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The intention of households in the Daklak province to instal smart grid rooftop solar electricity systems

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Abstract

Background: Smart grid rooftop solar electricity is a useful power resource and a viable alternative to conventionally generated energy. In the context of Vietnam, it could help people control their own source of electrical power and reduce power outages. This problem is expected to worsen in the future. Previous studies have shown that very few smart grid rooftop solar electricity systems have been installed by households in the Daklak Province, in the Central Highlands of Vietnam, and that as of 30th May 2019, only 18 out of 435,688 households had installed such a system. Moreover, only a small number of people knew about this resource.

Method: Based on previous investigations, this study proposed a research model that includes factors, which might affect the intention to instal smart grid rooftop solar electricity systems. However, the amount of money that people would be willing to pay (WTP) for the installation of such systems depends on their current electricity consumption. Therefore, to investigate this issue, a questionnaire was developed to survey 300 households in the Daklak Province, in the Central Highlands of Vietnam. A probit binary model was used to analyse the collected data from the questionnaire for this study.

Results: After interviewing the respondents from the 300 households in the research area and introducing into the concept and benefits of the smart grid solar electricity generating systems, they were more aware and knowledgeable of the concept. Thirty-three percent of households mentioned that they intended to instal such a system and were willing to pay between USD 1240 and USD 2220 for an appropriate-sized system based on their current electricity consumption and needs. Those households that possessed a high awareness of smart grid rooftop solar power were more likely to express the intention to instal such a system. However, it was also revealed that government incentives and household attitudes were important factors that influence the intention to instal such a system. In contrast, factors such as environmental concerns and the innovativeness of households were less influential.

Conclusion: The awareness and understanding of the 309 households surveyed in this study regarding smart grid rooftop solar electricity systems and government incentives were the leading factors that affected the people's intention to instal such systems. The majority of the respondents were willing to pay between USD 1240 and USD 2220 for installing such a system. In progressing this initiative in Vietnam, based on the results of this study, the Vietnamese government could identify those households that have the necessary degree of knowledge and awareness of such systems and offering incentives to instal such systems. The government could also develop communication

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programmes and other initiatives to enhance the understanding and awareness of the community of rooftop solar electricity so that programmes for the development of alternative energy sources could be more effective.

Keywords: Household, Intention, Central Highlands, Rooftop solar, Smart grid, Vietnam

Background

Most energy consumed globally is generated from conventional resources. According to the International Energy Agency (IEA), 81% of the total primary energy consumption globally in 2017 was derived from fossil fuels [1, 2]. However, there are many drawbacks to using fossil fuels, since the generation of emissions from the combustion of these fuels has adverse effects on climate change, global warming [3], and humanity [4]. Moreover, increasing energy consumption will ultimately lead to exhausting conventional resources in the future [5]. According to Shafiee and Topal [6], in approximately 35 years from 2005, natural oil supplies will be completely depleted, while natural gas and coal stocks will be exhausted in 37 years to a 107 years' time, respectively. As a result, coal will potentially be the only fossil fuel resource still existing after 2042, and it, too, will be depleted in 2112 based on current and future energy demands [6]. Therefore, research relating to these drawbacks and limitations, afforded to energy derived from fossil fuels, has attracted the attention and interest of many scientists to investigate renewable energy resources in many countries worldwide [7].

As the overall situation relating to the generation and consumption of electricity in Vietnam is unstable, and based on current projections, it is expected that power cuts will occur regularly from 2020, especially during the hot season [8]. Coal, gas and hydropower resources account for over 90% of the electricity generated in Vietnam, with 35% of total power production based on hydropower [9–11]. However, hydropower dams give rise to certain problems for the environment and society. For instance, in areas where dams are constructed, local communities must be aware [12–14] that the local ecosystem is threatened, and the environment harmed. In contrast, dams also bring several advantages, such as the generation of power, land irrigation and control of flooding [15–17]. In Vietnam, more than 200,000 people have been relocated due to the construction of hydropower dams, which involved the destruction of 44,557 homes and the loss of 133,930 hectares of land [18]. Moreover, the volume of river discharge and the capacity for power generation may decline due to deforestation in constructing hydropower dams [19].

Wind power, biomass energy and solar power are all sustainable sources of energy, the use of which is supported by the Vietnamese government through feed-in tariffs (FITs), whereby consumers can sell the electricity they generate to the electricity grid. Solar power particularly, is seen as a suitable source in generating electricity in the Central Highlands and the southern area of Vietnam [20]. The Central Highlands have a high potential for the generation of solar energy since it has an annual 'sunshine' duration of between 2000 and 2600 h [21]. After evaluating the solar radiation at 171 sites in Vietnam, Polo et al. [20] showed that the Central Highlands and South Vietnam, with the highest potential concentration of solar energy, had the capacity to generate an average of about 5.6 kWh/m^2 of electricity per day. Daklak Province has an available rooftop space of 22.4 km^2 for the installation of the system [22]. The Vietnamese government is also seeking to promote the installation of rooftop solar electricity generation systems at the second-highest FIT price for electricity that is generated directly from the burning of biomass [23–26].

Smart grid rooftop solar electricity systems offer further benefits compared to off-grid and hybrid solar systems given they are cheaper to instal and do not require a battery, which needs to be replaced every 2 to 5 years. Smart grid systems are also appropriate for installation in the Central Highlands since more than 95% of houses and other dwellings in this region are currently connected to the electricity grid [27].

There are five provinces in the Central Highlands of Vietnam, namely, Kontum, Gialai, Daklak, Daknong, and Lamdong, where Daklak is optimally located in the middle of the Central Highlands and regarded as the metropolis of the area [28]. This province also has the highest population in the region, with 1,919,147 people and 435,688 households, and the total duration of sunshine in 2018 was 2431.30 h [29]. However, even though rooftop solar electricity systems are available in the province, as at the 30th May 2019, only 18 from the 435,688 households had installed such systems, and almost all are smart grid systems [30]. It was therefore interesting to investigate why the number of people who had installed smart grid rooftop solar systems was so low and what are, the factors affecting the intention of people to instal such systems, and what percentage were willing to pay for installing instal the system. Accordingly, this study focused on these three issues.

Literature review

Definition of a smart grid

A smart grid (SG) is defined as a smart electricity/power grid, a future grid, a mobile grid, or an internal grid that is an evolution of the twentieth-century electrical grid. Conventional power grids are typically used to distribute power from a few central generators to a vast number of users. In contrast, a smart grid uses two-way electricity and information to create an integrated and distributed advanced electricity supply network [31].

In Vietnam, SG development was adopted by the Government in 2012 through Decision 1670/QD-TTg of October 2012, which encourages investments in renewable energy and SGs. SGs have two-way power, where customers can sell the surplus power from their renewable energy supply to the grid and buy electricity from the grid [32].

SG rooftop solar electricity systems

SG PVs can be mounted on the rooftops of buildings, offices or other commercial and industrial buildings. In comparison to other forms of solar energy, an SG rooftop PV offers a two-way exchange, where electricity can be directly targeted either from a power utility to consumers or in the opposite direction when the consumers' systems generate more power than they consume. As such, an SG rooftop PV can help the PV system to run smoothly and in a stable manner in the following ways [33]:

- If the customer's need is > than the capacity generated by the system, the inverter will withdraw the power required from the grid;
- If the customer's need is = to the capacity generated by the system, the power generated from the rooftop solar electricity system will be used to meet the customer's requirements;
- If the customer's need is < than the capacity generated by the system, the surplus electricity will be sent to the grid.

The process of determining the relationship between the generation of electricity and the need of consumers' and controlling or regulating the flow of power occurs continuously and automatically, without the need for user intervention.

In Vietnam, the surplus energy acquired from domestic solar power systems and the power available from the grid has been determined by two-way meters from 1st July 2019, based on Decision No. 02/2019/QD-TTg. Nevertheless, consumers can sell power to EVN at an FIT price of USD 9.35/1kWh independent of the power they purchase from the grid [26].

Smart grid rooftop solar systems are highly suitable for the Central Highlands as 95.17% of households in this region are currently connected to the electricity grid [27]. The benefits of SG rooftop PVs are lower installation costs and the fact that consumers will not need to replace the batteries every 2 to 5 years. In addition, unused electricity from the system can be sold to EVN at a reasonable price.

Methodology

Study area

As mentioned earlier, the Central Highlands of Vietnam have a high potential for solar energy, and almost all households in the area are currently connected to the electricity grid. Therefore, it is a suitable region for the installation of smart grid rooftop solar electricity systems. Daklak Province comprises a city, named Buon Ma Thuot, a town, and 13 districts. This study was conducted in Eatam Ward in Buon Ma Thuot City (see Fig. 1). This ward is close to the centre of Buon Ma Thuot and has 1,154 households [29]. The economy of Eatam is reasonably well developed, having a large university; the Tay Nguyen University.

