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Willingness to pay for residential PV: reconciling gaps between acceptance and adoption

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***Abstract*—**

Photovoltaic (PV) has recorded an impressive development in the last years. The increasing economic potential and further technological improvement will continue to reduce the cost of PV. However, it is not yet well adopted by household customers. Adversely, there is lacking empirical evidence for understanding residential PV adoption behaviour, which this study addresses with empirical research. Although a variety of models can be used to explain social acceptance (SA) and willingness to pay (WTP) for renewable energy, they overlook the connection between SA and WTP in the final purchase decision of a decision-maker. Based on a survey of both SA and WTP in the same observation sample of 2039 Vietnamese residents, this study introduces well-established models with a new linking psychological and economic aspects to measure multiple outcomes involving residential PV behaviours to testing hypotheses with no precedent in the literature. The theoretical and integrative moderated mediation models help to understand residential PV behaviour and suggest solutions for development by revealing how different factors affect SA and WTP in different manners. *Environmental interest* reveals the predictive power within the SA and WTP behaviour models. Meanwhile, *PV knowledge* drives SA, but not WTP in Vietnam. *Attitude* and *Perceived behavioural control* not only impact SA and WTP directly but also mediate the effect of *Environmental interest* and SA and WTP. *Age & Marital status & Children* and *Place of residence* are important covariates that drive in the SA and WTP models, respectively. Lastly, *Income* is the covariate in the SA model, but the moderator in the WTP model. In practical implications, this study provides evidence that residential PV is a lifestyle product rather than an economical product, but it is not considered as an essential good for household customers. Thereby, suggestions are given to policymakers and stakeholders to promote market development.

***Index Terms*—Developing country, Willingness to pay, Social acceptance, Residential photovoltaic**

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1 INTRODUCTION

From 2011 till now, reports show strong growth of solar PV, with the power sector leading the way (IEA, 2019). New technological advances over the last twenty years have driven this increased reliance on solar by decreasing costs, and new technological developments promise to augment this solar usage by further decreasing costs and increasing solar panel efficiency (Aramesh et al., 2019). Currently, emerging countries such as China, India, and Brazil have been world leaders in renewable energy use, especially solar. However, residential solar uptake has been struggling in many other Asian developing countries for the last few years (Burke et al., 2019; IEA, 2019).

One of the most mentioned barriers is the lack of information dissemination and consumer awareness about technology (Seetharaman et al., 2019). Additionally, the existing problem in communication and intervention levels to accelerate solar uptake under limited resource conditions in the developing countries has not been resolved after significant effort made in research (Rai et al., 2016; Barroco and Herrera, 2019).

The main issue lies in the most applied approaches to investigate the topic. Most studies in residential solar focus on top-down and technically-orientated analyses using economic models (Rao and Kishore, 2010) and techno-economic assessments (Burke et al., 2019) to determine the domestic and international political effect (Shidore and Busby, 2019), infrastructure and local roles (Geall et al., 2018) as well as prioritising targets (Behuria, 2020). Economic models study price-responses based on revealed preference data, e.g., historical and demographic data. However, they have proven to be incomplete and to have restricted explanatory power without supplementation of psychological and sociological models, especially for studying the new-born markets for residential PV (Liebe et al., 2011). Residential PV promotion can not only be addressed by a purely top-down study, but a bottom-up study is required with a focus on the social aspects because the adoption decision is made based on psychological profiles — personality, values, opinions, attitudes, interests, and lifestyles.

Literature shows that Social Acceptance (SA) and Willingness To Pay (WTP) are equally, if not more important than technological advances for the successful adoption of residential solar (Dunphy and Herbig, 1995; Schumacher et al., 2019; Klaus et al., 2020). However, in the few socially-designed studies on this topic, the majority have been conducted in developed countries (Wolsink, 2018), where the issue of high up-front investment is less relevant than in developing countries (Waseem and Hammad, 2015; Alsabbagh, 2019). That makes the findings hardly applicable to developing countries due to the different ethically-minded consumer behaviours (Sudbury-Riley and Kohlbacher, 2016). Nevertheless, the knowledge gap related to the social aspects of residential solar PV in developing countries needs to be filled (Sommerfeld et al., 2017; Alsabbagh, 2019) to boost the residential PV technology uptake in these countries.

Nonetheless, the complex interplay of the various factors that influence SA and WTP, along with the dynamic nature of SA and WTP makes defining and measuring them a difficult task. Firstly, direct or indirect methods could evoke the hypothetical bias, and extant evidence is mixed (e.g. Miller et al. 2011). Secondly, among the socio-economic researches on renewable energy, the confused interpretation of SA and WTP is often addressed (Wolsink, 2018). SA speculates public responses to political and social changes, e.g. towards the penetration of

renewable energy, while WTP estimates public reaction in the real market (Wolsink, 2018). The confusion leads to an existing issue of misconstructed support policy. Thirdly, throughout the prior work, although some business models already exist, hardly any econometric model exposes the determinants of SA and WTP and the correlation between them (Rai et al., 2016). Without a clear definition and measurement of SA and WTP, policymakers cannot be expected to create sufficient and transferable policies to conform to these concepts.

Focusing on end-user decision-making in developing countries, a case study on Vietnam is conducted, which investigates the SA and WTP towards the residential PV technology and their influencing factors in order to provide suggestions to overcome the social resistance of adoption. This paper integrates theoretical ideas from the social psychology of The Theory of Planned Behaviour (TPB) and from the market response of Choice-Based Conjoint (CBC), which are designed to reveal the self-interest of a respondent. The psychological TPB measures SA provides a relatively complex explanation of the informational and motivational influences of the psychological driving factors (attitude, social pressure, risk control) in the execution of a particular behaviour of SA, especially in the field of environmental science (Klöckner, 2013; Si et al., 2019). The CBC, measuring the WTP, is used to determine how people value different attributes (feature, function, benefits) that make up an individual product or service (Ratcliffe, 2000). Combining both questions of SA and WTP for residential PV in one survey allows us to extend our analysis beyond literature with tracking the gap between a person's perception toward the product and reaction in the store.

In this manner, the main contributions of this paper are:

- Discover the econometric models explaining the relationship between impact factors of SA and WTP, SA and WTP.
- Identify and compare drivers, mediators and moderators of the two concepts and then to combine them to support each other in order to provide robust policies.
- Identify the gap between a person's perception of the product and his/her behaviour in the marketplace.

The remainder of this paper is organised as follows: Section 2 presents the literature review of the related research topic, as well as identify gaps concerning communication in general and residential PV in particular. We discuss the questionnaire styles, hypotheses based on the well-known factors driving residential customers adopting residential solar and propose our methodology in Section 3. The results and findings of the driving factors of the SA and WTP are presented in section 4. The discussions and policy implication are provided in section 5. Conclusion and outlook are summarised in section 6.

2 LITERATURE REVIEW

Residential PV is crucial to lowering the environmental impact of the residential sector (Shahsavari and Akbari, 2018). However, the broad implementation and extensive use require customer adoption (Yaqoot et al., 2016). Therefore, it is necessary to investigate customer behaviour towards this technology to understand the process of interesting, accepting, selecting and purchasing such a product (Sovacool, 2014). Policymakers need to explore public opinion toward this product to create a sustainable development plan for residential PV adoption (Richard, 2016; Bhowmik et al., 2017). Yet, although the research field is growing, its merits for understanding and predicting individual adoption of residential PV can only hardly unfold (Geels et al., 2018). There is only a few empirical research in the energy field, i.e., 2.2%, dedicated to understanding end-user behaviour (Sovacool, 2014). Far too little attention has been paid to specific behaviours related to residential PV SA and WTP (Si et al., 2019).

Even though customers' awareness and acceptance are often considered as one of the biggest barriers in technology spread (Barroco and Herrera, 2019), it only gets attention in behaviour research recently (Table 1). Most of the research has focused on customer's preferences and WTP toward residential PV (Column 3, Table 1) with the favourite CBC method used (Column 4, Table 1) for developed countries (Column 5, Table 1).

Table 1. Summary of social research on residential PV from 2010 to 2019

Source	**Objective**	**Object**	**Subject**	**Direct/ Indirect survey**	**Sample size**	**Region**	**Correlation model**
(Alsabbagh, 2019)	Public perception & policy suggestion	Random	SA & WTP	D/ TPB	764 valid	Bahrain	-

(Hille et al., 2018)	Drivers for PV adoption	PV owners	Preference & WTP	I/ ACBC	6104 representative sample; 408 valid	Switzerland	-
(Sommerfeld et al., 2017)	Public perception	PV owners	SA	D	22 valid	Queensland, Australia	-
(Wolske et al., 2017)	Interest in residential PV panels	Non- adopter homeowners	SA	D/ DOI, TPB, and VBN	904 valid	US	Direct impact
(Korcaj et al., 2015)	Intention to adopt PV system	Homeowners	WTP	TPB	200 valid	Germany	Direct impact
(Ida et al., 2014)	Greenhouse gas emissions reduction	Random	Preferences & WTP	I/ CBC	8997 valid; 649 from high- and 694 from low-interest	Japan	-
(Islam and Meade, 2013)	Technology attributes & adoption time	Random	Preferences & adoption time	I/ CBC	298 valid	Ontario, Canada	-
(Wissink et al., 2013)	PV impact on home purchasing	Dwelling buyers	Preferences & WTP	I/ CBC	227 valid	Netherlands, Eindhoven	-
(Chen et al., 2013)	Market analysis	PV owners	Preferences	I/ ML	22 valid	California, USA	-
(Scarpa and Willis, 2010)	Policy suggestion	Random	WTP	I/ CBC	1241 valid	UK	-

Acronyms: "-": not implied, "x": implied, DOI: Diffusion of Innovations theory, TPB: Theory of Planned Behaviour, VBN: Value-Belief-Norm theory, ACBC: Adaptive Choice-Based Conjoint, CBC: Choice-Based Conjoint, ML: Machine Learning

Apart from the lack of empirical research on residential PV in developing countries, we noticed two other main research problematics, including the importance of considering both SA and WTP, and the possibility of different factors interaction impact on SA and WTP, which will be discussed in turn in Section 2.1 and Section 2.2.

2.1 The importance of considering both SA and WTP

SA research focuses on understanding the complex, multi-level and polycentric process of transforming social-technological systems, while WTP estimation presents a proxy attitude and focuses at the public trade-off point. Literature confuses these two definitions, such as claims WTP as a reflection of SA. The confusion needs to be uncovered (Wolsink, 2018). ***SA*** is a multi-dimensional conceptual model, which covers the social responsibility in government and law; informs business and policy through social and commercial marketing. Whereas WTP studies are of limited value for evaluating social acceptance, the method can reflect ***market acceptance*** in real-life decisions with individual cost-benefit assessments (Wüstenhagen et al., 2007). Because WTP does not reflect any acceptance process, such as the recognition of consumers or the engagement of citizens in the process of establishing renewable energy infrastructure, the combination view of social and market acceptance is a proper approach to understand comprehensively residential PV behaviour. Comparing SA and WTP forms the distinguish contrast aspects of acceptance involving different actors and emphasises upon each dimension inter-relates across different segments.

As outlined in *Figure 1*, SA and WTP are the two stages of adoption when measuring customer behaviour towards a specific technology. While economists rely on the concept of preferences in order to determine what people value and identify the WTP, psychologists and sociologists have a strong affinity to the attitude concept and determine the SA. The main difference between the two concepts is that preferences pertain two choices between alternatives, whereas attitudes focus on "the desirability of a single action or object" (Liebe et al., 2011).

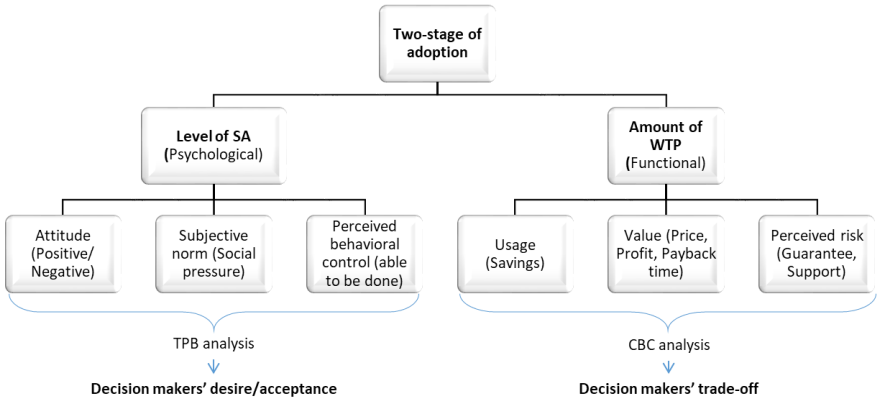

Figure 1. Two-stage of adoption behaviour (Ram and Sheth, 1989; Ajzen, 1991)

SA is a personal intention towards technology, and various factors influence it. This was a necessary amendment once behaviour was being measured, as a consumer may have a very favourable attitude towards a product, but not towards the act of purchasing it (Solomon, 2006). However, if a person buys the product but does not accept it, it is unlikely that full adoption will occur. There are other stages beyond simple WTP, and this is where acceptance plays an important role. In this paper, we focus on finding the factors influencing progression through different approaches. Therefore, a common consideration of planned behaviour analysis (Theory of Planned Behaviour, TPB) and conjoint analysis (Choice-Based Conjoint, CBC) are necessary.

