Drivers Affecting the Adoption of Solar Photovoltaic Technology: A Case Study of Vietnamese Households

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ABSTRACT

This study used the Theory of Reasoned Action (TRA) to examine and predict the adoption of solar photovoltaic systems by Vietnamese households. The research examined various factors, including perceived risk, perceived benefit, government incentive policies, environmental knowledge, environmental concern, attitudes, and subjective norms, that influence the intention to adopt solar photovoltaic technology in Vietnam. It was based on a survey of 358 household representatives from urban areas in Southern Vietnam. Participants answered questionnaires rated on a 5-point Likert scale. The data collected were analyzed using Cronbach's Alpha, Confirmatory Factor Analysis (CFA), and Structural Equation Modeling (SEM). The SEM analysis confirmed both positive and negative relationships within the model. As a result, the study provides essential recommendations to significantly increase the adoption of solar photovoltaic technology in Vietnam, address the primary barriers, and capitalize on opportunities for faster growth.

KEYWORDS

Circular economy, solar photovoltaic, Vietnamese households

1. INTRODUCTION

Global population growth and economic development have led to increased energy consumption. Energy is essential for a country's growth, but many economies still rely heavily on fossil fuels despite technological progress (Hasheem et al., 2022). Achieving "net-zero" emissions is a global goal, and individuals need to be encouraged to adopt cleaner technologies to lower their carbon footprint (Alsulami et al., 2024). Clean energy funds and mandated green power options have proven effective in promoting the adoption of renewable energy. Many nations have introduced policies to expand the use of non-hydro renewable energy in their electricity sectors, aiming to increase the deployment of cleaner sources such as solar, wind, and biomass (Shrimali & Kniefel, 2011). In the summer of 2024, Vietnam's electricity consumption reached a record of over 1 billion kWh, underscoring the mounting demand, particularly during the hot periods. It emphasizes the importance of implementing effective demand management and energy-saving strategies to maintain a stable and sustainable power supply. Developing renewable energy sources to address electricity shortages has become a top priority. Experts and business leaders in the renewable energy sector view Vietnam as a promising market for distributed solar investments. In line with its renewable energy ambitions, Vietnam has set ambitious targets for rooftop solar energy, aiming for 80 percent of factories and 20 percent of residential and office buildings to adopt rooftop solar by 2050, mainly for on-site use rather than feeding surplus power back into the grid.

Understanding what drives the intention to adopt solar photovoltaic (PV) technology in Vietnamese households from a circular economy perspective is essential for shaping policy and investment choices. This research seeks to identify and analyze these drivers, offering insights that can help speed up the shift to renewable energy and support Vietnam's sustainability objectives.

2. ANALYTICAL FRAMEWORK

Several studies have examined the factors influencing the adoption of green energy sources and the complex relationship between the circular economy and renewable energy, especially solar power

(Van Opstal & Smeets, 2022; Opstal & Smeets, 2023; Milousi & Souliotis, 2023; Maqbool et al., 2023; Goh et al., 2024). These studies emphasize the importance of perceived risks and benefits in the residential adoption of solar energy and other power sources (Tanveer et al., 2021; Zulu et al., 2021; Schulte et al., 2022; Shakeel et al., 2023; Siitonen et al., 2024). Earlier research mainly focused on countries with established strategies for reducing carbon emissions (Asif et al., 2022). In Vietnam, previous studies have highlighted the key role of government incentives in encouraging households to adopt solar systems (Nguyen et al., 2022; Jirakiattikul et al., 2021). However, Vu et al. (2023) found that these incentives did not positively influence adoption intentions. This reveals a research gap, indicating the need for further investigation into how recent policy changes could better promote nationwide solar system adoption. Factors like environmental concern and environmental knowledge, analyzed within the frameworks of the Theory of Reasoned Action (TRA) and the Theory of Planned Behavior (TPB), have been studied in different contexts with varied results. Despite this, a detailed analysis of these factors specific to Vietnam remains largely unexplored, motivating our study to provide valuable insights. Based on existing literature, the author propose the research model and the following hypotheses:

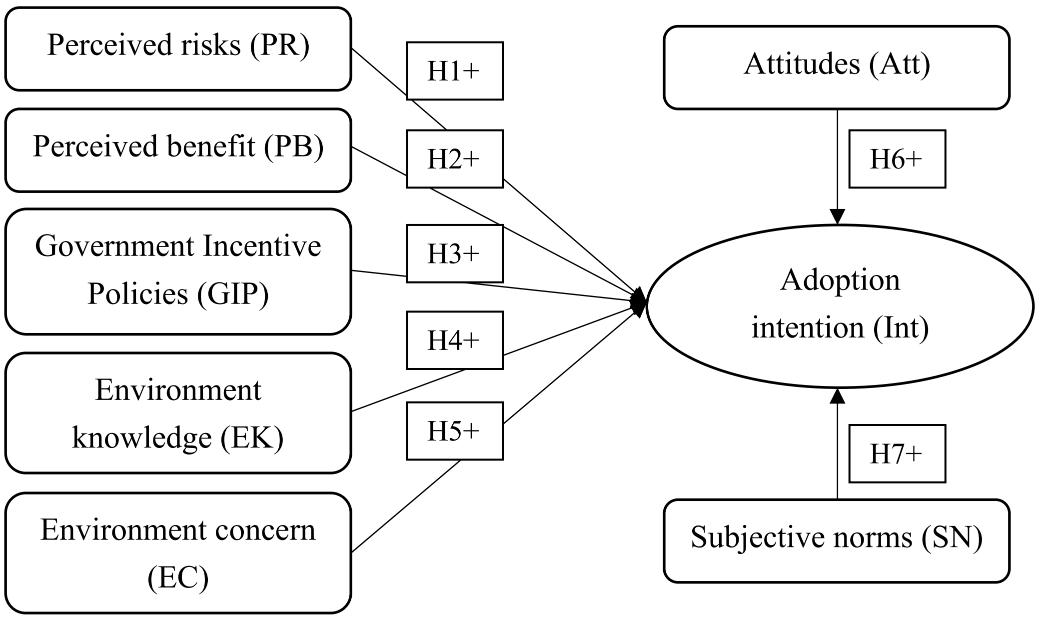

Figure 1. Research model

Source: The author

Hypothesis 1 (H1): Perceived risk has a negative affect on adoption intention toward solar PV technology.

Hypothesis 2 (H2): Perceived benefit has a positive affect on adoption intention toward solar PV technology.

Hypothesis 3 (H3): Government incentive policies have a positive affect on adoption intention toward solar PV technology.

Hypothesis 4 (H4): Environmental knowledge has a positive affect on adoption intention toward solar PV technology.

Hypothesis 5 (H5): Environmental concern has a positive affect on adoption intention toward solar PV technology.

Hypothesis 6 (H6): Attitudes have a positive affect on adoption intention toward solar PV technology.

Hypothesis 7 (H7): Subjective norms have a positive affect on adoption intention toward solar PV technology.

3. METHODOLOGY

This study focused on urban areas in Southern Vietnam, examining electricity demand in the first quarter of 2025. Data was collected using convenience sampling through an online survey conducted in March 2025. Participants from Southern Vietnam voluntarily responded to a Google Forms questionnaire distributed via Facebook and Zalo. Using a 5-point Likert scale, we collected 358 valid responses that met our research criteria for analysis. The questionnaire is divided into two parts: the "Introduction," which includes five demographic questions about gender, age, education, income, and marital status; and the "Research Framework and Formulation of Hypotheses," which contains 24 questions on specific constructs. Each construct is assessed with three items. Perceived risks are adapted from Tanveer et al. (2021) and Ma et al. (2023), while perceived benefits are based on Akroush et al. (2019). Government incentive policies are referenced from Vu et al. (2023), and Environmental knowledge is sourced from Asif et al. (2022) and Vu et al. (2023). Environmental concern is adapted from Irfan et al. (2021) and Asif et al. (2022). Attitudes (ATT) are informed by Aggarwal et al. (2019), Asif et al. (2022), and Vu et al. (2023), while subjective norms are derived from Asif et al. (2022) and Vu et al. (2023). Lastly, adoption intention toward solar PV is measured based on Khoo et al. (2023). Using the convenience sampling method, out of 300 collected questionnaires, 358 were deemed valid and included in the analysis. The respondent profile shows a predominantly male demographic, with 60.06% identifying as male and 39.94% as female. Most respondents are between 26 and 35 years old (42.46%), followed by those aged 36 to 45 years (25.13%), while younger (9.78%) and older (17.32%) age groups are less represented. The majority have completed college (58.87%), with fewer holding undergraduate (15.36%) or postgraduate degrees (25.77%). In terms of income, the largest group earns between 30,000,000 and 40,000,000 VND per month (32.12%), with significant numbers also in the 20,000,000 to 30,000,000 VND range (49.72%). Regarding marital status, 69.27% are married, 24.58% are single, and a smaller percentage are widowed (2.23%) or divorced (3.92%). This profile reflects a well-educated, predominantly male, middle-aged sample with strong representation of married individuals and diverse income levels.

