relative advantage on intention is not statistically significant. However, environmental awareness plays a pivotal mediating role by translating perceived advantage, usefulness, and ease of use into stronger adoption intention. Inference from these results suggests that, in resource-constrained rural settings, adoption intentions are not triggered by comparative advantage alone; rather, entrepreneurs' environmental awareness is a key mechanism that converts perceived benefits into behavioural intention.

The study contributes to the literature in three ways. First, it provides context-specific evidence from rural SME entrepreneurs in Bangladesh, an underexamined but policy-relevant population for energy transition research. Second, it clarifies the mechanism through which environmental awareness strengthens adoption intention, positioning awareness as an explanatory bridge between technology perceptions and behavioural intention. Third, the study offers actionable insights for stakeholders: adoption can be accelerated by combining usability-focused interventions (training, technical support, simplified installation, and maintenance guidance) with structured environmental awareness initiatives and targeted financing mechanisms that reduce initial investment barriers.

Despite these contributions, several limitations should be acknowledged. The study relies on cross-sectional self-reported survey data, which may still carry some risk of common method bias even though procedural and statistical checks were conducted. The sample focuses on selected districts within the Dhaka division, and Gazipur includes semi-urban zones, which may limit generalizability to more remote regions. In addition, the model does not explicitly incorporate financial constructs (e.g., perceived affordability, subsidy awareness, or payback expectations) that could shape adoption decisions in rural SMEs.

Furthermore, the polychoric robustness check (Appendix 2) revealed that two paths — the direct PU → IU effect and the indirect PEOU → EA → IU pathway — are sensitive to the treatment of Likert-scale data as continuous versus ordinal. Specifically, the PU → IU path reversed sign and became non-significant under polychoric estimation, and the PEOU-mediated indirect path lost significance. These findings suggest that the direct effect of perceived usefulness on adoption intention and the PEOU-mediated path should be interpreted with caution and treated as exploratory in the context of this study.

Future research should employ longitudinal or multi-source designs to strengthen causal inference and reduce single-source bias. Studies could expand sampling to more remote districts and compare regions with different infrastructure access. Finally, future models should incorporate financial and institutional conditions (e.g., subsidy awareness, access to credit, and perceived cost–benefit projections) and examine whether these factors moderate the TAM relationships, thereby producing a more comprehensive explanation of renewable energy technology adoption in rural entrepreneurial contexts.

7 Implications of the Study

The study contributes to the existing body of knowledge on technology adoption by exploring the technology of renewable energy (RET) adoption among rural entrepreneurs in Bangladesh, which has been underrepresented in previous studies. Combining the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory, the paper gives a more detailed insight into the way entrepreneurs in resource-constrained settings perceive and embrace new technologies. The results support the TAM as they establish the fact that the perceived usefulness and the perceived ease of use are still the key motivators of adoption. The intentions to adopt are stronger in entrepreneurs who believe that the use of RETs is advantageous in energy cost reduction, efficiency, and business performance enhancement. Likewise, ease of use can also be used as a significant factor that determines the adoption of RETs by the rural entrepreneur, but in this case, more people might consider them simple, reliable, and with fewer technical skills involved.

Simultaneously, the study builds on the DOI theory by showing how relative advantage and compatibility contribute to the decisions to adopt. RETs that distinctly indicate superiority to the traditional energy sources and that can be fitted into the current business practices of the entrepreneurs will more readily be adopted. The integration of the TAM consideration of cognitive appraisals of usefulness and ease with the DOI consideration of the features of innovation will enable this study to

add a more comprehensive perspective of renewable energy adoption to the rural entrepreneurial ecosystem.

Nevertheless, this research expands the conventional TAM model by showing how environmental consciousness is an important factor in the presence of technology to be adopted. Although cost savings and operational efficiency are still the driving forces in economic benefits, the results indicate that the rural entrepreneur who has a higher level of environmental awareness is likely to embrace RETs despite the lack of immediate financial benefits. This underscores the fact that the motivation of sustainability may win over pure economic factors in the rural environment, where energy scarcity and exposure to the environment are burning issues.

In terms of DOI, this is relevant to the significance of values-based compatibility, which is an innovation that will fit in not just with the business requirements but also with personal and social values. When entrepreneurs conceive that the implementation of RET will not conflict with their environmental beliefs, they have higher chances of championing those technologies even though they may not be profitable immediately. This study balances the constructs of perceived usefulness and ease of use of TAM with the innovation attributes of DOI, especially relative advantage and compatibility, to build a more comprehensive view of adoption behavior. In particular, it demonstrates that environmental awareness may work as a mediating variable, supporting the link between the cognitive appraisals of TAM and the innovation characteristic perception of DOI. By doing this, the study will contribute to the two models by showing how economic rationality and environmental consciousness interact to influence the uptake of green technologies by rural entrepreneurs.

7.1 Practical Implications

This study provides valuable insights for policymakers, NGOs, microfinance institutions, and renewable energy providers in Bangladesh by highlighting concrete measures to support the adoption of renewable energy technologies (RETs) among rural entrepreneurs. One key intervention is the development of targeted training and awareness programs in collaboration with local NGOs and community-based organizations. These programs should not only emphasize the economic and environmental benefits of RETs but also provide hands-on training in installation, operation, and maintenance, thereby addressing the technical challenges that rural SMEs frequently face. Community workshops and public-private partnerships can serve as effective platforms for building knowledge and confidence in renewable energy use.

To overcome financial barriers, policymakers should work with microfinance institutions and rural banks to design low-interest loan schemes and micro-credit facilities tailored to RET adoption. Government subsidies or tax incentives for small-scale entrepreneurs can further reduce the upfront costs of installing RETs, making them a viable option for rural SMEs. Pilot projects and demonstration sites in selected villages should be expanded to showcase real-world examples of successful adoption. These case studies can be shared through local media and community events to inspire trust and foster a culture of innovation among rural entrepreneurs.

