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Article

Factors influencing the decision to use rooftop solar power systems in Vietnam

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Abstract: Renewable energy is gaining momentum in developing countries as an alternative to non-renewable sources, with rooftop solar power systems emerging as a noteworthy option. These systems have been implemented across various provinces and cities in Vietnam, accompanied by government policies aimed at fostering their adoption. This study, conducted in Ho Chi Minh City, Vietnam investigates the factors influencing the utilization of rooftop solar power systems by 309 individuals. The research findings, analyzed through the Partial least squares structural equation modeling (PLS-SEM) model, reveal that policies encouragement and support, strategic investment costs, product knowledge and experience, perceived benefits assessment, and environmental attitudes collectively serve as predictors for the decision to use rooftop solar power systems. Furthermore, the study delves into mediating and moderating effects between variables within the model. This research not only addresses a knowledge gap but also furnishes policymakers with evidence to chart new directions for encouraging the widespread adoption of solar power systems.

Keywords: rooftop solar power systems; decision-making; renewable energy adoption; PLS-SEM

1. Introduction

A rooftop photovoltaic (PV) system, commonly known as a rooftop solar power system, consists of solar panels installed on the rooftop of residential or commercial buildings or structures (Armstrong, 2014). Installers are authorized to supply solar electricity to the public grid, receiving a fair premium tariff per generated kWh. This tariff is designed to acknowledge the benefits of solar electricity and offset the current additional costs associated with photovoltaic (PV) electricity (HandWiki, 2022). The adoption of rooftop solar power systems represents a pivotal shift towards sustainable energy practices globally, with nations increasingly recognizing the importance of renewable energy in combating climate change and ensuring energy security.

One of the primary motivations for embracing renewable energy, particularly solar energy and photovoltaic systems is the urgent need to mitigate climate change and reduce greenhouse gas emissions (Kabeyi and Olanrewaju, 2022). Solar energy, being a clean and renewable resource, offers a way to significantly decrease reliance on fossil fuels, thereby curbing pollution and preserving the environment. Dependence on finite fossil fuels, coupled with geopolitical tensions, underscores the importance of transitioning to renewable energy sources like solar power (Hille, 2023). By harnessing the abundant sunlight, countries can enhance their energy security and reduce vulnerability to supply disruptions. Moreover, solar energy is inherently sustainable, as it relies on an essentially limitless resource: sunlight. Unlike fossil fuels, which are finite and contribute to environmental degradation, solar power offers a sustainable solution that can meet current and future energy needs without depleting natural resources.

The renewable energy sector presents significant economic opportunities. Investing in solar infrastructure stimulates job growth, fosters innovation, and promotes economic development in both urban and rural areas (Romero-Castro et al., 2022). Solar energy has the potential to democratize access to electricity, particularly in regions with limited grid infrastructure. Off-grid and decentralized solar solutions empower communities to generate their clean power, improving energy access and promoting social equity. Rapid advancements in solar technology, such as improvements in efficiency and reductions in costs, drive increased adoption and deployment of photovoltaic systems. Continued innovation in energy storage, grid integration, and smart technologies further enhances the feasibility and attractiveness of solar energy. Besides, transitioning to solar energy and other renewables offers significant public health benefits by reducing air and water pollution associated with fossil fuel combustion. Cleaner air leads to improved respiratory health and lower healthcare costs, benefiting communities worldwide. Recognizing the importance of these motivations, this article underscores the urgency of accelerating the transition to a sustainable energy future.

A digital questionnaire conducted among customers of the State Electricity Company (PLN) in Setyawati (2020) highlighted various consumer concerns regarding the adoption of solar photovoltaic systems. These concerns include substantial initial investment expenses, extended duration for return on investment, and inadequate access to information. Additionally, institutional challenges were identified, such as the restricted involvement of PLN and the absence of government funding mechanisms in Indonesia. Meanwhile, Zander et al. (2019) demonstrated that factors influencing decision-making are likely to include electricity usage, rising electricity costs, and decreasing storage solution expenses, potentially leading individuals to conclude that solar photovoltaic systems are financially advantageous even without government subsidies in Australia.

Vietnam stands at a crucial juncture in its energy trajectory, grappling with the dual challenge of meeting rising electricity demand and mitigating environmental concerns. Against this backdrop, the adoption of rooftop solar power systems emerges as a promising avenue to address these challenges while capitalizing on the country's abundant solar resources. The Vietnamese government has issued documents and initiatives showing interest in and promoting the use of rooftop solar power by citizens (The Prime Minister, 2017, 2020). Numerous investigations have been undertaken, encompassing the evaluation of the technical potential of rooftop solar power (Phap et al., 2020), an examination of the performance of rooftop solar power generation coupled with battery storage in an office building (Nguyen-Thanh et al., 2021), and the formulation, simulation, and economic scrutiny of a rooftop solar PV system (Nguyen and Van, 2021) in Vietnam. However, a limited number of studies provide a thorough depiction of the various factors influencing citizens' decisions to utilize rooftop solar power systems. Than et al. (2022) only explored the factors that affect the decision to invest in rooftop photovoltaic systems from subjective aspects of individuals (finance, attitude, knowledge...) in Vietnam. Moreover, the factors incorporated into the model are not entirely suitable, and there is redundancy. However, the growth in the use of solar power systems is also greatly influenced by policies encouragement and support. Supportive policies, such as feed-in tariffs, net metering, and renewable energy targets, can significantly influence individuals' decisions to invest in rooftop solar by making it more financially advantageous. This study aims to examine the subjective and objective factors influencing the use of rooftop solar power systems. Conducting this study contributes to the existing knowledge gap and supports policymakers in making more informed decisions in the future.

