Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

The Role of Clean Energy Policies in Promoting Green Finance and Sustainable Economic Development in Emerging Economies

Sabariah Yaakub
Universiti Utara Malaysia
Shahid Ali
nice.shahidsiddiqui@gmail.com
Universiti Utara Malaysia
Norazah Mohd Suki
Universiti Utara Malaysia

Research Article

Keywords: Wind power; policy instruments; green investment; HWT growth, instrumental analysis; Pakistan

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11458302/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

The Role of Clean Energy Policies in Promoting Green Finance and Sustainable Economic Development in Emerging Economies

Sabariah Yaakub [1], Shahid Ali [1], Norazah Mohd Suki [2,3,4]

[1] Othman Yeop Abdullah Graduate School of Business (OYAGSB), Universiti Utara Malaysia, Kuala Lumpur, Malaysia, y.sabariah@uum.edu.my
[2] Othman Yeop Abdullah Graduate School of Business (OYAGSB), Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia, azahsuki@yahoo.comOthman
[3] Faculty of Economics and Administrative Sciences, Atatürk University, 25240 Erzurum, Turkey
[4] Ramon V. del Rosario College of Business, De La Salle Universiti, 2401 Taft Ave, Malate, Manila, 1004 Metro Manila, Philippines,

*** Corresponding author:** nice.shahidsiddiqui@gmail.com; ali.shahid@uum.edu.my; Tel; +60-01-1125-60214

Abstract: The global reliance on fossil fuels can be alleviated through green investment in sustainable energy. This study critically analyses the effectiveness of current RE policy instruments in attracting green investment for developing household wind turbines (HWT) in Pakistan. The foremost purpose of the research is to evaluate the most significant policy instruments for implementing wind technology. The study used a purposive (non-probability) sampling approach to administer an opinion poll on energy strategy and collect data from 476 respondents (response rate 81.65%). The study used partial least squares structural equation modeling (PLS-SEM) to test the hypotheses. The results empirically support the proposed hypothesis, suggesting that the designated variables have a significant positive impact on HWT adoption. The model explained 54.6% of the variation in intention (R^2) and supported H1, H3, H4, H6, and H7. However, the results did not support H2. The outcomes suggest that Feed-in Tariffs are the most efficient strategy for attracting green investment in the country's HWT sector. The results also indicate that AI-based good governance positively and significantly moderates the nexus between RE policy instruments and green investment for HWT. Regulatory authorities must prioritize energy-related policies. In both developed and developing nations, renewable energy (RE) policies have emerged as a critical concern. The study results offer a practical guide and key policy recommendations for energy-sector officials, legislators, and administrative institutions to implement innovative RE strategy tools that encourage residents to invest in green energy in Pakistan.

Keywords: Wind power; policy instruments; green investment; HWT growth, instrumental analysis; Pakistan

1. Introduction

Over the past decade, political and economic discourse has focused on climate change and energy issues [1]. Reliable energy resources are essential to modern life [2]. Conversely, Pakistan faces a serious power crisis that strains the national budget [3]. Power shortages significantly affect individuals' professional and non-professional interests [4]. Like other developing nations, Pakistan requires immense power to sustain its large population and industrial sector [5]. The gap between power needs and available resources has grown out of control in recent years, and it is particularly pronounced in summer. The country experiences severe load shedding, with urban areas facing 6 to 10 hours of power outages per day and rural areas 12 hours [2]. In Pakistan, nonetheless, 51 million people, or 27% of the population, lack access to electricity, and some residents lack access to clean water [6]. Pakistan's total established energy production capability was approximately 46,605 MW (46.6 GW) by the end of May 2025. By 2030, capacity is expected to rise to 53,315 MW. Pakistan's total RE potential is approximately 167.7 GW, exceeding the citizens' total energy requirement [7]. The National Electric Power Regulatory Authority (NEPRA) reports thermal plants at 25,937 MW (55.7%), hydel at 11,368 MW (24.4%), nuclear at 3,620 MW (7.8%), and RE at 5,680 MW (12.2%), with 2,813 MW under net metering. Total power construction for 2025 is 69,750 GWh (169.75 TWh), based on power generation [8].

However, actual electricity generation depends on average wind speed, turbine height, and local conditions [9]. A household wind turbine with a capacity of 2–5 kW can satisfy a significant portion of a household's electricity requirements. At a 25% capacity factor, the average output would be about 10,950 kWh per year. Nevertheless, a 5-kW turbine cannot produce 5 kW continuously; it can only average 1.25 kW (5 kW × 25%) [10]. A wind turbine can produce 1–10 kW of electricity and water-pumping capacity for a household farm. In rural areas, households can produce 10–100 kW of electricity for workshops and farms [11]. Overall, small communities can produce 100 kW–1 MW of energy in villages for agricultural/industrial facilities. Commercial wind turbines can produce 1–6 MW of grid electricity, while 8–20 MW of grid electricity can be produced by large, modern offshore turbines [12]. The Government of Pakistan also describes the Gharo–Keti Bandar coastal belt, 60 km wide and 180 km long, as having an estimated 50,000 MW of exploitable potential. Currently, the southern zone's wind capacity is approximately 1.84 GW [13]. Annual wind energy generation depends on turbine size and specific household use. For lighting and electronics, the potential annual generation is (0.5 kW ~400–1,000 kWh/year). However, this turbine size can produce (1 kW ~800–2,000 kWh/year) for basic household loads. If you increase the turbine size to 3 kW, it can produce (~2,500–6,000 kWh/year) to support a significant household. Similarly, a 5-kW turbine (~4,000–10,000 kWh/year) suits large households and small farms, while a 10-kW turbine (~8,000–20,000 kWh/year) can generate energy for large homes, farms, and businesses [14].

By the end of May 2026, the national energy composition will include 121,691 GWh of total power generated throughout the financial year 2025-26. This figure includes 32% hydroelectric, 57% thermal, 8% nuclear, and 3% RE [15]. The country's normal energy need is 17,000 MW; however, the actual energy production is 14,000 MW in any period. Consequently, the administration faces an average deficit of 3,000 MW, which may rise to 5,200 MW in summer. The alternative RE policy sets clear objectives, including a 20% share of the energy mix by 2026 and 30% by 2030 [16]. To achieve sustainable economic growth in Pakistan, Pakistan must replace conventional energy generation methods with RE resources [17]. Pakistan's energy consumption (kWh per head) is 892, according to the Asian Development Bank. It is expected to grow at a compound annual growth rate (CAGR) of 5.8% by 2030 [18]. At present, the country's primary energy source is fossil fuels. Inadequate

policies have kept RE's share of the overall energy mix small. The national economy cannot support heavy dependence on fossil fuels. Therefore, to address the energy crisis effectively, the government must establish a new energy strategy that effectively employs RE resources, including biogas and wind. Pakistan possesses extensive wind power potential. Effective policy incentives, a strong market base, research facilities, and its tropical geography can help address the country's energy crisis [19].

Currently, the administration relies on 67% non-renewable sources to meet power needs, a share increasing by 10% per annum [20]. Pakistan's RE sector is negligible, contributing only 0.5% of the country's energy requirements. By the end of 2025, global wind energy installed capacity reached 1,299 GW [21]. Pakistan's geography offers abundant potential for all categories of RE resources, including wind power, with an estimated potential of nearly 81 million tons per year [22]. Fortunately, this is the case. Wind energy can significantly impact the country's economy by generating low-cost energy through wind turbines and combustion technologies. In Pakistan, the wind resource is 5.5 Wh m-2 d-1. In the seaside zones of Baluchistan and Sindh, wind speed is 5-7 m s-1, and wind power potential exceeds 20,000 MW [23]. The average monthly wind intensity in Pakistan ranges from 136.05 to 287.36 W/m2. However, the practical wind radiation intensity exceeds 200 W/m2. Pakistan can generate 45MW to 83MW of energy per month from 100 m2 in the areas [24]. This investigation examines four RE strategy mechanisms designed to encourage residents to install wind power. The policy mechanisms comprise renewable portfolio standards (RPS), Feed-in Tariffs (FIT), fiscal measures (FM) or tax incentives, and emissions trading schemes (ETS) to encourage Pakistani residents to invest in the wind energy sector.

The literature has a gap regarding RE policy mechanisms. Pakistan's large population and industrial growth have exacerbated the gap between energy supply and demand. The RE sector in Pakistan has predominantly been deficient in the following areas: (i) RE generation sources, (ii) advanced energy sector directions, (iii) arguments and wind energy introduction, (iv) a comprehensive energy sector evaluation, (v) energy mix, and (vi) the demand and supply gap of the alternative energy sector. Although previous research has examined the wind energy sector [25–27], it has identified gaps. These gaps include (i) the effective use of existing policy tools and the adoption of new RE policy methods to encourage residents by providing tax inducements for RE investment. (ii) the policy gap can be addressed by incorporating new apparatuses into the current policy to entice resident stockholders in the wind energy segment of Pakistan, with a particular emphasis on HWT; (iii) sophisticated and operative policy apparatuses, for example, contemporary FIT, tax inducements for HWT, and RPS, are necessary to attract residents in the household wind energy part on a global scale; (iv) the country necessitates green outlay through the investigation of RE strategy and policy tools. We use a quantitative method to test the hypotheses that RE policy instruments correlate with green investment in the current study. This investigation is divided into numerous sections. This study addresses the following gaps in the literature: scrutinizing cost-benefit analysis with practical considerations to encourage the adoption of wind technology through domestic wind turbines in Pakistan; and highlighting installation and operational barriers to encourage residents to adopt HWT. This study used a non-probability (purposive) sampling procedure to select respondents. The study collected evidence to achieve its objectives through surveys using quantitative data-collection methods. The study used PLS-SEM to analyze the collected data.

Furthermore, this investigation anticipates the administration of agreements among municipalities, government agencies, and wind technology and RE technology investors,

particularly in HWT [28]. This policy typically provides producers with long-term contracts lasting 15 to 20 years. It also addresses advanced renewable tariffs and RE payments for RE expertise. FIT further encourages RE by subsidizing RE prices, reducing the cost of exporting generated energy, and funding any required electrical infrastructure upgrades [29]. This policy method can attract investment in RE initiatives. FM suggests that RE is positively and significantly influenced, particularly in HWT [30]. RPS strategies efficiently boost wind power production in the United States [31]. ETS aims to reduce carbon emissions by setting up a cap and using a market for tradable emission permits. Energy production payments (EPP), Tendering (TEND), and other policy instruments in Europe suggest that interaction with ETS is adversely associated with ETS, contingent on the reduction prices of numerous knowledge and the carbon emission constraint. ETS policy can significantly increase access to RE sources. ETS policy tools occasionally reduce the efficiency of EPP and TEND. Established on this confirmation, this research elected these four policy tools.

This study examines the substantial impacts of RE policies on the sustainability of domestic wind energy in Pakistan. It will also highlight the obstacles that must be overcome to attract investment in the wind technology sector and promote sustainable green technology. This investigation aims to reduce energy costs by categorizing and evaluating how policy instruments are implemented and how well they perform. Additionally, this analysis evaluates the efficiency of green power, with particular emphasis on domestic wind turbine technology, to address this knowledge gap. Accordingly, this analysis aims to identify and explain the most significant policy obstacles that impede residents' awareness of and adoption of wind technology. This study examines wind energy use and the key policy instruments for residents in Pakistan. This research assesses the key characteristics of household wind energy resources in Pakistan to support the continued development and maintenance of wind technology. This research aims to encourage rural Pakistanis to adopt household wind technology for household and commercial use by highlighting Pakistan's wind energy potential and promoting green energy. Residents in the study area prioritized wind turbines over advanced agricultural techniques, reflecting their preferred worldview. Conversely, the biggest obstacle to domestic wind energy adoption is the slow adoption rate, driven by a lack of awareness. This study is primarily driven by energy conservation and development-based motives for adopting HWT facilities [32]. The results suggest that Pakistan's transparent and affordable strategy significantly and positively motivates residents to implement household wind energy. This study's findings will benefit non-legislative administrations, practitioners, policymakers, and organizations working to optimize inefficient processes.

The research is divided into several sections: the second section presents "Formulation of hypotheses," the 3rd section presents "Research methodology," the fourth section presents "Statistical analysis and empirical results," and the fifth section presents "Discussion and implications." Finally, the sixth section presents the "Conclusions and recommendations."