2.2 Possibility of different factors interaction affecting SA and WTP

Eco-friendly behaviour results from multiple motivations (Chandel et al., 2016; Yadav and Pathak, 2017). In the context of residential PV behaviour, consumers may apply some additional environmental criteria in the decision-making process (Michelsen and Madlener, 2016; Bashiri and Alizadeh, 2018) to find a practical trade-off between environmental concern and traditional criteria, such as price, quality, availability, etc. Meanwhile, consumers also need information gathering and relevant knowledge to assist them to make a choice, which is consistent with traditional decision-making, where consumers are confident in choosing the cheapest product (Michelsen and Madlener, 2016; Bashiri and Alizadeh, 2018).

Existing empirical studies on environmental behaviour generally extend two to five other variables into behaviour models to explain behaviour. The extension factors are some of the commonly used latent variables, especially Environmental interest (e.g. environmental concern, environmental awareness) and Knowledge (e.g. environmental knowledge, and environmental education). Table 2 shows the results of various scholars integrated concepts of Environmental interest and Knowledge from different theoretical frameworks. Scholars have proven that product knowledge is one of a leading factor in people's intention towards green consumption (Chen and Deng, 2016; Choi and Johnson, 2019). The same has been shown for energy-efficient and energy-saving behaviour (Tan et al., 2017; Li et al., 2019), and on renewable energy consumption (Bang et al., 2000). Therefore, in this study, these two variables are considered in order to discover the impact factors on SA and WTP.

Although research on consumer behaviour considers a wide range of factors influencing consumers and acknowledges a broad range of consumption activities beyond purchasing (Wüstenhagen et al., 2007; Chandel et al., 2016), previous research in the residential PV and relating topics focuses mostly on explaining the relation between two specific variables (Table 2). However, in psychological research, the role of the three variables is vital (Chmura Kraemer et al., 2008; Mackinnon, 2011; Bolin, 2014). X may cause the third variable M and M may cause Y; both X and M may cause Y, and the relation between X and Y may differ for each value of M, along with others. M can play the role of mediation or moderation, which researchers need to discover in their study.

Table 2. An overview of different behavioural models explaining renewable energy behaviour

Topic	Ref	Relation	Y	Determinant factors			Demographic factors							Extended factors		Method	Country
				Att	SN	PBC	F	Age	In	MS	HHS	EB	EL	K	EI		
Residential PV system	(Wolske et al., 2017)	X→Y	SA	+	+	+	-	-	-		-	+	+		+	TPB	US
	(Korcaj et al., 2015)	X→Y	WTP	+	+	+									+	TPB	Germany
Energy-Efficient Appliances	(Li et al., 2019)	X→M→Y	WTP	+	+	+								+	+	TPB	China
Green electricity	(Litvine and Wüstenhagen, 2011)	X→Y	SA	+	-	+										TPB	Switzerland
			WTP	+	~	+											
	(Borchers et al., 2007)	X→Y	WTP				-	-	+			~				Re	US
Renewable energy	(Sardianou and Genoudi, 2013)	X→Y	WTP				+	+	+	+		+	+			Re	Greece
	(Bang et al., 2000)	X→Y	WTP	+										+	+	TRA	US
Energy choices	(Spence et al., 2010)	X→Y	SA												+	Re	UK

Sustainable innovations	(Noppers et al., 2014)	X→Y	WTP												+		Netherlands
Green products	(Choi and Johnson, 2019)	X→Y	WTP	+	+	~								+	~	TPB	UK
	(Yadav and Pathak, 2017)	X→Y	WTP	+	+	+										TPB	India
	(Maichum et al., 2016)	X→M→Y	WTP	+*	+*	+*								+	+	TPB	Thai
	(Chen and Deng, 2016)	X→M→Y	WTP	+	+	+								+*		TPB	China

Note:
Factors: Att: Attitude, SN: Subjective norm, PBC: Perceived behavioural control, F: Female, In: Income, MS: Marital status, HHS: Household size, EB: Electricity bill, EL: Education level, K: Related knowledge, EI: Envirolmental Interest.
Method: Re: Regression, TRA: Theory of reasoned action
*Symbol: *: moderators, +: positive effect, -: negative effect, ~: insignificant effect, Blank: The factor has not been analysed in the study.*

Many different approaches have been adopted in the study of consumer decision making, but the residential PV topic has not been intensively studied. Consumer behaviour models in this field are not sufficient enough to aid in understanding different behavioural conditions toward residential PV. In this study, we have to refer to several social-psychological theories and empirical research in similar topics, e.g. green electricity, renewable energy, green purchase to build our theoretical model.

However, this research will not focus on explaining the relationship between only two variables, but try to answer the sequence X → M → Y, with M can be a moderator or a mediator. We solve the problem of the unclear role of the impact variables on SA and WTP by answering the question of which variables should be considered as a target, moderator, mediator, and covariate variables. Thereby, three main questions (1) what is it motivates people to accept residential PV and purchase it, (2) how the motives interact and (3) how the interaction changes individual orientation for solar PV adoption will also be answered.

The hypothetical method proceeds by formulating a hypothesis in a form that can be falsifiable, using a test on observable data where the outcome is not yet known. It is used to research customer behaviour during the product development process, especially in the new-born market. We use the two widely used methods to measure SA and WTP, which is the Theory of Planned Behaviour (TPB) uses direct questions to discover people's perception of a product (Ajzen, 1991), and Choice-Based Conjoint analysis (CBC) uses indirect surveys (Schmidt and Bijmolt, 2019). Aware of these methods could evoke the hypothetical bias, and therefore extant evidence is mixed, we conducted factor analyses to check the possibility of common method bias.

3 METHODOLOGY

There are many influences on purchasing behaviour, including social, technological, political, economic, and personal factors. Taking into account the gaps indicated in Section 2, this section presents our theoretical framework model and its components in Section 3.1. Section 3.2 proposes the statistical methods used for the analysis of the data. Section **Fehler! Verweisquelle konnte nicht gefunden werden.** and 3.4 are devoted to revealing the design and process used to conduct this research, respectively.

3.1 Framework model and main contributions

Relevant hypotheses, ignored by other studies, are developed, and then, a framework model is set up (Figure 2). The framework acts as the basic baseline for this study. Three main groups of variables that are claimed to impact the final SA and WTP are the determinant factors (Attitude, Subjective norm and Perceived behavioural control), socio-demographic variables (e.g. Gender, Age, Income, Level of education, etc.), and extended factors (PV knowledge and Environmental interest). The main critical content is to choose our hypotheses of which variables is considered as the target, covariate, moderator and mediator variables effect on SA and WTP.

In order to identify the role for each variable, we use the idea of cognitivism that an individual is viewed as an 'information processor' making a decision based on intrapersonal causation (Ajzen, 1991). The recognized

problem will be the target variable, which indicates the origin of the demand for residential PV. The information search, alternative evaluation, and choices will be considered as mediator or moderator factors. The outcome evaluations are SA and WTP. Based on this theory, we propose 6 hypotheses from H1 to H6. Detailed hypothesis' foundation can be found in Appendix B.

- *H1: Environmental interest and/or PV knowledge is the target variable impact SA and WTP.*
- *H2: SA and WTP towards residential PV are positively related to Attitude, Subjective norm and Perceived behavioural control.*
- *H3: Attitude, Subjective norm and Perceived behavioural control mediate the relationship between the target variable and SA and WTP.*
- *H4: Any demographic factor causes SA and WTP is the determinant of SA and WTP.*
- *H5: Any demographic factor divides the population into different groups is the covariate factors.*
- *H6: Demographic factors moderate the indirect relationship between the target variable and SA and WTP.*

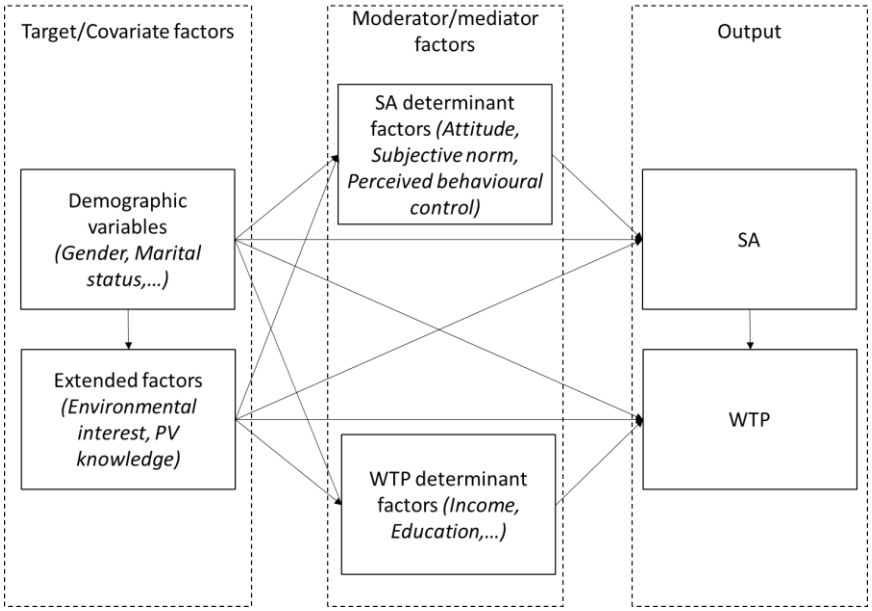

Figure 2. Model construction of the influencing factors of residents' acceptance toward rooftop PV.

3.2 Moderated mediation model

In this paper, we use also the Theory of Planned Behaviour (TPB) and Choice-Based Conjoint (CBC) analyses to study SA and WTP for residential PV (Appendix C). Different from previous studies (Sardianou and Genoudi, 2013; López-Mosquera et al., 2014; Bashiri and Alizadeh, 2018), the decision of the participant is not a binary choice, but the probability of buying the product. The relation between different groups of variables with SA and WTP is analysed based on Spearman's rank correlation (for skewed variables), and simulation analyses with detailed methods are indicated in Appendix D.

An examination of the raw data carried out before data analysis revealed to ensure that data of all participants were included, multiple imputations were used to estimate values for the missing data. For all variables, mean ± standard deviations and medians with ranges were used. The statistical significance level for all the tests was set at a P-value of below 0.05.

First of all, this paper uses construct validity and reliability of the questionnaire to control the effectiveness of the questionnaire items. Construct validity is reflected by two parameters: factor loading and cross-loading. The

reliability of the questionnaire is reflected by Cronbach's alpha coefficient and combined reliability (Aizstrauta et al., 2015). All the parameters are calculated using SPSS and R.

Secondly, to test the research hypotheses, the standardized path coefficients and their significance level are calculated to judge the validity of hypotheses. If the level of the t-test is smaller than the significance level of 0.05, then the hypothesis is tenable. The standardized path coefficients reflect the influence degree of each factor. To improve the reliability of the results, SPSS – PROCESS V3.5 and the bootstrap method are used to test the mediating and moderating effects and verify the significance of the mediating effects.

The dependent variables are the acceptance score for SA and the Price sensitivity for WTP. Twelve socio-demographic features (Table A. 4) and two extended moderating variables (PV knowledge level and Environmental interest), which are suspected of having a relationship with SA, are considered as possible independent variables. We apply the Chi-Square test to analyse their independence from each other. This research tests the theory through deductive approaches.

For moderated mediation analysis, the SPSS macro PROCESS was applied with different moderators and mediators. The regression/path coefficients are all in unstandardized form as standardized coefficients generally have no useful substantive interpretation (Bolin, 2014). Model fit was also examined using the following criteria: a chi-square/df of ≤2, a P-value of >0.05, a comparative fit index of ≥0.95, and a root mean square error approximation of <0.06 (Hu and Bentler, 1999).

Logistic regression analyses are conducted to identify the predictors of SA and WTP outcomes with the potential predictors, including demographic variables and extended moderating/mediating variables. Correlation test is made for each outcome. A hierarchical model building procedure is used to select variables for inclusion in the final set of models. Variables are separated into three conceptual blocks: demographics, moderating factors and determinants of the output. Each block of predictors was regressed separately on each outcome in a logistic regression model. Significant predictors ($p < 0.05$) in any block model are retained in the set of final models used to estimate the simultaneous effects of predictors. This procedure ensures the inclusion of the same set of participants in each outcome and to facilitate interpretability of results. Three interactions are also considered for each outcome to provide for the exploration of moderation effects. All variables in an interaction block model with a significant interaction term for a given outcome are included in the final model for that specific outcome.