Sample size and data collection

The target population for this research comprised 1154 households in Eatam Ward [29]. The sample was calculated based on the following formula [34]:

$$n = \frac{N}{1 + Ne^2},$$

where n is the size of the sample, N is the size of the population, and e is the sampling error (±5%). Thus, the sample was determined as:

$$n = \frac{1,154}{1 + 1,154x0.05^2} = 297.03.$$

Furthermore, the sample size adopted was 300 households.

A draft questionnaire was developed based on a review of previous studies, with the selected items appropriately adjusted to the Vietnamese situation. The questionnaire

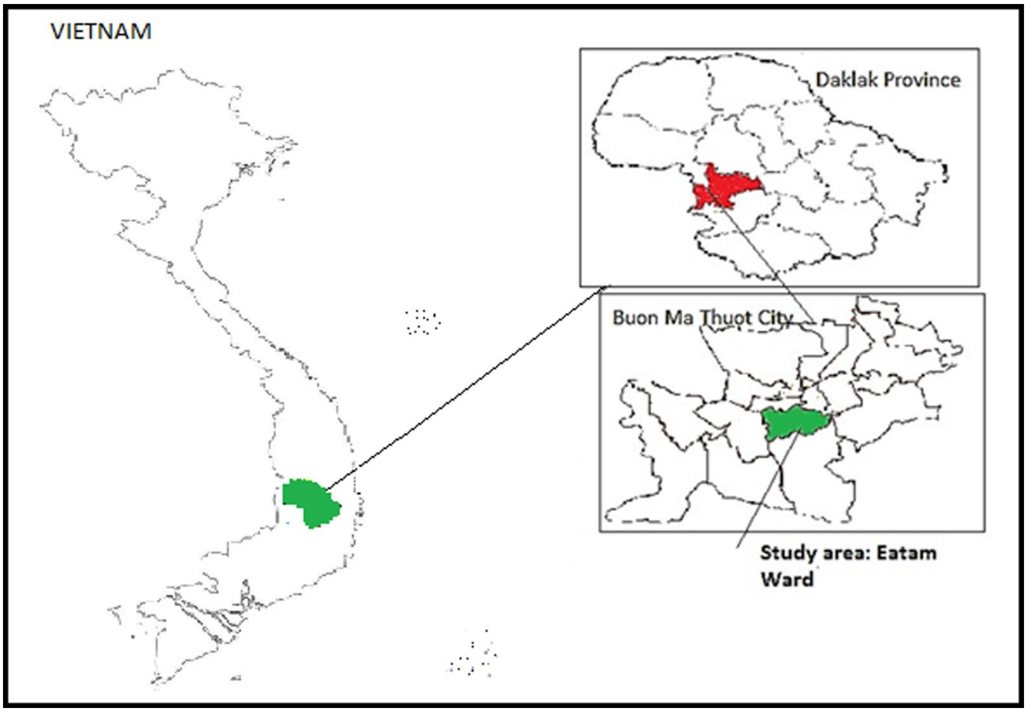

Fig. 1 The study area (source: https://daklak.gov.vn/web/english)

(refer to Appendix 1) commenced with an introduction about smart grid rooftop solar energy systems, after which, the items that constituted the main part of the questionnaire were addressed to the respondents. A pre-survey was conducted before the main study to ensure that all the items in the questionnaire were capable of being understood by the respondents in the main survey. After the pre-survey, the main survey was conducted in the research area between May and July 2019 with the 300 households purposively selected by convenience sampling. The survey investigated the intention of the participating households to instal rooftop solar systems in the future. Only those households that had not installed smart grid rooftop solar electricity systems participated in the survey. The sample was selected so that only those households whose dwellings had a rooftop deemed appropriate for the installation of a rooftop solar power system were included. The questionnaire consisted of two parts. Part 1 contained questions relating to the factors that affected their intention to instal a rooftop solar power system, while Part 2 collected information relating to the demographics of the households.

In Vietnam, unmarried people often live with their parents and are unable to make their own personal decisions. They also do not have their own house, so the installation of solar systems is not possible. Therefore, only households that comprised a married couple and their relatives were included in the survey. In some families, the husband answered the survey items, while in others, the items were answered by the wife. The items were all addressed to the participants in the local language, Vietnamese, by the researchers, who recorded the respondents' answers.

Data analysis

The research model was designed according to previous research. Customers mostly purchase electricity based on the payment of a monthly bill rendered in arrears for the actual amount of electricity consumed during the preceding period. However, installing a rooftop solar power system involves a substantial, long-term financial commitment, and there are uncertainties associated with the payback period and future utility costs as well as the likelihood of improvements occurring in rooftop solar technologies. Ek found in 2005 that individuals who show a positive attitude towards wind power pay more attention to the unfavourable consequences of environmental problems to humans and the ecosystem resulting from conventional electricity generation, and are probably, therefore, more focused on collective or altruistic values [35]. Attitudes are composed of views and opinions toward objects that vary in specificities [36]. Therefore, people may have beliefs and may care or be concerned about specific problems such as the effects of fossil fuels on climate change and global warming. Consequently, this may lead them to adopt certain behaviours, as posited in the theory of planned behaviour [37]. According to Roberts, consumers will opt for environmentally friendly products if they have good knowledge of such products or the contribution of the products to the health of the environment or of other individuals [38]. Faiers and Neame meanwhile, suggested that consumers may be uncertain and confused if they do not have sufficient knowledge about products [39]. Previous empirical research has concluded that environmental concerns and values, and the innovativeness of consumers will have an impact on people's intention to instal solar electricity systems [40–42]. Government incentives have also been found to have a strong influence on such intentions [42].

Based on the theory of planned behaviour (TPB), the intention of households to instal smart grid rooftop solar electricity systems would be influenced by their awareness of rooftop solar electricity generation and other environmental concerns, the innovativeness and attitudes of the households, and the incentives being offered by the government to instal such systems, as illustrated in Fig. 2.

A probit binary model was used in this research to analyse the factors that affect the intention of households to instal smart grid rooftop solar systems, as illustrated in Eq. 1 below:

$$\boldsymbol{Y} = \beta x + \varepsilon, \tag{1}$$

where $\boldsymbol{Y}$ is the dependent variable: intention to instal smart grid rooftop solar system, $\boldsymbol{\beta}$ is the coefficient valuation, and $\boldsymbol{x}$, independent variables: awareness about rooftop solar electricity, environmental concerns, innovativeness, attitudes, government incentives. The independent variables were measured using items employed in earlier studies (see Table 1) [41–43].

In this research, the dependent variable for each household (Yi) was assessed as a binary variable as follows:

$Yi = 0$: the household does not intend to instal a rooftop solar electricity system;

$Yi = 1$: the household intends to instal a rooftop solar electricity system; where Yi is the intention to instal of family i

Since Y can only have values of 0 and 1, it cannot be explained by a linear regression model. However, a probit model can show the probability of Y falling between 0 and 1 based on a cumulative normal distribution given any Z-score, with (Z) € [0, 1].

Thus, it can be stated that:

$$Y = \phi\left(X\beta' + \varepsilon'\right),$$
$$\phi^{-1}(Y) = X\beta' + \varepsilon',$$

$$\mathbf{Y}* = \mathbf{X}\beta' + \varepsilon'. \tag{2}$$

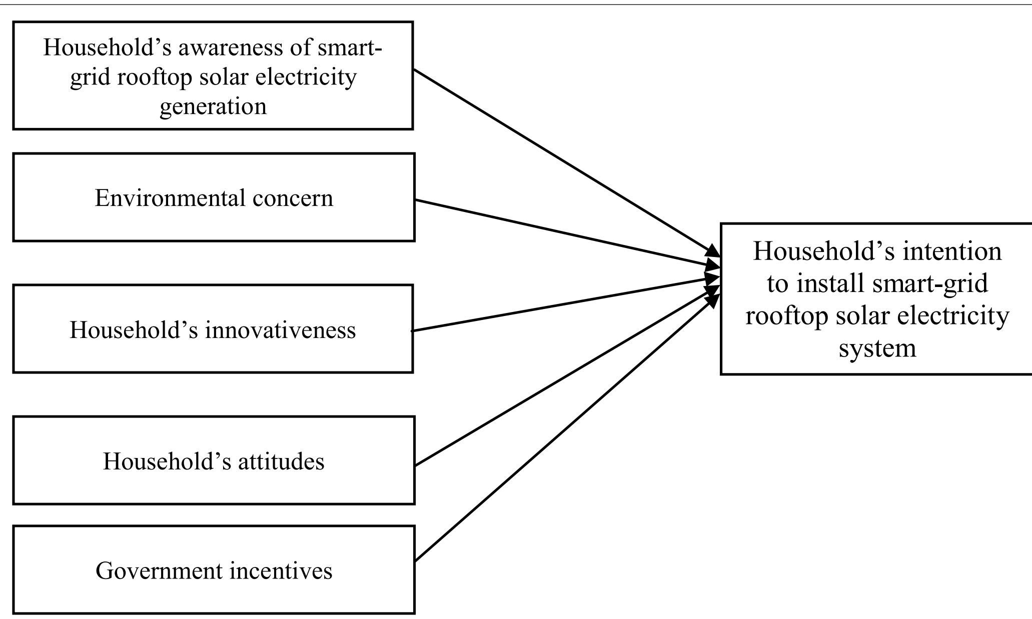

Fig. 2 Research model [40–42]