2. Formulation of Hypotheses

2.1. Emission trading scheme and green technology investment in wind turbines

The ETS scheme, which regulates emissions trading ("cap and trade" or adjustment exchange) and RE production and consumption, is a market-based method for cost-effectively reducing greenhouse gas emissions and pollution. Empirical evidence shows that investment in RE is positively influenced by the ETS and RE certificates (R.E.C.), particularly in the wind region [33]. The ETS has two basic elements: a pollution boundary and tradable payments corresponding to the boundary (identifiable emissions property). It enables the purchase and sale of glasshouse gas emissions, reducing costs and providing

economic encouragement. Previous research shows that ETS does not have a statistically significant impact on residents' attraction at full intensity, but it is strongly correlated with HWT. Previous studies show that adopting wind energy and subsidies significantly and positively increases residents' awareness and empowers them in society. Empirical evidence shows that ETS and R.E.C. strongly affect savings in RE, particularly in wind regions [34]. These studies support the feasibility of wind energy pathways for pastoral populations. The coevolution of the technological and social sectors catalyzed the HWT innovation process. The technical and social sectors coevolve during the household wind energy innovation process. To attract residents to produce energy at low cost, Pakistan's HWT sector must implement ETS. ETS serves as a source of RE production, and its proceeds fund operations. ETS also covers administrative outlays and utilization, which has attracted investment from the Chinese government and helps mitigate economic losses [33].

This theoretical argument posits that ETS can improve innovative residents' activities using wind technology. Previous studies have empirically validated this relationship and reported a positive association between low-cost wind technology and residents' innovation. The ETS is designed to reduce carbon emissions by setting an emissions cap and facilitating the trading of emission permits. In Europe, other policy mechanisms interact with the ETS. The energy production payment (EPP) and Tendering (TEND) are closely linked to the ETS, depending on the reduction price of several expertise and the carbon-emissions boundary. ETS policy instruments can expand renewable energy sources [35]. Household wind energy is a critical energy source for households; it is a byproduct of other readily accessible operations and can empower residents [36]. These studies corroborate this hypothesis. Wind energy is a viable solution to these energy and ecological concerns, particularly for developing countries. In addition, implementing HWT has a beneficial and substantial effect on income, residents' empowerment, and agricultural yields, while it has a detrimental effect on fuelwood costs and collection time [37]. We have developed a hypothesis based on a substantial body of evidence. Consequently, we recommend the following hypothesis.
Hypothesis 1 (H1): There is a positive correlation between ETS and green technology investment in wind turbines (GTIWT)

2.2. Fiscal measures and GTIWT

To encourage investment in real estate, the administration funds one-time investment costs, fully or partly. FM supports real estate funds through tax declines. To implement the green path, the authority must fund commercial and statutory support, demonstrate strong diplomatic commitment, and address the mandate-source imbalance by supplying energy from thermal energy production [38]. Literature supports the hypothesis for this investigation. Some relatives are more closely associated with rural families and substantially influence their adoption of HWT, unlike friends and other relatives. FM or tax inducements suggest a positive and substantial influence on Pakistan's HWT schemes and complementary power strategies among resident shareholders. Pakistani residents are drawn to carbon taxes and emissions trading as carbon evaluation mechanisms. FM has an explicit and substantial effect on RE proposals, specifically HWT, when local investors use tax incentives [39]. This theoretical argument suggests that FM can enhance innovative residents' activities using wind technology. Prior studies have empirically supported this relationship, reporting a positive correlation between residential wind energy innovation and low-cost technology. Export diversification and RE can improve load capacity while preserving environmental conditions [40].
Pakistan faces strategic challenges in the real estate sector, creating uncertainty among remote and local stakeholders about investment decisions. To address these concerns,

resident investors need financial and tax incentives. FM promotes ecological objectives, is profitable, and focuses on tax policy. Other financial instruments also support environmental objectives by complementing one another [30]. Carbon taxes on wind and geothermal energy are among the most common ways to protect the natural environment from harmful activities and shift them toward cleaner energy sources [41]. Modifications to fiscal plans in power plans will expand proceeds charges and restore tax proceeds to residents [42]. These investigations support this hypothesis. These prior investigations provide corroborating evidence. This substantial evidence supports this hypothesis. Highlighting technology is a low-cost approach that encourages the use of clean, cost-effective renewable energy sources to improve wind turbine performance and facilitate their widespread implementation in Punjab, Pakistan. Investment capital will increase because of increased excitement and perceived feasibility of RE initiatives for residents [43]. Constructed on these findings, we formulated the second assumption as follows.

Hypothesis 2 (H2): There is a significant correlation between FM and GTIWT

2.3. Renewable portfolio standard and GTIWT

The RPS mechanism mandates that electricity companies utilize renewable energy resources and generate a specific percentage of electricity. Overall electricity capacity has increased by one-third because of RPS, and wind capacity remains significantly positive. Consistent estimates show the most substantial effect. RPS is either negligible or severely negative for wind power [44]. Prior research has empirically validated this relationship. Accordingly, based on the theoretical justification and corroborating findings from prior research, we propose the following hypothesis: the RPS policy tool has an optimistic impact on reducing outlay risk and increasing cumulative returns for residents when appropriately implemented in HWT. Regrettably, Pakistan does not currently implement RPS [45]. RPS can attract GTIWT interest in the RE zone globally [46]. To achieve these ambitious objectives, Pakistan needs policy instruments. Drawing on the literature, we propose a hypothesis for this investigation. To pursue a green pathway, the government must close the demand-supply gap through wind power generation, which requires strong financial, legislative, and political commitments [47]. Developed countries primarily use this policy instrument to attract local investors to the wind energy sector. However, developing countries such as Pakistan also need to implement it. Empirical evidence from various studies shows that RPS obligations effectively promote investment in RE. These findings corroborate this hypothesis. These prior investigations provide corroborating evidence. This third hypothesis is based on substantial evidence.

The research suggests that RPS obligations have a substantial, positive impact on energy generation, particularly on wind energy development in European states [48]. RPS strategies efficiently advance wind power production in the United States (del Río and Bleda, 2012). RPS and RE policy reforms effectively promote wind energy and wind energy production in China [31]. RPS strategies can be more efficient when linked with carbon-assessing rules, as these plans restrain electricity generation from established fossil fuel resources. Implementing wind energy for economic and social advancement can incentivize rural residents to participate in innovative initiatives. Residents are increasingly aware of the benefits of adopting HWT, so they seek solutions that reduce energy costs. According to this theoretical argument, wind technology can support innovative domestic wind energy activities. Implementing these policies can promote the expansion of alternative power expertise, growth, and incentives [49]. Commercial expansion, growth, monetary extension, and farming affect CO2 positively, whereas RE use affects CO2 emissions negatively [50]. The 3rd hypothesis is recommended because of the preceding discussion.

Hypothesis 3 (H3): There is a significant correlation between RPS and GTIWT

2.4. Feed-in-Tariff

A FIT is a policy instrument that is intended to encourage investment in renewable energy sources. It compensates small-scale wind energy or HWT producers at a premium over the market rate for the energy they supply to the grid. These policies aim to stabilize and regulate RE prices [51]. This mechanism pays the renewable energy producer. Empirical findings, particularly in the biomass and wind subsector, show that FIT is substantially and positively correlated with total GTIWT attraction [52]. This analysis assesses the effectiveness of RE policy mechanisms in attracting GTIWT in developing nations such as Pakistan. FIT has a beneficial impact on the per-capita volume of photovoltaic capacity a nation adds annually. The information understates the potential impact of FIT, as a well-designed FIT can have a much stronger effect than the common FIT currently used. The efficacy of a well-made FIT can be seven times greater than the impact of FIT. When FIT tariffs are low, regularity substantially affects its efficiency [53]. The investigation shows that FIT has a substantial, positive influence on a variety of economic indicators, particularly in wind power. Economic growth is positively correlated with RE production capacity. RE production strategies can improve attractiveness to foreign investment [54]. Pakistan established an FIT strategy to foster renewable energy development and overcome the supply-demand gap. Pakistan failed to achieve its desired results because it implemented the FIT strategy poorly in the RE division. The FIT policy failed to foster a competitive environment among management, the private sector, and Pakistan's residents in electricity production [55].

To establish sustainable regulatory conditions and financial incentives for HWT expansion, Pakistan must revise its FIT plan. Common methods for reducing RE investment risk and increasing returns include RPS, auctions, and FIT. The FIT strategy mechanism is more effective at inviting residents' investment in HWT because of its long-term agreement. The Chinese government encourages RE investment through tax incentives and monetary subsidies; however, tax incentives have a stronger effect. The primary driver is the Chinese government's subsidies for developing micro, minor, and middle-sized RE companies and residents [56]. Practical assessments show that the FIT program increases returns and productivity. The FIT strategy is more advantageous for households in enhancing inventory turnover. The FIT plan instrument has been demonstrated to mitigate the benefits deficit. Regional programs can influence RE utilization, globalization, and economic growth, and they can substantially affect CO2 emissions. In 2011, China implemented FIT policies to encourage wind power utilization[57]. FIT strategies aim to reduce RE costs by promoting green technology adoption and accelerating circulation. Under the FIT mechanism, the administration secures green power and sets a price above the market price. Established on the claims, we propose the 4^{th} assumption.

Hypothesis 4 (H4): There is a positive association between FIT and GTIWT

2.5. The moderating role of AI-based awareness of good governance (AIAGG)

AI cognizance is a condition of good governance. The complementarity between these factors has a negative effect on CO2 emissions in the economic sector and on administrative and organizational control. By using AI-based awareness to develop the financial industry, carbon emissions can be reduced through effective political and institutional governance [58]. To improve the impact and output of RE deliverers, they must continually develop and maintain their professional skills. This study requires implementing AI-based guidelines and good governance [59]. To address the energy crisis and attract GTIWT, Pakistan must implement AI-based good governance across all segments of life, with particular emphasis on the

renewable energy sector. Rule of law is the governance indicator associated with green growth that has the highest maximum criterion value and is of paramount importance in Pakistan. AI-based good governance can significantly contribute to achieving environmental sustainability goals. By using all governance indicators, politicians and corporations can understand the significance of ISO 14001 accreditation in promoting environmental preparedness in Pakistan [60]. Good governance is a key issue amid biased, national, and reserve-based disputes, even as the country faces internal and external challenges. Pakistan has focused on four categories of indicators: corruption suppression, inequality, deprivation, and discrimination. Taking these indicators seriously will significantly contribute to establishing good governance in the nation. Pakistan and Germany are currently engaged in RE plans. Good control supports the link between waste disposal, environmental degradation, and RE; however, the relationship between investment and environmental deprivation is weak [61].

Additionally, we examine the efficacy of GTIWT in the RE segment in relation to policy instruments. After a thorough literature review, we identified several specific research gaps. The effective utilization of current policy instruments and the implementation of new RE policy tools to attract local depositors by providing them with tax inducements for RE investment. The strategy gap is the need to introduce new instruments into the current plan to invite overseas stakeholders into Pakistan's RE segment, with particular emphasis on HWT. The RE sector requires sophisticated, efficient strategy mechanisms, such as recent FITs, tax inducements for HWT, and RPS, to attract investment worldwide. By analyzing RE strategy and policy mechanisms, the nation can attract green investment. Figure 1 illustrates the correlation between all parameters and green investment. As a conclusion of the preceding argument, we propose the fifth assumption.