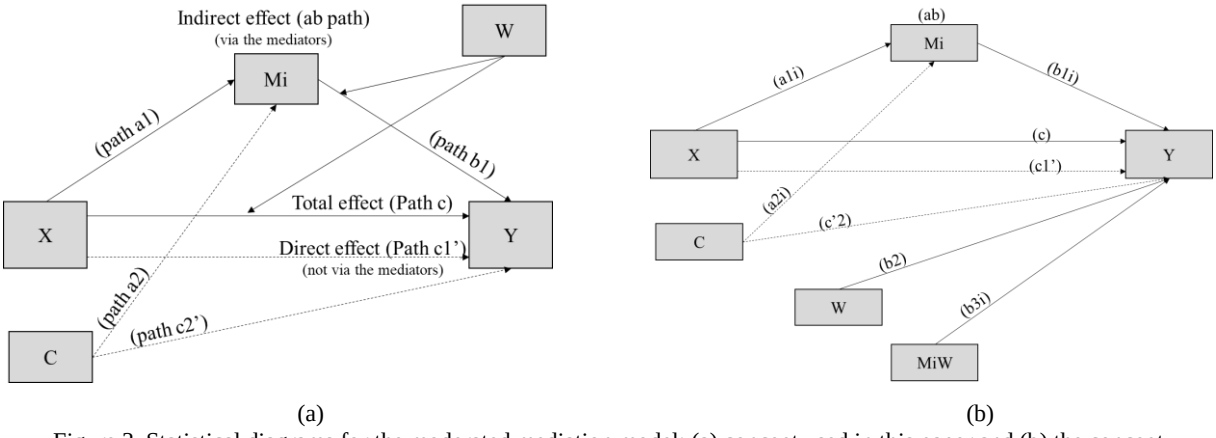

Figure 3. Statistical diagrams for the moderated mediation model: (a) concept used in this paper and (b) the concept interpretation. Illustrated using a directed acyclic graph showing the causal pathways between target variable *X* and outcome *Y*, mediators (M_i), moderate (*W*), and measured covariates (*C*).

A regression model with the bootstrapping function of 20000-50000 bootstrap samples is used to perform testing of hypotheses, which have SA and Price elasticity (represented for WTP) as dependent variables, respectively. We run regular, mediator and moderator regression models to test the statistical significance and to find the best explanation for the independent variables—the level of confidence for all confidence intervals in output 95%. A heteroscedasticity consistent standard error and covariance matrix estimator are used. The F-test is used to test the statistical significance of the model and the critical values for one-tailed t-tests greater than 2.33 (significance level =1%) was applied for each independent variables.

The concept of the model with one target variable (X) and one final behavioural output (Y), is illustrated in Figure 3. X has both direct (c1'-path) and indirect (through M with a-path and b-path) effects on Y. The total effect is c-path, which is the summary of c1'-path and ab-path. The effects between mediators are d-path which is not illustrated in Figure 3 to simplify. Covariates (C), characteristics of the participants in an experiment, are included in all models to strengthen the results' validity.

W. might moderate the indirect and/or direct effect of X on Y It means the effects of X on Y are conditional, depending on the value of W. There are two locations within the model where W may serve as a moderator: the direct effect of X on Y and the effect of X on M.

The relationship between all mentioned independent and dependent variables is described in the moderated mediation model to perform how the direct/indirect effects are calculated and how moderators and mediators and covariates are integrated. The moderated mediation model equations (Bolin, 2014):

$$Y = b_0 + \sum b_{1i} M_i + b_2 W + \sum b_{3i} M_i W + c_1' X + c_2' C + \varepsilon \quad \text{eq.3-1}$$

$$M_i = a_{0i} + a_{1i} X + a_{2i} C + \sum d_{ik} M_{ik} + \varepsilon \quad \text{eq.3-2}$$

d_{ik} is the d-path effect between the mediator M_i and the mediator M_k.

To calculate the total, indirect and/or conditional effects by substituting equation eq.3-2 in equation eq.3-1 with $M_1, \dots, M_k$, we have eq.3-3.

$$\begin{aligned} Y = b_0 + \sum b_{1i}(a_{0i} + a_{1i} X + a_{2i} C + \sum d_{ik} M_{ik}) + b_2 W \\ + \sum b_{3i} W (a_{0i} + a_{1i} X + a_{2i} C + \sum d_{ik} M_{ik}) + c_1' X + c_2' C + \varepsilon \end{aligned} \quad \text{eq.3-3}$$

Multiplying out brackets, we have eq.3-4.

$$\begin{aligned} Y = b_0 + \sum a_{0i} b_{1i} + \sum a_{1i} b_{1i} X + \sum a_{2i} b_{1i} C + \sum a_{i1} b_{1i} d_{ik} X + b_2 W + \sum a_{0i} b_{3i} W \\ + \sum a_{1i} b_{3i} XW + \sum a_{2i} b_{3i} CW + \sum \sum b_{3i} d_{ik} M_{ik} W + c_1' X + c_2' C + \varepsilon \end{aligned} \quad \text{eq.3-4}$$

The indirect effect of X on Y through $M_1, \dots, M_k$ is $a_{i1} b_{1i} d_{ik}$.

3.3 Survey design

Apart from the questionnaire of PV awareness and ownership, the survey consists of four other parts. The first one contained questions about the respondent's house ownership, their house type, and their role in the household decision. This part aims to identify the house suitability for installing residential PV and the chance of respondent's adoption.

In the second part, in order to recognize SA based on TPB, the participants were asked to indicate their knowledge about residential PV based on levels from no knowledge to expert, their opinion and perception based on the 5-point Likert scale plus an option to refuse to answer the question. For further details about the questionnaire, refer to Table A. 2. The measurement scale items used in the study were borrowed from past studies, which have been validated.

The third part was designed for WTP investigation by repeatedly giving the participants different technology choices with different attributes and levels (Figure A. 1). While the attributes are features of the PV system, the attribute levels are certain specifications of these features. For realistic but also meaningful choice scenarios, product attributes, and attribute levels with high relevance have been based on a broad literature review.

Previous studies consider four main attributes: technical, cost, saving, polity attributes (Table A. 1). In this study, we adjust the four main attributes into five attributes. Each attribute has different attribute levels based on current

and expected future of solar PV in Vietnam and other developing countries (Energy Initiative, 2015; Ludin et al., 2018; Qazi et al., 2019). Details of the attributes and levels are presented in Table A. 3.

The survey presented customers with six sets of three alternative combinations of attributes of an available or expected available PV system in the market. Participants can select compiled preference bundles and the no-purchase option. Repeated choices by participants from sets of alternatives reveal their trade-offs between different attributes. Each individual was asked to choose one alternative from each choice set. This choice is modelled using Random Utility Theory, which is based on the hypothesis that individuals will make choices based on the characteristics of a good (an objective component) along with some degree of randomness (a random component). This way helps the analyst reconcile theory with the observed choice. The random component arises either because of randomness in the preferences of the respondent or the fact that the researcher does not have the complete set of information available to the respondent. However, if the participant chooses no-purchase or purchase of all visible bundles, it means the price levels do not overlap with a consumer's WTP range. This response will be considered exhibiting extreme response behaviour. The Sawtooth Software's module SSI Web has been used to design the survey.

The fourth part collects demographic characteristics of the respondents, such as gender, age, marital status, number of children, place of residence, Household size (HH size), electricity bill (Euro/month), income (Euro/month), level of education, house type, house ownership, household decision, which are summarized from previous studies (Table 2). They were claimed to be a major influencing factor for residential PV, green and energy-efficient purchasing.

3.4 Procedure for recruitment of participants

The research sample is a typical emerging country of low middle-income countries, Vietnam, selected based on the abundant untapped solar resources conditions, and emerging economic and social development. The country is facing a continuous surge in power demand and consumption over the coming decade, which will stimulate an urge for the development of alternative energy sources. Residential energy consumption has risen at twice the rate of annual economic growth, 13% vs 6% on average (Pablo-Romero et al., 2017; Le Phu, 2020). Positive demographics and rapid urbanization will also further stoke its electricity consumption growth rates (Khuong et al., 2019). The larger economic potential for solar PV (Khuong et al., 2020), coupled with an increasingly supportive regulatory environment, the country's solar PV sector is poised for a new dawn.

This paper analysed data from the survey of random individual consumers aged from 20 to 69 years old living in urban and non-urban areas in Vietnam. The survey was conducted in March and April 2020 with one pilot and two real surveys. Firstly, a trial version was conducted with 202 respondents, including 15 psychologist, 22 solar energy experts, and the rest are randomly surveyed by emailing. After a revision, the second version was partly distributed by emailing (300 mails sent), randomly asked in the field trips (at ten different locations), and via social network across Vietnam and partly via direct distribution to relatives, friends, working adults at their workplace. 1719 responses were qualified out of 2174 completed surveys. In order to analyse the PV adopter's typical characteristics, we released the third survey focusing only on current PV adopters and finally got 320/420 completed feedbacks. In total, both surveys made up the gross sample N=2039 observations. The composition and distribution of the samples are shown in Table A. 4.

4 SURVEY RESULTS AND SA AND WTP MODELS

This section presents the survey results (Section 4.1) and the results of regression modelling for SA (Section 4.2) and WTP (Section 4.3). After testing different fit-in models for SA and WTP, a mediation model is used to predict SA, while a moderated mediation is used for WTP.

Extreme and bias responses are deleted based on normality and validation tests (Table D.1. 1). A moderated mediation model is a multiple linear regression model for analyzing multifactor data. The major problem in dealing with regression analysis is the presence of outliers in data, which is the observations of extreme and/or bias lie outside the overall pattern of distribution. It is an observation whose dependent-variable value is unusual, given its value on the predictor variables. In this study, all variables are tested normality and skew. Then we use Cooks and Mahalanobis distances at the proportion of outliers 10% to identify outliers (Hadi and Simonoff, 1993). The cleaned data of the gross sample N = 2002, which excluded outliers, is processed for the moderated mediation model for assessing the model-to-data fit.

4.1 General results from the survey

The survey was conducted to investigate SA and WTP of the people in Vietnam toward residential PV. In general, residential PV received a positive reaction from the random respondents with more than 60% of them finding residential PV is a purchasable product. However, the acceptance level seems to be less optimistic, with only around 20% of the population having the SA score above 4 out of the maximum 5 (Figure 4). We also observe a positive signal of WTP toward residential PV with more than 55% of participants willing to pay for the product. However, along with this, we see that almost 20% of respondents completely neglecting the product. Most of the higher-approval people are at an average of 40-49 years old, with the highest level of knowledge about PV system (average of 2.75/5), the highest electricity bill (3.15/5) and the highest income (5/8).

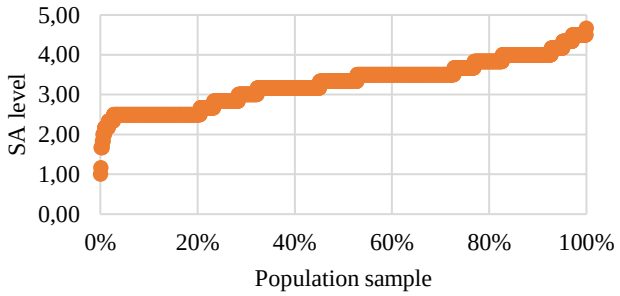

Figure 4. Overall SA toward residential PV

Among all the five considered attributes, including total investment (price), guarantee and manufacturer (or product origin) show their importance relative to others in a person's decision in buying PV system for their home (Figure 5). Meanwhile, the different saving potential and scheme support are less significant in people's decision-making process.

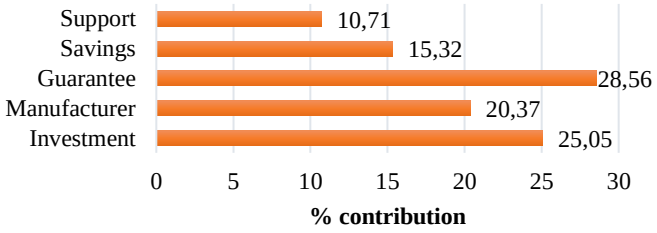

Figure 5. The contribution of each factor to the customer's final decision

The calculated WTP values show people, in general, would pay about 100 Euro more for a product with a guarantee. However, it does not matter for them if the guarantee is 10 or 15 years. Among all the suppliers, Japan and Germany are the favourites of the public (Figure 6). Accordingly, consumers are willing to pay around 30 to 60 Euro more in total for these products than for products from Korea, Taiwan and China, respectively.
There is a possibility of an interaction effect between investment and guarantee (Table D.2. 7). It means that people expect prices to come with a warranty. However, this effect is insignificant.

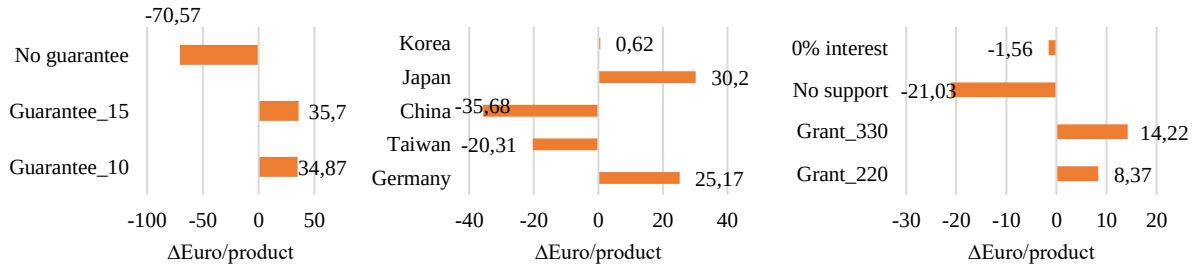

Figure 6. The difference that customer will pay compared with the average WTP

4.2 Mediation model for SA

First, we tested the correlation between all variables to select the correlated variables for the SA model (Table D.2. 1). Age & Marital status & Children (AMC), Income, Electricity bill and Place of residence can be used for calculating the action paths between variables in the moderated mediation model. Based on that, different model constructs are defined and pretested before identifying the final model (Appendix E. 1**Fehler! Verweisquelle konnte nicht gefunden werden.**).