The article is stated in the following order. Section 2 presents the literature review, and section 3 describes the methodology, including research design, data collection, ethical considerations, measurement, and data analysis. Section 4 provides the results and some context-based discussion. Finally, the article draws some conclusions.

2. Literature review

2.1. Policies encouragement and support

Government initiatives, as elucidated by Taib et al. (2022), play a pivotal role in influencing people's actions or providing support. According to the findings by Kumar et al. (2019), variable government initiatives significantly shape consumer purchasing behavior. Liem and Nhan (2020) observed that excess power generated from rooftop solar systems, flowing into the national power grid through a power compensation mechanism, not only lowers monthly electricity bills but also contributes supplementary income to households. This governmental policy has a profound impact on the adoption of solar energy by individuals. Simplifying licensing processes and enhancing infrastructure in specific areas can boost deployment rates, with local governments and municipalities playing an active role (Bódis et al., 2019). Countries with abundant solar potential should focus on eliminating barriers to rooftop PV, requiring a centralized top-down approach to drive implementation, given the current emphasis on electricity affordability (Bódis et al., 2019). Additionally, public engagement in energy issues has been linked to adoption intentions (Parkins et al., 2018). From a policy perspective, community factors can be addressed through various public policy scenarios, such as installing solar panels in visible public spaces like community centers or facilitating venues for public engagement (Parkins et al., 2018). Hence, hypothesis H1 is proposed as below:

H1: Policies encouragement and support would positively influence decision to use rooftop solar power systems.

2.2. Strategic investment costs

In the consumer purchasing process, factors such as product prices and investment considerations hold significant importance. The cost of a product is influenced by various factors, including initial design, operational, and maintenance costs (Wadu Mesthrige and Kwong, 2018). Consumer perceptions of product costs are diverse and are shaped by individual financial backgrounds, educational levels, social exposure, and other variables. The study by Brucks (1985) emphasized that customers' views on product costs are intricately linked to their socio-economic conditions and educational backgrounds. The findings reveal that PV investment in certain Eastern European countries faces challenges in attractiveness despite similarities in resource availability. The underlying issue lies in addressing structural problems related to financing and pricing of electricity options (Bódis et al., 2019). Tan (2011) highlighted that high installation and investment costs act as significant deterrents for not adopting solar energy products. While there is interest in solar products, many individuals refrain from purchasing due to the perceived high costs, and a prolonged payback period is identified as a key obstacle (Zhai and Williams, 2012). Continued cost reductions in the PV technology sector, coupled with improvements in system efficiency, are expected to enhance the competitiveness of rooftop solar power systems (Bódis et al., 2019). Interactions among consumers indicate that a primary motivation for installing rooftop solar power systems is to reduce electricity bills (Bansal et al., 2019). Since, hypothesis H2 is proposed as below:

H2: Strategic investment costs would positively influence decision to use rooftop solar power systems.

2.3. Product knowledge and experience

Knowledge, a pivotal factor influencing every stage of the consumer decision-making process, encompasses how consumers acquire, manage, and analyze products in general (Alba and Hutchinson, 1987). Consumer product knowledge is multifaceted, encompassing subjective understanding, objective awareness, and knowledge gained through product experiences, with evaluations being influenced by these product-related encounters (Brucks, 1985). Stephahn's (2019) research indicated that a broader awareness of solar power systems among users significantly impacts the adoption of such technology. To facilitate adoption, companies are advised to furnish relevant information, knowledge, and operational techniques for solar energy products (Kumar and Hundal, 2020; Tan, 2011). Advertising plays a crucial role in disseminating product awareness, motivating purchases, altering perceptions and attitudes, and cultivating a positive public image (Alba and Hutchinson, 1987; Brucks, 1985). However, the perceived knowledge of the energy system is a key predictor of adoption intentions (Parkins et al., 2018). Instead of focusing solely on specific renewable energy options, governments can foster openness to adopting renewable energy by encouraging people to think and learn about the solar power system more broadly (Parkins et al., 2018). Interestingly, a majority of respondents learned about rooftop solar power systems through word of mouth, primarily from friends and family. Awareness campaigns and advertisements played a minor role in informing respondents about the installation of solar PV systems. This suggests that individuals rely heavily on the experiences and recommendations of acquaintances when making decisions regarding the installation of these systems (Bansal et al., 2019). Therefore, hypothesis H3 is proposed as below:

H3: Product knowledge and experience would positively influence decision to use rooftop solar power systems.