Hypothesis 5 (H5): Moderating role of AIAGG between IDGE and GTIWT

Hypothesis 6 (H6): Direct role of IDGE and GTIWT

Hypothesis 7 (H7): Direct role of AIAGG and GTIWT

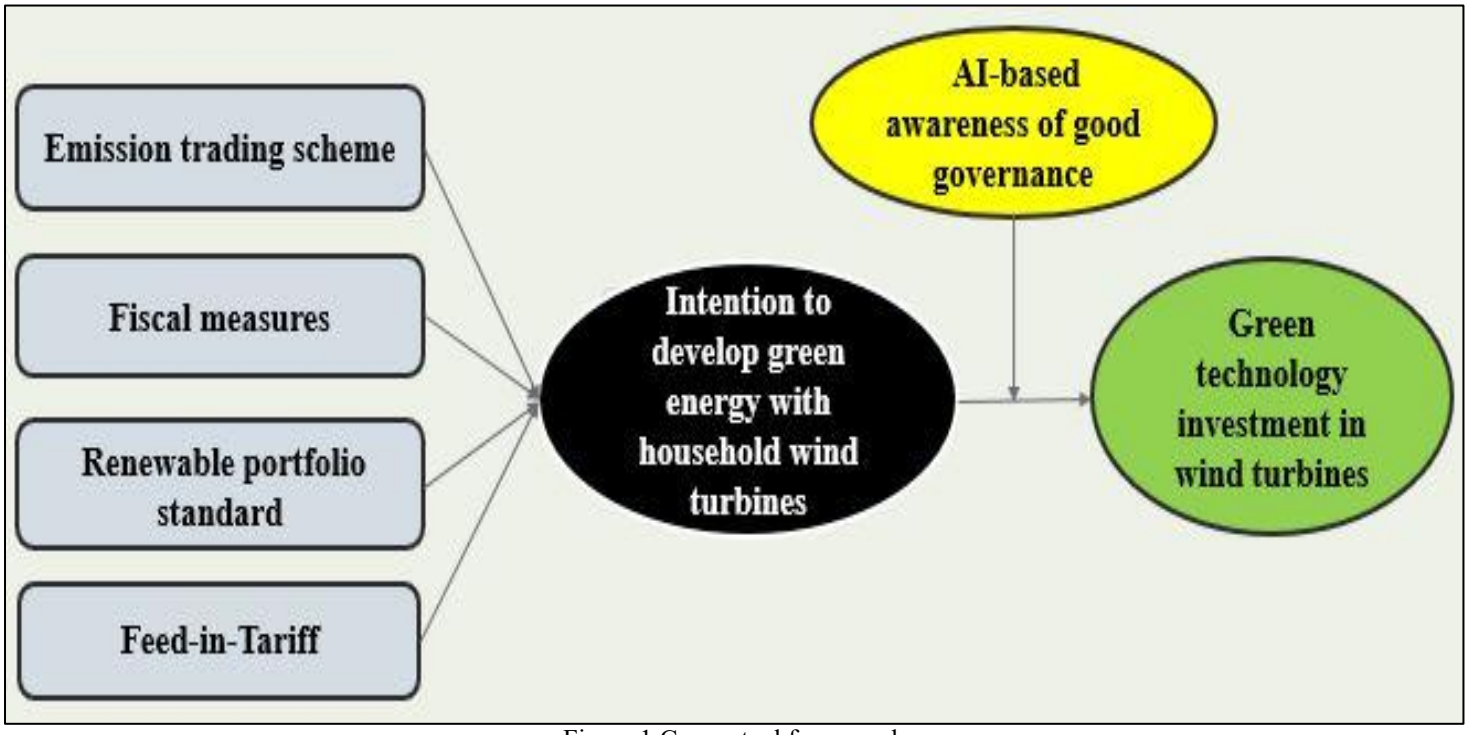


Figure 1 Conceptual framework

3. Research Methodology

The present survey used purposive sampling, a non-probability approach, to gather data and engage energy policy researchers and GTIWT experts in the HWT sector to promote sustainable development. To reach our sample energy policymakers, energy economists, and energy policy researchers, we used four policy instruments and purposive sampling. To accomplish this objective, we implemented the survey from November 2025 to January 2026. The researchers obtained responses through both open-ended and closed-ended questionnaires. The authors made a considerable effort to distribute the questionnaires in person. Purposive sampling is important for evaluating the entire population and for generalizability [62]. This study aims to assess the effectiveness of RE policy tools in attracting GTIWT and to investigate how AI-based good governance and economic funding moderate the relationship between RE strategy methods and GTIWT in Pakistan. The following criteria were used to select the respondents: (i) respondents are from a variety of regions with a wide range of fields. We categorized respondents by sector and gender: government policymakers (106), energy economists (141), energy policy researchers (105), and energy policymakers (121) (see Appendix A). We considered relevant experience, and the minimum qualification level for respondents was the undergraduate level. We used these criteria to select respondents with diverse cultures, behaviors, and backgrounds. Accordingly, the sample size chosen for this study is significant, and the results are substantial and beneficial because they reflect the respondents' diverse characteristics [63].

Respondents were selected based on their level of interest in the research topic and objectives. Participants needed a strong understanding of, or experience with, wind technology and its application to residents' goals. Participants had to be at least 22 years of age and have experience with HWT. To ensure relevance, the study also selected respondents from the target geographic area. Individuals who did not possess any prior knowledge or expertise in household wind energy were excluded. To identify respondents who could provide incisive and trustworthy information, the study used purposive sampling. These selection criteria ensured the collected information was relevant to the study questions and suitable for PLS-SEM analysis [64]. Additionally, participants were required to have at least five years of experience in the alternative energy sector. This minimum condition was not mandatory. Table 1 provides a comprehensive summary of the statistical analysis of respondents' demographic characteristics. Furthermore, this sampling procedure was implemented to encompass the entire population, and the findings align with the hypothesis's predictions [65]. This analysis drew respondents from a variety of traditional conditions and interactive structures and was conducted in four agronomic capitals (Faisalabad, Lahore, Gujranwala, and Sialkot) and adjacent pastoral neighborhoods in Pakistan. The demographic descriptions of the respondents, including age, qualifications, education, direct experience, and gender, align with the employment guidelines and reflect the diverse characteristics of those who submitted a standard response in this investigation. The first section of the inquiry form collects the participant's personal information, while the next section describes HWT.

This investigation examines the hypothesized relationship between the dependent variable (DV) and the independent variables (IVs). The current study demonstrates the predictable moderation of the IV-DV association. This analysis examines the potential of wind technology by focusing on residents' economic development. The correlation between the IV and DV is controlled by AI-based understanding of good governance. We preferred wind power as the resource for residents to investigate its economic advantages. Catastrophes result from ecological, sociological, and economic factors. The statistics collection procedure,

variable selection, and respondent characteristics are sub-sections contingent on the research methodology. These sub-sections are elucidated in the subsequent paragraphs:

3.1. Statistics Collection Procedure

The researchers contacted various professionals, and 597 respondents participated in this study. Of these, 583 consented to participate; however, 14 responses were rejected as invalid or incomplete. After obtaining approval, the researchers delivered open- and closed-end questionnaires. Finally, we used 476 complete surveys. We excluded 107 questionnaires because they were incomplete, inadequate, or irrelevant. The response rate was 81.65%. Overall, 476 sample results were valid for this study. We used purposive sampling to select respondents. The distribution of applicants around the corresponding groupings is illustrated by the percentages (%) in Appendix A1, which were calculated using descriptive statistics, as the demographic characteristics of the respondents were analyzed [66]. To conclude the analysis, the researchers assessed information from September 2025 to February 2026. The researchers obtained participants' information through familiar contacts with shareholders, established sites for RE specialists and legislators, and approaches to RE groups and authority administrators. The study sample is representative of the findings. The questionnaires are divided into two sections; the initial section details the respondents' information. The second portion includes an opinion poll on RE policy mechanisms designed to interest GTIWT, promote environmental HWT improvement, and improve energy resources and affordable power.

3.2. Variable Selection

We adapted scale items from prior research for the current investigation. We used eight items (FIT) to evaluate the Feed-in-Tariff (FIT) policy methods construct. We extracted and modified these items from the preceding investigation [52]. We adopted and modified the emission trading scheme (ETS) items from [35] and assessed them using seven items. The study used eight items to measure fiscal measures (FM), adapted and modified from [67]. We assessed the renewable portfolio standard (RPS) using six items, adapted from [31]. The study used four items to assess intent to use green energy with HWT (IDGE). We adapted these items from the original research. We incorporated and controlled all elements of this representative variable from the literature [68]. Eight elements measure AI-based good governance (AIAGG). Lastly, we selected five items assessing investment in green technology in wind turbines (GTIWT) as unpredictable. These items were adapted and revised from the literature [69].

3.3. Demographic Attributes of the Respondents

Most respondents (421, 88.44%) were female, while only approximately 55 (11.55%) were male. Additionally, 113 (23.73%) participants were aged 22 and younger, followed by 71 (14.92%) and 51 (10.71%) aged 23–33 and 34–43, respectively. Among participants aged 54–63 years, the phase diversities were 91 (19.12%) and 85 (17.86%). Conversely, 118 (24.79%) respondents had a minimal level of education, which is classified as under-metric. 91 respondents (19.12%) completed a metric degree. 81 respondents (17.01%) had completed education in the Faculty of Arts. 87 (18.28%) respondents had completed a bachelor's degree, while 99 (20.80%) had completed a master's degree in various subjects. We also assessed participants' knowledge: 121 (25.42%) had 0–5 years of experience, while the largest group had 6–10 years (86; 18.06%). However, some participants had 16–20 years of experience (85; 17.01%), and a small number had 20 years of experience (87; 18.28%). Nevertheless, the demographic profile of the respondents is illustrated in Table 1. 111 (21.72%) respondents had adopted the TESUP Atlas model, 78 (16.39%) had adopted the Icewind Freya, 58

(12.18%) had adopted the Semtive Nemoi, 64 (10.09%) had adopted an ANTARIS Series, and 48 (10.08%) had adopted a Colite DS3000. 50 (10.50%) respondents had adopted the TESUP Magnum, 46 (9.66%) had adopted the Primus Wind Power AIR 40, and 51 (10.71%) had adopted a Primus Wind Power AIR MaX. Table 1 shows the demographic features of respondents

Table 1. Demographic Features of Respondents (household women, local small investors, and entrepreneurs) (N=476).

Variables	Characteristics	Frequency	%
Gender	Male	421	88.44
	Female	55	11.55
Age	Less than 22	113	23.73
	23–33	71	14.92
	34–43	51	10.71
	44–53	65	13.65
	54–63	91	19.12
	64 and above	85	17.86
Respondents' education	Under metric	118	24.79
	Metric	91	19.12
	Faculty of Arts	81	170.1
	Bachelor	87	18.28
	Master	99	20.80
Respondent's experience	0–5 years	121	25.42
	6–10 years	86	18.06
	11–15 years	97	20.38
	16–20 years	85	17.86
	20 and above	87	18.28
Selected residential wind turbines	TESUP Atlas	78	16.39
	Icewind Freya	81	17.01
	Semtive Nemoi	58	12.18
	ANTARIS Series	64	10.09
	Colite DS3000	48	10.08
	TESUP Magnum	50	10.50
	Primus Wind Power AIR 40	46	9.66
	Primus Wind Power AIR MaX	51	10.71

4. Empirical Results

4.1. Data Analysis and Results

This study used structural equation modeling to analyze the data [23]. This study analyzed the rational dimensions using PLS-SEM, a component-focused method. The authors used PLS-SEM because it is appropriate and well supported in the literature [70]. Using SEM in contemporary research offers several advantages for equitable analysis compared with conventional statistical methods. PLS-SEM can support our quantitative assessment by improving result accuracy, calculation efficiency, and ease of interpretation [71]. As a second-generation procedure, PLS-SEM can address challenges associated with first-generation research. PLS-SEM is a multivariate evaluation tool that also helps examine multiple variables within the same study and time frame. PLS-SEM is becoming more prevalent in business research because it can address multiple, intricate relationships simultaneously; however, inappropriate analytical techniques can produce inaccurate findings, underscoring the need for appropriate statistical tools in management and social science research [64].

Measurement and structural assessment models are two-stage analysis methods in PLS-SEM that generate results in two stages [72]. Using the validity and reliability of the RE policy methods currently employed in this analysis to attract GTIET in Pakistan, the measurement valuation prototype provides an internal measurement of the template. This study analyses RE policy methods using structural equation modeling. The primary statistical analyses were performed using PLS 4.0 software. PLS-SEM is used to examine relationships among the variables in the template under study. Furthermore, covariance-based structural equation modeling has lower statistical power than partial least squares path modeling. PLS-SEM is preferred because it captures relationships among many variables. Additionally, Smart-PLS, a modification-based SEM, employs PLS, also known as path modeling, to assess relationships between variables [73]. Smart-PLS's primary objective is hypothesis testing, and it makes it easy to implement complex models in business research. In this investigation, we used measurement model assessment and structural model assessment as the two primary Smart-PLS approaches. We can verify the measurement model's construct validity and reliability through discriminant and convergent validity. Cronbach's alpha, composite reliability, and item loads can assess convergent validity based on correlations among all research items. Fornell-Larcker, cross-loadings, and the Heterotrait-Monotrait ratio, however, can assess correlations between the study variables and support discriminant validity. Additionally, the study tests and reviews the hypotheses using path analysis in the measurement model; the discussion section details the analysis.

The current investigation used path analysis to establish connections between the variables. The results suggest that RE policy mechanisms, including FIT, RPS, FM, and ETS, positively affect GTIWT in Pakistan. Nevertheless, the measurement model results demonstrate the convergent validity of the RE procedure method objects used in the present survey. The Convergent Validity table shows that Alpha and CR exceed 0.70, while AVE and loadings exceed 0.50. These values across all items suggest high inter-item correlation and convergent validity. The study also assesses convergent validity by examining correlations among all items. The convergent validity table indicates that CR exceeds 0.70, AVE exceeds 0.50, Cronbach's alpha exceeds 0.70, and factor loadings exceed 0.50. These results suggest that the elements are highly correlated and support convergent validity. Table 2 presents all convergent validity results.