Table 1 Items used to measure independent variables

Variable measured	Explanation and items
Household_awareness	Households' awareness of smart grid rooftop solar electricity
Awareness1	1. A smart grid rooftop solar electricity system will provide electricity for my family during the day
Awareness2	2. I will reduce my monthly electricity bill by installing a smart grid rooftop solar system
Awareness3	3. I believe that smart grid rooftop solar electricity will be the source of power in the future
Awareness4	4. A smart grid solar rooftop system can generate electricity in the winter
Awareness5	5. A smart grid rooftop solar system can increase the lifespan of the roof by protecting it from external factors
Environmental_concern	The household's concern about the environmental protection aspects of smart grid rooftop solar energy systems
Environmental_concerning1	1. Smart grid rooftop solar energy can help to protect the environment
Environmental_concerning2	2. If I instal a smart grid rooftop solar electricity system, I will contribute to the preservation of nature and humanity
Environmental_concerning3	3. The owner of a smart grid rooftop system can feel better because they do not harm the environment
Household_innovativeness	The household's innovativeness in relation to new energy resources
Household_innovativeness1	1. If I knew that a smart grid rooftop solar electricity system was available, I would be interested in trying it
Household_ innovativeness2	2. I have discovered more information about smart grid solar rooftop electricity installation services than my friends
Household_ innovativeness3	3. I would instal a smart grid rooftop solar system even though none of my friends had tried one before me
Household_attitude	Attitude toward installing a rooftop solar electricity system
Household_attitude1	1. I believe that smart grid rooftop solar electricity is a good and reliable investment in the long-term
Household_attitude2	2. I believe that a smart grid rooftop solar electric system will raise the utility of my house
Household_attitude3	3. I believe that smart grid rooftop solar electricity can decrease global warming, so, it is good for the environment
Government_incentive	Government incentives relating to smart grid rooftop solar electricity
Government_incentive1	1. I think that the Vietnamese government policies encouraging rooftop solar electricity are good
Government_incentive2	2. The government now provides a 20-year feed-in tariff to buy back electricity from rooftop PV at 9.35 US cent/kWh, which is attractive to me
Government_incentive3	3. I think that incentive policies for rooftop solar electricity will encourage people to instal rooftop solar electricity on their houses
Government_incentive4	4. I think that incentive policies for rooftop solar electricity will continue into the future

Source: [40–42]

Here, $\varepsilon' \sim N(0,\sigma^2)$, where Y^* ranges from $-\infty$ to ∞. Y^* is also called a latent variable.

Whether or not a family intends to instal a rooftop solar electric system can be expressed as the relationship between the linear regression model (Eq. 1) and the latent variable (Eq. 2) as follows:

$$\begin{aligned} &Y = 0 \text{ if} Y* < 0 \text{ (the household is not likely to instal a solar electricity system)}, \\ &Y = 1 \text{ if} Y* >= 0 \left(\text{the household is likely to instal a solar electricity system}\right). \end{aligned} \tag{3}$$

Thus, a probit model was used to estimate the probability of people installing a solar electricity system.

The conditional probability of customer i, being likely to instal a solar electricity system (i.e. Yi = 1) given xi, is expressed as:

$$P(\text{Yi} = 1) = P(Yi = 1|xi) = P\left(\beta' xi + \varepsilon_{1i} \geq 0\right)|xi) = P\left(\frac{\varepsilon_i}{\sigma} \geq \frac{-\beta' xi}{\sigma}\right) = \emptyset\left(\frac{-\beta' xi}{\sigma_1}\right), \tag{4}$$

where Ø is the cumulative standard normal distribution function.

The conditional chance of $Y = 0$ (i.e. prefers not to instal a solar electricity system) is given by:

$$P(Yi = 0|xi) = 1 - \emptyset\left(\frac{-\beta' xi}{\sigma_1}\right). \tag{5}$$

Therefore, the probability of the observed household is:

$$\prod_{I=}^{N_1}\left[\emptyset\left(\frac{-\beta' xi}{\sigma_1}\right)\right].\prod_{N_1-1}^{N}\left[1-\emptyset\left(\frac{-\beta' xi}{\sigma_1}\right)\right], \quad (6)$$

where N1: household wants to instal a rooftop solar system, and N-N1: household does not want to instal a rooftop solar system.

In this model, a higher value of β'i indicates that the household is more likely to instal a solar electricity system. The value of β'i indicates that a one-unit change in Xi leads to a β'i change in the Z-score of probability Y. The SPSS v.20 software program was used to calculate the probabilities and to conduct other statistical analyses.

Determination of reliability

The reliability of the items in the research instrument through which the data were measured was determined using Cronbach's alpha, and the corrected item–total correlation. Cronbach's alpha is a coefficient of coherence that shows the close connection of items to a group. The purpose of Cronbach's alpha is to determine if the observed variables measure the same for a concept that is being measured. The contribution of the variables is reflected by the corrected item–total correlation, whereby it is allowed to eliminate inappropriate variables in the research model. The reliability is considered acceptable if the Cronbach's alpha is ≥ 0.7, and the corrected item–total correlation is > 0.3 [44].

Exploratory factor analysis

An exploratory factor analysis (EFA) was used to determine the factors that affect the intention of households to instal rooftop solar electricity generation systems. The conditions of the analysis were as follows:

Factor loading > 0.5 and Kaiser–Meyer–Olkin (KMO) $0.5 \leq \text{KMO} \leq 1$;
Bartlett test (Sig. < 0.05) and the average variance extracted $> 50\%$; and
Variables with KMO < 0.5 were removed from the model [44].

Multicollinearity diagnostics

Multicollinearity is the phenomenon of independent variables strongly correlating with each other. A regression

Table 2 Profile of respondents

	Category	Frequency	Percentage
	Total (households)	300	100
Gender	Female	147	49.0
	Male	153	51.0
Marital status	Married	300	100
Education	Primary school	0	0
	Secondary school	2	0.7
	High school	160	53.3
	College	102	34.0
	Postgraduate	36	12.0
Smart grid rooftop solar system status	Do not have a rooftop solar electricity system	300	100
Level of electricity consumption	From 0 to 50 kWh	0	0
	From 51 to 100 kWh	49	16.3
	From 101 to 200 kWh	119	39.7
	From 201 to 300 kWh	87	29.0
	From 301 to 400 kWh	31	10.3
	Over 400 kWh	14	4.7
Age	From 20 to 30 years old	7	2.3
	From 31 to 40 years old	109	36.3
	From 41 to 50 years old	125	41.7
	From 51 to 60 years old	55	18.3
	Over 60 years old	4	1.3

model with multicollinearity will render the results of quantitative analysis not meaningful and incorrect. Variance inflation factors (VIFs), which measure collinearity and tolerance, were applied in this research to determine the multicollinearity phenomenon. Menard [45] stated that a tolerance of below 0.20 is a major concern, while a tolerance of just under approximately 0.10 probably implies a severe collinearity problem. Because a VIF is the opposite of the tolerance, a tolerance of 0.20 relates to the rule of 5 and a tolerance of 0.10 to the rule of 10 [46]. Hair et al. [47] proposed that a VIF of less than 10 is representative of irrelevant collinearity [48]. Kennedy [49] claimed that a VIF > 10 indicates harmful collinearity for standardized results [50].