2.4. Perceived benefits assessment

The literature sheds light on the motivations driving the purchase of green products, elucidating why consumers opt for eco-friendly choices (Arshad Ali et al., 2020). This decision-making process presents a win-win situation for both the planet and its inhabitants. Notably, consumers exhibit a willingness to invest in pricier yet environmentally friendly products, presenting a significant opportunity for governmental initiatives aimed at fostering eco-friendly policies (Peattie, 2001). Furthermore, research by Duy and Kien (2014) emphasized the positive influence of the benefit factor on the acceptance of renewable energy. The tangible benefits derived from using renewable energy become easily discernible to consumers. An analysis of responses reveals that a substantial 95% of respondents possess awareness of rooftop solar power systems. While they acknowledge the potential economic and environmental benefits associated with these systems, the precise magnitude of these gains remains uncertain (Bansal et al., 2019). Consequently, consumer awareness of these benefits prompts them to weigh the efficiency advantages when considering product adoption, particularly in the context of this study on rooftop solar power. Thus, hypothesis H4 is proposed as below:

H4: Perceived benefits assessment would positively influence decision to use rooftop solar power systems.

2.5. Environmental attitudes

Environmental attitudes, defined as cognitive judgments closely tied to environmental protection, reflect an individual's worldview regarding the human-nature relationship or the environment (Stern, 2000). This mindset establishes a positive correlation with green behavior (Kotchen and Reiling, 2000). Ajzen (1991) underscored the influence of positive attitudes toward a specific behavior and attitudes concerning ecology and the environment on the decision-making process. Parsad et al. (2020) research indicated that households contemplating solar panels may be swayed by one of three motivational factors, with environmental motivation being a prominent driver. Additionally, Wahid et al. (2011) found a positive and significant relationship between environmental concern and volunteer participation among environmental volunteers in Penang. Consequently, hypothesis H5 is proposed as below:

H5: Perceived benefits assessment would positively influence decision to use rooftop solar power systems.

3. Methodology

3.1. Research design

The main aim of the study is to analyze the determinants that impact the choice to embrace rooftop solar power systems. The authors performed a study among individuals utilizing rooftop solar power systems in Go Vap District, Ho Chi Minh City, Vietnam. Ho Chi Minh City is the most populous city in Vietnam, with a high population density and significant energy demand. Like many urban centers, Ho Chi Minh City experiences environmental challenges such as air pollution and climate change. Meanwhile, Go Vap District has been considered as one of the highly urbanized districts of Ho Chi Minh City and has experienced periods of uncontrolled development. Compared to other districts, Go Vap also possesses a large land fund. According to statistics from the Ho Chi Minh City Statistics Office in 2019, the population of Gò Vấp district is 602,180 people. This makes it the second most populous district in the city (after Binh Tan district). Moreover, it is economically diverse, with various industries and income levels represented. According to the survey data of the Ho Chi Minh City Power Development Planning Project for the period 2016–2025, considering up to the year 2035, during the dry season, the number of sunlight hours reaches around 300 h per month (in October), and during the rainy season, the number of sunlight hours reaches around 150 h per month (in March). It has the highest rate of rooftop solar power system installation in Vietnam. Studying rooftop solar adoption in this environment allows for a comprehensive understanding of how economic and social factors influence decision-making. The study utilized a quantitative research approach, and the questionnaire was subjected to pre-testing with individuals who have expertise in or utilize rooftop solar power systems. To select individuals for the study, the authors employ a purposive sampling method. This method involves selecting participants based on specific criteria relevant to the research objectives. In this case, researchers purposefully select individuals who meet the criteria of having expertise in or utilizing rooftop solar power systems and residing in Gò Vấp District. Additionally, the educational backgrounds of participants may vary, but they may include individuals with backgrounds in engineering, environmental science, renewable energy, or related fields, or they may use rooftop solar power systems. These criteria ensure that the participants have relevant knowledge and experience to provide meaningful responses to the questionnaire. The assessment of all items was conducted using a 5-point Likert scale, where a rating of 1 indicated complete/strong disagreement and a rating of 5 indicated complete/strong agreement.

3.2. Data collection

According to Hair et al. (2014), the ideal number of samples for the Maximum Likelihood measure is often between 100 and 150. In the context of SEM analysis, a small sample is defined as being less than or equal to 100, a medium sample is defined as falling between 100 and 200, and a large sample is defined as exceeding 200. A total of 309 valid replies were received out of the 400 survey questionnaires given, resulting in a response rate of 77.25%.

3.3. Ethical considerations

The research rigorously followed ethical protocols for conducting investigations involving human participants, guaranteeing explicit agreement from both respondents and interviewers. The survey participants were extensively informed about the study through detailed information presented on the first page.

3.4. Measurement of variables

A questionnaire for this research was developed to assess the factors affecting people’s decision to use rooftop solar power systems. The survey questionnaire included 5 sub-scales based on the research hypothesis. The 5 sub-scales included: (1) policies encouragement and support (coded as PES); (2) strategic investment costs (coded as SIC); (3) product knowledge and experience (coded as PKE); (4) perceived benefits assessment (coded as PBA); (5) environmental attitudes (coded as EA); and (6) decision to use rooftop solar power systems (coded as DURSPS). All items were reported based on the 5-point Likert scale from 1—Completely/strongly disagree to 5—Completely/strongly agree. **Table 1** provides an overview of the questionnaire.

Table 1. Constructs and items.