4.2. Measurement Assessment Model

In this research, the measurement model is necessary to evaluate the strength and dependability of all constructs addressed in the study. The measurement model confirmed the validity and reliability of the constructs and validated the influence of the entire set of items [70]. The measurement model is based on reliability assessments, including internal consistency reliability and item reliability, as well as validity tests, including discriminant validity and convergent validity [74]. Item consistency was assessed using outer loadings, while internal consistency reliability was assessed using CR; Convergent validity was assessed using AVE. The cross-loadings of all elements exceed the inception estimate of 0.50 [75]; Refer to Table 2. The analysis confirmed that typical case loadings must exceed 0.50 for all observations, and each item must contribute to the construct. The AVE should exceed the recommended value of 0.50. When each construct's CR exceeds 0.70, the measurements are considered reliable [76]. The selected RE policy instruments showed CR amounts ranging from 0.728 (ETS) to 0.762 (RPS). All AVE amounts fall within the range of 0.610 (RPS) to 0.748 (ETS). The other factor is loadings range from 0.50 to 0.937. Tables provide a comprehensive list of all verified reliability values, as indicated by the measurement

assessment model. All elements meet convergent validity in this study, and the component loadings exceed 0.50. Table 2 indicates convergent validity analyses.

Table 2. Convergent validity analyses

Constructs	Items	Loadings	α	CR	AVE
Emission trading scheme	ETS1	0.840	0.909	0.728	0.748
	ETS2	0.818			
	ETS3	0.825			
	ETS4	0.809			
	ETS5	0.795			
	ETS6	0.755			
	ETS7	0.792			
	ETS1	0.840			
Fiscal measures	FM1	0.860	0.931	0.743	0.675
	FM2	0.815			
	FM3	0.846			
	FM4	0.844			
	FM5	0.846			
	FM6	0.820			
	FM7	0.780			
	FM8	0.759			
Renewable portfolio standard	RPS1	0.898	0.952	0.762	0.610
	RPS2	0.937			
	RPS3	0.792			
	RPS4	0.900			
	RPS5	0.931			
	RPS6	0.936			
Feed-in-Tariff	FIT1	0.917	0.924	0.738	0.654
	FIT2	0.829			
	FIT3	0.783			
	FIT4	0.821			
	FIT5	0.809			
	FIT6	0.833			
	FIT7	0.826			
	FIT8	0.790			
AI-based awareness of good governance	AIAGG	0.837	0.941	0.751	0.710
	AIAGG2	0.867			
	AIAGG3	0.853			
	AIAGG4	0.821			
	AIAGG5	0.877			
	AIAGG6	0.859			
	AIAGG7	0.833			
	AIAGG8	0.790			
Intention to develop green energy with household wind turbines	IDGE1	0.869	0.887	0.722	0.747
	IDGE2	0.891			
	IDGE3	0.872			
	IDGE4	0.823			
Green technology investment in wind turbines	GTIWT1	0.917	0.943	0.757	0.716
	GTIWT2	0.923			
	GTIWT3	0.931			
	GTIWT4	0.833			
	GTIWT5	0.909			

We assessed discriminant validity by comparing the bold values in the cross-loadings table with those of other influences in each rank. Additionally, the values in the right and left

sections of the table are smaller than those in boldface. The boldfaced significances in Table 3 suggest that all influences have robust associations with one alternative but ineffective correlations with other components. To verify discriminant validity, we compared the boldfaced assessments in the cross-loads table row with the other components. In this investigation, the discriminant validity of these boldfaced assessments is strong and surpasses that of the other components in each row. When evaluated with the boldfaced standards, the other left- and right-side evaluations are lower. Table 3 presents the cross-loadings.

Table 3 Cross-loadings

Factors	AIAGG	ETS	FIT	FM	GTIWT	IDGE	RPS
AIAGG	**0.837**	0.323	0.345	0.326	0.606	0.779	0.609
AIAGG2	**0.867**	0.397	0.353	0.394	0.657	0.793	0.646
AIAGG3	**0.853**	0.366	0.332	0.364	0.596	0.783	0.587
AIAGG4	**0.821**	0.393	0.314	0.396	0.635	0.758	0.631
AIAGG5	**0.877**	0.397	0.323	0.386	0.637	0.769	0.623
AIAGG6	**0.859**	0.415	0.389	0.410	0.592	0.791	0.588
AIAGG7	**0.833**	0.399	0.426	0.405	0.510	0.772	0.505
AIAGG8	**0.790**	0.348	0.362	0.343	0.622	0.723	0.619
ETS1	0.392	**0.840**	0.401	0.815	0.215	0.397	0.230
ETS2	0.362	**0.818**	0.309	0.737	0.284	0.359	0.286
ETS3	0.371	**0.825**	0.454	0.729	0.252	0.362	0.250
ETS4	0.345	**0.809**	0.474	0.743	0.210	0.347	0.207
ETS5	0.374	**0.795**	0.450	0.619	0.228	0.384	0.226
ETS6	0.345	**0.755**	0.334	0.633	0.211	0.349	0.206
ETS7	0.348	**0.792**	0.406	0.659	0.239	0.339	0.235
FIT1	0.359	0.464	**0.776**	0.482	0.152	0.375	0.149
FIT2	0.351	0.405	**0.829**	0.450	0.189	0.375	0.190
FIT3	0.330	0.427	**0.783**	0.451	0.187	0.337	0.179
FIT4	0.306	0.354	**0.821**	0.395	0.175	0.297	0.165
FIT5	0.357	0.376	**0.809**	0.393	0.176	0.362	0.165
FIT6	0.353	0.408	**0.833**	0.427	0.193	0.363	0.184
FIT7	0.315	0.350	**0.826**	0.391	0.101	0.329	0.100
FIT8	0.334	0.450	**0.790**	0.478	0.143	0.347	0.139
FM1	0.367	0.789	0.478	**0.860**	0.238	0.383	0.240
FM2	0.392	0.740	0.401	**0.815**	0.215	0.397	0.230
FM3	0.382	0.732	0.454	**0.846**	0.250	0.372	0.248
FM4	0.348	0.603	0.472	**0.844**	0.213	0.347	0.212
FM5	0.375	0.662	0.473	**0.846**	0.233	0.367	0.235
FM6	0.365	0.693	0.455	**0.820**	0.227	0.372	0.223
FM7	0.368	0.633	0.398	**0.780**	0.269	0.351	0.279
FM8	0.348	0.692	0.406	**0.759**	0.239	0.339	0.235
GTIWT1	0.640	0.262	0.186	0.269	**0.917**	0.597	0.739
GTIWT2	0.684	0.267	0.196	0.258	**0.923**	0.651	0.798
GTIWT3	0.685	0.246	0.184	0.242	**0.931**	0.652	0.704
GTIWT4	0.618	0.273	0.174	0.253	**0.833**	0.589	0.710
GTIWT5	0.639	0.266	0.182	0.273	**0.909**	0.601	0.736
IDGE1	0.677	0.397	0.323	0.386	0.637	**0.869**	0.623
IDGE2	0.659	0.415	0.389	0.410	0.592	**0.891**	0.588
IDGE3	0.633	0.399	0.426	0.405	0.510	**0.872**	0.505
IDGE4	0.690	0.348	0.362	0.343	0.622	**0.823**	0.619
RPS1	0.684	0.267	0.196	0.258	0.723	0.651	**0.898**
RPS2	0.637	0.269	0.181	0.275	0.712	0.592	**0.936**
RPS3	0.584	0.265	0.166	0.248	0.700	0.562	**0.792**
RPS4	0.673	0.253	0.176	0.249	0.611	0.640	**0.900**
RPS5	0.644	0.252	0.165	0.257	0.601	0.603	**0.931**
RPS6	0.639	0.266	0.182	0.273	0.609	0.601	**0.936**

Notes: N = 476; ETS, emission trading scheme; FIT, feed-in tariff; FM; fiscal measures, GTIWT; green technology investment in wind turbines, AIAGG; AI-based awareness of good governance; RPS, renewable portfolio standard

The research also assesses correlations between unpredictability and discriminant judgment. The Fornell-Larcker measure is a commonly used technique for evaluating discriminant strength in studies involving underlying unpredictability. Investigators have criticized the Fornell-Larcker criteria. If the discriminant validity is less than 0.85 [77] or 0.90 [78], Larcker's hypothesis is rejected. The Fornell-Larcker measure is a standard result commonly used to estimate the discriminant strength of models in structural modeling. However, the current study demonstrates that the Fornell-Larcker measure may not consistently identify a deficit in discriminant strength under specific circumstances. When estimating the discriminant power of measurement standards, researchers often disregard the Fornell-Larcker criterion. It is utilized to determine whether the dimensions of a construct are adequately obvious to necessitate belief in their explanation [79]. Its adaptability is enhanced because it requires only one measurement technique. Table 4 explains discriminant Validity with Fornell-Larcker

Table 4. Discriminant Validity with Fornell-Larcker

Factors	**AIAGG**	**ETS**	**FIT**	**FM**	**GTIWT**	**IDGE**	**RPS**
AIAGG	0.743						
ETS	0.451	0.705					
FIT	0.420	0.502	0.709				
FM	0.418	0.466	0.538	0.722			
GTIWT	0.324	0.429	0.204	0.486	0.603		
IDGE	0.323	0.351	0.433	0.447	0.585	0.664	
RPS	0.317	0.291	0.398	0.289	0.494	0.578	0.600

The HTMT ratio is a more suitable measure of discriminant validity than the Fornell-Larcker criteria, as numerous researchers have criticized the latter [80]. The discriminant validity will be deemed legitimate if the value is less than 0.85 or 0.90. Table 4 reveals that all estimates are below 0.90 [77]. Discriminant validity has also been noted in the conclusions section adjacent to the variable quantity. Cross-loadings are used to evaluate discriminant validity. The values depicted in the figures suggest that the Nexus-with-itself variables are more significant than the other variables. The variables show low correlation, supporting discriminant validity. The most recent method employed to evaluate discriminant validity is the HTMT ratio. The HTMT ratio values exceed 0.90, as indicated by the figures. These results suggest discriminant strength and weaker associations among variables. Table 5 displays all highlighted values.

Table 5. Discriminant Validity with HTMT

Constructs	**Full Collinearity VIF**
AIAGG	1.537
ETS	2.151
FIT	2.247
FM	2.467
GTIWT	2.378
IDGE	2.778
RPS	2.214

We used the comprehensive VIF methodology to assess the likelihood of CMB. VIF values ranged from 1.537 to 2.778 for all structures and remained below the level mentioned of 3.3. Consequently, the research posed no meaningful risk of general approach bias. Table 6 presents the CMB estimation; however, Figure 2 illustrates the measurement model.

Table 6. Evaluation of CBM

Factors	AIAGG	ETS	FIT	FM	GTIWT	IDGE	RPS
AIAGG							
ETS	0.487						
FIT	0.451	0.545					
FM	0.479	0.448	0.578				
GTIWT	0.364	0.515	0.418	0.307			
IDGE	0.366	0.501	0.477	0.491	0.747		
RPS	0.653	0.413	0.421	0.308	0.648	0.735	