Table 3 Reliability statistics

	Scale mean if item deleted	Scale variance if item deleted	Corrected item–total correlation	Cronbach's alpha if item deleted
Awareness1	14.02	12.852	0.127	0.721
Awareness2	13.71	10.314	0.651	0.460
Awareness3	14.02	12.284	0.197	0.684
Awareness4	13.69	10.557	0.616	0.478
Awareness5	13.56	10.996	0.533	0.516
Cronbach's alpha of the first factor				**0.634**
Environmental_concern1	7.32	4.687	0.707	0.866
Environmental_concern2	6.94	4.748	0.768	0.804
Environmental_concern3	6.95	4.984	0.793	0.787
Cronbach's alpha of the second factor				**0.871**
Innovativeness1	6.17	2.344	0.729	0.787
Innovativeness2	6.11	2.031	0.740	0.770
Innovativeness3	6.07	2.105	0.696	0.813
Cronbach's alpha of the third factor				**0.849**
Household_attitude1	6.39	2.019	0.809	0.801
Household_attitude2	6.60	2.274	0.748	0.854
Household_attitude3	6.53	2.357	0.764	0.841
Cronbach's alpha of the fourth factor				**0.882**
Government_incentive1	11.14	4.776	0.647	0.768
Government_incentive2	11.06	4.491	0.633	0.773
Government_incentive3	11.13	4.619	0.628	0.775
Cronbach's alpha of the fifth factor				**0.817**

Source: calculation based on the survey

Table 4 Cronbach's alpha of the first factor after removal of items, Awareness1 and Awareness3

	Scale mean if item deleted	Scale variance if item deleted	Corrected item–total correlation	Cronbach's alpha if item deleted
Awareness2	7.25	4.329	0.798	0.816
Awareness4	7.23	4.457	0.768	0.843
Awareness5	7.10	4.421	0.760	0.850
Cronbach's alpha of the first factor				0.884

Source: calculation based on the survey

Table 5 Multicollinearity diagnostics

Coefficients[a]								
Model		Unstandardized coefficients		Standardized coefficients	*t*	Sig.	Collinearity statistics	
		B	Std. error	Beta			Tolerance	VIF
1	(Constant)	−1.542	00.152		−10.153	0.000		
	Awareness	0.149	0.023	0.323	6.498	0.000	0.823	1.214
	Environmental_concerning	0.067	0.022	0.151	3.080	0.002	0.842	1.187
	Customer_innovativeness	0.097	0.032	0.145	3.038	0.003	00.889	1.125
	Attitude	0.145	0.033	0.222	4.379	0.000	0.787	1.270
	Government_incentive	0.091	0.033	0.133	2.770	0.006	0.880	1.136

[a] Dependent variable: WTP

Results

Profile of respondents

The study was conducted with a sample of 300 households in the Daklak province, of which 51% were males, and 100% were married. The electricity consumption for the majority of the people was at levels 3 and 4, with percentages of 39.7% and 29%, respectively. The detailed information of the respondents is given in Table 2.

Table 6 Rotated component matrix

	Component				
	1	2	3	4	5
Government_incentive4	0.816				
Government_incentive2	0.789				
Government_incentive3	0.782				
Government_incentive1	0.776				
Awareness2		0.894			
Awareness4		0.875			
Awareness5		0.853			
Environmental_concern2			0.890		
Environmental_concern3			0.869		
Environmental_concern1			0.845		
Household_attitude1				0.905	
Household_attitude2				0.852	
Household_attitude3				0.832	
Customer_innovativeness2					0.877
Customer_innovativeness1					0.862
Customer_innovativeness3					0.849

Source: calculation based on the survey

Factor analysis

Reliability statistics

Before analysing the factors that affected the intention to instal a smart grid rooftop solar electricity system, the Cronbach's alpha was calculated to test the reliability of each of the items in the survey.

The reliability was considered acceptable if the Cronbach's alpha was ≥ 0.7, and the corrected item–total correlation was > 0.3 [44] As can be observed from Table 3, the reliability of all the items in the survey was acceptable except for the items, Awareness1 and Awareness3. Removing those two items from the model and repeating the process produced the revised Cronbach's alpha for factor 1, as shown in Table 4.

After removing the two items, all the variables were considered to be suitable for the model. An EFA was, therefore, conducted with all the variables without Awareness1 and Awareness3.

Exploratory factor analysis

In this study, the KMO was found to be equal to 0.785, with the significance of the Bartlett test being equal to 0.000, and the sum of the variance extracted being 76.791%. All the factor loadings were higher than 0.5, as illustrated in the rotated component matrix illustrated in Table 6.

Multicollinearity diagnostics

The results would be incorrect and would not be meaningful if there was multicollinearity. Therefore, the study had to be diagnosed for multicollinearity before any analysis could be performed. As shown in Table 5, all the VIFs were well under 5, and the tolerance was greater than 0.2. Therefore, there was no multicollinearity in the model. Thus, all the variables were appropriate for analysis.

Table 7 Categorical variable information

			N	Percent (%)
Dependent variable	Intention_to_instal	Do not intend to instal	201	67.0
		Intend to instal	99	33.0
		Total	300	100.0

Source: calculation based on the survey

Table 8 Parameter estimates

Parameter	β'	Std. error	*Z*	Sig.	95% confidence interval	
					Lower bound	Upper bound
PROBIT[a]						
Awareness	0.364	0.079	4.597	0.000	0.209	0.519
Environmental_concern	0.140	0.070	2.004	0.045	0.003	0.278
Household_innovativeness	0.146	0.082	1.787	0.074	− 0.014	0.307
Household_attitude	0.201	0.078	2.567	0.010	0.048	0.355
Government_incentive	0.256	0.098	2.606	0.009	0.064	0.449
Intercept	− 5.390	0.525	− 10.272	0.000	− 5.914	− 4.865

[a] PROBIT model: PROBIT(p) = intercept + $\beta' X$

Source: calculation based on the survey

Probit binary model

After testing the reliability of the items, conducting the EFA, and removing the results of the items, Awareness1 and Awareness3, from the data, the probit binary model was used to explore the intention of the sample of 300 households to instal a smart grid rooftop solar system. As noted above, the intention to instal was a binary dependent variable with a value of 0 indicating that the people who had no intention of installing a solar electricity system, and a value of 1 indicating a positive intention. As shown in Table 6, the independent variables used in the model were labelled as Household_awareness, Environmental_concern, Household_innovativeness, Attitude, and Government_incentive, which corresponded with the five factors derived from the following items:

Awareness = mean (Awareness2, Awareness4, Awareness5).

Environmental_concern = mean (Environmental_concern1, Environmental_concern2, Environmental_concern3).

Household_innovativeness = mean (Customer_innovativeness1, Customer_innovativeness2, Customer_innovativeness3).

Household_attitude = mean (Attitude1, Attitude2, Attitude3).

Government_incentive = mean (Government_incentive1, Government_incentive2, Government_incentive3, Government_incentive4).

Table 9 Probability of intention to instal a smart grid rooftop solar electricity system

Probability of intention to instal a smart grid rooftop solar electricity system	Number of households	%
From 0 to 0.100	192	64
From 0.101 to 0.200	74	25
From 0.201 to 0.300	15	5
From 0.301 to 0.400	14	5
From 0.401 to 0.500	5	2
From 0.501 to 0.600	0	0
From 0.601 to 0.700	0	0
From 0.701 to 0.800	0	0
From 0.801 to 0.900	0	0
From 0.901 to 1.00	0	0
Total	300	100

Source: calculation based on the survey

The model that was used to predict the dependent variable was as follows:

$$\begin{aligned} Intention\ to\ install* &= \beta'_0 + \beta'_1 Household\_Awereness + \beta'_2 Environmental\_Concern \\ &+ \beta'_3 Household\_Innovativeness + \beta'_4 Household\_attitude \\ &+ \beta'_5 Government\_Incentive_e + \varepsilon' \end{aligned}$$

From the total of 300 households, 99, representing 33% of the surveyed sample, indicated that they intended to instal smart grid rooftop solar systems on their houses (refer to Table 7). However, most households (67%) had no intention of installing such a system. The reasons that were given by those who did not intend to instal rooftop solar systems varied; some said that they did not have enough money to instal such a system. In contrast, some did not know about rooftop systems and had doubts about their efficiency, and wanted to know what guarantee existed in that such systems would operate as they were intended to.

From the results in Table 8, the Sig. of Customer_innovativeness was 0.74, which is higher than 0.05, and thus, the effect of Customer_innovativeness on the intention to instal was not significant. The remaining four Sig. values were all less than 0.05, and therefore, those four factors had a significant effect on the dependent variable. Most of the coefficient β values were positive, with the exception of Intercept β'o, which means that the effects were all in the same direction, i.e. the effects were all positive. The β' of the awareness variable was the highest, indicating that this factor had the greatest effect on the intention to instal a solar electricity system. Government incentives were also found to be an important factor in the people's decision to instal smart grid rooftop solar electricity systems in their houses.