Constructs	Variable code	Items	Sources
Policies encouragement and support (PES)	CS1	The government has specific regulations regarding support, incentives, and encouragement for the use of rooftop solar power.	(Duy and Kien, 2014; Kumar et al., 2019; Parsad et al., 2020; Phuong and Nghi, 2020; Stephahn, 2019)
	CS2	I have been informed about the government's policies and the benefits of using rooftop solar power.	
	CS3	The government and the electricity sector have created favorable conditions for the people when they have the need to invest in and use rooftop solar power.	
	CS4	When my rooftop solar power system produces excess electricity that I don't use, I can easily sell this surplus electricity back to the electricity sector.	
	CS5	I believe that the government is encouraging and promoting rooftop solar power systems more than investing in other large-scale projects in Ho Chi Minh City.	
Strategic investment costs (SIC)	CP1	In my opinion, the installation cost of rooftop solar power systems is currently suitable for income levels.	(Duy and Kien, 2014; Kumar et al., 2019; Phuong and Nghi, 2020)
	CP2	In my opinion, the investment cost is suitable for the quality of the product.	
	CP3	I think the government should support households with the initial investment costs.	
	CP4	I assess that the rooftop solar power system is a worthwhile investment.	
	CP5	The product prices and installation costs are relatively stable, with not much difference among the supplying companies.	
Product knowledge and experience (PKE)	KT1	I can easily find information about the technical standards of rooftop solar power systems.	(Duy et al., 2017; Duy and Kien, 2014; Kumar et al., 2019; Parsad et al., 2020; Stephahn, 2019)
	KT2	I have the necessary knowledge to assist someone with the technology and installation of rooftop solar power systems.	
	KT3	In my opinion, rooftop solar power systems are very easy to operate and maintain.	
	KT4	The installation of rooftop solar power systems is straightforward and does not compromise the aesthetic appeal of the house.	
	KT5	I know where to seek support when deciding to use and install a rooftop solar power system.	

Table 1. (*Continued*).

Constructs	Variable code	Items	Sources
Perceived benefits assessment (PBA)	LI1	Rooftop solar power is like a home-based independent system with a backup power source in case of a main power outage.	(Duy et al., 2017; Duy and Kien, 2014; Kumar et al., 2019; Phuong and Nghi, 2020)
	LI2	Using rooftop solar power can save monthly electricity costs for households.	
	LI3	Utilizing electricity from a rooftop solar power system is a good solution when the national electricity prices frequently increase.	
	LI4	In my opinion, installing rooftop solar power has increased the value of my home.	
	LI5	Using rooftop solar power makes activities and production more proactive.	
Environmental attitudes (EA)	MT1	I know that electricity from the national grid is generated from fossil energy sources such as coal-fired power plants, oil, natural gas, etc., causing significant environmental pollution.	(Duy and Kien, 2014; Kumar et al., 2019; Liem and Nhan, 2020; Parsad et al., 2020)
	MT2	I understand that global warming is a crucial issue that needs attention.	
	MT3	Using electricity from a rooftop solar power system contributes significantly to environmental protection.	
	MT4	I am willing to pay a higher cost to use rooftop solar power because I know it is beneficial for the environment.	
	MT5	While making any product purchase, I always consider environmentally friendly products.	
Decision to use rooftop solar power systems (DURSPS)	QD1	The decision to install a rooftop solar power system is the right one.	(Duy et al., 2017; Duy and Kien, 2014; Phuong and Nghi, 2020)
	QD2	The decision to install a rooftop solar power system is a suitable choice for present and future electricity use.	
	QD3	I am willing to recommend rooftop solar power to friends and colleagues.	

3.5. Data analysis

This study applies the partial least squares structural equation modeling (PLS-SEM) methodology to examine the hypothesized theory (Hair et al., 2011). PLS-SEM is particularly suitable for investigations seeking to identify primary explanatory factors within a target framework (Ringle and Sarstedt, 2016). The process of data analysis is carried out with the SmartPLS 4.0 software, which consists of two distinct stages: evaluation of measurement model and evaluation of the structural model. The study first evaluates the reliability, convergent validity, and discriminant validity of the measurement model for each scale. Construct reliability is evaluated using metrics such as composite reliability (CR), average variance extract (AVE), Cronbach's α, rho_a, and indicator loadings. A CR cutoff value of 0.7 is considered satisfactory for internal consistency reliability, while AVE must exceed 0.5, and Cronbach's alpha should be greater than 0.70 (Fornell and Larcker, 1981; Hair et al., 2014). The assessment of discriminant validity is conducted through the utilization of the Fornell-Larcker criterion and the heterotrait-monotrait ratio (HTMT), where a threshold value of 0.85 is considered as an acceptable indication of discriminant validity (Fornell and Larcker, 1981). In the second stage, the authors examine the size and significance of the coefficients, applying the Bootstrap method with 5000 samples to test the significance of the coefficients.