In the final model, a mediation model (Model 11, Table 3) is identified to predict SA (Y) toward residential PV. Environmental interest is recognized as the main intervention (X) or target variable, the two demographic factors (AMC and Income) are covariates (C1, C2) and PV knowledge, Subjective norm, Attitude, and Perceived risk are the mediators (M1 to M4), respectively.

Environmental interest has the strongest positive impact on the mediators and SA, especially on PV knowledge (a11=.588) and Perceived behavioural control (a14=.120). It means that people with more interest in the environmental topic seem to have more knowledge about PV (model 7, Table 3) and have a positive effect on personal attitude (model 9, Table 3) and perceived risk (model 10, Table 3). Interestingly, people with higher Environmental interest are less affected by social pressure – Subjective norm (a12=-.077) when it comes to accepting residential PV (model 8, Table 3).

Subjective norm represents social pressure impacts heavily on personal Attitude (d32=.405 in model 9) and Perceived behavioural control (d42=.300 in model 10). However, it has an insignificant impact on SA (model 11).

Covariates, AMC and Income, are not influenced by the intervention, Environmental interest, but explain a part of the variability of SA. Covariates do not change the relationship between Environmental interest and SA. On their own, covariates predict at least part of the mediators and SA. AMC impacts negatively on Attitude, but positively on Perceived behavioural control. In comparison, Income has a positive impact on PV knowledge and Subjective norm.

The results show that all the models in Table 3 used to regress (or analyse) PV acceptance are statistically significant. With the involvement of mediators, the moderated mediator model (model 11, Table 3) has significantly higher R-sq values than no mediator models (model 6, Table E.1. 2**Fehler! Verweisquelle konnte nicht gefunden werden.**), which means 23.6% (R-sq= 23.6%, F=85.840, p-value =0.000) and 4.4% (R-sq= 4.4%, F=29.828, p-value =0.000) of the independent variable can be explained by the dependent variables, respectively.

The final model (model 11) reveals a significant positive relationship between the Attitudes and Perceived behavioural control of a person towards PV products. Among all the impact factors on SA, the Attitude factor is the decisive factor with b2=.225, followed by the Perceived behavioural control factor b4=.195. Moreover, the high Environmental interest with c1'=.073 and PV knowledge with b1=.052 and would possibly convert into higher acceptance of respondents towards a PV system.

Table 3. Results of the mediation models for predicting SA towards residential PV.

*Highlighted cell: **. Or *.Correlation is significant at the 0.01 or 0.05 level (2-tailed).*

Model	Dependent variable	*Covariates*		*Target variable*	*Mediators*				R-sq	F(HC0)	p-value	Sig.
		AMC (ci1-path)	Income *(ci2-path)*	Eco *(a-path)*	PVK *(di1-path)*	SN *(di2-path)*	Att *(di3-path)*	PBC *(di4-path)*				
7	PVK (M1)	.039	.052**	.588**					.197	206.207	.000	Yes
8	SN (M2)	-.033	.071**	-.077	-.003				.030	14.459	.000	Yes
9	Att (M3)	-.082*	.009	.086**	-.017	.405**			.255	98.455	.000	Yes
10	PBC (M4)	.072**	-.009	.120**	.002	.300**	.433**		.477	282.738	.000	Yes
11	SA (Y) *(b and c'-paths)*	.086**	.016*	.073**	.052**	.005	.225**	.195**	.236	85.840	.000	Yes

Factors: Eco: Environmental interest, PVK: PV knowledge level, Att: Attitude, SN: Subjective norm, PBC: Perceived behavioural control.

Table 4 shows that the direct effect c′, which is the effect of Environmental interest explaining a portion of SA independently of M, and some of the significant indirect effects representing partial mediation. Indirect effects are calculated as in eq.3-4, and the value of the indirect effects are presented in Table 4. The direct effect of Environmental interest on SA is c1'=.073. However, the total effect is c = .137 with .064 indirect impact coming from mediator impact. The whole models include 15 possible indirect effects, but only 6 of them are significant (Table 4). The relationship between Environmental interest and SA is mediated by Subjective norm, and Attitude, but not from PV knowledge and Perceived behavioural control.

Two types of partial mediation can be distinguished, which are complementary and competitive partial mediations. The complementary partial mediation is where the direct effect c′ and indirect effect point in the same positive direction, which indicates that a portion of the effect of Environmental interest on SA is mediated through PV knowledge (M1), Perceived behavioural control (M4) and other combination of the mediators (Table 4).

In a competitive partial mediation, the direct effect c′ and indirect effect a × b point in a different direction, e.g. the combination of M2xM3, M2xM4 and M2xM3xM4 (Table 4). In the competitive partial mediation, we see that Subjective norm is played as the opposer. It can be concluded that the Subjective norm or social pressure will reduce the magnitude of the relationship between Environmental interest and SA. However, the effect strength is quite miniature of around -.008 to -.003 (Table 4).

Table 4. The significance of direct and indirect effects and their magnitude

X impacts Y	**Model**	**Path**	**Effect**	**SE**	**LLCI**	**ULCI**	**Significant**
Total effect	**Eco → SA**	**c**	**.137**	**.018**	**.101**	**.173**	Yes
Direct effect	**Eco → SA**	**c'**	**.073**	**.019**	**.035**	**.111**	Yes
X impacts Y through		**Total indirect effect**	**.064**	**.013**	**.039**	**.089**	**Mediated**
M1	Eco → PVK → SA	a1 b1	0.036	0.01	0.016	0.057	Complementary
M4	Eco → PBC→ SA	a4 b4	0.028	0.006	0.017	0.04	Complementary
M2 x M3	Eco → SN→ Att → SA	a2 d32 b3	-0.008	0.003	-0.015	-0.002	Competitive
M2 x M4	Eco → SN→ PBC→ SA	a2 d42 b4	-0.005	0.002	-0.01	-0.001	Competitive
M3 x M4	Eco → Att → PBC→ SA	a3 d43 b4	0.009	0.002	0.004	0.013	Complementary
M2 x M3 x M4	Eco → SN→ Att → PBC→ SA	a2 d32 d43 b4	-0.003	0.001	-0.006	-0.001	Competitive

Factors: Eco: Environmental interest, PVK: PV knowledge level, Att: Attitude, SN: Subjective norm, PBC: Perceived behavioural control, SE: booted standard error, LLCI & ULCI are booted lower and upper levels for confidence interval a path.

4.3 Moderated mediation model for WTP

Different from the SA model in Section 4.2, we discovered a more complex model involving both mediator and moderator variables to predict WTP with Y being the Price sensitivity of the population. The best model explaining Price sensitivity (Y) consists of one target variable, one covariate, five mediators and two moderators (detail model in Table 5). The mediator variables, including PV knowledge (M1), Subjective norm (M2), Attitude (M3), Perceived behavioural control (M4) and SA (M5), are the variables that can explain how internal psychological significance take on person reaction in the market. The moderator variables, e.g. Income (W) and Age (Z) of the respondents, are quantitative and can affect the direction and strength of the relationship between the target variable, Environmental interest (X), and the dependent or criterion variable, Price sensitivity (Y). The moderator variables specify when certain effects will hold, while the mediators explain how or why such effects occur. Place of residence (C1) and Children (C2) play the role of the covariates in this moderated mediation model.

The model can explain 7.72% of the Price sensitivity of the population (R-sq= 7.72%, F=8.445, p-value =0.000). Among all the possible effects, there are four significant direct effects on the Price sensitivity coming from Environmental interest (X), Perceived behavioural control (M4), Income (W) and Place of residence (C1). Perceived behavioural control (M4) has the strongest effect with b14= 1.593, followed by Income (W) with b2 = 1.183. Environmental interest (X), and Place of residence (C1) has a similar effect on the Price sensitivity of c2' = 0.7 (Table 5). When these variables' values increases, the Price sensitivity is decreased.

Five significant indirect effects are revealed, which are the interaction of PV knowledge (M1), Subjective norm (M2) with the two moderators, and Perceived behavioural control (M4) with Income (W). All the significant indirect effects are quite weak compared with the direct effects. Two of them lessen the Price sensitivity, while others enhance it when they increase (Table 5).

Table 5. Results of the moderated mediation model for predicting personal Price sensitivity towards residential PV

Variable	**Symbol**	**Effect**	**Coefficient**	**SE**	**p-value**	**LLCI**	**ULCI**	**Significant**	**Price sensitivity**
PBC	M4	Direct	1.593	0.505	0.002	0.603	2.584	Yes	Lessen
Income	W	Direct	1.183	0.375	0.002	0.448	1.918	Yes	Lessen
Eco	X	Direct	0.750	0.153	0.000	0.450	1.049	Yes	Lessen
PoR	C1	Direct	0.720	0.132	0.000	0.461	0.979	Yes	Lessen
PVK x Age	M1 x Z	Indirect	0.286	0.079	0.000	0.132	0.441	Yes	Lessen
SN x Income	M2 x W	Indirect	0.220	0.075	0.003	0.073	0.366	Yes	Lessen
PVK x Income	M1 x W	Indirect	-0.154	0.050	0.002	-0.253	-0.056	Yes	Enhance
SN x Age	M2 x Z	Indirect	-0.244	0.111	0.029	-0.463	-0.026	Yes	Enhance
PBC x Income	M4 x W	Indirect	-0.376	0.097	0.000	-0.565	-0.186	Yes	Enhance
SA	M5	Direct	-0.845	0.497	0.089	-1.819	0.129	No	-
Att	M3	Direct	-0.776	0.481	0.107	-1.720	0.168	No	-
Age	Z	Direct	-0.609	0.575	0.290	-1.737	0.519	No	-
SN	M2	Direct	-0.308	0.384	0.424	-1.061	0.446	No	-
Children	C2	Direct	-0.252	0.263	0.337	-0.768	0.263	No	-
Att x Income	M3 x W	Indirect	-0.082	0.089	0.360	-0.257	0.093	No	-
PVK	M1	Direct	0.001	0.288	0.998	-0.564	0.565	No	-
SA x Age	M5 x Z	Indirect	0.056	0.151	0.710	-0.241	0.353	No	-
PBC x Age	M4 x Z	Indirect	0.072	0.148	0.627	-0.218	0.363	No	-
SA x Income	M5 x W	Indirect	0.083	0.095	0.382	-0.104	0.270	No	-
Att x Age	M3 x Z	Indirect	0.099	0.149	0.503	-0.192	0.391	No	-

Factors: PBC: Perceived behavioural control, Eco: Environmental interest, PoR: Place of residence, PVK: PV knowledge level, SN: Subjective norm, Att: Attitude, SE: booted standard error, LLCI & ULCI are booted lower and upper levels for confidence interval a path.

The conditional indirect effect was calculated based on different Income and Age groups, using 10,000 bootstraps resamples. Results revealed that the indirect effect between Environmental interest and Price sensitivity through PV knowledge, Subjective norm and Perceived behavioural control was significant in nine different groups of Income and Age respondents (Table E.2. 1**Fehler! Verweisquelle konnte nicht gefunden werden.**).

The indirect effect of PV knowledge and Subjective norm was recognized positive with the older groups (age from 50-69) but negative with other groups. The indirect effect of PV knowledge was significantly different among the nine groups, while the indirect effect of Subjective norm and Perceived behavioural control were less different among them.

The index of moderated mediation was negative for Income and positive for Age, with 95% confidence. As this confidence interval does not include zero, the conclusion is that the indirect effects (PV knowledge (PVK), Subjective norm (SN) and Perceived behavioural control (PBC) of Environmental interest) on Price sensitivity welcomed negatively moderated by Income and positively moderated by Age. It means that Income increase enhances the Price sensitivity, while Age increase lessens the Price sensitivity (the total effect in Table E.2. 2**Fehler! Verweisquelle konnte nicht gefunden werden.**).

5 DISCUSSION AND POLICY IMPLICATIONS

Detail model interpretation and comparison with literature will be discussed in Section 5.1 to reveal the drivers and barriers of SA and WTP toward residential PV products. Policy implication will be discussed in Section 5.2. The theoretical contribution, the limitations, and directions for further research are discussed in Section 5.3.

5.1 Drivers, mediators and moderators of SA and WTP

Environmental interest is a game-changer

Among all considered variables, Environmental interest plays the most important role as the target variable or significant predictor causing SA and WTP. The results indicate that people's higher interest in protecting the environment will potentially translate into positive SA and increase the likelihood of adoption. This finding is generally in line with the hypotheses and confirm previous research that Environmental interest has a direct and positive effect on WTP (Schwarz, 2007; Claudy et al., 2011) and is the most matters to people's WTP (Maichum et al., 2016; Li et al., 2019). In contrast to previous studies, this study emphasizes the importance of the indirect effect of Environmental interest not only on WTP but also on personal SA, Attitude and Perceived behavioural control.

The indirect effect of Environmental interest is almost equally important to the direct effect, as reported coefficient of .073 and .064 on SA. It means the SA level is regulated passively and proactively through individual

Environmental interest. However, there is a large deviation between direct and indirect effects of Environmental interest on WTP, with .75 compared to -.045 (Table E.2. 1). The conditional indirect effects of Environmental interest (X) on Price sensitivity (Y) through moderators are presented in Table E.2. 1. It can indicate that with people's increased concern about environmental problems, they seem to be strongly motivated in deciding on investing in PV, even though they may not see the item less risky than the other people do.