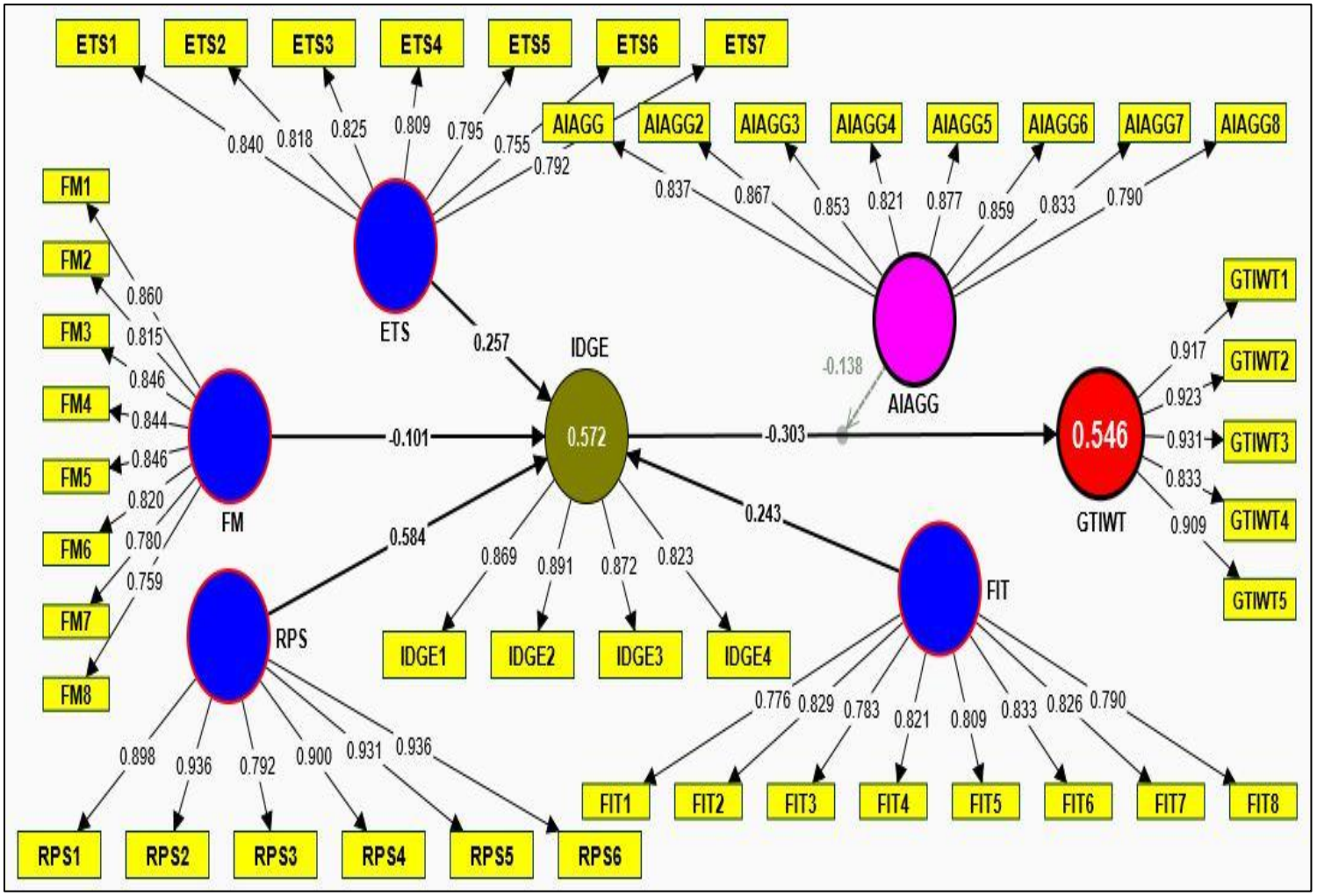


Figure 2. Measurement assessment model

4.4. Structural Assessment Model

PLS-SEM has two critical phases: the structural prototypical and the measurement typical. This discussion focuses on the structural evaluation template, which assesses correlations between exogenous and endogenous variables. This section reports statistical values such as path coefficients (β values), coefficient of determination (R2), predictive relevance (Q2), effect size (f2), and t values. The PLS-SEM literature has established criteria for estimating the significance level of path coefficients and evaluating hypotheses. We assessed hypothesis significance using bootstrapping with 5000 subsamples at the 5% significance level (one-tailed) (Hair et al., 2011). The findings indicate that only H2 is not supported. The outstanding suppositions, such as ETS ($\beta = 0.257$, $t = 1.938 > 1.64$, $p < 0.05$), RPS ($\beta = 0.584$, $t = 17.345 > 1.64$, $p < 0.05$), FIT ($\beta = 0.243$, $t = 4.977 > 1.64$, $p < 0.05$), IDGE as

direct relation ($\beta = 0.354$, $t = 2.110 > 1.64$, $p < 0.05$), and AIAGG as moderator ($\beta = 0.138$, $t = 3.735 > 1.64$, $p < 0.05$) and AIAGG as direct relation ($\beta = 0.917$, $t = 5.306 > 1.64$, $p < 0.05$) have a substantial and constructive influence on GTIWT.

The representation has strong explanatory power because the R^2 value for GTIWT is 0.546. This suggests that RE policy mechanisms can influence wind turbine GTIWT. Nevertheless, the model's efficiency and efficacy do not depend solely on R2; this single value is insufficient to evaluate the model [81]. Consequently, measuring predictive relevance in the structural assessment model is a suitable approach in Q^2. The Q^2 value is more sophisticated and refined than zero, as the strong predictive relevance of the latent exogenous standards shows [80]. The model's predictive relevance is both positive and significant, as evidenced by the Q^2 value of 0.291 in the current study. This suggests that adopting RE policy mechanisms, including FIT, ETS, FM, and RPS, has increased GTIWT in HWT. F^2 has a technical value. The three effect sizes, small, medium, and large, are represented by 0.02, 0.15, and 0.35, respectively [77]. Therefore, the effect sizes of the f^2 values vary from medium to large (refer to Table 7). This study employs a variety of statistical techniques, which are detailed in Table 7. FM has no encouraging or substantial effect on GTIWT, and all variables in this study's model that show a positive and significant relationship have t-values greater than 1.64. The results suggest that the moderating variables are significantly correlated with the constructs in the structural pattern, which is designed to interest GTIWT for HWT in Pakistan. Table 7 displays hypothesis testing using structural evaluation model. Figure 3 illustrates the structural evaluation template.

Table 7. Structural evaluation model results (Hypothesis testing)

Factors	Hypothesis	B-values	S.D.	T-values	P-values	Supported	R^2	Q^2	f^2
H1	ETS -> IDGE	0.257	0.133	1.938	0.045	Yes			0.155
H2	FM -> IDGE	0.101	0.144	0.705	0.483	No			0.011
H3	RPS -> IDGE	0.584	0.034	17.345	0.000	Yes			0.215
H4	FIT -> IDGE	0.243	0.049	4.977	0.000	Yes			0.205
H5	IDGE -> GTIWT	0.354	0.168	2.110	0.037	Yes	0546	0.291	0.140
H6	AIAGG x IDGE -> GTIWT	0.138	0.037	3.735	0.000	Yes			0.190
H7	AIAGG -> GTIWT	0.917	0.173	5.306	0.000	Yes			0.223

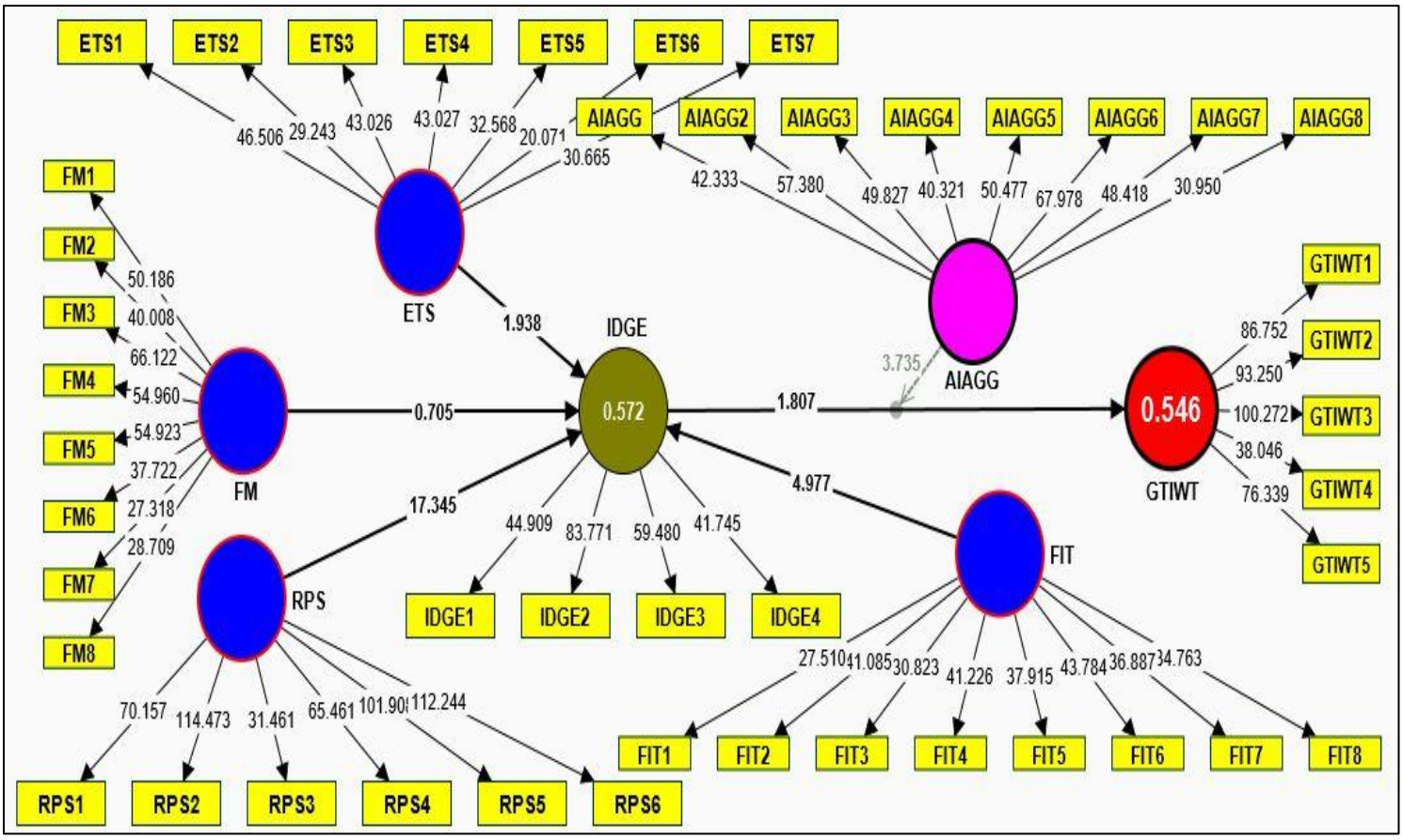


Figure 3. Structural assessment models.

5. Discussion and implications

Policymakers and residents have been compelled to explore alternative energy sources in Pakistan because of severe electricity load-shedding and energy shortages. GTIWT is positively correlated with the RE policy instruments. The results suggest that the FIT strategy is the most appropriate RE policy instrument for attracting wind-based GTIWT. The results corroborated the previous investigation [30], which indicated that the FIT strategy has a positive impact on RE share. The FIT policy instrument guarantees RE producers a fixed compensation rate for a designated duration. The results also indicated that the selected RE plan instruments, including RPS, FIT, and ETS, have a positive and substantial effect on GTIWT, particularly in Pakistan's HWT. The results align with previous research [82], which shows that FIT is a significant policy instrument with the potential to attract global GTIWT in RE. The study supported five of the six hypotheses but rejected one because it lacked an arithmetic implication. ETS ($\beta = 0.257$, $t = 1.938 > 1.64$, $p < 0.05$) is accepted as the first hypothesis, as indicated by the statistical analysis. This study examines the effectiveness of energy policy instruments for wind technology to address this knowledge gap. The results confirmed the previous investigation's findings [9]. The study's supplementary objective is to encourage residents to integrate wind technology into their households by incorporating three factors that may influence their energy intentions and provide low-cost energy benefits: economic growth, significant environmental change, and wind technology integration.

The research found that FIT is the most efficient policy method for significantly attracting GTIWT for HWT in Pakistan and globally. The outcomes align with previous research by [83], which indicates that RE strategy methods, such as FIT, enable RE generation development worldwide. The RPS strategy has a beneficial impact on the fascinating GTIWT for HWT; however, Pakistan has not implemented it. The results align with the previous study [84], show that the RPS mechanism positively affects local investors by reducing investment risk and increasing returns when designed appropriately in HWT. FM or tax

incentives have an insignificant effect on alternative power schemes, specifically in HWT schemes, through residents in Pakistan. Accepting the third hypothesis supports the current research. The statistical test supports this finding (RPS: $\beta = 0.584$, $t = 17.345 > 1.64$, $p < 0.05$). These results are consistent with the previous study (Khan et al., 2020a), indicating that RPS has a substantial positive effect on HWT projects by attracting local investors through tax incentives. In contrast, public investing is negatively correlated with GTIWT, as stakeholders do not rely on management resources. The current research supports the fourth hypothesis. The FIT is accepted, as indicated by the statistical test ($\beta = 0.243$, $t = 4.977 > 1.64$, $p < 0.05$). Pakistan's energy shortage is not being effectively addressed by the immense potential of renewable energy sources because of a lack of attractive infrastructure and supportive policies [2]. This study addresses the policy deficit by proposing the implementation of advanced instruments within existing policies to attract local investors in HWT. The most potent policy instruments for attracting global investment in the RE segment are FITs, tax incentives, and RPS.