4. Results

4.1. Measurement model (outer model)

The estimation findings of the measurement model, as shown in **Table 2**, included outer weights, outer loadings, CR, Cronbach's α, AVE, and rho_a. All components had a CR greater than 0.70, which meets the criterion for internal consistency dependability as defined by Hair et al. (2014). The outer loadings for all items fell within the range of 0.743 to 0.876, meeting the criterion for indicator dependability (Hair et al., 2014). Nevertheless, three items (coded as CP3, KT2, and MT4) were still included, even though their loadings were below 0.70. This decision was based on their high reliability, as stated by Hair et al. (2016). Removing these items did not result in an improvement in their reliability. The variables exhibited internal consistency reliability, with values ranging from 0.721 to 0.885. The rho_a coefficients, which varied between 0.730 and 0.908, satisfied the predetermined conditions (Hair et al., 2019). The AVE for all constructs varied between 0.577 and 0.686, above the threshold of 0.5 and satisfying the criterion for discriminant validity as outlined by Hair et al. (2014).

Table 2. Results from measurement model.

Latent variable	Manifest variable	Outer loadings	Outer weights	α	rho_c	AVE
	CS1	0.821	0.258			
	CS2	0.749	0.172			
PES	CS3	0.743	0.253	0.840	0.881	0.598
	CS4	0.755	0.179			
	CS5	0.794	0.423			
	CP1	0.817	0.266			
	CP2	0.824	0.273			
SIC	CP3	0.662	0.177	0.842	0.887	0.613
	CP4	0.800	0.263			
	CP5	0.799	0.288			
	KT1	0.839	0.316			
	KT2	0.411	0.147			
PKE	KT3	0.782	0.260	0.802	0.866	0.577
	KT4	0.876	0.270			
	KT5	0.795	0.295			
	LI1	0.861	0.273			
	LI2	0.847	0.249			
PBA	LI3	0.856	0.222	0.885	0.916	0.686
	LI4	0.761	0.249			
	LI5	0.813	0.216			

Table 2. (*Continued*).

Latent variable	Manifest variable	Outer loadings	Outer weights	*α*	rho_c	AVE
	MT1	0.827	0.286			
	MT2	0.774	0.280			
EA	MT3	0.785	0.295	0.765	0.847	0.546
	MT4	0.289	0.114			
	MT5	0.866	0.326			
	QD1	0.792	0.457			
DURSPS	QD2	0.835	0.443	0.721	0.842	0.640
	QD3	0.773	0.347			

Note: *α*: Cronbach's alpha; rho_c: Composite reliability; AVE: Average variance extracted; PES: Policies encouragement and support; SIC: Strategic investment costs; PKE: Product knowledge and experience; PBA: Perceived benefits assessment; EA: Environmental attitudes; DURSPS: Decision to use rooftop solar power systems.

By utilizing the heterotrait-monotrait test, which is recognized for its thorough assessment of discriminant validity (Dijkstra and Henseler, 2015), **Table 3** demonstrates that the values for all components were significantly below 1, hence verifying the presence of discriminant validity.

Table 3. Discriminant validity (HTMT).

	SIC	PES	PKE	PBA	EA	DURSPS
SIC						
PES	0.231					
PKE	0.202	0.380				
PBA	0.311	0.200	0.288			
EA	0.189	0.317	0.269	0.443		
DURSPS	0.318	0.349	0.514	0.529	0.594	

Note: PES: Policies encouragement and support; SIC: Strategic investment costs; PKE: Product knowledge and experience; PBA: Perceived benefits assessment; EA: Environmental attitudes; DURSPS: Decision to use rooftop solar power systems.

4.2. Structural model (inner model)

The inner VIFs, ranging from 1.059 to 3.772 and all below 5, indicated the absence of multicollinearity issues in this model (Hair et al., 2011). Among the pathways, SIC to DURSPS demonstrated the biggest effect size ($f^2 = 0.420$, $p < 0.001$), showing a strong effect. In contrast, the path from EA to DURSPS has the smallest effect size ($f^2 = 0.124$, $p < 0.01$), indicating a minimal effect (Chin, 1998). In terms of the variance predicted in endogenous constructs, the adjusted R^2 ranged from 8.8% ($p < 0.05$) to 55.0% ($p < 0.001$), suggesting a moderate to large level of predictive accuracy (Hair et al., 2013). All Q^2 values greater than zero indicated that the result values are effectively reconstructed, showcasing the model's predictive significance.

The results of the structural model assessment, depicted in **Table 4**, revealed that PES had a positive effect on DURSPS ($\beta = 0.121$, 95% CI [0.024, 0.226], $p < 0.05$). Additionally, SIC was found to have a positive effect on DURSPS ($\beta = 0.453$, 95% CI [0.367, 0.544], $p < 0.001$). Similarly, PKE demonstrated a positive impact on DURSPS

(β = 0.296, 95% CI [0.227, 0.365], $p < 0.001$). PBA also exhibited a positive influence on DURSPS (β = 0.346, 95% CI [0.255, 0.427], $p < 0.001$), and EA was shown to have a positive effect on DURSPS (β = 0.263, 95% CI [0.180, 0.344], $p < 0.001$). Therefore, hypotheses H1, H2, H3, H4, and H5 were confirmed.

Interestingly, the analysis revealed that PBA mediated the path from EA to DURSPS (β = 0.113, 95% CI [0.071, 0.158], $p < 0.001$). Moreover, Income positively influenced DURSPS (β = 0.082, 95% CI [0.006, 0.156], $p < 0.05$), but it had a negative moderating effect on the relationship between PBA and DURSPS (β = −0.099, 95% CI [−0.168, −0.031], $p < 0.01$).