In fact, most of the people who answered the questionnaire had limited knowledge concerning smart grid rooftop solar electrical systems, and many thought that such systems were only intended to generate hot water via solar power. Therefore, the researcher needed to provide an introduction concerning smart grid solar systems before administering the main survey.

Table 9 shows the probabilities of households deciding to instal smart grid rooftop solar systems in their houses. As can be seen, only 2% of the sample recorded a probability from 0.401 to 0.500, and none of the probability measurements exceeded 0.500. The majority of the probability measurements of the intention to instal solar electricity systems were between 0 and 0.010. The detailed probabilities of the intention to instal smart grid rooftop solar electricity systems for each household appear in Appendix 2.

It was also indicated that people would be willing to pay (WTP) to instal a rooftop solar electricity system or would encourage other people to do so if there was support from the government. The largest group (39.3%) of respondents suggested that the government should support 30% of the installation cost for smart grid rooftop solar electricity systems, with the second-largest group (27%) supporting the idea that preferential-rate loans should be made available by commercial banks. Other methods of encouraging people to instal smart grid rooftop solar electricity systems that are not detailed in Table 10 included the idea that people should be able to pay for the installation by instalments over a 3 to 5-year period or that the government should support 50% of the installation cost. Some people also suggested that there should be more communication activities to provide information about smart grid rooftop solar electricity.

Table 10 Willingness to pay for system installation cost

	Households	Percent
Willing to pay an installation cost of 620–744 USD	13	13.1
Willing to pay an installation cost of 1240–1488 USD	38	38.4
Willing to pay an installation cost of 1850–2220 USD	34	34.3
Willing to pay an installation cost of 2470–2964 USD	10	10.1
Willing to pay an installation cost of 3330–3960 USD	4	4.0
Total	99	100.0

Source: calculation based on the survey

The amount of money that households in the area would be willing to pay for installing a smart grid rooftop system

In the introduction to the questionnaire, the cost of installing a smart grid rooftop solar system was indicated to be in proportion to the level of electricity used (see Appendix 1). The households that indicated that they intended to instal such a system were made aware of the cost of installing a system with a generating capacity appropriate for their needs, and they indicated their willingness to pay (WTP) that cost. The breakdown of the amount that the households intending to instal a rooftop solar electricity system were willing to pay (WTP) is shown in Table 10.

Discussion

Research limitations

Even though all areas of Vietnam are appropriate for the exploitation of solar energy [20], the current research concentrated on only one area in Vietnam—the Central Highlands, which has the highest potential due to the duration of sunshine it enjoys annually. In addition, only five factors (awareness, environmental concerns, household innovativeness, household attitudes, and government incentives) were considered, with the data being gathered by a series of items measured using a five-point Likert scale, based on which a model was constructed to determine the effects of the independent variables on the intention of households to instal smart grid rooftop solar electricity systems in the research area. Moreover, only those households occupied by married couples and their families were analysed.

Policy implications

The research provides important information for the Vietnamese government, enabling them to enhance their policy of developing alternative energy resources. Based on the results, the awareness of households of smart grid rooftop solar electricity systems and government incentives were the two most influential factors that affect the intention of the people to instal such systems. Based on these findings, the following two policy measures are proposed for adoption by the government as they are likely to encourage the installation of rooftop electricity generation systems.

Firstly, the Government should identify those households that possess a high awareness concerning rooftop solar power and offer incentives directly to them. The results of this research showed that people with a high level of awareness (i.e. scores of 2.5 to 5 in the Awareness section of the questionnaire) had a higher intention to instal. The Government can also conduct some communication programmes to enhance the awareness of people about rooftop solar electricity so that programmes for the development of alternative energy will be more effective. As happens in Vietnam with every government programme, the People's Committee will disseminate information to the local people through workshops or meetings and hence, should send invitations to households with the potential to instal rooftop solar systems to attend at a particular date and time. At the meeting, experts in smart grid rooftop solar systems should talk about the functionality and usefulness of these systems so that people will clearly understand the benefits. The Chairman of the Committee should then introduce the incentives that are available to the people who have been invited and have attended the meeting.

In terms of government incentives and based on the recommendations made by the respondents in the research area, the following measures are suggested for implementation in the long-term by the Vietnamese government:

- Require commercial banks to offer preferential loans with lower interest rates than for those applying for other forms of credit for the installation of domestic electricity generation systems based on renewable energy sources.
- Offer a monetary gift (e.g., VND 5 million) when people instal a rooftop solar system on their house.
- Subsidize 10–30% or even 50% of the installation cost of domestic solar rooftop electricity systems in the same way as support is currently being offered to companies that instal such systems and in a similar way as the Indian government is offering such support in their PV rooftop programme.
- Enhance communication activities concerning smart grid rooftop solar electricity.

Conclusion

The study demonstrated that households have so far installed only a very small number of smart grid rooftop solar electricity systems in the Daklak Province, Vietnam. Moreover, few people are aware of the advantages of using renewable energy resources. However, after the information of rooftop solar electricity systems had been provided in this survey to the respondents in the research area, they understood the concept and 33% indicated an intention to instal such a system in their house, with the majority willing to pay (WTP) between USD 1240 and USD 2220. People with a high level of awareness of smart grid rooftop solar power are more likely to pay to instal such a system, but government incentives and household attitudes are also important factors to consider that influence the intention to instal. However, it was found that environmental concerns and the innovativeness of households were less influential factors.

Appendix 1. Questionnaire: intention to instal smart grid rooftop solar system in Daklak province—Vietnam

BEFORE THE SURVEY

Check if the household has a rooftop appropriate for a smart-grid rooftop solar installation
The survey will only be conducted with households where the rooftop of their house or apartment has a lot of sunshine throughout the day and the roof is not obscured by other houses or by big trees. Therefore, the researcher has to observe before going inside and conducting the survey. The people who answer the question must be above 18 years old.

After observing the rooftop, ask the following question:
(Because the research concentrates on households who have a rooftop appropriate for installing a solar power system, besides observing the house, the area of the rooftop and the electricity consumption should be established in advance.)
1. How much do you pay for electricity every month?……………….. (USD)
2. How big is your rooftop in square meters?………………..m^2
If people do not have an appropriate rooftop area, the survey should stop here.
If people have an appropriate rooftop area, the survey can continue.
3. What is your rooftop made from?
□ Corrugated iron □ Tiles □ Flat concrete □ Other

Have you installed a rooftop solar electricity system in your house?
□ Yes
□ No
If people answer 'yes', then ask them when they installed that system. Is it an off-grid, hybrid or smart-grid system? (If people hesitate before answering, the researcher should give a brief explanation of off-grid and hybrid systems to the respondent to help them to understand). How much did they pay for that the system?
These questions are just used for collecting information, but at this point, stop the survey.
If they answer no, then continue the survey.
Ask them the question: What do you know about smart grid rooftop solar electricity systems?
If they have knowledge of smart-grid systems then turn to the questionnaire and conduct the survey to collect data.
If they say they know little or nothing about smart–grid systems, then give them the introduction before turning to the questionnaire.
Introduction about smart-grid rooftop solar electricity systems.

A smart grid system includes solar panels, an inverter, and two-way metering. Its operation depends on the grid so it is called a smart grid-tie solar electric system. The smart grid will help the solar system operate stably and smoothly in the following ways:

- When the capacity generated by the system < customer's electricity needs, the inverter will take the excess power needed from the grid
- When the capacity generated by the solar electrical system = customer's electricity needs, the power which is generated by the solar electrical system will be used totally for the customer's needs.

- When the capacity generated by the solar electricity system > the electricity needs of the customer, the surplus power will be sent to the grid.

This process occurs automatically every day without the intervention of the consumer. The surplus electricity generated by the solar electrical system and the power needed from the grid is measured by a two-way meter and the process is termed “net metering”. The customers can also sell electricity independently from that which they buy at an FIT price of 9.35 USD/1kWh which is guaranteed for 20 years.

The lifetime of the system is 25 years.

Smart-grid solar rooftop systems are common in Vietnam because they are cheaper than off-grid systems and the customers do not have to buy and replace a battery every 2 to 5 years. EVN will record the net metering and calculate the electric bill for their customers.

The smart-grid solar rooftop energy system is easy to use in the Central Highlands because 95.17 % of households in this area already have grid electricity in their houses.

The advantage of smart-grid solar systems is the lower cost of installation. Unused solar power will be sold to the grid and paid for by EVN. However, when the mains electricity power is lost, the system also stops supplying power to the grid to protect the system and the grid.