Numerous researchers have encountered obstacles in RE policy tools. However, no investigator has yet characterized and assessed current RE policy tools across various influences to determine the most effective instrument for attracting GTIWT in Pakistan. This research gap requires thorough investigation. This investigation aims to identify the most efficient policy mechanism for Pakistan to attract investment. We compared the effectiveness of four RE strategy mechanisms, FIT, RPS, FM, and ETS, in attracting investors to Pakistan to improve the HWT segment. Statistical testing supports IDGE as a direct effect ($\beta = 0.354$, $t = 2.110 > 1.64$, $p < 0.05$), and this research accepts the 5th hypothesis. Statistical testing also supports the 6th hypothesis, which is acknowledged and supports the proposed exploration. AIAGG serves as a moderator ($\beta = 0.138$, $t = 3.735 > 1.64$, $p < 0.05$). The results suggest that the FIT policy is the most effective policy method for HWT. This is due to several factors, including long-standing (15-20 years) agreements, cost advantages, strong credibility, and diverse values across RE resources. The model has strong explanatory power, with an R2 of 0.546 for IDGE → GTIWT. This study suggests that RE policy mechanisms can influence GTIWT for wind power plans. Consequently, the analytical importance measurement of the structural template is a suitable approach in Q^2. In the current investigation, the Q^2 value is 0.291, suggesting that the demonstration has substantial analytical application and is positive. This study indicates that green investment in HWT is increasing due to the adoption of RE plan mechanisms such as FIT, ETS, and RPS. The t-values in the current research exceed 1.64, and H2 has a negative and insignificant impact on green investment in HWT. All variables in this study's model show positive, significant relationships.

By integrating critical socioeconomic, energy policy instruments, and sustainability factors into a unified theoretical framework, this research contributes to literature. It explains how these factors influence residents' development and the outcomes of sustainable wind technology. The research also identifies the mechanisms underlying the proposed relationships, thereby enabling a deeper theoretical understanding that extends beyond direct associations with green energy. Furthermore, it builds upon previous research by examining these relationships in an emerging-economy context, where such evidence is scarce. Overall, the findings reinforce the current theoretical explanation by providing a context-specific framework to guide future research on the adoption of sustainable wind technology and green energy.

5.1 Theoretical Contributions

The FIT strategy is important to Pakistan if implemented effectively. Furthermore, we conducted semi-organized discussions with management policymakers, energy economists, energy policy researchers, and energy policymakers to address the substantial obstacles to HWT in Pakistan. Finally, we offer policy recommendations for administrative bodies and legislators to remove these barriers, revise RE policy approaches, and engage local stakeholders to advance HWT in Pakistan. Pakistan has substantial renewable energy potential, particularly in HWT; however, policy obstacles substantially impede investment in the energy sector. Therefore, the nation must implement alternative renewable energy technologies effectively and efficiently to overcome these formidable obstacles and attract international investment. The RE sector, particularly HWT, lacks clear RE policies that enable participation by international and local private investors. Delays in allocations or clearances discourage international and local private stakeholders from pursuing renewable developments. Acquiring energy producers under a secure-rate power purchase contract is an inadequate incentive for global or local power producers to invest in renewable energy sources because costs fluctuate. The environmental structure is inadequate and vulnerable to both domestic and worldwide shareholders.

The current FIT approach is poorly employed, fails to attract investment, and is not justified. It focuses mainly on conventional, outdated power bases and needs attractive programs for renewable energy. The subsidy mix is unbalanced, as most grants are allocated to fossil fuels to attract investment rather than renewable sources. Inadequate collaboration and expertise among numerous policymaking departments, groups, associations, and other participants may delay policy implementation. International investors are demotivated, and delays in allocating projects to international or local investors limit the expansion, encouragement, and commercialization of renewable energy. The energy sector lacks an inclusive organizational structure because it lacks a central body. Current energy policies are ineffective at controlling energy costs and practices, leading to misuse of funding and grants because of the absence of international-level legislation. Renewable technology penetration is limited in Pakistan because policy regulators lack awareness, and the RE sector faces non-combination problems in controlling strategy.

5.2. Practical Implication

The RE sector faces obstacles to professional, high-speculative activity and financial constraints, mainly due to limited access to small-scale lending facilities. The short benefit cycle and low returns are among the many factors that discourage domestic investors from investing in Pakistan's real estate sector. Nevertheless, these conditions can entice investors, including high efficiency, shorter growth periods, and low fund budgets for investment preferences. Inadequate economic funding in the RE industry creates an obstacle: high investment costs. This lack of support also hinders equipment operation and maintenance, along with constraints on working assets and a weak customer support infrastructure. Political issues in Pakistan have consistently undermined RE policy. Despite political resistance, the government apparatus has failed to implement necessary changes, even though essential and emerging RE procedures require significant reform. Pakistan faces operational RE challenges, including political influence, unrealistic targets, inadequate environmental research and development, and insufficient planning. Pakistan's democratic government's primary shortcoming is policy prioritization: theoretically sound but rarely implemented. Political parties abuse their authority, diverting subsidies meant for the renewable energy sector to other sectors. A complete lack of political will is confronting the alternative energy sector. Political party conflicts largely consume Pakistan's energy sector. Political parties focus on upcoming elections rather than Pakistan's community problems. Political parties

must reevaluate their principles and recognize the national significance of the energy shortage.

6. Conclusions and recommendations

Even in developed or developing economies, a nation's economic development and progress depend on a neutral energy source across all regions. Pakistan, an improving economy, generates electricity using conventional fossil fuels to meet its energy needs. However, the current imbalance between energy demand and supply stems from population growth and heavy industrial development. Additionally, the findings indicate that the RE policy tools chosen in this analysis, including RPS, FIT, and ETS, have a substantial positive impact on GTIWT, particularly for HWT in Pakistan (see Table 7). The research determined that FIT is the most applicable policy tool for attracting GTIWT for HWT in Pakistan and worldwide. The RPS policy positively affects GTIWT attraction for HWT; however, Pakistan has not implemented it. FM or tax inducements have a negligible effect on alternative power schemes, specifically HWT projects funded by overseas stakeholders in Pakistan. In contrast, resident funds show a favorable correlation with GTIWT, as stakeholders do not rely on management assets. The research also suggests that carbon assessment and emissions negotiation are carbon-evaluation tools that strongly appeal to GTIWT; however, Pakistan has not implemented them. The lack of perceived long-term stability is why private investment is not being attracted to government funds or public speculation for HWT estimates. In this article, we examined how RE policy mechanisms fail to attract GTIWT to Pakistan's RE sector, particularly in HWT.

Furthermore, Pakistan's renewable energy strategies and tax incentives are inadequate for attracting stakeholders to its wind power sector. We found that other factors, rather than policy instruments, often attract GTIWT. The outcomes suggest that the FIT strategy interests GTIWT in RE across all classifications, but Pakistan does not employ it properly. In addition to attracting residents to HWT in Pakistan, RPS policies have a substantial and positive impact on Pakistan's wind and substitution energy strategies by attracting local stakeholders. The findings suggest that the moderating variable (AI-based good governance) is strongly correlated with positive indicators in the structural model designed to attract green investment in HWT in Pakistan. In Pakistan, GTIWT is attracted to carbon pricing instruments, including emissions trading and carbon taxation. Pakistan's practical transportation and economic sources are insufficient to facilitate the expansion of renewable energy equipment. These findings also apply to other South Asian states, such as India, Sri Lanka, and Bangladesh, through the implementation of FIT, RPS, and ETS policy mechanisms to encourage investment in the renewable energy sector, particularly HWT. Pakistan's administration has followed restricted policy approvals to address the HWT obstacles mentioned above and advance the RE sector [45]. To increase demand for HWT in Pakistan, the government, stakeholders, and RE-related institutions must collaborate cohesively and integrate their efforts. These conclusions are implicit; this investigation requires additional quantitative studies. Nevertheless, we suggest pursuing this promising research area further.

Consequently, to attract GTIWT interest in wind power estimates in other developing countries, potential authors must examine the effects of other RE policy mechanisms, including C.T. and NEMET. Additionally, future research must expand the sample size of countries and country-level data due to data constraints. The consistent evaluation can be applied to other Asian development territories or contexts to assess the feasibility of RE policy mechanisms for regional authorities and to encourage GTIWT to invest in low-carbon power machinery. Pakistan's federal government does not manufacture wind turbines, and

local wind-system technology is unavailable. The nation's equipment and essential components depend on imported technology. Accurate wind maps are not used to assess wind speed intensity. The installation and operation of large-scale HWT projects depend on foreign sources. Pakistan faces technical challenges, including a lack of standards and energy storage, inadequate exploration and expansion, limited infrastructure, and limited knowledge of maintenance and operations. RE technology lacks procedures and guidelines on durability, reliability, and performance. These issues prevent RE from achieving its large-scale commercialization objectives. Storage disrupts electricity grids because of the primary technical issue: an imbalance between demand and supply. The final section presents the conclusions. Therefore, researchers interested in adopting HWT must identify the remaining components while considering this study's findings. In a developing nation like Pakistan, we have chosen RE policy instruments.

Consequently, the findings of the present investigation are not equally applicable to both developed and underdeveloped nations. Therefore, the authors must conduct further research to determine the most effective methods for encouraging investors to invest in HWT in developed countries. GTIWT is influenced by a variety of factors and policy instruments that are not included in this investigation. Future researchers should examine additional factors not addressed in this study. Data collection in this study is not comprehensive because it relies on a single source. Future scholars should include additional data sources when replicating this research to strengthen data validity. Similarly, the research assessed the RE policy instruments currently in operation and implemented through a nationwide strategy in Pakistan, an expanding nation, to attract international investment. As a result, the current investigation applies equally to developed and developing countries. Authors must therefore, in the expectations, determine the influence of other strategy mechanisms on RE to interest investment in both developed and underdeveloped nations.

6.1. Policy recommendations

Additionally, the administration should recruit local and international experts specializing in HWT from advanced countries. The nation should reduce its heavy reliance on fossil-fuel power and improve RE capacity by implementing RPS and FIT. These policy tools can attract and encourage energy producers to invest in HWT. To promote renewable energy development, the nation must implement sustainable, innovative financing programs. The administration should retain attractive RE finance and loan provisions and requirements, particularly for small shareholders, to promote RE development. To address tariff restrictions, establish tax standards, and obtain power from non-utility generators, NEPRA and AEDB should consult. Develop power purchase mechanisms and measures tailored to commercial-scale household wind energy turbines. This investigation yields empirical and theoretical implications. The substantial literature review makes a global contribution to the literature on CO_2 emission reduction and RE policy. This study investigates the effectiveness of four RE policy mechanisms, FIT, RPS, FM, and ETS, in attracting GTIWT to the nation. By establishing the effect of these four RE policy tools on GTIWT for both expanding and acquiring nations, such as Pakistan, this study expands the literature. To encourage local and external stakeholders to support the sustainable growth of HWT schemes in Pakistan, the present study offers practical strategies for relevant RE regulatory bodies, ADEB and NEPRA, to adopt and effectively implement the current policy tools.

Because the study's guidelines enhance the energy sector's performance by attracting GTIWT to HWT projects, they are of paramount significance to RE policymakers and competent authorities in Pakistan. Effective planning of RE policy mechanisms can engage both regional and overseas stakeholders, thereby improving HWT project performance by

improving GTIWT in the nation. Therefore, RE policy mechanisms can attract substantial financing for HWT initiatives, provided expert management frameworks and an administration-owned legislative framework, such as WAPDA in Pakistan, define them adequately. Furthermore, Pakistan's RE guidelines and tax incentives are inadequate to attract shareholder financing for HWT. We also found that factors other than policy instruments attract GTIWT. For instance, a FIT policy can attract GTIWT in RE across all categories; however, Pakistan has not implemented it effectively.

Appendix A

Table A1. Horizontal cross-questioning and the way respondents (energy policymakers, energy economists, and energy policy researchers) engaged in the semi-structured interview. Measure progress by implementing sustainable household wind turbine performance, as determined by HWT proprietors.