Table 4. Results from structural model.

	Path coefficients	**95% CI lower**	**95% CI upper**	***P* values**
Direct effects				
PES → DURSPS	0.121	0.024	0.226	< 0.05
SIC → DURSPS	0.453	0.367	0.544	< 0.001
PKE → DURSPS	0.296	0.227	0.365	< 0.001
PBA → DURSPS	0.346	0.255	0.427	< 0.001
EA → DURSPS	0.263	0.180	0.344	< 0.001
Income → DURSPS	0.082	0.006	0.156	< 0.05
Income x PBA → DURSPS	−0.099	−0.168	−0.031	< 0.01
CP → PBA	−0.208	−0.323	−0.093	< 0.001
PES → EA	0.302	0.194	0.419	< 0.001
PKE → CP	−0.169	−0.287	−0.043	< 0.01
PKE → PBA	0.162	0.050	0.275	< 0.01
EA → PBA	0.326	0.221	0.426	< 0.001
Indirect effects				
EA → PBA → DURSPS	0.113	0.071	0.158	< 0.001

Note: CI: Confidence interval; PES: Policies encouragement and support; SIC: Strategic investment costs; PKE: Product knowledge and experience; PBA: Perceived benefits assessment; EA: Environmental attitudes; DURSPS: Decision to use rooftop solar power systems.

5. Discussion

The primary objective of this study is to examine the factors influencing the use of rooftop solar power systems. The outcomes of the structural model assessment (**Figure 1**) indicated that policies encouragement and support (PES) positively affected decision to use rooftop solar power systems (DURSPS). Additionally, strategic investment costs (SIC) demonstrated a positive impact on decision to use rooftop solar power systems (DURSPS), along with product knowledge and experience (PKE) and perceived benefits assessment (PBA), which were also found to have positive influences on decision to use rooftop solar power systems (DURSPS). Furthermore, environmental attitudes (EA) positively influenced decision to use rooftop solar power systems (DURSPS). Notably, the analysis unveiled that perceived benefits assessment acted as a mediator in the relationship between environmental attitudes and decision to use rooftop solar power systems. Moreover, Income exhibited a positive direct effect on decision to use rooftop solar power systems, but it had a negative moderating effect on the association between perceived benefits assessment and decision to use rooftop solar power systems.

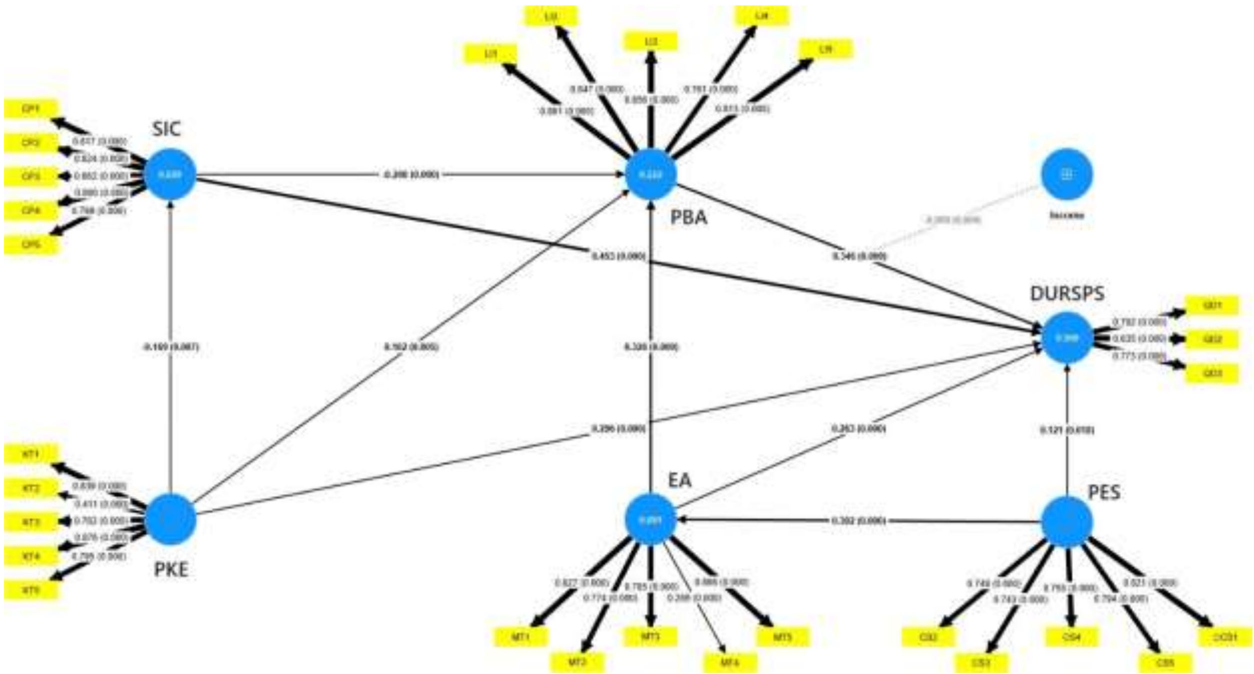

Figure 1. Partial least squares structural equation modeling results.