4. RESULTS AND DISCUSSION

4.1. Reliability testing

Nunnally and Bernstein (1978) define a scale as reliable when the Cronbach's Alpha coefficient (α) is at least 0.7. Hair et al. (2010) note that while a Cronbach's Alpha of 0.6 may sometimes be acceptable, it should be interpreted cautiously. A higher Cronbach's Alpha generally indicates greater scale reliability. The Corrected Item-Total Correlation should typically be 0.30 or higher to be considered acceptable. Values below 0.30 may suggest that an item does not contribute well to the overall scale and might need revision or removal.

Table 1: Cronbach's Alpha reliability test

Construct	Sign	Cronbach's α	Corrected Item-Total Correlation	
			Lower bound	Upper bound
Perceived risk	PR	0.748	0.703	0.732
Perceived benefits	PB	0.839	0.793	0.827
Government incentive policies	GIP	0.825	0.800	0.816
Environmental knowledge	EK	0.854	0.814	0.845
Environmental concern	EC	0.803	0.788	0.793
Attitudes	Att	0.824	0.726	0.811
Subjective norms	SN	0.888	0.839	0.874
Adoption intention	Int	0.837	0.799	0.832

Source: Analysis results from SPSS 26

In Table 1, all constructs show strong internal consistency, with Cronbach's Alpha values indicating excellent to good reliability. The item-total correlations are generally high, suggesting that the items are well-aligned with their respective constructs. No items were removed from any scale, which indicates that all items contribute effectively to measuring the constructs. Thus, all items met the criteria for inclusion in the next step.

4.2. Confirmatory factor analysis

The results in Table 2 show that the model fits the data well. The CMIN/df value is 1.459, which is within the acceptable range of 1 to 3, indicating a reasonable fit (Hu & Bentler, 1999). The GFI (Goodness of Fit Index) is 0.911, which is above 0.9, suggesting a good fit of the model to the data. Similarly, the CFI (Comparative Fit Index) is 0.976, exceeding the 0.9 threshold, confirming a good fit. Lastly, the RMSEA (Root Mean Square Error of Approximation) is 0.041, below 0.05, indicating an excellent fit (Hu & Bentler, 1999). Based on these indices, the model is considered to fit the data well.

Table 2: Model Fit

Indicator	Index	Conclusion
CMIN/df	1.564	Accepted (CMIN/df value between 1 and 3)
GFI	0.913	Accepted (GFI > 0.9)
CFI	0.945	Accepted (CFI > 0.9)
RMSEA	0.042	RMSEA < 0.05 (The model fits very well)

Source: Analysis results from AMOS 20

Table 3 displays the model validity measures, including Composite Reliability (CR), Average Variance Extracted (AVE), and Maximum Shared Variance (MSV). All constructs demonstrate high internal consistency, with CR values surpassing 0.8, well above the acceptable threshold of 0.7 (Bagozzi & Yi, 1988). The AVE values, which indicate convergent validity, are all above 0.5, confirming that the constructs explain a significant portion of the variance. Furthermore, the MSV values are lower than the AVE values, supporting discriminant validity by showing that the constructs are distinct from each other (Fornell & Larcker, 1981). Overall, the model shows strong reliability, convergent validity, and discriminant validity.

Table 3: Model Validity Measures

	CR	AVE	MSV	PR	PB	GIP	EK	EC	Att	SN	Int
PR	0.847	0.676	0.463	**0.822**							
PB	0.828	0.634	0.282	-0.238	**0.796**						
GIP	0.843	0.649	0.327	-0.236	0.385	**0.805**					
EK	0.818	0.621	0.202	-0.378	0.252	0.364	**0.788**				
EC	0.803	0.700	0.172	-0.284	0.315	0.212	0.450	**0.837**			
Att	0.845	0.625	0.287	-0.352	0.156	0.200	0.325	0.402	**0.791**		
SN	0.836	0.673	0.173	-0.155	0.383	0.179	0.374	0.391	0.264	**0.820**	
Int	0.855	0.686	0.284	-0.213	0.266	0.251	0.216	0.374	0.130	0.135	**0.828**

Source: Analysis results from SmartPLS 4.3

4.3. Structural equation modeling

After identifying the relationships among the variables in the model and testing its fit, a Structural Equation Modeling (SEM) analysis is conducted as follows.