Variable	Items	Cross-examinations	%
Emission trading scheme	EST1	The ETS viewpoint is a crucial tool for home wind turbine energy policy.	25.4
	EST2	Installing an ETS has the potential to boost profits and attract new residents and owners for HWT.	21.5
	EST3	The broad adoption of home wind turbine technology allows the ETS to obtain sufficient electricity.	25.6
	EST4	Improved home wind turbine technology may affect ETS's profitable development.	24.4
	EST5	One of the most important tools for residential wind turbine energy strategy is the successful implementation of the ETS	18.3
	EST6	Emissions-trading policy instruments could increase revenue and attract new residents for HWT.	6.0
	EST7	ETS policy instruments affect the technology of home wind turbines, which may evolve.	4.3
Fiscal measures	FM1	Implementing FM for operating domestic wind turbines can increase prosperity and minimize natural resource consumption.	20.2
	FM2	Natural resource reduction is the term used to describe FM implemented to justify environmental preservation and the operation of household wind turbines.	14.5
	FM3	It is imperative to implement FM that provide government support for domestic wind turbines to modify residents' behavior.	10.6
	FM4	Implementing FM for domestic wind turbines has the potential to enhance residents' prosperity.	10.5
	FM5	To support the operation of domestic wind turbines and preserve the environment, FM are implemented.	9.7
	FM6	The government provides FM to modify residents' behavior by supporting domestic wind turbines.	8.0
	FM7	The potential of wind turbines to enhance prosperity and reduce the consumption of fossil fuels can be supported by FM	15.5
	FM8	To support the operation of domestic wind turbines and preserve the environment, FM are implemented.	10.6
Renewable portfolio standard	RPS1	Utilizing domestic wind energy can improve the economic feasibility of an RPS.	17.2
	RPS2	Implementing RPS in HWT can support organizations' financial and environmental growth.	16.4
	RPS3	Understanding its implementation is a prerequisite for approving domestic HWT in pastoral regions under the RPS policy.	22.2
	RPS4	Adopting RPS policy instruments for HWT in the study area has the potential to reduce the use of grid-linked energy.	14.5
	RPS5	Household wind turbine technology has the potential to mitigate	19.3

		the impact of RPS policy and fossil fuel-based power.	
	RPS6	The RPS policy instrument can enhance the economic efficacy of wind energy.	10.4
Feed-in-Tariff	FIT1	The contentment of users with the Feed-in-Tariff policy for wind turbines to encourage residents	14.2
	FIT2	The Feed-in-Tariff policy for wind turbines is implemented to encourage efficient resource utilization.	11.4
	FIT3	The Feed-in-Tariff policy for wind turbines is designed to enhance the performance of existing household wind turbines.	22.3
	FIT4	The Feed-in-Tariff policy offers a natural energy strategy and efficient justifications to motivate residents to engage in HWT.	13.1
	FIT5	The Feed-in-Tariff policy can encourage residents to propose clean energy plans.	16.5
	FIT6	The Feed-in-Tariff policy can encourage the local community's clean energy strategy to contribute to sustainable development.	11.5
	FIT7	To encourage residents, the Feed-in-Tariff policy permits the operation of domestic wind turbines.	6.6
	FIT 8	The Feed-in-Tariff policy is recognized as a sustainable energy strategy and provides effective incentives to recruit investors in green energy.	15.8
Intention to develop green energy with household wind turbines	IDGE1	Raise awareness of the environmental consequences of incorporating household wind turbine technology.	26.6
	IDGE2	Acceptance of household HWT depends on residents' intention to change their financial behaviour by using household wind turbines to generate green energy.	27.4
	IDGE3	The objective is to attract residents involved in rural and pastoral ventures by using household wind turbines to develop renewable energy.	25.8
	IDGE4	Residents' profitability is enhanced by their intention to develop green energy.	20.2
AI-based awareness of good governance	AIAGG1	The adoption of HWT can be facilitated by comprehending AI-based awareness of good governance.	20.2
	AIAGG2	By raising awareness, artificial intelligence has the capacity to draw in new residents.	23.2
	AIAGG3	The adoption of HWT for the benefit of rural residents can be facilitated by AI-based awareness of good governance.	17.4
	AIAGG4	AI-based awareness of good governance can also be advantageous to rural residents.	7.0
	AIAGG5	AI-based awareness of good governance, which enables the administration to attribute the presence of domestic wind turbines to residents.	11.3
	AIAGG6	The potential to lure domestic HWT in rural areas is present due to AI-based awareness of good governance.	8.3
	AIAGG7	AI-based awareness of the adoption of good governance in HWT has the potential to attract new residents.	7.1
	AIAGG8	The comprehension of HWT can be facilitated by AI-based awareness of the adoption of good governance.	5.5
Green technology investment in wind turbines	GTIWT1	A critical instrument for the development of a residential wind turbine energy policy is the investment in green technology in wind turbines.	18.5
	GTIWT2	The potential to increase profits and attract new residents is present with the investment of green technology in wind turbines.	22.5
	GTIWT3	Residents who are engaged in resident ventures in rural areas may be attracted to green technology investments in wind turbines.	19.6

GTIWT4	The presence of green technology investment in wind turbines in rural areas is attributable to the awareness of HWT.	21.3
GTIWT5	The administration can attribute the presence of wind energy to the investment in green technology in wind turbines.	18.0

Author contribution SA: formal analysis, data handling, conceptualization, supervision, writing-original draft, variable construction, and methodology; : SY: funding acquisition; NMS: writing and editing, formal analysis

Data availability: The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

Declarations:

Ethical approval: This study received ethical approval from the Research Committee of Othman Yeop Abdullah Graduate School of Business (OYAGSB), Universiti Utara Malaysia, Kuala Lumpur, Malaysia. (protocol, 1881–16 on 24 March 2026). All procedures involving human participants were conducted in accordance with the ethical standards and regulations of Universiti Utara Malaysia, Kuala Lumpur, Malaysia, and complied with the principles of the Declaration of Helsinki.

Consent to Participate: Informed consent was obtained from all individual participants prior to their participation in the study. Participation was voluntary, and respondents were informed about the purpose of the research, as well as the anonymity and confidentiality of their responses.

Data Availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Consent to publish: Not applicable

Funding: No funding was received from any public, commercial, or non-profit funding agencies for the preparation of this study.

Clinical number: Not applicable

Competing interests: The authors have no competing interests to declare.

References

[1] Jahanger A, Hossain MR, Awan A, Sunday Adebayo T, Zubair Chishti M. Linking tourist's footprint and environmental tragedy through transportation, globalization and energy choice in BIMSTEC region: Directions for a sustainable solution using novel GMM-PVAR approach. J Environ Manage 2023;345. https://doi.org/10.1016/j.jenvman.2023.118551.

[2] Rehmani AM, Kazmi SAA, Altamimi A, Khan ZA, Awais M. Techno-Economic-Environmental Assessment of an Isolated Rural Micro-Grid from a Mid-Career Repowering Perspective. Sustain 2023;15. https://doi.org/10.3390/su15032137.

[3] Balocha MH, Chauhdary ST, Ishaka D, Kaloib GS, Nadeemb MH, Wattoo WA, et al. Hybrid energy sources status of Pakistan : An optimal technical proposal to solve the power crises issues. Energy Strateg Rev 2019;24:132–53. https://doi.org/10.1016/j.esr.2019.02.001.

[4] Khan MI, Khan IA, Chang YC. An overview of global renewable energy trends and current practices in Pakistan - A perspective of policy implications. J Renew Sustain Energy 2020;12. https://doi.org/10.1063/5.0005906.

[5] Ali S, Yan Q, Hussain MS, Irfan M, Ahmad M, Razzaq A, et al. Evaluating Green Technology Strategies for the Sustainable Development of Solar Power Projects : Evidence from Pakistan. Sustainability 2021;13:1–29. https://doi.org/10.3390/su132312997.

[6] Zameer H, Wang Y. Energy production system optimization: Evidence from Pakistan. Renew Sustain Energy Rev 2018;82:886–93. https://doi.org/10.1016/j.rser.2017.09.089.

[7] Ali Z, Din KU, Farid MA, Batool A. Harnessing Solar Potential in Pakistan: A Review of Renewable Energy Policies and Future Prospects. Adv J Econom Financ 2026;4:180–93. https://doi.org/299/330.

[8] NEPRA. NEPRA, "State of industry Report 2018," National Electric and Power Regulatory Authority (NEPRA),Government of Pakistan,. 2026.

[9] Kaplan EA, Büyükkör Y, Sarıtaş T, Aslan A. Digitalization and renewable energy sustainability: an empirical analysis of artificial intelligence and wind power in Europe. Environ Dev Sustain 2026. https://doi.org/10.1007/s10668-026-07895-0.
[10] Torres-Madroñero JL, Alvarez-Montoya J, Restrepo-Montoya D, Tamayo-Avendaño JM, Nieto-Londoño C, Sierra-Pérez J. Technological and operational aspects that limit small wind turbines performance. Energies 2020;13:1–39. https://doi.org/10.3390/en13226123.
[11] Moreira Chagas CC, Pereira MG, Rosa LP, da Silva NF, Vasconcelos Freitas MA, Hunt JD. From megawatts to kilowatts: A review of small wind turbine applications, lessons from the US to Brazil. Sustain 2020;12. https://doi.org/10.3390/su12072760.
[12] Omer-Alsultan G, Alsahlani AA, Mohamed-Alsultan G, Abdulkareem-Alsultan G, Nassar MF, Kurniawan TA, et al. Towards zero emission: exploring innovations in wind turbine design for sustainable energy a comprehensive review. Serv Oriented Comput Appl 2024. https://doi.org/10.1007/s11761-024-00426-7.
[13] Hassan A, Saleem M, Hasnain A. Pakistan's Climate Change Dilem...ortunities for Sustainable Development.pdf. J Emerg Trends Soc Sci Humanit 2025;2:41–51. https://doi.org/https://joetssh.com/index.php/joetssh/article/view/38.
[14] López M, Rodríguez N, Iglesias G. Combined floating offshore wind and solar PV. J Mar Sci Eng 2020;8. https://doi.org/10.3390/JMSE8080576.
[15] NEPRA. NEPRA Indicative Generation Capacity Expansion Plan IGCEP 2021-30; 2021; 2025.
[16] GOP-Government of Pakistan. AEDB-Alternative Energy Development Board: Alternative And Renewable Energy Policy, Islamabad. 2019.
[17] Afridi ZUR, Qammar NW. Technical challenges and optimization of biogas plants. ChemBioEng Rev 2020;7:119–29. https://doi.org/10.1002/cben.202000005.
[18] SAARC. USAID. South Asian regional intitative for energy integration: Developing power system intewgration & cross boader elctricity trade in SAARC region: current status & future outlook. 2025.
[19] Ilyas SZ, Hassan A, Mufti H. Review of the renewable energy status and prospects in Pakistan. Int J Smart Grid 2021;5. https://doi.org/10.20508/ijsmartgrid.v5i4.220.g174.
[20] Awan U, Knight I. Domestic sector energy demand and prediction models for Punjab Pakistan. J Build Eng 2020;32. https://doi.org/10.1016/j.jobe.2020.101790.
[21] IRENA. Statistical Review of World Energy International Renewable Energy Agency (IRENA). 2025.
[22] Jan ST, Alanazi A, Feroz M, Alanazi M. Techno-economic analysis of renewable energy sources' potential in the rural northern region of Kalam in Pakistan. vol. 27. Springer Netherlands; 2025. https://doi.org/10.1007/s10668-023-04350-2.
[23] Ali S, Yan Q, Sun H, Irfan M. Sustainable green revolution through the development of solar power projects in Pakistan: a techno-economic analysis. Environ Sci Pollut Res 2023. https://doi.org/10.1007/s11356-023-28117-4.
[24] Shah SB, Harijan K, Tunio MM, Abro R, Shaikh PH, Kumar L, et al. Economic Viability of Photovoltaic Power Plant for Sukkur – Pakistan. Eurasian J Anal Chem 2018;13. https://doi.org/10.29333/ejac/94448.
[25] Amir SM, Liu Y, Shah AA, Khayyam U, Mahmood Z. Empirical study on influencing factors of biogas technology adoption in Khyber. Energy Environ 2019;31:308–29. https://doi.org/10.1177/0958305X19865536.
[26] Ullah H, Kamal I, Ali A, Arshad N. Investor focused placement and sizing of photovoltaic grid-connected systems in Pkiastan. vol. 121. Elsevier Ltd; 2018. https://doi.org/10.1016/j.renene.2017.12.048.
[27] Balsalobre-lorente D. Assessing Wind Energy Projects Potential in Pakistan : Challenges and Way Forward. Energies 2022;15. https://doi.org/10.3390/en15239014.
[28] Das S, Dutta R, Pati S, Chowdhury R, De S. Enhancing Sustainability in Distributed Hybrid Cogeneration Through Smart Energy Management: A Multi-Criteria Decision-Making Approach. Process Integr Optim Sustain 2025:937–58. https://doi.org/10.1007/s41660-025-00590-z.
[29] Anukoonwattaka W, Mikic M. MYANMAR : OPENING UP TO ITS TRADE AND FOREIGN DIRECT INVESTMENT List of Figures List of Tables. United Nations ESCAP Econ Soc Comm Asia Pacific 2012;1. https://doi.org/10.2139/ssrn.2247006.
[30] Wall R, Grafakos S, Gianoli A, Stavropoulos S. Which policy instruments attract foreign direct investments in renewable energy? Clim Policy 2019;19:59–72. https://doi.org/10.1080/14693062.2018.1467826.
[31] Janak J. Do renewable portfolio standards increase renewable energy capacity? Evidence from the United States. J Environ Manage 2021;287. https://doi.org/10.1016/j.jenvman.2021.112261.
[32] Uzair Yousuf M, Malik MH, Umair M. 4E Analysis of solar photovoltaic, wind, and hybrid power systems in southern Pakistan: energy, exergy, economic, and environmental perspectives. Sci Technol