Apart from that, PV knowledge does not have a direct or indirect impact on WTP, but a slightly indirect effect on SA (b1=.052). Environmental interest is the original motivation to raise PV knowledge (a11=.588). It means that if the government wants to encourage people to use residential PV, the first thing they should do is to draw people's attention to the environmental matter, which will associate with a higher chance of SA for the PV product.

Behavioural intention, not interpersonal behaviour mediates SA and WTP

In the SA and WTP models, the two behavioural intention, including Attitude, Perceived behavioural control, but not the interpersonal behaviour, Subjective norm, play the mediated role in the chain. This finding is in contrast to previous studies on green energy (Low Carbon Technologies - LCTs), which claimed social pressure in Asian countries plays a vital role promoting LCTs (Sudbury-Riley and Kohlbacher, 2016; Quoquab and Mohammad, 2019). A plausible explanation may be related to the lag of cultural acceptance of new concepts within the society in Asian countries.

Although not showing the strong effect on SA and WTP, Subjective norm is emphasized as a vital effect on Attitude (d32 = .40) and Perceived behavioural control (d42 = .30) (Table 3). It means that while Attitude and Perceived behavioural control significantly predict SA and WTP, Subjective norm would play the role of a bridge between interpersonal behaviour and outcome consume behaviours.

Demographic feature covariates and moderates SA and WTP

Through structural equation modelling, we support hypotheses of previous studies about age (Gilly and Zeithaml, 1985; Lunsford and Burnett, 1992; Barr et al., 2005), and income (Welsch and Kühling, 2009), which can be used to establish customer segmentation when considering SA and WTP. This study also supports the assumption that people with higher income seem to be more likely to adopt a PV system than the averages (Jager, 2006; Islam and Meade, 2013; Rai et al., 2016). Moreover, income promotes personal attitudes and perceived behavioural control with residential PV, but also contributes to lessening people's sensitivity toward price changes of residential PV. Conversely, in Vietnam, we did not find evidence of higher education lead to higher SA and WTP or difference between gender toward SA and WTP as proposed by (Borchers et al., 2007; Sardianou and Genoudi, 2013; Wolske et al., 2017).

Going beyond previous studies, this study does not provide a vague relationship between Income, Age and SA and WTP, but it emphasizes the different reactions of nine subgroups of Income & Age combinations (Table E.2. 1). For example, the groups which are most sensitive to price changes are the group of 50-69 years old with low and middle income, and the two groups of 20-29 and 30-49 years old with high income. The increasing Environmental interest in these groups leads to increased PV knowledge and then change their Price sensitivity significantly. However, interestingly, the 50-69-year-old group had an increased sensitivity, while the other two groups had decreased Price sensitivity. This should be taken into account in terms of market segmentation strategies.

However, as the level of PV knowledge increases, the change in Price sensitivity decreases. When the level of PV knowledge increases to a certain level (3/5), the Price sensitivity levels between groups are asymptotic (Figure 7).

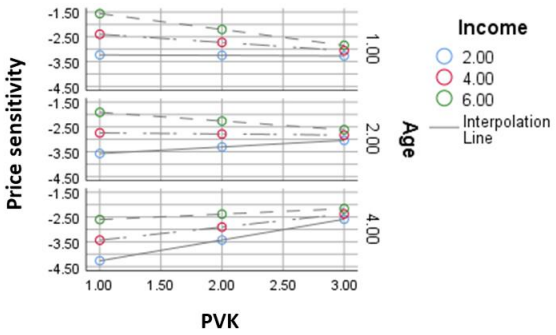

Figure 7. Interaction between PV knowledge and WTP in different Income & Age groups

This study added some demographic characters, which reflect people's living condition, such as household size, house type, house owner and household decision to investigate whether the living condition can become a motive for SA and WTP toward residential PV. However, the results reveal only the direct effect of the Place of residence on the Price sensitivity. It means people who live in urban and suburban areas seem to be less sensitive when residential PV products change in price.

Unexposed relation between SA and WTP

While (Guagnano et al., 1986) and (Labay and Kinnear, 1981) found a negative correlation between SA and WTP toward solar technology in general, the study by (Faiers and Neame, 2006) points to a positive correlation. Using similar moderating variables and including both SA and WTP in the survey, we are able to compare the control and cushion effects of different variables on producing behaviour toward residential PV. The findings in this study reject both hypotheses and conclude that there is no direct or indirect effect between SA and WTP in Vietnam. It may indicate that increasing SA will not necessarily lead to higher adoption. Alternatively, if people in general willing to pay more for residential PV, it may not indicate that they accept the product.

5.2 Policy implications

This study offers insights about residential PV behaviour for policymakers and stakeholders. This study identifies the factors that boost customers intention to accept and adopt residential PV and defines different roles for different characters of the behaviour. Therefore, policymakers and stakeholders can refer to when attaining residential PV development and success in developing countries.

Why are people not buying?

First of all, the proposed models suggested three main results behind the refusal behaviour of the public toward purchasing rooftop PV for their own house.

- Relatively low Environmental interest in society. Despite the decisive role on SA and WTP, Environmental interest level in Vietnam remain relatively low at the average of 2.88/5 (Figure 4).
- Lack of knowledge. By comparing between PV owner and people who willing to buy PV product at any price (Unconditional WTP), at a certain price (Conditional WTP) and who will very unlikely buy PV product at all (Unlikely), we see that the PV knowledge of the PV owner is not so much better than the other, around 2.8/5 and 2.3/5, respectively (Figure 8, left).
- Lack of understanding about customer preference. People do not buy products solely based on price. They do factor in price with around 25% of their decision, but they will buy based on the guarantee and brand, which leads to another issue. It is an access problem. People prefer a product from Germany or Japan. However, they are not available everywhere and also expensive (Figure 5).
- Not yet an essential-product. Consumers will reach out to the product when their electricity bill and income reach a certain level (Figure 8, right).

It may be time for the policymakers and stakeholders to evaluate why the market is not working and whether they target the right market with the right policy and message.

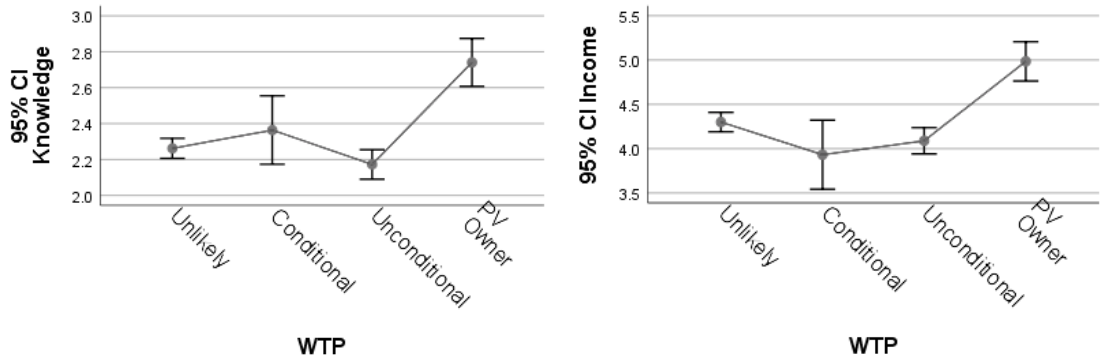

Figure 8. Comparing knowledge and income of different customer groups based on their WTP at 95% Confidence interval (CI)

Residential PV is a lifestyle product

In the field of energy research, these lifestyle approaches are utilised to conclude energy consumption and environmental awareness concerning different lifestyle groups. The final decision to install is dominated by financial and environmental benefits delivered through residential PV systems. Older stakeholders with a higher income tend to live a greener and more energy-efficient lifestyle, while principally younger, mixed-income lifestyles are more likely to have low environmental awareness (Hierzinger et al., 2011). In terms of residential PV adoption, adopters rank significantly higher on Environmental interest than average (Jager, 2006).

In this paper, we also find out that the demand is driven by four main factors, including two demographic factors (Income and age-family-children) and two psychological factors (Environmental interest and PV knowledge). By itself, residential PV seems to be quite potential for self-sufficient development since these factors are projected to continue increasing in all scenarios without any strong external impacts such as policy and force in the national master plan in Vietnam (Ministry of Planning and Investment Portal, 2020).

Policy suggestions

For policymakers, it seems that they should mostly focus on the fundamental of residential PV need, which is Environmental interest. By developing environment-friendly awareness and promotion activities within the population, policymakers can educate the population about the importance of protecting the environment and how using renewable energy can support this idea in daily life. The education on environment and the importance of PV in reducing environmental effect can be directly translated to higher SA and WTP as well as indirectly to the more positive attitude and perceived behavioural control, which can also lead to higher SA and WTP. However, since SA does not affect WTP, it means that even if SA is favourable, it does not mean that PV product will be consumed. Policymakers alone cannot heat the PV market. It requires joint efforts from all stakeholders.

For stakeholders, first of all, it is necessary to establish a market segmentation policy. Since Income and Age play the role of moderator and covariate in residential PV behaviour, it seems logical to use these characters to divide the whole market into different segments and then develop a different strategy for each segment separately. Moreover, the findings of the Place of resident effect on WTP suggested that the people living in Urban and Suburban are less price-sensitive than in Non-urban areas. Therefore, if stakeholders, instead of continually searching for financial support from the government to establish a market in rural areas in developing countries, they could enter the market with less resistance from customers in Urban and Suburban areas.

5.3 The theoretical contributions and critical discussion

This study was undertaken to develop a theoretical and integrative model in support of residential PV understanding and development. As such, the current research made an effort linking psychological and economic aspects to measure multiple outcomes involving residential PV behaviours. To date, psychological and adoption behaviour combination have been considered minimally (discussed in Section 2.1) as an antecedent of other measures within the renewable energy literature.

5.3.1 Theoretical contributions

The findings offered the theoretical premise of a complex interaction between different variables and SA and WTP, as evidenced in the structural equation model and moderated mediation analysis. We determine the role of each variable in contact with SA and WTP and compare the effect between the two models. In both models, Environmental interest is identified as the target variable, causing people behaviour toward residential PV. PV knowledge, Attitude and Perceived behavioural control not only impact SA and WTP directly but also mediate the effect of Environmental interest and SA and WTP. AMC and Place of residence are covariates in the SA and WTP models, respectively. Lastly, Income is the covariate in the SA model, but the moderator in the WTP model moderating the indirect effect of Environmental interest and SA and WTP through PV knowledge, Subjective norm and Perceived behavioural control. These contributions are beyond recent studies.

The proposed integrative framework and models allow identifying direct and indirect relationships between Environmental interest, Income and Perceived behavioural control with both SA and WTP. The proposed models can improve the predictive utility of the original TPB model from around 4.4% to 23.5% for SA and from around 2% to 7.7% for WTP.

This study provides continued support for an amended mediation model in previous studies of green purchase behaviour (Litvine and Wüstenhagen, 2011; Chen and Deng, 2016; Maichum et al., 2016) but brings it one step forward with a more complex model of extra consideration for covariates and moderators to create the moderated mediation models. Additionally, the current work serves to provide support (through the use of PROCESS macro) for the continued utilization of moderated mediation models within the renewable energy literature; for which little other research exists to date.

It is not common to test more than two mediators, even though the previous studies found many more variables that are related to the outcome, SA or WTP. To our knowledge, this study might be the first test of a four/five-serial-mediator model for renewable energy behaviour study. Using four/five-serial mediators together forms a highly complex model, particularly for interpretation purposes, as the model can create up to twelve distinct effects that Environmental interest has on SA and WTP, eleven indirect effects and one direct effect. Discovering chains of causality is not only important for confirming theory and giving a basic understanding of the processes in question, but it also represents a first step toward understanding residential PV behaviour properly, as it provides possible targets for intervention. Serial mediation also made the data fit the model perfectly, more so than parallel multiple mediator models.

The complex nature of behaviour toward residential PV entangles more than just linear relations between a variety of behavioural determinants and the final behaviour as in most of the literature in the related field has been explained. The relationship between or among behavioural antecedents has an indirect influence on final behaviour, SA and WTP, through a mediating variable, such as PV knowledge, Attitude and Perceived behavioural. This study is the first attempt to develop a model integrating SA, WTP, demographic and extended variables in the residential PV behaviour study. The combination of SA and WTP, especially in which WTP is not a binary variable but a quantitative variable of Price sensitivity, is largely non-existent in the related literature.

5.3.2 Critical discussion

This study has many strengths, including being the first test of the theoretical predictions made concerning residential PV behaviour based on the use of multiple variables within a psychosocial and economic framework. This study, therefore, provided the opportunity to compare mechanisms and theories between integrated models of SA and WTP. Besides, using serial mediation allowed us to identify how one mediator impacts upon others in a chain of indirect effects.

Since this study goes beyond literature by combining SA and WTP in moderated mediation models to explain residential PV behaviour, the results should be cautiously interpreted. The study is conducted with survey data in a developing country, Vietnam, with 2004 qualified samples. Results do not primarily permit the generality of the model outside the context of developing countries. Future research should replicate this model in other destination contexts that may help cross-validate the current findings. Data for the proposed model was cross-sectional and correlational, prohibiting the inference of causal relationships within the model. Concomitantly, all the predictor and outcome variables were obtained from the same population, and the interpretations are offered tentatively.