Note: PES: Policies encouragement and support; SIC: Strategic investment costs; PKE: Product knowledge and experience; PBA: Perceived benefits assessment; EA: Environmental attitudes; DURSPS: Decision to use rooftop solar power systems.

The positive impact of "policies encouragement and support" on the "decision to use rooftop solar power systems" underscores the significance of supportive policies in influencing decisions related to the adoption of solar energy solutions. This suggests that individuals and entities are more likely to embrace rooftop solar power systems when there are policies in place that encourage and support such initiatives. The finding has practical implications for policymakers, highlighting the importance of crafting and implementing policies that facilitate the adoption of renewable energy technologies. Moreover, the quantification of rooftop PV potential at the local level reveals that this potential is influenced not only by technical and economic factors but also by policy and market mechanisms (Bódis et al., 2019). The Electricity and Renewable Energy Authority of Vietnam has stated: "The goal is to have 100,000 rooftop solar power systems, equivalent to 1000 MW, installed and operational nationwide by the end of 2025." Vietnam has received significant support from international donors, notably the GET-FIT project—"Vietnam renewable energy development program: Support for rooftop solar power development," funded by the German Reconstruction Bank with a total non-repayable grant of 14.5 million euros. The beneficiaries of this support are households eligible for installing rooftop solar power systems. Specifically, households installing rooftop solar power systems will receive approximately 3 million VND per 1 kW in support. According to surveys, on average, each eligible household can install about 2 to a maximum of 3 kW. Therefore, the anticipated support per household ranges from 6 to 9 million VND, equivalent to about 15% of the installation cost. In 2023, the Ministry of Industry and Trade issued a decision establishing the feed-in tariff for grid-connected solar power at 1184.90 VND/kW for ground-mounted solar projects, lower than the previous rate of 1644 VND/kW before 31 December 2020. Nevertheless, prevailing policies in Vietnam indicate that the government continues to demonstrate its backing for individuals and enterprises in installing rooftop solar power systems for self-consumption, thereby alleviating financial burdens, rather than solely for commercial purposes. The support would be enough to enhance the willingness to install solar systems, but would not cause a financial burden for the government. This emphasizes the multifaceted nature of factors contributing to the feasibility and adoption of rooftop solar systems, with policy considerations playing a crucial role alongside technical and economic aspects. Additionally, the study by Parkins et al. (2018) suggests that promoting a broader understanding of the energy system, rather than focusing solely on specific renewable energy options, can lead to a more open attitude toward adopting renewable energy. This insight complements the idea that policy measures encouraging awareness and education about the overall energy system can contribute to fostering a positive attitude and, consequently, adoption of renewable energy solutions.

The study's unexpected finding of a positive impact of "strategic investment costs" on the "decision to use rooftop solar power systems" challenges conventional expectations. In contrast to the common assumption that higher costs would deter adoption, this result suggests a nuanced relationship between investment costs and decision-making. One possible explanation is that individuals assessing rooftop solar power systems may view higher strategic investment costs as indicative of higher quality, efficiency, or long-term benefits. Additionally, the positive impact may be influenced by factors such as a favorable economic environment or anticipated future cost savings. Incentives, subsidies, or attractive financing options could make higher strategic investment costs more appealing, contributing to a positive decision-making process. Moreover, previous research highlighted how the interplay of high financing costs and low retail electricity prices can impede the growth of PV installations in these regions (Bódis et al., 2019). This insight underscores the importance of considering contextual factors and economic conditions in understanding the dynamics of rooftop solar adoption. The current investment cost to install a 1kW solar energy system in Vietnam is 13–16 million VND. If the average monthly electricity bill is less than 1 million VND, the economic benefit of installing solar power is very low. The capital recovery time is quite long, so you have to reconsider whether to install it or not. If you still want to install to use clean energy, you can consider a 3 kW capacity system. If the average monthly electricity bill is more than 1 million VND, you can install solar power from 3–10 kW. With an investment for this system of about 16–18 million VND/1 kW (depending on installation location, roof structure, and product type), we just multiply the capacity by the investment output. For example, a 3 kW system will cost from 48–58 million (3 × 16 million and 3 × 18 million). The payback period only takes about 4–5 years. The larger the system investment, the smaller the investment for 1 kWp, and the shorter the payback period.

The positive impact of "product knowledge and experience" on the "decision to use rooftop solar power systems" highlights the crucial role of individuals' understanding and familiarity with these systems in shaping their adoption decisions. Consumers equipped with better product knowledge and experience are more likely to opt for rooftop solar power systems, emphasizing the significance of awareness, education, and practical experience in influencing decisions related to renewable energy technologies. Enhanced product knowledge provides individuals with a clearer understanding of the benefits and functioning of rooftop solar power systems, fostering increased confidence and trust in their efficacy. Notably, the study by Parkins et al. (2018) found a connection between perceived knowledge of the energy system, public engagement in energy issues, and adoption intention. However, the existing challenge lies in households lacking awareness of the complete process, cost, and payback periods associated with adopting rooftop solar power systems (Bansal et al., 2019). This underscores the importance of comprehensive education and awareness initiatives to address these knowledge gaps and promote sustainable energy adoption.