A 1kWp rooftop solar system in Vietnam costs about 1000-1200USD. The duration of sunshine in the Central Highlands of Vietnam is 2000-2600 hours/per year. Therefore, a 1kWp rooftop solar electricity system can generate at least 2000/365 = 5.4 (kWh) electricity to meet the consumer’s needs if installed in the Central Highlands. The kWp that is appropriate for different levels of electricity consumption is as follows:

1. Grid electricity used monthly	0-50kWh	51-100kWh	101-200kWh	201-300kWh	301-400kWh	401-500kWh
2. Electricity bill every month (USD)	≤ 3.92	≤ 8.10	≤ 18.81	≤ 35.52	≤ 52.92	≤ 68.33
3. Area of rooftop – (6-7m^2/1kWp) (m^2)	6-7	6-7	7-8	11-13	15-18	20-24
4. Smart-grid instalation cost (USD) [(4)*1000 or 1200]	300-360	620-744	1,240-1,488	1,850 -2,220	2,470-2,964	3330-3960

The electricity price (electricity bill every month) is based on the new Decision No.648/QD-BCT

Rooftop solar power does not attract special consumption tax and the personal income tax and VAT rates are zero if the investment income is less than USD 4,244 per year. The personal income tax rate is 0.5 % and VAT is 1 % if the investment income is greater than USD 4,244 per year. Rooftop solar power projects with a capacity of less than 50kWp (< 01MW) are exempted from the need for an electricity operation license.

According to Circular 302/2016/TT-BTC, there is no excise duty on an investment that produces an income lower than 100 million VND. Income from 100-300 million VND is subject to a duty of 300,000 VND and in income from 300-500 million VND attracts a duty of 500,000 VND. The duty on an income of from 500-1000 million VND is1000,000 VND.

In this study, the highest electricity consumption is more than 400kWh (from 400-500kWh) which means that the highest solar generation capacity required is 3.33 kWp. If people sell all the power generated to the grid the benefit per year in this situation is still well under the threshold of USD 4,244 per year, and would, therefore, attract no personal income tax, no VAT, and no excise duty.

A consumer using all the electricity generated for their own needs, will also not have to pay any tax or duty.

<u>QUESTIONNAIRE</u>

The questions in this survey concentrate on the intention of households in Daklak Province to install smart-grid rooftop solar electricity systems. People are also encouraged to make suggestions to help energy development in the future.

The results will help the Vietnamese government to improve its policies which encourage people to install rooftop solar systems to reduce their dependence on conventional energy resources.

<u>Part 1.</u>

This part was started with the questions that explained in table 1 of the main text with five Likert Scale’s answer: strongly agree, agree, neutral, disagree, strongly disagree

After people answer the above questions, the authors remind people about the rooftop solar system size that is appropriate for their electricity consumption established in the first part and also remind them of the initial cost of the rooftop solar system.

....

Then ask them:

1. Do you intend to install a smart-grid rooftop system in your house in the near future?

□ Yes (go on to question 3)

□ No (continue to question 2)

2. Why have you not yet installed a smart-grid rooftop solar electricity system up to now?

……

3. What would you recommend the Vietnamese Government should offer to encourage the installation of smart-grid rooftop solar electricity systems besides the FIT of 9.35 US cents?

□ Subsidize 10 % of the installation cost
□ Subsidize 20 % of the installation cost
□ Subsidize 30 % of the installation cost
□ Give a 5-million VND bonus to people who install a system
□ Require commercial banks to give preferential-rate loans
Other…………………………………………………………………………………………………

Part 2. Respondents' Social demographics

1. Age
□ From 20-30 years old □ From 31-40 years old □ From 41-50 years old
□ From 51-60 years old □ Over 60 years old
2. Gender
□ Female □ Male
3. Education:
□ Primary School □ Secondary School □ High School □ College □ Postgraduate
4. Level of electricity consumption
□ From 0-50kWh □ From51-100kWh □ From 101-200kWh □ From 201-300kWh □ From 301-400kWh □ Over 400 kWh

Appendix 2

See Table 11.

Table 11 Probability of households' intention to install a smart-grid rooftop solar electricity system

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
PROBIT										
1	4.333	3.333	3.000	4.000	4.250	3	0	0.467	−0.467	0.156
2	4.333	4.667	3.333	4.000	4.500	4	1	0.953	0.047	0.238
3	1.333	5.000	3.000	3.000	3.000	3	0	0.025	−0.025	0.008
4	3.667	3.000	3.000	3.000	3.000	6	0	0.205	−0.205	0.034
5	2.667	1.667	2.333	2.333	4.750	3	0	0.047	−0.047	0.016
6	1.667	3.333	2.000	3.667	3.250	4	0	0.028	−0.028	0.007
7	3.333	2.333	2.000	2.667	3.500	4	0	0.067	−0.067	0.017
8	3.667	2.667	3.000	3.000	3.250	5	0	0.177	−0.177	0.035
9	2.667	3.000	2.000	3.000	2.000	4	0	0.019	−0.019	0.005
10	4.000	4.667	3.000	4.000	3.500	4	1	0.510	0.490	0.127
11	4.000	3.667	3.000	3.000	4.000	3	1	0.265	0.735	0.088
12	4.000	3.667	3.333	3.667	4.000	6	1	0.727	0.273	0.121
13	5.000	3.333	3.667	3.667	3.750	4	0	0.771	−0.771	0.193
14	4.000	3.667	3.000	3.000	4.000	6	0	0.529	−0.529	0.088
15	5.000	4.333	3.000	3.000	3.750	4	1	0.676	0.324	0.169
16	4.000	4.000	3.000	4.000	3.750	6	0	0.728	−0.728	0.121
17	3.667	5.000	3.000	4.000	4.000	3	1	0.417	0.583	0.139
18	4.667	5.000	3.333	4.667	3.000	2	1	0.427	0.573	0.213
19	4.000	4.000	4.000	4.000	4.000	3	1	0.507	0.493	0.169
20	2.667	3.000	4.333	3.000	3.000	3	0	0.070	−0.070	0.023
21	3.667	1.000	2.000	3.000	3.000	3	0	0.037	−0.037	0.012
22	3.667	3.000	3.000	3.000	3.000	4	0	0.137	−0.137	0.034
23	5.000	3.333	3.000	3.000	3.000	4	0	0.393	−0.393	0.098
24	3.333	2.667	3.333	3.000	3.750	3	0	0.120	−0.120	.040
25	4.333	4.667	3.333	3.000	4.250	3	1	0.493	0.507	.164
26	4.000	4.000	3.000	2.333	3.750	5	0	0.332	−0.332	0.066
27	3.333	4.000	3.000	3.000	4.000	3	0	0.183	−0.183	0.061
28	2.333	3.000	3.667	2.667	4.500	3	0	0.088	−0.088	0.029
29	2.333	3.000	2.333	3.000	3.000	3	0	0.024	−0.024	0.008
30	2.667	3.000	4.333	3.000	3.000	4	0	0.093	−0.093	0.023
31	2.333	3.000	2.333	3.000	3.000	2	0	0.016	−0.016	0.008
32	4.000	5.000	3.000	2.667	3.000	4	1	0.273	0.727	0.068
33	4.000	4.333	3.000	2.667	3.000	2	0	0.114	−0.114	0.057
34	2.000	1.667	3.333	2.000	3.750	5	0	0.025	−0.025	0.005