Energy Transit 2024;79. https://doi.org/10.2516/stet/2024088.
[33] Zhang M, Liu L, Wang Q, Zhou D. Valuing investment decisions of renewable energy projects considering changing volatility. Energy Econ 2020;92:104954. https://doi.org/10.1016/j.eneco.2020.104954.
[34] Tu Q, Betz R, Mo J, Fan Y. The profitability of onshore wind and solar PV power projects in China - A comparative study. Energy Policy 2020;132:404–17. https://doi.org/10.1016/j.enpol.2019.05.041.
[35] Lin B, Jia Z. Is emission trading scheme an opportunity for renewable energy in China ? A perspective of ETS revenue redistributions. Appl Energy 2020;263:114605. https://doi.org/10.1016/j.apenergy.2020.114605.
[36] Regional E, Sustainability P, Wind U, Optimization FL. Establishing Regional Power Sustainability and Feasibility Using Wind Farm Land-Use Optimization. Land 2021;10:442. https://doi.org/10.3390/land10050442.
[37] Das P, Amin SMM, Lipu MSH, Urooj S, Ashique RH, Al Mansur A, et al. Assessment of Barriers to Wind Energy Development Using Analytic Hierarchy Process. Sustain 2023;15. https://doi.org/10.3390/su152215774.
[38] Matos C, Ferrando-carrasco R, Florido N, Cabrera P. Wind Energy in Spain : Technological Evolution , Market Dynamics and Policy Outlook to 2030. Processes 2026;14:1–20. https://doi.org/10.3390/pr14152437.
[39] Polzin F, Migendt M, Täube FA, von Flotow P. Public policy influence on renewable energy investments-A panel data study across OECD countries. Energy Policy 2015;80:98–111. https://doi.org/10.1016/j.enpol.2015.01.026.
[40] Zeeshan F, Sultan S, Sunday AT, Korkut PU, Farrukh S. Role of Export Diversification and Renewable Energy on the Load Capacity Factor in Indonesia : A Fourier Quantile Causality Approach. Front Environ Sci 2022;9:434. https://doi.org/10.3389/fenvs.2021.770152.
[41] Cardenas LM, Franco CJ, Dyner I. Assessing emissions-mitigation energy policy under integrated supply and demand analysis: The Colombian case. J Clean Prod 2016;112:3759–73. https://doi.org/10.1016/j.jclepro.2015.08.089.
[42] Alola AA, Adebayo TS, Onifade ST. Examining the dynamics of ecological footprint in China with spectral Granger causality and quantile-on-quantile approaches. Int J Sustain Dev World Ecol 2021:1–14. https://doi.org/10.1080/13504509.2021.1990158.
[43] Islam MT, Shahir SA, Uddin TMI, Saifullah AZA. Current energy scenario and future prospect of renewable energy in Bangladesh. Renew Sustain Energy Rev 2014;39:1074–88. https://doi.org/10.1016/j.rser.2014.07.149.
[44] Wijayatunga PDC, Prasad D. Clean energy technology and regulatory interventions for Greenhouse Gas emission mitigation: Sri Lankan power sector. Energy Convers Manag 2009;50:1595–603. https://doi.org/10.1016/j.enconman.2009.02.005.
[45] Aized T, Shahid M, Bhatti AA, Saleem M, Anandarajah G. Energy security and renewable energy policy analysis of Pakistan. Renew Sustain Energy Rev 2018;84:155–69. https://doi.org/10.1016/j.rser.2017.05.254.
[46] Ogunrinde O, Shittu E, Dhanda KK. Investing in renewable energy: Reconciling regional policy with renewable energy growth. IEEE Eng Manag Rev 2018;46:103–11. https://doi.org/10.1109/EMR.2018.2880445.
[47] Izdebski W, Kosiorek K, Mirowski K, Pietrek G, Grzeszczyk TA. Economic and Social Determinants of Biogas Production Processes in Europe. Energies 2026;19:1–21. https://doi.org/10.3390/en19081897.
[48] Zhang Q, Wang G, Li Y, Li H, Mclellan B, Chen S. Substitution e ff ect of renewable portfolio standards and renewable energy certi fi cate trading for feed-in tariff. Appl Energy 2017;227:426–35. https://doi.org/10.1016/j.apenergy.2017.07.118.
[49] Malik S, Qasim M, Saeed H. Green finance in Pakistan : Barriers and solutions October 2018 Asian Development Bank Institute. Asian Dev Bank Inst (ADBI), Tokyo This 2018;880. https://doi.org/10419/190301.
[50] Nevzorova T, Karakaya E. Explaining the drivers of technological innovation systems: The case of biogas technologies in mature markets. J Clean Prod 2020;259:120819. https://doi.org/10.1016/j.jclepro.2020.120819.
[51] Wijayatunga PDC. Regulation for renewable energy development: Lessons from Sri Lanka experience. Renew Energy 2014;61:29–32. https://doi.org/10.1016/j.renene.2012.04.026.
[52] Carley S, Baldwin E, MacLean LM, Brass JN. Global expansion of renewable energy generation: An analysis of policy instruments. Environ Resour Econ 2017;68:397–440. https://doi.org/10.1007/s10640-016-0025-3.
[53] Lüthi S, Wüstenhagen R. The price of policy risk — Empirical insights from choice experiments with European photovoltaic project developers. Energy Econ 2012;34:1001–11.

https://doi.org/10.1016/j.eneco.2011.08.007.
[54] Malik SA, Rahman A. Technology in society solar energy technology : Knowledge , awareness , and acceptance of B40 households in one district of Malaysia towards government initiatives. Technol Soc 2020;63. https://doi.org/10.1016/j.techsoc.2020.101416.
[55] Shah SAA, Zhou P, Walasai GD, Mohsin M. Energy security and environmental sustainability index of South Asian countries: A composite index approach. Ecol Indic 2019;106:105507. https://doi.org/10.1016/j.ecolind.2019.105507.
[56] Fu W, Zhou Y, Li L, Yang R. Understanding household electricity-saving behavior: Exploring the effects of perception and cognition factors. Sustain Prod Consum 2021;28:116–28. https://doi.org/10.1016/j.spc.2021.03.035.
[57] Polzin F, Egli F, Steffen B, Schmidt TS. How do policies mobilize private finance for renewable energy?—A systematic review with an investor perspective. Appl Energy 2019;236:1249–68. https://doi.org/10.1016/j.apenergy.2018.11.098.
[58] Budea S, Maravela GL, Florea GF, Mihai A, Voicu I. Design and the Operation Analysis of a Hybrid Solar Wind System for Sustainable Urban Energy. Energies 2025;18:1–15. https://doi.org/10.3390/en18236362.
[59] Khan SA, Mahmood W, Iqbal S, Farooq Q. The Impact of Integration in Supply Chain Macro Processes on Supply Chain Performance with The Moderating Role of Information System Support 2021;22:477–93.
[60] Abid N, Ikram M, Wu J, Ferasso M. Towards environmental sustainability : Exploring the nexus among ISO 14001 , governance indicators and green economy in Pakistan. Sustain Prod Consum 2021;27:653–66. https://doi.org/10.1016/j.spc.2021.01.024.
[61] Usman M, Kousar R, Yaseen MR, Makhdum MSA. An empirical nexus between economic growth, energy utilization, trade policy, and ecological footprint: a continent-wise comparison in upper-middle-income countries. Environ Sci Pollut Res 2020;27:38995–9018. https://doi.org/10.1007/s11356-020-09772-3.
[62] Calder BJ, Phillips LW, Tybout AM. Designing research for application. J Consum Res 1981;8:197–207. https://doi.org/10.1086/208856.
[63] Yeh S-S, Guan X, Chiang T-Y, Ho J-L, Huan T-CT. Reinterpreting the theory of planned behavior and its application to green hotel consumption intention. Int J Hosp Manag 2021;94:102827. https://doi.org/10.1016/j.ijhm.2020.102827.
[64] Chin W, Cheah J-H, Liu Y, Ting H, Lim X-J, Cham TH. Demystifying the role of causal-predictive modeling using partial least squares structural equation modeling in information systems research. Ind Manag Data Syst 2020;120:2161–209. https://doi.org/10.1108/IMDS-10-2019-0529.
[65] Cheng EWL. Choosing between the theory of planned behavior (TPB) and the technology acceptance model (TAM). Educ Technol Res Dev 2019;67:21–37. https://doi.org/10.1007/s11423-018-9598-6.
[66] Jr JFH, Marko S, Hopkins L, Kuppelwieser VG. Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. Eur Bus Rev 2014;26:106–21. https://doi.org/10.1108/EBR-10-2013-0128.
[67] Ali S, Yan Q, Irfan M, Ameer W, Atchike DW, Acevedo-Duque Á. Green Investment for Sustainable Business Development: The Influence of Policy Instruments on Solar Technology Adoption. Front Energy Res 2022;10. https://doi.org/10.3389/fenrg.2022.874824.
[68] Supriyati, Bahri RS, Komarudin E. Computerized of International Financial Report Standard For Good Governance in Small Medium Enterpreses. Mater. Sci. Eng., 2019. https://doi.org/10.1088/1757-899X/662/5/052009.
[69] Luo Y, Salman M, Lu Z. Heterogeneous impacts of environmental regulations and foreign direct investment on green innovation across different regions in China. Sci Total Environ 2021;759:143744. https://doi.org/10.1016/j.scitotenv.2020.143744.
[70] Hair JF, Risher JJ, Sarstedt M, Ringle CM. When to use and how to report the results of PLS-SEM. Eur Bus Rev 2019;31:2–24. https://doi.org/10.1108/EBR-11-2018-0203.
[71] Henseler J, Ringle CM, Sarstedt M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. J Acad Mark Sci 2015;43:115–35. https://doi.org/10.1007/s11747-014-0403-8.
[72] Urbach N, Ahlemann F. Structural equation modeling in information systems research using Partial Least Squares. Int Conf Inf Syst ICIS 2012 2010;11:5–40. https://doi.org/228467554.
[73] Iqbal MB, Li J, Yang S, Sindhu P. Value-driven career attitude and job performance: An intermediary role of organizational citizenship behavior. Front Psychol 2022;13. https://doi.org/10.3389/fpsyg.2022.1038832.
[74] Jr JFH, Hult GTM, Ringle CM, Sarstedt M. A primer on partial least squares structural equation modeling (PLS-SEM). Sage publications. Eur J Tour Res 2014;6:211–3.

[75] Arbuckle JL. IBM SPSS Amos 20 user's guide." Amos development corporation, SPSS Inc. 2011.
[76] Anderson JC, Gerbing DW. Structural equation modeling in practice : A review and recommended two-step approach. Psychol Bull 1988;103:411–23. https://doi.org/1989-14190-001.
[77] Jacob C. Statistical power analysis for the behavioral sciences. Abingdon. England. Routledge 1988;2:15–21.
[78] Ali S, Yan Q, Dilanchiev A, Irfan M, Fahad S. Modeling the economic viability and performance of solar home systems: a roadmap towards clean energy for environmental sustainability. Environ Sci Pollut Res 2023;30:30612–31. https://doi.org/10.1007/s11356-022-24387-6.
[79] Baloch ZA, Tan Q, Kamran HW, Nawaz MA, Albashar G, Hameed J. A multi-perspective assessment approach of renewable energy production: policy perspective analysis. Environ Dev Sustain 2022;24:2164–92. https://doi.org/10.1007/s10668-021-01524-8.
[80] Akbar A, Ali S, Ahmad MA, Akbar M, Danish M. Understanding the antecedents of organic food consumption in pakistan: Moderating role of food neophobia. Int J Environ Res Public Health 2019;16:4043–51. https://doi.org/10.3390/ijerph16204043.
[81] Hair Jr JF, Hult GTM, Ringle CM, Sarstedt M, Danks NP, Ray S. Partial least squares structural equation modeling (PLS-SEM) using R: A workbook 2021.
[82] Rasheed H Bin, Zad HS, Malik MS, Arif M, Hashmi SK, Irfan M. Structural Design and Development of a Small-Scale Vertical Axis Wind Turbine for Urban Household Power Generation †. Eng Proc 2025;111:1–11. https://doi.org/10.3390/engproc2025111021.
[83] Akram MN, Abdul-Kader W. Designing a Sustainable Off-Grid EV Charging Station: Analysis Across Urban and Remote Canadian Regions. Batteries 2026;12. https://doi.org/10.3390/batteries12010017.
[84] Rybak A, Rybak A, Kolev SD. Forecasting the Development of Offshore Wind Energy in Poland in the Context of the Energy Transformation and Sustainable Development Goals. Energies 2025;18:1–21. https://doi.org/10.3390/en18205380.