Table 4: Summary of Structural Model Results

Hypothesis	Independent variables	Dependent variables	β	Results
H1	PR	Int	-0.374^{***}	Supported
H2	PB	Int	0.325^{*}	Supported
H3	GIP	Int	0.437^{***}	Supported
H4	EK	Int	0.379^{**}	Supported
H5	EC	Int	0.312^{ns}	Rejected
H6	Att	Int	0.214^{**}	Supported
H7	SN	Int	0.388^{***}	Supported
*Notes: *significant at p < 0.05, **significant at p < 0.01, ***significant at p < 0.001, ns not significant at p > 0.05*				

Source: Analysis results from AMOS 20

In Table 4, the relationship between perceived risks (PR) and adoption intention toward solar PV technology (Int) is statistically significant, with a β coefficient of -0.374 and a p-value of 0.000. This shows a negative connection, indicating that higher perceived risks are associated with a lower likelihood of adopting solar PV. The results of this study agree with the findings of Tanveer et al. (2021). Perceived benefits (PB) also has a significant positive effect on adoption intention for solar PV technology (Int), with a β coefficient of 0.325 and a p-value of 0.030, emphasizing that greater perceived benefits increase the likelihood of adopting solar PV. These results agree with those reported by Irfan et al. (2021).

Government incentive policies (GIP) have a strong positive impact on the adoption intention toward solar PV technology (Int), with a β coefficient of 0.437 and a highly significant p-value of 0.000. This highlights the important role that supportive government policies play in boosting engagement intention. In contrast, this finding differs from those reported by Vu et al. (2023), who found that government incentive policies had no positive effect on the intention to adopt. However, earlier research in Vietnam also stressed that government incentives are essential for motivating households to adopt solar energy systems (Nguyen et al., 2022; Jirakiattikul et al., 2021).

Similarly, environmental knowledge (EK) positively influences adoption intention toward solar PV technology (Int), with a β coefficient of 0.379 and a p-value of 0.003, indicating that higher environmental knowledge is linked to a greater intention to engage in the behavior. This finding supports the work of Zheng et al. (2018). Individuals with greater environmental knowledge are more likely to engage in environmentally positive behaviors, whereas those with less knowledge tend to exhibit fewer such behaviors. Conversely, the relationship between ecological concern (EC) and adoption intention toward solar PV technology (Int) is not statistically significant, with a β coefficient of 0.312 and a p-value of 0.067, which exceeds the usual significance threshold of 0.05. It indicates that environmental concern does not have a significant effect on intention. This result contradicts the findings of Irfan et al. (2021), who suggested that ecological concern has an essential influence on consumers' willingness to adopt solar energy technologies.

Attitudes (Att) have a significant positive effect on adoption intention toward solar PV technology (Int), with a β coefficient of 0.214 and a p-value of 0.035, indicating that more favorable attitudes increase the likelihood of engaging in the behavior. Subjective norms (SN) also positively influence adoption intention toward solar PV technology, with a β coefficient of 0.388 and a p-value of 0.000, demonstrating a strong association. This suggests that stronger subjective norms are linked to higher intention to participate in the behavior. The findings support the principles outlined in the TRA model (Ajzen & Fishbein, 1980).

5. CONCLUSION

Overall, this findings show that perceived risks (PR) negatively affect the intention to adopt solar PV technology (Int), meaning that higher perceived risks are linked to a lower willingness to adopt solar PV. Conversely, perceived benefits (PB), government incentive policies (GIP), environmental knowledge (EK), attitudes (Att), and subjective norms (SN) all positively influence the intention to adopt solar PV technology (Int). This indicates that greater perceived benefits, supportive government policies, increased environmental knowledge, favorable attitudes, and stronger subjective norms lead to a higher willingness to adopt solar PV. On the other hand, environmental concern (ENC) does not have a significant impact on intention, suggesting that concern for the environment alone does not substantially influence the adoption decision.

Based on the above discussion, to boost the adoption of solar PV systems, the government needs to continue and expand its incentive programs. It involves increasing subsidies, providing tax credits, and offering low-interest loans. Such financial incentives can substantially lower the upfront costs of solar PV systems, making them more affordable and appealing to households. The government should also invest in educational campaigns and public awareness initiatives that emphasize the benefits of solar energy, raise awareness of environmental issues, and highlight the advantages of solar PV systems. By doing so, the government can foster a more informed and positive outlook toward solar energy adoption.

Solar PV companies should focus on clear and effective communication about the advantages of solar PV systems. This includes sharing detailed information on cost savings, energy efficiency, and environmental benefits. Creating targeted marketing strategies and educational materials can help boost perceived benefits and encourage more people to adopt solar PV. Companies should also take steps to address consumer concerns about solar PV systems. This involves providing transparent details about system reliability, maintenance, and financial incentives. Additionally, offering strong customer support and warranty services can help reduce perceived risks and build trust with consumers.

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