Further research should address these limitations by using the longitudinal analysis to capture and control disparities and the causal direction among variables. Because residential PV is relatively new in Vietnam, bias and extreme responses could be a limitation of this study. Further research is needed to validate the findings.

The findings of this study showed a potential of dividing the population into different segments based on their characters and the conditional indirect effects of Environmental interest on SA and WTP via different mediators, e.g. Attitude, Perceived behavioural control. Future research should deepen into this subject to build market diffusion of residential PV in Vietnam.

The study is also susceptible to confounding or epiphenomenal associations, for even though statistical control was applied, there was an absence of randomness. Further analysis as part of a prospective study should, therefore, be carried out in such a way that includes randomness. The random assignment cannot by itself guarantee the presence of a causal order; however, a longitudinal study might provide stronger evidence.

The theory of planned behaviour in WTP studies is often interpreted in favour of economic valuation. In our approach, the price was incorporated in conjoint designs as an additional attribute in order to provide WTP estimates. This practice, however, has some shortcomings. For example, WTP does not only depend on the composite product and a budget constraint but also on alternative product offerings, so-called reference products. Therefore, the theoretical problem of including price as an attribute in conjoint analysis remains unresolved.

6 CONCLUSION AND OUTLOOK

Over the last years, residential PV shows more techno-economic potential, especially in developing country, which has stimulated increasing attention of policymakers, stakeholders as well as public. Moreover, it has been recognised as a positive environmental contributor. In order to understand residential PV behaviour, this study attempts to define the conceptual framework of key drivers of SA and WTP toward residential PV. Different from previous studies, WTP has not measured by a binary choice, but the probability of buying the product. This theoretical framework links with several social-psychological theories, which are the theory of planned behaviour and conjoint-based economic theory model. The current research is one of the first of its kind linking psychological and economic aspects to measure multiple outcomes involving residential PV behaviours.

The main investigative survey was then conducted in Vietnam. Total data of 2039 participants were collected in 2019, using web-based questionnaires. Factor analysis was used to assess the measurement models of the proposed conceptual framework. Moderated mediation model then is used to test all of the proposed hypotheses. This study confirms and emphasizes the importance of Environmental interest effect not only direct but also indirect on WTP and SA. Moreover, it is found to impact directly and positively on Attitude and Perceived behavioural control. Attitude and Perceived behavioural control represent interpersonal behaviour toward residential PV is discovered not only predicting SA and WTP but also mediating the effect of Environmental interest on SA and WTP. Although Subjective norm shows the strong impact in promoting Attitude and Perceived behavioural control, it was not a significant direct predictor of SA and WTP toward residential PV.

Through structural equation modelling, this study confirms the assumption that people with higher income seem to have a more positive attitude and better perceived behavioural control as well as more likely to adopt PV system than the averages. However, we did not find evidence of higher education lead to higher SA and WTP or difference between gender toward SA and WTP.

This study added some demographic characters reflecting people living condition. However, only the Place of residence shows an effect on Price sensitivity, which shows the more WTP of people in urban and suburban than in rural areas. While the previous study claimed a positive correlation between SA and WTP toward solar technology (Faiers and Neame, 2006), this study rejects this hypothesis and concludes that there is no direct or indirect effect between SA and WTP in Vietnam.

Based on the moderated mediation models, this study identifies the factors that boost customers intention to accept and adopt residential PV and suggests policymakers and stakeholders act accordingly to promote residential PV development in developing countries. Policymakers should mostly focus on promoting Environmental interest among society by providing environment-friendly awareness and promotion activities. This education can be directly translated to higher SA and WTP as well as indirectly to the more positive attitude and perceived behavioural control, which can also lead to higher SA and WTP. Stakeholders should divide the market into different segments and then develop a different strategy for each segment separately. Moreover,

they should establish a market in Urban and Suburban areas instead of focusing on rural areas in developing countries.

This study has many contributions to the theoretical predictions of residential PV behaviour based on the use of multiple variables within a psychosocial and economic framework. It provided the opportunity to compare mechanisms and theories between integrated models of SA and WTP and identified how one mediator impacts upon others in a chain of indirect effects. However, the results should be cautiously interpreted and validated when using outside the context of developing countries. Future research should replicate this model in other destination contexts that may help cross-validate the current findings.

APPENDIX A. SURVEY CONSTRUCTION AND SAMPLES

Figure A. 1 CBC survey example

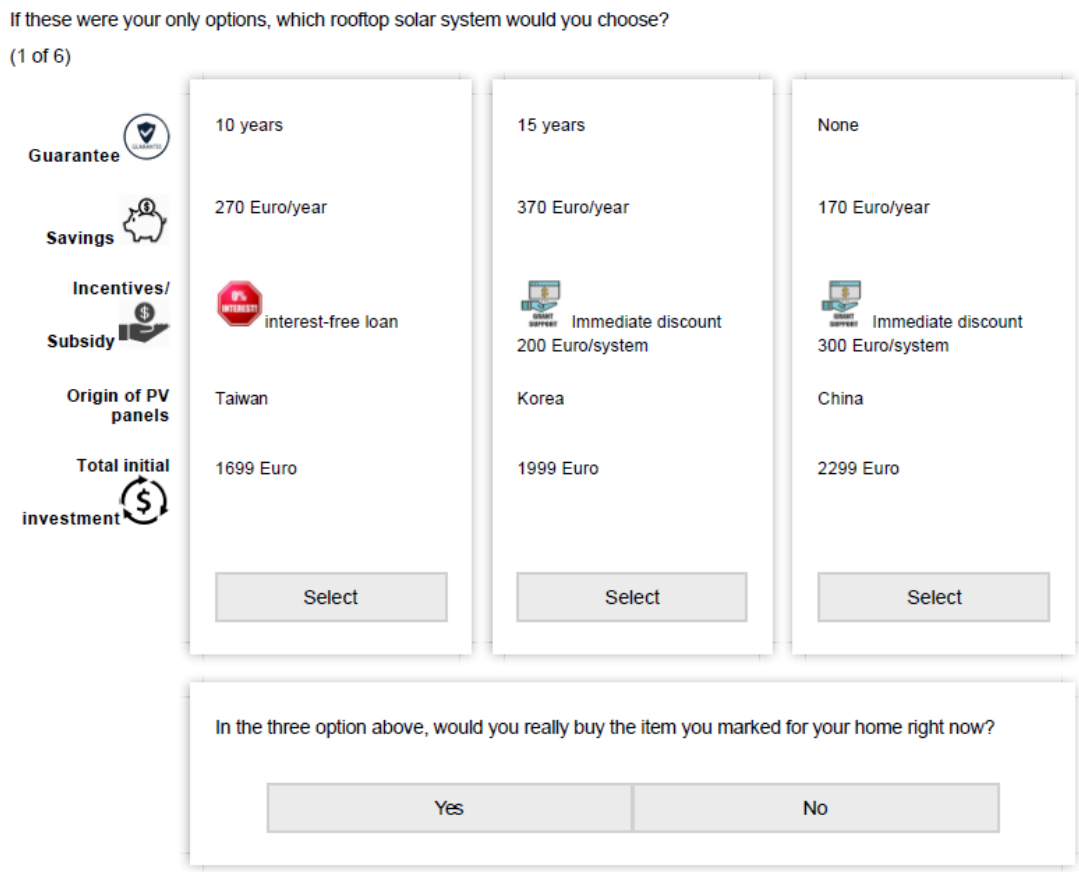

Table A. 1 Overview of product attributes used in previous conjoint surveys related to residential PV

Source	**Objective**	**Subject**	**Technical attribute**	**Cost attribute**	**Saving attribute**	**Policy attribute & others**	**Utility model**	**Country**
(Hille et al., 2018)	Financial and non-financial factors drivers for PV	Building installed PV	Roof type (+base price); Color PV system/ roof, Origin of PV;	Investment costs, Revenues from electricity sales	Reduction in electricity costs	Purchase premium		**Switzerland**
(Ida et al., 2014)	Potential for greenhouse gas emissions reduction due to smart equipment: PV & home energy	HH	Stylish designed PV	The initial cost of introducing PV	Reduction in greenhouse gas emissions; Annual reduction in fuel and lighting charges	Free inspection & maintenance period	Mixed logit models	Japan

	management systems							
(Islam and Meade, 2013)	Causal link: technology attributes & adoption time	HH		Total investment; Payback period; Inflation on fossil fuel cost	Energy cost saving; Saving in carbon emission	Tax incentives; export reward; policy changes	Random utility theory & discrete-time survival mixture	Canada
(Wissink et al., 2013)	Impact of PV systems to home purchasing	Dwelling buyers	Existing system; Dwelling size; Location; Building period			Price	Random utility theory & multi Nominal Logit model	The Netherlands
(Chen et al., 2013)	Key attributes contribute to a product's market success		Electrical (e.g. Power variance, Power ratio, Efficiency), Physical (e.g. Weight, Length, Width)	Economics (e.g. Cost, Time on the market)		Certification (e.g. IEC and IS0), Warranty (e.g. Workmanship)		US
(Axsen and Kurani, 2012)	Influence of energy policies & specific policy risks	PV project developers				FIT; Duration of the administrative process; Policy changes	Maximisation of a utility function	
(Scarpa and Willis, 2010)	Policy context of renewable energy production in the EU	HH	Type of technology	Capital cost; Maintenance cost	Energy saved by the technology	Recommendation (e.g.Friend, plumber)	Conditional & mixed logit models;	England

Table A. 2 Item and construct measures (translated from Vietnamese)

Type	Factor	No. Items	Question	Items	Ref	Measurement
Extended variables	PV Knowledge	1	How do you rate your general knowledge of residential PV?		(Schumacher et al., 2019)	5 Likert-scale of quality: 1: very poor, 2: poor, 3: fair, 4: good, 5: excellent.
	Environmental interest	8	How often do you discuss this topic in daily life?	Climate change Pollution Eco Inventions Saving energy Solution for a power blackout Renewable energy PV power PV household	(Klaus et al., 2020)	5 Likert-scale of frequency: 1: never, 2: rarely, 3: sometimes, 4: often, 5: always; plus refuse to answer option
SA's determinant	Attitude	4	I think the idea of using a PV system for a house is	Feasible Useful Ecological Electricity saving	(López-Mosquera et al., 2014; Li et al., 2019)	5 Likert-scale of agreement: 1: strongly disagree, 2: disagree, 3: neither nor, 4: agree, 5: strongly agree; plus refuse to answer option
	Subjective norm	3	"The people who are important to me think that ..... will pay for installing PV system."	Everyone I They	(Claudy et al., 2011; López-Mosquera et al., 2014; Li et al., 2019)	
	Perceived behavioural control	5	Installing rooftop PV in my house would be	Cost-effective Fit lifestyle Fit technology Saving bills Reliable	(Klaus et al., 2020)	
SA	SA	6	Please indicate if you agree with the following statements	Like the idea Support the idea I will install Not like the idea Not support the idea Not install	(Klaus et al., 2020)	

Table A. 3 Residential PV attributes and attribute levels used in the conjoint survey in this study

Attribute in literature	Modification	Explanation	Data type	Level	Ref
Cost attribute	Total investment (Euro/kWp)	The total investment expenditure of the system made at t=0 consists of capital cost and working capital.	Continuous data	799 1099 1399 1699	(Scarpa and Willis, 2010; Islam and Meade, 2013; Ida et al.,

				1999 2299	2014; Hille et al., 2018)
Saving attribute	Bill saving* (Euro/year)	The total electricity cost saved per year by using a residential PV system. The calculation is based on data from (EREA, 2019).	Continuous data	170 270 370 470 570	(Islam and Meade, 2013; Hille et al., 2018)
Policy attribute	Guarantee	The period of time for which the supplier guarantees the stability of the quality indexes of the product.	Discrete data	None 10 years 15 years	(Ida et al., 2014; Hille et al., 2018)
	Support	The expected financial support from the government for residential PV(Magazine, 2020).	Discrete data	None 0% Interest 200 Euro/system 300 Euro/system	(Axsen and Kurani, 2012; Wissink et al., 2013)
Technical attribute	Origin	Country of origin represents the country or countries of manufacture, production, design, or brand origin where the product comes from.	Discrete data	Taiwan Korea China Germany Japan	(Hille et al., 2018)