The observed positive impact of "perceived benefits assessment" on the "decision to use rooftop solar power systems" indicates that individuals' perceptions of the benefits associated with these systems significantly influence their adoption decisions. This result suggests that when individuals recognize tangible benefits such as cost savings, environmental advantages, or increased energy independence, they are more likely to choose rooftop solar power systems. Distributed energy resources, including rooftop solar and combined heat and power, offer a unique opportunity to reduce transmission and distribution network capacity requirements, decrease electrical losses, and potentially improve reliability and resiliency (Keen, 2019). Moreover, previous study emphasized that economic gains and reductions in electricity bills are the primary motivators for households to adopt these systems (Bansal et al., 2019).

The positive impact of "environmental attitudes" on the "decision to use rooftop solar power systems" underscores the role of individuals' environmental consciousness in shaping their choices regarding renewable energy technologies. This result suggests that individuals with more favorable attitudes towards environmental conservation and sustainability are more likely to opt for rooftop solar power systems. Environmental attitudes are often associated with a heightened awareness of climate change, a desire to reduce one's carbon footprint, and a commitment to environmentally friendly practices. Moreover, the study by Salamanca et al. (2016) revealed that the deployment of cool roofs and rooftop solar photovoltaic panels contributes to reducing near-surface air temperature throughout the day and decreases daily citywide cooling energy demand. Interestingly, cool roofs are more effective at daytime cooling, while rooftop solar panels prove more efficient at mitigating the urban heat island effect during the night. Additionally, solar energy systems, encompassing photovoltaics, solar thermal, and solar power, offer substantial environmental benefits compared to conventional energy sources, thereby contributing to the sustainable development of human activities (Tsoutsos et al., 2005).

The identification of "perceived benefits assessment" as a mediator in the relationship between "environmental attitudes" and the "decision to use rooftop solar power systems" suggests a nuanced pathway through which environmental attitudes influence adoption decisions. This result implies that individuals' positive attitudes toward the environment not only directly impact their decision to adopt rooftop solar power systems but are also mediated by their perceived assessment of the benefits associated with these systems. In other words, individuals with strong environmental attitudes may be more likely to adopt rooftop solar power systems because they perceive tangible benefits such as cost savings, environmental advantages, or increased energy independence. This finding aligns with the idea that individuals with positive environmental attitudes may be more attuned to the potential benefits of rooftop solar power systems and are, therefore, more inclined to view them as viable and advantageous options. The mediating role of perceived benefits assessment highlights the cognitive process through which individuals weigh the positive attributes of adopting renewable energy technologies when making decisions aligned with their environmental values.

The positive direct effect of "income" on the "decision to use rooftop solar power systems" suggests that higher income levels are associated with an increased likelihood of individuals or entities deciding to adopt rooftop solar power systems. This finding may seem counterintuitive at first, as one might expect lower-income individuals to be more motivated by potential cost savings associated with renewable energy adoption. One possible explanation is that individuals with higher income levels may have more financial resources to invest in rooftop solar installations, despite potential initial costs. They may view renewable energy adoption as a sustainable and environmentally conscious choice, and the positive direct effect suggests that higher income provides the financial means to act on these values. Additionally, individuals with higher income levels may be more inclined to consider long-term benefits and environmental impact, even if the initial investment is higher. The research showed that home ownership, unwillingness to sacrifice personal comforts to save electricity, being pro-energy efficiency, and income are positively related to rooftop solar installation (McCarthy and Liu, 2023). Moreover, the fraction of customers who adopt home rooftop solar power systems in any year is based solely on the money saved by doing so in that year (Cai et al., 2013).

The negative moderating effect of "income" on the association between "perceived benefits assessment" and the "decision to use rooftop solar power systems" suggests that the influence of perceived benefits on the decision-making process is attenuated or weakened for individuals with higher income levels. This result implies that while perceived benefits positively impact the decision to adopt rooftop solar power systems, the strength of this relationship diminishes among those with higher incomes. One interpretation of this finding could be that individuals with higher incomes may have different decision-making priorities or considerations than those with lower incomes. While perceived benefits, such as cost savings and environmental advantages, might be significant drivers for individuals with lower incomes, those with higher incomes might weigh other factors more heavily in their decision-making process.

This cross-sectional study has inherent limitations. Given its nature, causal relationships cannot be inferred from the observed results. The study exclusively concentrates on modeling the factors influencing individuals' intention to use, lacking comparative analyses. Future research endeavors should delve into comparative studies to explore variations comprehensively. It's crucial to acknowledge that the obtained results are specific to a particular segment of the population. To enhance the generalizability of research findings, future studies should aim for larger and more diverse samples, ensuring a broader representation of the population.

6. Conclusion

The findings of this research affirm a positive impact of various factors on the decision to use rooftop solar power systems. Specifically, policies encouragement and support, strategic investment costs, product knowledge and experience, perceived benefits assessment, and environmental attitudes emerged as significant influencers in shaping individuals' decisions to adopt rooftop solar power systems. These results underscore the multifaceted nature of the decision-making process, where a combination of supportive policies, strategic investment considerations, product knowledge, perceived benefits, and positive environmental attitudes collectively contribute to the adoption of renewable energy technologies. The identification of these influential factors provides valuable insights for policymakers, businesses, and researchers aiming to promote sustainable energy practices and enhance the adoption of rooftop solar power systems.

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