Furthermore, environmental awareness should be operationalized through structured campaigns that go beyond generic messaging. For example, NGOs and local government bodies can organize village-level exhibitions or storytelling sessions featuring entrepreneurs who have successfully implemented RETs. Such initiatives would link renewable energy adoption to broader goals of reducing carbon emissions, improving community health, and ensuring long-term environmental sustainability. Importantly, involving rural entrepreneurs in the design and decision-making process for RET initiatives will create a sense of ownership and ensure that the technologies are aligned with local needs and realities. Furthermore, awareness campaigns should be tailored to highlight RET benefits in relation to local environmental challenges, such as soil degradation from diesel use, to make adoption more relatable for rural entrepreneurs. Additionally, leveraging Bangladesh's high mobile penetration, simple mobile-based RET management tools can be introduced to improve ease of use and build user confidence. By combining financial support, capacity-building, and community-driven awareness efforts, these practical measures can significantly accelerate RET adoption, foster sustainable entrepreneurship, and contribute to achieving Bangladesh's national goals for renewable energy and climate resilience.

Declarations

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Appendix 1

Constructs Measurement Items

Relative Advantage (Ahmad *et al.*, 2014):

1. Environmental concern has significant benefits.
2. Solar energy will decrease air pollution.
3. Solar energy will offer competitive benefits to my country.
4. Solar energy will reduce conventional energy use.

Perceived Usefulness (Ali *et al.*, 2023):

1. Introducing solar photovoltaic technology in my house allows me to do something for others.
2. Introducing solar photovoltaic technology in my firm allows me to save money.
3. Introducing solar photovoltaic technology in my firm allows me to reduce costs.
4. Introducing solar photovoltaic technology in my firm allows me to reduce emission of greenhouse gases.

Perceived Ease of Use (Ahmad *et al.*, 2014):

1. Solar energy is easy to install renewable energy materials.
2. Easily understandable manuals.
3. Easy to operate.
4. Easy to master on operating the machine.

Environmental Awareness (Alam, *et al.*, 2014; Irfan *et al.*, 2020):

1. I am worried about environmental problems.
2. I am worried about climate change.
3. In my opinion, air pollution and shortage of water are the biggest environmental problems.
4. Solar energy would improve the environment.

Intention to use (Ali *et al.*, 2023):

1. I intend to use solar electricity for my firm.
2. I plan to have some solar energy technology for my firm for the generation of electricity.
3. I am planning to have solar electricity for my firm in 3–4 years; 2–3 years; before 1 year.
4. The probability of introducing solar photovoltaic technology in my firm is very high.
5. I will introduce solar photovoltaic technology in my firm in a more effective way.

Appendix 2: Polychoric Robustness Check

To address reviewer concerns about ordinal measurement (Section 3.6.1), the structural model was re-estimated using a polychoric correlation approach. Polychoric correlations estimate the latent bivariate normal association underlying pairs of observed ordinal responses, providing a more conservative treatment of Likert-scale items than Pearson correlation. Specifically, item-level polychoric correlation matrices were computed via maximum-likelihood estimation for all 21 items, and polychoric-weighted factor scores were derived for each construct using the first principal component of the within-block polychoric matrix. Standardized path coefficients were then estimated by ordinary least-squares regression on the standardized factor scores, with 5,000 bootstrap resamples used to obtain standard errors and two-tailed p-values. Table A1 presents a complete comparison of the primary Pearson-based PLS-SEM estimates against the polychoric re-estimation.

Table A1. Comparison of Main PLS-SEM Estimates and Polychoric Re-estimation

Path	Main Estimate (β)	Main p-value	Polychoric Estimate (β)	Polychoric p-value	Direction Consistent?	Significant? (Both)
Panel A: Direct Structural Paths (Exogenous Constructs → Intention to Use RET)						
RA → IU	0.006	0.950	0.103	0.089	Yes	No
PU → IU	0.121	0.046	-0.091	0.111	No	Mixed
PEoU → IU	0.238	0.017	0.541	0.000	Yes	Yes
Panel B: Structural Paths → Environmental Awareness (Mediator)						
RA → EA	0.306	0.000	0.554	0.000	Yes	Yes
PU → EA	0.27	0.000	0.136	0.012	Yes	Yes
PEoU → EA	0.343	0.000	0.08	0.201	Yes	Mixed
Panel C: Environmental Awareness → Intention to Use RET						
EA → IU	0.587	0.000	0.37	0.000	Yes	Yes
Panel D: Indirect (Mediated) Paths via Environmental Awareness						
RA → EA → IU	0.174	0.000	0.205	0.000	Yes	Yes
PU → EA → IU	0.166	0.000	0.050	0.024	Yes	Yes
PEoU → EA → IU	0.203	0.001	0.030	0.178	Yes	Mixed

Note. Main estimates are from the primary PLS-SEM analysis in SmartPLS 4.0 using Pearson-based correlations with 5,000 bootstrap subsamples. Polychoric estimates are derived by re-estimating the structural model using polychoric factor scores, computed from item-level polychoric correlation matrices to account for the ordinal nature of five-point Likert-scale indicators. Bootstrap standard errors were obtained from 5,000 resamples. Direction Consistent = both estimates are in the same sign direction. Significant (Both) = both main and polychoric estimates reach $p < 0.05$; Mixed = one approach is significant and the other marginal/non-significant; No = neither approach is significant. RA = Relative Advantage; PU = Perceived Usefulness; PEoU = Perceived Ease of Use; EA = Environmental Awareness; IU = Intention to Use RET. β = standardized path coefficient. p-values are two-tailed.