Table A. 4 Distribution of sample

	Description	Scale	N	%	Cumulative %	Mean	Std. Error of Mean	Std. Deviation	Variance
Gender	Of respondent	M	1231	60.4	60.4	1.4	0.011	0.489	0.239
		F	808	39.6	100				
Age	Of repondent	20-29	498	24.4	24.4	2.52	0.026	1.191	1.42
		30-39	542	26.6	51				
		40-49	593	29.1	80.1				
		50-59	262	12.8	92.9				
		60-69	144	7.1	100				
Marital status	Of respondent	Single	488	23.9	23.9	2.53	0.021	0.961	0.924
		Engaged	133	6.5	30.5				
		Married	1310	64.2	94.7				
		Divorced	62	3	97.7				
		Others	46	2.3	100				
Children	Of respondent	No	590	28.9	28.9	1.71	0.01	0.454	0.206
		Yes	1449	71.1	100				
Place of residence	Place of the respondent' home	Urban	1030	50.5	50.5	1.7	0.017	0.784	0.614
		Suburban	599	29.4	79.9				
		Countryside	410	20.1	100				
H.H. size	Number of people in the respondent'shouse	1	130	6.4	6.4	2.24	0.014	0.611	0.373
		2-4	1349	66.2	72.5				
		5-7	497	24.4	96.9				
		>7	63	3.1	100				
Electricity bill (Euro/month)	Electricity bill of the household	<20	283	13.9	13.9	2.68	0.026	1.163	1.352
		20-39	698	34.2	48.1				
		40-59	633	31	79.2				
		60-79	292	14.3	93.5				
		80-99	72	3.5	97				
		>100	61	3	100				
Income (Euro/month)	Net income of the household	<250	147	7.2	7.2	4.33	0.041	1.87	3.498
		250-499	237	11.6	18.8				
		500-749	343	16.8	35.7				
		750-999	335	16.4	52.1				
		1000-1249	365	17.9	70				
		1250-1499	364	17.9	87.8				
		1500-1749	150	7.4	95.2				
		>1750	98	4.8	100				
Education	Of respondent	High school	245	12	12	2.86	0.022	0.978	0.956
		College	340	16.7	28.7				
		Uni	962	47.2	75.9				
		After Uni	434	21.3	97.2				
		Others	58	2.8	100				
House type	of the respondent's house	Apartment	265	13	13	2.28	0.021	0.954	0.91
		Single	1316	64.5	77.5				
		Complex	154	7.6	85.1				
		Row	228	11.2	96.3				
		Others	76	3.7	100				
House ownership	Of respondent	No	522	25.6	25.6	1.74	0.01	0.437	0.191
		Yes	1517	74.4	100				
Household decision	Of respondent	No	292	14.3	14.3	2.09	0.014	0.61	0.372
		Together	1262	61.9	76.2				
		Own	485	23.8	100				

APPENDIX B. HYPOTHESIS FOUNDATION

In order to identify the role for each variable, we use the idea of cognitivism that an individual is viewed as an 'information processor' making a decision based on intrapersonal causation (Ajzen, 1991). Typically they tend to follow the traditional five-step classification outlining problem recognition, information search, alternative evaluation, choice and outcome evaluation as the key stages in their decision processes (Solomon, 2006). The recognized problem will be the target variable, which indicates the origin of the demand for residential PV. The information search, alternative evaluation, and choices will be considered as mediator or moderator factors. The outcome evaluations are SA and WTP.

First of all, environmental knowledge and Environmental interests are the most matters to people's Willingness to purchase green products (Maichum et al., 2016; Li et al., 2019). Taking into account environmental awareness, Environmental interests, and environmental knowledge, can improve the predictive utility of the original TPB model (Chen and Deng, 2016; Maichum et al., 2016; Li et al., 2019). Based on that, we propose the hypothesis H1.

The target variable is hypothesised to influence SA and WTP via the mediating variables, e.g. SA's and WTP's determinants. That is, consumers are more likely to accept and buy residential PV if they think this kind of action has positive consequences for the target variable.

TPB measure SA with three determinants of behavioural intention (Ajzen, 1991). The attitude towards behaviour refers to an individual's positive or negative evaluation of buying a residential PV system. The subjective norm captures an individual's perception of social pressure from reference group members to enact the behaviour. Perceived behavioural control includes the perceived ease or difficulty of adopting the residential PV system (Litvine and Wüstenhagen, 2011; López-Mosquera et al., 2014).

The literature claims that the higher level of attitude, subjective norm and perceived behavioural control strengthens the individual's intention toward residential PV (Korcaj et al., 2015; Wolske et al., 2017). Attitudes and perceived behavioural control had a critical impact on emission reduction behaviour (Shi et al., 2017; Ru et al., 2019). The subjective norm factors and perceived behaviour control usually are reported as important factors driving an individual's willingness to save energy (Gao et al., 2017; Ru et al., 2018). The perceived behavioural control factor usually indicated as "risk" or "uncertainty", which is often cited as an essential factor with a positive effect on influencing adoption (Labay and Kinnear, 1980; Guagnano et al., 1986; Dunphy and Herbig, 1995; Arts et al., 2011; Ozaki, 2011). However, among the developing countries, people in Peninsular Malaysia have a negative attitude toward the use of renewable energy (Kardooni et al., 2016). These findings will be verified in Vietnam by the following the hypotheses H2 and H3:

Socio-economic and demographic factors that either determine or strongly correlate with SA and WTP are claimed in the literature. A determinant is a factor or cause that makes something happen or leads directly to a decision, while covariates are characteristics of the participants in an experiment (Miller and Chapman, 2001). These characteristics could be used to understand how the final decision is different between different groups or populations, and provide a suggestion regarding how to control for the influence of any covariate. Determinant and covariates are usually confused in behaviour research. This paper will test whether any demographic factor will work as the determinant or covariate factor of SA and WTP.

For example, older consumers show a negative correlation between age and innovativeness (Gilly and Zeithaml, 1985; Arts et al., 2011). Therefore, it is used to distinguish customer group by age. Other variables, such as the level of education and income, have been attributed to the positive effect on innovation adoption (Arts et al., 2011). People in California (the US) and Groningen (the Netherlands) with higher income and higher education seem to more likely to adopt PV system than the averages (Jager, 2006; Islam and Meade, 2013; Rai et al., 2016). Based on these, we test the hypotheses H4 to H6.

APPENDIX C. STATISTICAL ANALYSIS METHOD

Appendix C. 1 SA analysis

The three determinants are measured using statements answered on 5-point Likert scales plus the option of "do not know". The variable *attitude towards PV system* consisted of an index based on four items and had a standardised Likert range from 1 to 5. The items measured to what extent respondents perceived the product as pleasant and beneficial. The question aiming at the *subjective norm* revealed to what extent friends, relatives, and society, in general, are in favour of installing PV. The *perceived behavioural control* was also an index based on five items measuring to what extent respondents perceived the adoption as easy and feasible.

The construct perceived behavioural control is formed by combining the perceived presence of factors that may facilitate or impede the performance of behaviour and the perceived power of each of these factors. Actual behavioural control refers to the extent to which a person has the skills, resources, and other prerequisites needed to perform a given behaviour. Actual behavioural control is difficult to assess accurately, and so perceived behavioural control is measured through specially designed questionnaires and serves as a proxy measure of the influence. In the TPB, behavioural intention is controlled by a dynamic mix of the attitude, subjective norm, and perceived behavioural control variables (eq. C.1. 1). Actual behaviour is again derived mainly from behavioural intention but is mediated to some degree by perceived behavioural control.

$$A_k = \sum_{i=1}^{N} B_i a_i \text{ (Solomon, 2006)} \qquad \text{eq. C.1. 1}$$

Where, A_k is the person's overall SA towards the product k with i attribute characteristics. B_i is the strength of belief that the product possesses attribute i, and a_i is the evaluation of the intensity of feeling (liking or disliking) towards attribute i. N is the number of relevant beliefs considered by that person

Appendix C. 2 WTP analysis

This paper uses CBC to identify the WTP of a person who faces different choices when he/she intends to purchase a residential PV system (Scarpa and Willis, 2010; Franceschinis et al., 2017). CBC is a survey-based statistical technique used in market research that helps determine how people value different attributes (feature, function, benefits) that make up an individual product or service**.** To estimate product choice probabilities at different prices based on CBC, we assume the existence of a (preferred) status quo product. The respondents of the interview are a priori assumed to buy this product. The WTP for a competing product is then estimated as the price at which the respondent would switch away from the status quo product. With this set of assumptions, WTP cannot be estimated for customers who would actually not buy the status quo product in the first place or have a different (unknown) status quo product.

The residential PV production is described with i attributes and j alternatives of each attribute. Total utility of the person is U_{ij} when purchasing one product with i attributes, and each attribute has one specific alternative. The person will choose alternative $j_2$over j_1 of attribute i if and only if $U_{i2} > U_{i1}$. Based upon random utility theory, individuals will make choices based on the characteristics of a good (an objective component) along with some degree of randomness (a random component) which helps the analyst reconcile theory with observed choice. The random component arises because of randomness in the respondent's preferences or absence of their ideal set in the survey. The utility that an individual i assigns to some alternative can be described as in eq. C.2. 1eq. C.2. 1.

$$U_{ij} = \nu_{ij} + \varepsilon_{ij} \qquad \text{eq. C.2. 1}$$

This paper assumes that utility U_{ij} is composed of ν_{nij}, a non-stochastic utility function and ε_{ij} is a random component. If it is assumed that ν_{ij} is a linear utility function then $\nu_{ij} = \beta x_{ij}$. x_{ij} is systematic component. The systematic component x_{ij} separates the price attribute, p_{ij}, from non-price attributes, z_{ij}, as can be seen in eq. C.2. 2. The coefficient δ presents that with every price change, the utility will change by δ.

$$\nu_{ij} = \delta p_{ij} + \varphi' z_{ij} \qquad \text{eq. C.2. 2}$$

p_{ij} is the price of a normalised system, z_{ij} are other attributes such as manufacturer, ease of use.

By differentiating eq. C.2. 2 concerning each attribute $\frac{\partial v_{ij}}{\partial z_{ij}}$, we obtained the marginal utility provided by the attribute. By differentiating concerning price $\frac{\partial v_{ij}}{\partial p_{ij}}$, we got the marginal utility of price. By differentiating concerning the ratio of saving and income $\frac{\partial v_{ij}}{\partial q_{ij}}$, we got the marginal utility of benefit. The WTP or the marginal rate of substitution between attribute z_{ij} and price is the ratio between these two derivatives. Thus, the WTP is the ratio between the coefficient of the other k attributes and the coefficient of the price variable (Breidert et al., 2006) as in eq. C.2. 3.

$$\omega = -\frac{\hat{\varphi}}{\hat{\delta}} = -\left[\frac{\widehat{\varphi_1}}{\hat{\delta}}, \frac{\widehat{\varphi_2}}{\hat{\delta}}, \dots, \frac{\widehat{\varphi_k}}{\hat{\delta}}\right] \quad \text{eq. C.2. 3}$$

$\hat{\varphi}, \hat{\delta}$ is the mean of all ϕ and δ. The negative sign represents the inverse relationship between price and WTP. When the price increases, the WTP is decreased.

Using the coefficient of WTP, ω, eq. C.2. 2 can be rewritten as in eq. C.2. 4. Instead of calculating ϕ and δ, the parameter of the model is ω, and the unit changes from the utility in eq. C.2. 1 to currency in eq. C.2. 4.

$$v_{nij} = \delta(\omega' z_{ij} - p_{ij}) \quad \text{eq. C.2. 4}$$

To account for consumer heterogeneity and overcome the information inefficiency, we assume that a common multivariate normal distribution links respondents' preferences. This assumption does not constrain the data very much but offers a high level of detail, so hierarchical Bayes is currently the most widespread technique applied to CBC data (Eggers and Sattler, 2011).

APPENDIX D. DATA PREPARATION AND ANALYSIS

Appendix D. 1 Validation test for TPB questionnaires

Construct validity is used to reflect the confidence level of the sample measurements representing the true overall score. The measurement results show that the factor loading is larger than the cross-loading. A factor loading with a value above 0.50 is valid, and that item should be retained (Hair, 2017). Conversely, if the factor loading value of the item is less than 0.50, the item should be deleted. As shown in Table D.1. 1, the factor loading values of all the question items are higher than 0.50, which indicates that the scale used in this study had high construct validity.

Cronbach analyses are conducted on all the subscale of psychological questions (Table D.1. 1). The results show that the Cronbach alpha of all subscales is greater than 0.7, which is the recommended value (Cho, 2016). This value indicates that the subscales have an adequate level of inter-item reliability. Further analyses found that deleting any of the items would not have significantly increased the alpha level of the attitude and the Environmental interest questions. However, analyses revealed that by deleting the item about "self-reflection" in the Subjective norm question, the item defining residential PV as an expensive product in the Perceived Risk, the alpha level could be raised about 5-10% score. If deleting the item of "installing residential PV" in the Acceptance questions, the alpha level of this question is not significantly increased. After the pilot-test, instead of deleting, we rephrase the "self-reflection" and "expensive" items in the subjective norm and perceived risk to ensure the reliability of the question.

Table D.1. 1 Validation tests for the reliability of the SA questionnaire

	Loading	Cronbach's Alpha	N of Items	Delete item	Cronbach's Alpha if item deleted
Attitude	.711	.758	4	-	-
Sub_norm	.725	.714	3	Sub_me	.759
Perceived_risk	.752	.744	5	Expensive	.761
Eco_interest	.810	.870	8	-	-
Acceptance	.785	.737	6	Implement	.745

Appendix D. 2 Correlation and variable selection

In this paper, the SA and WTP analysis were conducted using different indices based on demographics and psychological determinants. Demographics are broken down by any combination of age, gender, income, education, marital status, household type and size, and place of residence, which can explain the most of the deviations between different levels of SA. Some factors can produce spurious associations, particularly in a nonexperimental study such as this one. Therefore, demographic and extended factors were statistically accounted for (Table D.2. 1).

There was a significant correlation between all demographic and extended factors with SA with the possibility of both direct and indirect effect. Exceptions are the factors place of residence, HH size and Education. Among these three, HH size and eduction do not show any significant correlation with any determinants of SA, so these two factors will not be considered as impact factors on SA. In contrast, Place of residence reveals significant effects on SA's determinants. Thus it may have an indirect effect on SA.