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
35	3.000	3.000	3.000	2.667	3.000	3	0	0.049	−0.049	0.016
36	3.000	3.333	3.667	3.000	3.750	3	0	0.126	−0.126	0.042
37	2.333	5.000	3.000	2.333	2.750	3	0	0.039	−0.039	0.013
38	5.000	5.000	5.000	5.000	2.750	2	1	0.669	0.331	0.335
39	3.000	2.333	2.333	3.000	4.250	2	0	0.053	−0.053	0.026
40	4.000	3.000	3.000	3.000	3.750	3	0	0.197	−0.197	0.066
41	4.000	3.000	2.333	2.000	3.500	3	0	0.092	−0.092	0.031
42	4.333	3.333	3.667	3.000	3.500	3	0	0.286	−0.286	0.095
43	4.000	5.000	3.000	2.667	3.000	5	1	0.342	0.658	0.068
44	5.000	2.000	2.667	4.333	4.500	3	1	0.573	0.427	0.191
45	3.000	3.000	3.333	5.000	4.500	3	1	0.328	0.672	0.109
46	2.333	2.333	2.667	3.000	3.500	2	0	0.020	−0.020	0.010
47	4.667	3.667	2.667	2.667	5.000	3	1	0.499	0.501	0.166
48	3.333	2.333	3.000	3.000	4.250	5	1	0.215	0.785	0.043
49	3.667	3.000	3.000	2.667	4.000	4	0	0.205	−0.205	0.051
50	4.333	2.333	2.000	2.000	2.000	4	0	0.045	−0.045	0.011
51	3.667	5.000	2.000	3.333	3.500	4	0	0.271	−0.271	0.068
52	4.000	4.000	4.000	4.000	4.000	6	1	1.015	−0.015	0.169
53	5.000	5.000	3.000	5.000	5.000	4	1	1.774	−0.774	0.443
54	3.000	1.667	4.000	3.000	3.500	5	0	0.120	−0.120	0.024
55	4.000	5.000	3.667	4.000	4.000	3	1	0.580	0.420	0.193
56	1.667	3.000	3.000	3.000	3.750	3	0	0.028	−0.028	0.009
57	3.000	1.667	2.667	3.667	4.000	3	0	0.084	−0.084	0.028
58	5.000	4.000	3.000	4.000	4.750	3	1	0.8760	0.124	0.292
59	4.000	4.000	3.000	2.333	3.750	3	0	0.199	−0.199	0.066
60	5.000	4.333	4.667	4.000	4.000	3	1	0.979	0.021	0.326
61	4.333	3.333	4.333	2.667	4.750	4	1	0.677	0.323	0.169
62	4.333	2.667	3.000	3.000	4.000	4	0	0.341	−0.341	0.085
63	2.333	5.000	3.000	2.667	2.500	6	0	0.079	−0.079	0.013
64	3.000	3.000	3.333	5.000	4.500	4	1	0.437	0.563	0.109
65	1.667	3.000	3.000	3.000	3.750	6	0	0.055	−0.055	0.009
66	5.000	5.000	4.333	3.667	4.750	3	1	1.170	−0.170	0.390
67	4.000	1.000	3.000	2.000	2.000	2	0	0.015	−0.015	0.007

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
68	4.333	2.000	2.667	3.333	4.000	3	0	0.222	−0.222	0.074
69	4.667	3.667	2.000	2.000	3.750	3	1	0.193	0.807	0.064
70	5.000	3.333	3.000	3.000	3.000	3	0	0.295	−0.295	0.098
71	4.000	3.000	2.333	2.000	3.500	4	0	0.122	0−0.122	0.031
72	2.333	2.333	2.667	3.000	3.500	4	0	.0400	−0.040	0.010
73	5.000	5.000	5.000	2.000	3.000	3	1	0.501	0.499	0.167
74	3.333	2.333	2.000	2.667	3.500	3	0	0.051	−0.051	0.017
75	4.000	5.000	3.000	3.000	4.500	5	1	0.750	0.250	0.150
76	4.000	5.000	3.667	4.000	4.000	3	1	0.580	0.420	0.193
77	4.667	3.333	2.000	2.333	3.000	3	0	0.136	−0.0136	0.045
78	3.667	1.000	2.000	3.000	3.000	3	0	0.037	−0.037	0.012
79	2.333	5.000	3.000	2.333	2.750	4	0	0.052	−.0052	0.013
80	3.667	3.000	3.000	3.000	3.000	2	0	0.068	−0.068	0.034
81	3.333	4.000	2.000	3.667	4.250	4	0	0.269	−0.269	0.067
82	2.333	3.000	4.000	2.333	3.750	2	0	0.035	−0.035	0.018
83	4.333	3.667	2.000	4.333	4.500	5	1	0.817	0.183	0.163
84	3.000	2.000	2.667	3.000	3.500	3	1	0.050	0.950	0.017
85	3.000	3.333	3.667	3.000	3.750	3	0	0.126	−0.126	0.042
86	1.667	3.000	5.000	3.333	3.750	3	0	0.068	−0.068	0.023
87	3.667	4.667	2.667	3.333	4.000	2	0	0.189	−0.189	0.094
88	5.000	4.333	3.000	5.000	5.000	2	1	0.814	0.186	0.407
89	5.000	4.000	3.000	4.000	4.750	3	1	0.876	0.124	0.292
90	4.667	4.000	3.000	3.333	3.250	3	0	0.352	−0.352	0.117
91	3.000	4.000	3.000	3.000	3.750	3	0	0.125	−0.125	0.042
92	3.667	3.667	3.333	4.667	4.000	5	1	0.690	0.310	0.138
93	4.667	4.000	3.000	3.333	3.250	3	0	0.352	−0.352	0.117
94	4.000	3.000	3.000	3.333	3.500	4	1	0.264	0.736	0.066
95	3.000	2.333	2.000	2.333	3.000	3	0	0.022	−0.022	0.007
96	3.000	3.667	2.667	3.000	4.500	5	0	0.254	−0.254	0.051
97	2.333	5.000	3.000	2.333	2.750	6	0	0.078	−0.078	0.013
98	5.000	2.333	2.000	3.000	3.250	4	0	0.260	−0.260	0.065
99	5.000	4.667	2.000	3.000	3.500	4	0	0.524	−0.524	0.131
100	3.000	3.667	2.667	3.000	4.500	5	0	0.254	−0.254	0.051

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
101	5.000	4.000	3.000	4.000	4.750	5	1	1.460	−0.460	0.292
102	4.333	4.333	5.000	4.333	4.500	3	1	0.981	.019	0.327
103	4.333	3.333	2.667	3.000	3.000	2	0	0.114	−0.114	0.057
104	5.000	4.000	3.000	4.333	3.500	3	0	0.634	−0.634	0.211
105	3.667	4.667	2.667	3.333	4.000	6	0	0.566	−0.566	0.094
106	3.000	3.000	3.000	3.000	3.000	4	0	0.078	−0.078	0.019
107	2.667	2.333	2.667	3.000	3.250	6	0	0.070	−0.070	0.012
108	3.667	3.333	3.000	3.000	3.500	4	1	0.199	.801	0.050
109	2.000	2.333	3.667	2.667	3.500	6	0	0.054	−0.054	0.009
110	2.333	2.667	3.667	2.667	4.000	3	0	0.058	−0.058	0.019
111	3.000	5.000	2.333	3.000	4.500	2	0	0.134	−0.134	0.067
112	3.667	5.000	2.333	3.000	3.750	3	0	0.222	−0.222	0.074
113	2.333	3.000	3.667	2.667	4.500	3	0	0.088	−0.088	0.029
114	3.667	3.333	3.000	3.000	3.500	3	1	0.149	.851	0.050
115	1.667	3.333	2.000	3.667	3.250	4	0	0.028	−0.028	0.007
116	3.000	3.000	3.000	2.333	2.750	4	0	0.047	−0.047	0.012
117	5.000	5.000	5.000	2.000	3.000	6	1	1.002	−0.002	0.167
118	4.667	4.667	3.333	3.333	3.250	3	1	0.444	.556	0.148
119	4.667	5.000	3.000	2.667	4.000	2	0	0.323	−0.323	0.161
120	3.667	2.667	3.000	3.000	3.250	3	0	0.106	−0.106	0.035
121	5.000	5.000	4.333	4.333	2.750	3	1	0.765	0.235	0.255
122	2.000	4.333	2.667	4.000	4.250	2	0	0.077	−0.077	0.038
123	2.333	3.667	3.000	2.667	3.000	2	0	0.023	−0.023	0.011
124	3.000	5.000	3.000	2.333	4.250	4	0	0.220	−0.220	0.055
125	4.000	4.000	3.667	2.000	4.500	3	0	0.301	−0.301	0.100
126	4.333	4.000	3.000	3.333	4.000	5	0	0.660	−0.660	0.132
127	4.333	3.333	3.000	4.000	4.250	3	0	0.467	−0.467	0.156
128	2.000	5.000	3.333	3.000	2.000	3	0	0.028	−0.028	0.009
129	5.000	4.000	4.000	2.333	4.250	3	1	0.581	.419	0.194
130	2.333	2.667	3.000	3.000	3.500	5	0	0.065	−0.065	0.013
131	3.000	3.000	3.000	3.000	3.000	4	0	0.078	−0.078	0.019
132	4.000	4.667	3.000	3.000	4.000	3	0	0.339	−0.339	0.113
133	2.667	3.667	2.333	3.000	3.250	4	0	0.067	−0.067	0.017