Table D.2. 1 Correlation between the possible intervention variables and the SA and its determinant variables

*Highlighted cell: **. Or *.Correlation is significant at the 0.01 or 0.05 level (2-tailed).*

Variable		Attitude	Subjective_norm	Perceived	SA	Indirect/ direct effect
Demographic	Age	-0.003	.074**	0.033	.054**	Both
	Marital status	-.068**	.065**	-0.003	.066**	Both
	Children	0.022	.118**	.087**	.152**	Both
	Place of residence	-.051**	-.069**	-.038*	-0.034	Indirect
	HH size	0.016	0.015	0.020	-0.020	No
	Electricity bill	0.023	.084**	.067**	.087**	Both
	Income	.053**	.127**	.069**	.092**	Both
	Education	0.033	-0.024	-0.028	0.028	No
Extended	Environmental interest	.050**	-.056**	.066**	.098**	Both
	Knowledge	.039*	0.000	.060**	.129**	Both

After excluded two unimportant factors, all the proposed mediators here, including demographic and extended variables, were analyzed with the autocorrelated test to assess whether to include them in the moderated mediation model. The analysis found that the demographic variables are highly correlated with each other (Table D.2. 2). Therefore, we used factor analysis to reduce 15 demographic variables into fewer numbers of factors.

Table D.2. 2 Correlation between the possible intervention variables

*Highlighted cell: **. Or *.Correlation is significant at the 0.01 or 0.05 level (2-tailed).*

	Demographic factors						Extended factors	
	Age	Marital status	Children	Place of residence	Electricity bill	Income	Environmental interest	Knowledge
Age	1.000	.459**	.481**	-0.037	.160**	.226**	-.153**	-.043*
Marital status		1.000	.651**	-.126**	.196**	.215**	-.096**	-0.011
Children			1.000	-.061**	.140**	.238**	-.126**	-0.002
Place of residence				1.000	-.211**	-.216**	-0.029	0.010
Electricity bill					1.000	.381**	0.016	.063**
Income						1.000	-.033*	.060**
Environmental interest							1.000	.322**
Knowledge								1.000

Factor loading shows the variance explained by the variable on the new-formed factors. Results show the three possibilities of new-formed factors (highlighted in Table D.2. 3) that extract maximum common variance from all variables.

Table D.2. 3 Factor analysis results

Variable		Component		
		1	2	3
Demographic factors	Age	.769	-.152	-.184
	Marital status	.861	-.027	-.251
	Children	.872	-.087	-.167
	Place of residence	-.072	-.005	.678
	Electricity bill	.159	.089	-.747

	Income	.353	.051	-.743
Extended factors	Knowledge	.012	.809	-.057
	Ecological	-.237	.750	-.001

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

We conduct a reliability test for the new factors (Table D.2. 4). However, only the Age& Marital status& Children has factor loading higher than 0.7 and F-test significant, represents that the factor extracts sufficient variance from the constructed factors. The Electricity &Income factor has factor loading lower than 0.7, and F-test non-significant means that the new factor is insufficient. Age& Marital status& Children is used for calculating the action paths between variables in the moderated mediation model.

Table D.2. 4 Reliability test results of the new-formed demographic factors

New factor	Constructed factors	Loading	F	P-value	Sig.	New factor	Constructed factors	Loading	F	P-value	Sig.
Age& Marital status& Children	Age Marital status Children	.785	4.020 3.796 18.804	.003 .004 .000	Yes Yes Yes	Electricity bill &Income	Electricity bill Income	.509	1.349 2.580	.249 .036	No No

Table D.2. 5 Correlation between Price sensitivity with the WTP's determinant candidates

*Highlighted cell: **. Or *.Correlation is significant at the 0.01 or 0.05 level (2-tailed).*

	Age	Marital status	Children	Place of residence	HH size	Electricity bill	Income	Education	Knowledge	Ecological
Correlated coefficient	-0.021	-0.009	-.047*	.107**	0.033	0.043	0.029	.057*	.068**	.127**
Sig. (2-tailed)	0.338	0.701	0.035	0.000	0.137	0.053	0.191	0.011	0.002	0.000

Table D.2. 6 Correlation between Price sensitivity with the WTP's determinant mediators

	Attitude	Subjective_norm	Perceived	Acceptance
Correlated coefficient	-.128**	-.071**	-.048*	-.074**
Sig. (2-tailed)	0.000	0.001	0.031	0.001

Table D.2. 7 Testing interaction effects between different attributes of a PV system

Effect	Log-Likelihood Fit	Chi-Square Value	P-Value	Gain over Main Effects	Interaction effect
Main Effects	-10059.65				
+ Investment x Guarantee	-10040.08	39.15	0.00	0.17%	Slightly
+ Guarantee x Savings	-10049.80	19.71	0.00	0.09%	Unsignicant
+ Investment x support	-10056.87	5.56	0.14	0.02%	No
+ Guarantee x support	-10055.54	8.22	0.22	0.04%	No
+ Manufacturer x support	-10052.92	13.45	0.34	0.06%	No
+ Manufacturer x Savings	-10057.38	4.53	0.34	0.02%	No
+ Investment x Manufacturer	-10057.48	4.34	0.36	0.02%	No
+ Manufacturer x Guarantee	-10055.68	7.93	0.44	0.03%	No
+ Savings x support	-10058.66	1.99	0.58	0.01%	No
+ Investment x Savings	-10059.59	0.11	0.74	0.00%	No

APPENDIX E. MODEL RESULTS

Appendix E. 1 No-mediated regression models for SA

The first group of regression models are no-mediated models using demographic factors as target variables (**Fehler! Verweisquelle konnte nicht gefunden werden.**). The second group are the regression model with extended variables (**Fehler! Verweisquelle konnte nicht gefunden werden.**). In the first group, AMC (Age& Marital status & Children) and Income accounted for 2.1% of the unique variance in SA in model 2, while Electricity bill and place of resident do not reveal significant effects in model 3 and 4 (Table D.2. 5).

Table E.1. 1 Using demographic factors as the only interventions

Model Summary[e]							
Model	R	Change Statistics					

		R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson	Significant
1	.101[a]	.010	.010	.64344	.010	20.933	1	2037	.000		Yes
2	.140[b]	.020	.019	.64053	.009	19.546	1	2036	.000		Yes
3	.145[c]	.021	.020	.64025	.001	2.828	1	2035	.093		No
4	.145[d]	.021	.019	.64038	.000	.125	1	2034	.724	.380	No

a. Predictors: (Constant), AMC
b. Predictors: (Constant), AMC, Income
c. Predictors: (Constant), AMC, Income, Electricity bill
d. Predictors: (Constant), AMC, Income, Electricity bill, Place of residence
e. Dependent Variable: Acceptance

To improve the explanation of the model, we add the effects of Environmental interest or PV knowledge into model 2. Model 5 with PV knowledge added is significant with the explanation of 3.5% of the population (R-sq=.035, F=21.812, P<0.0001). Model 6 replaces PV knowledge by Environmental interest and can increase the explanation to 4.4%. Because the model 6 with the Environmental interest factor has a much stronger effect on SA compared with PV knowledge effect, .137 and .083, respectively, we choose the Environmental interest as the intervention to run the moderated mediator models (Table D.2. 6).

Table E.1. 2 The extended regression models

*Highlighted cell: **. Or *.Correlation is significant at the 0.01 or 0.05 level (2-tailed).*

Model	Dependent variable	AMC	Income	Environmental interest	PV knowledge	R-sq	F(HC0)	p-value	Significant
5	SA	.070**	.027**		.083**	.035	21.812	.000	Yes
6	SA	.083**	.033**	.137**		.044	29.828	.000	Yes

Appendix E. 2 Results of the WTP model

Table E.2. 1 The conditional indirect effects of Environmental interest (X) on Price sensitivity (Y) through moderators.

Income (Euro/month)	Age	Coefficient	SE	BootLLCI	BootULCI	Significant
Eco ↑→ PVK ↑→ Pr↓						
<500	20-29	-0.013	0.114	-0.239	0.205	No
<500	30-49	0.155	0.098	-0.039	0.346	No
<500	50-69	0.489	0.124	0.247	0.735	Yes
500-1249	20-29	-0.193	0.096	-0.385	-0.005	Yes
500-1249	30-49	-0.026	0.068	-0.163	0.108	No
500-1249	50-69	0.309	0.091	0.133	0.492	Yes
>1250	20-29	-0.373	0.114	-0.604	-0.148	Yes
>1250	30-49	-0.206	0.086	-0.375	-0.032	Yes
>1250	50-69	0.128	0.094	-0.047	0.322	No
Total effect	Income	-0.090	0.031	-0.151	-0.028	Yes
	Age	0.167	0.046	0.077	0.260	Yes
Eco↑ → SN↑ → Pr↓						
<500	20-29	0.007	0.017	-0.029	0.044	No
<500	30-49	0.023	0.017	-0.006	0.063	No
<500	50-69	0.053	0.030	0.004	0.123	Yes
500-1249	20-29	-0.021	0.017	-0.061	0.005	No
500-1249	30-49	-0.005	0.010	-0.028	0.014	No
500-1249	50-69	0.026	0.019	-0.003	0.069	No
>1250	20-29	-0.048	0.027	-0.111	-0.005	Yes
>1250	30-49	-0.033	0.019	-0.077	-0.002	Yes
>1250	50-69	-0.002	0.015	-0.032	0.029	No
Total effect	Income	-0.014	0.008	-0.030	-0.001	Yes
	Age	0.015	0.010	0.000	0.039	Yes
Eco↑ → PBC↑ → Pr↓						
<500	20-29	0.12	0.05	0.03	0.22	Yes
<500	30-49	0.12	0.04	0.05	0.22	Yes
<500	50-69	0.14	0.06	0.04	0.27	Yes
500-1249	20-29	0.02	0.04	-0.06	0.10	No
500-1249	30-49	0.03	0.03	-0.02	0.09	No
500-1249	50-69	0.05	0.04	-0.02	0.13	No
>1250	20-29	-0.07	0.05	-0.18	0.02	No
>1250	30-49	-0.06	0.04	-0.15	0.01	No
>1250	50-69	-0.05	0.04	-0.13	0.03	No
Total effect	Income	-0.047	0.016	-0.082	-0.020	Yes
	Age	0.009	0.019	-0.028	0.048	No

Factors: Eco: Environmental interest, PVK: PV knowledge level, PBC: Perceived behavioural control, Pr: Price sensitivity, SE: booted standard error, LLCI & ULCI are booted lower and upper levels for confidence interval a path.

Table E.2. 2 Summary of the complex interaction between variables of the SA and WTP models and the hypothesis results

Note: "~": tested but insignificant, "-": tested but no interaction, black highlighted: not be tested.

Variable	Description	Mean	Std. Deviation	Mediators				Impact on SA		Impact on Price sensitivity		Role in the SA model	Hypothesis result	Role in the WTP model	Hypothesis result
				PV knowledge	Att	SN	PBC	Direct	Indirect	Direct	Indirect				
Environmental interest	Of respondent	2.807	0.75977	.588	.086	-	.120	.073	0.064	0.750	-.047	Target variable	Support	Target variable	Support
Income (Euro/month)	Net income of the household	4.33	1.87	.052	~	.071	~	.016	-	1.183	~	Covariate	Support	Moderator	Support
PoR	Place of the respondent' home	1.7	0.784	-	~	~	~	-	-	0.720	~	-	-	Covariate	Support
Age	Of respondent	2.52	1.191	~	~	~	-	~	-	~	~	Covariate	Reject	Moderator	Reject
Marital status	Of respondent	2.53	0.961	-	-	~	-	~	-	-	-	Covariate	Reject	Moderator	Reject
Children	Of respondent	1.71	0.454	-	-	~	~	~	-	~	-	Covariate	Reject	Covariate	Reject
Electricity bill (Euro/month)	Electricity bill of the household	2.68	1.163	~	-	~	~	~	-	-	-	Covariate	Reject	Covariate	Reject
Education	Of respondent	2.86	0.978	-	-	-	-	-	-	~	-	-	-	Covariate	Reject
PV knowledge	Of respondent	2.32	1.011		~	~	~	.052	0.036	~	~	Mediator	Support	Mediator	Support
Att	Of respondent	4.0362	0.73501	~		~	.433	.225	~	~	-.91	Mediator	Support	Mediator	Support
SN	Social pressure on the respondent	3.7193	0.90327	~	.405		.300	~	~	~	~	Mediator	Reject	Mediator	Reject
PBC	Of respondent	3.7601	0.74888	~	~	~		.195	0.028	1.593	~	Mediator	Support	Mediator	Support
SA	Of respondent	3.7692	0.64658							~	~	Output		Mediator	Reject
AMC	Zero-centred variable	0	0.585	~	-.082	.072	~	.086	-			Covariate	Support	Covariate	Reject
SN & PBC	Interaction								-0.005			Mediated			
SN & Att	Interaction								-0.008			Mediated			
Att & PBC	Interaction								0.009			Mediated			
SN& Att & PBC	Interaction								-0.003			Mediated			
PBC x Income	Interaction									-	-0.376			Moderated	
PVK x Age	Interaction									-	0.286			Moderated	
PVK x Income	Interaction									-	-0.154			Moderated	
SN x Income	Interaction									-	0.220			Moderated	
SN x Age	Interaction									-	-0.244			Moderated	

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