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
134	5.000	4.000	3.000	4.333	3.500	3	0	0.634	−0.634	0.211
135	4.000	5.000	3.000	3.000	4.500	4	1	0.600	.400	0.150
136	2.333	3.667	3.000	2.667	3.000	2	0	0.023	−0.023	0.011
137	4.000	3.000	3.000	3.000	3.750	4	0	0.262	−0.262	0.066
138	4.667	2.333	3.667	4.000	3.000	4	0	0.419	−0.419	0.105
139	4.667	3.333	2.000	2.333	3.000	3	0	0.136	−0.136	0.045
140	4.000	3.333	3.000	4.000	5.000	4	0	0.693	−0.693	0.173
141	2.000	3.000	3.000	3.000	2.000	3	0	0.011	−0.011	0.004
142	3.333	2.333	3.000	3.000	4.250	4	1	0.172	.828	0.043
143	4.333	4.667	3.333	3.000	4.250	3	0	0.493	−0.493	0.164
144	2.667	3.667	3.000	3.000	4.250	4	0	0.152	−0.152	0.038
145	2.333	3.000	3.000	3.667	4.000	3	1	0.083	0.917	0.028
146	3.333	4.000	3.000	3.667	3.750	2	1	0.139	0.861	0.070
147	3.667	3.000	3.000	3.000	3.000	3	0	.1020	−0.102	0.034
148	2.000	1.000	2.000	3.000	3.750	4	0	0.015	−0.015	0.004
149	5.000	4.667	2.000	3.000	3.500	4	0	0.524	−0.524	0.131
150	3.000	4.000	2.333	3.000	5.000	3	0	00.197	−0.197	0.066
151	3.667	5.000	3.000	4.000	4.000	4	1	.556	0.444	0.139
152	5.000	5.000	4.000	4.333	4.250	4	1	1.494	−0.494	0.374
153	4.333	3.667	2.000	3.000	3.500	2	1	0.132	0.868	0.066
154	2.000	3.000	3.000	3.000	2.000	2	0	0.007	−0.007	0.004
155	4.000	3.000	3.667	3.000	3.500	3	1	0.210	.790	0.070
156	2.333	5.000	2.000	3.667	4.000	3	0	0.112	−0.112	0.037
157	1.667	3.000	5.000	3.333	3.750	3	0	0.068	−0.068	0.023
158	4.667	2.333	3.667	4.000	3.000	3	0	0.315	−0.315	0.105
159	5.000	2.000	2.667	4.333	4.500	3	1	0.573	0.427	0.191
160	5.000	2.333	2.000	3.000	3.250	4	0	0.260	−0.260	0.065
161	4.667	4.667	3.333	3.333	3.250	3	0	0.444	−0.444	0.148
162	2.333	2.667	3.667	2.667	4.000	3	0	0.058	−0.058	0.019
163	2.667	4.333	3.333	3.667	3.500	5	0	0.228	−0.228	0.046
164	2.333	2.667	3.000	3.000	3.500	3	0	0.039	−0.039	.013
165	3.000	1.667	2.667	3.667	4.000	2	0	0.056	−0.056	0.028
166	2.000	5.000	3.333	3.000	2.000	4	0	.037	−0.037	0.009

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
167	4.667	2.333	3.000	3.000	4.500	2	0	.2430	−0.243	0.121
168	5.000	4.333	4.667	4.000	4.000	2	1	0.653	.347	0.326
169	5.000	5.000	2.667	5.000	3.750	3	1	0.913	.087	.304
170	3.333	3.000	2.000	2.667	3.500	3	0	0.064	−0.064	0.021
171	4.333	3.333	3.000	4.000	4.250	4	0	.6230	−0.623	0.156
172	4.000	4.667	3.333	4.000	4.500	4	1	0.809	0.191	0.202
173	1.667	3.000	3.000	3.000	3.750	2	0	0.018	−0.018	0.009
174	5.000	5.000	5.000	2.000	4.000	3	1	0.717	0.283	0.239
175	3.000	1.667	2.667	3.667	4.000	5	0	0.140	−0.140	0.028
176	4.667	2.333	3.000	3.000	4.500	4	0	0.485	−0.485	0.121
177	5.000	4.000	3.000	3.667	3.000	3	0	0.431	−0.431	0.144
178	3.667	3.667	3.000	3.000	3.000	4	0	0.167	−0.167	0.042
179	3.000	3.000	3.333	5.000	4.500	4	1	0.437	.563	0.109
180	5.000	3.333	3.667	3.667	3.750	2	0	0.386	−0.386	0.193
181	2.333	3.667	3.000	2.667	3.000	2	0	0.023	−0.023	0.011
182	3.333	3.000	2.333	3.000	3.000	5	0	0.103	−0.103	0.021
183	4.000	3.000	3.000	3.333	3.500	3	1	0.198	0.802	0.066
184	3.333	4.667	3.000	3.333	4.000	4	0	0.331	−0.331	0.083
185	3.667	3.667	3.333	3.333	4.000	5	0	0.437	−0.437	0.087
186	3.000	3.667	3.000	3.333	3.500	4	0	0.151	−0.151	00.038
187	1.667	1.000	2.000	2.000	1.500	3	0	0.001	−0.001	.000
188	3.667	3.667	3.000	4.000	3.750	3	0	0.272	−0.272	0.091
189	3.000	4.000	3.667	3.000	3.000	5	0	0.169	−0.169	0.034
190	3.333	3.000	2.000	2.667	3.500	4	0	0.085	−0.085	0.021
191	4.000	4.000	3.667	2.000	4.500	4	0	0.401	−0.401	0.100
192	3.000	1.667	2.667	3.667	4.000	3	0	0.084	−0.084	0.028
193	5.000	3.667	2.000	4.000	3.000	2	1	0.234	.766	0.117
194	4.667	3.333	3.667	3.000	4.000	4	1	0.580	.420	0.145
195	3.667	5.000	2.000	3.000	4.000	4	1	0.304	.696	0.076
196	2.333	2.667	3.000	3.000	3.500	3	0	0.039	−0.039	0.013
197	5.000	5.000	5.000	2.667	4.000	2	1	0.565	0.4350	0.283
198	3.000	3.000	3.000	2.333	2.750	2	0	0.024	−0.024	0.012
199	3.000	3.000	3.333	5.000	4.500	4	1	0.437	0.563	0.109

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
200	2.333	3.000	3.000	3.667	4.000	4	1	.110	0.890	0.028
201	5.000	5.000	4.000	4.333	4.250	3	1	1.121	−0.121	0.374
202	4.333	4.000	3.000	3.000	4.000	3	1	0.355	0.645	0.118
203	3.667	1.333	2.000	2.000	3.500	3	0	0.034	−0.034	0.011
204	4.333	3.333	3.000	4.667	4.250	5	1	0.950	0.050	0.190
205	5.000	5.000	3.000	5.000	5.000	4	1	1.774	−0.774	.443
206	3.333	4.333	3.667	3.667	3.750	4	0	0.365	−0.365	0.091
207	2.000	1.667	3.000	3.333	4.500	4	0	0.061	−0.061	0.015
208	2.000	1.000	2.000	3.000	3.750	6	0	0.023	−0.023	0.004
209	2.667	2.333	2.667	3.000	3.250	4	0	0.047	−0.047	0.012
210	4.000	2.333	3.000	3.000	2.500	5	0	0.136	−0.136	0.027
211	3.667	3.000	3.000	2.667	4.000	3	0	0.153	−0.153	0.051
212	3.667	5.000	2.333	3.000	3.750	3	0	0.222	−0.222	0.074
213	5.000	5.000	3.000	5.000	5.000	3	1	1.330	−0.330	0.443
214	3.333	3.000	2.000	2.667	3.500	3	0	0.064	−0.064	0.021
215	4.000	4.000	4.000	4.000	4.000	3	1	0.507	0.493	0.169
216	3.667	3.667	3.333	3.333	4.000	3	0	0.262	−0.262	0.087
217	1.333	5.000	3.000	3.000	3.000	4	0	0.034	−0.034	0.008
218	5.000	5.000	4.333	4.333	2.750	4	1	1.021	−0.021	0.255
219	3.667	5.000	2.000	3.000	4.000	4	1	0.304	0.696	0.076
220	4.333	3.333	2.667	3.000	3.000	2	0	0.114	−0.114	0.057
221	4.333	3.333	3.000	4.667	4.250	4	1	0.760	0.240	0.190
222	5.000	5.000	4.333	3.667	4.750	4	1	1.560	−0.560	0.390
223	1.333	5.000	3.000	3.000	3.000	5	0	0.042	−0.042	0.008
224	4.000	4.000	4.000	4.000	4.000	3	1	0.5070	0.493	0.169
225	3.333	4.000	2.000	3.667	4.250	3	0	0.202	−0.202	0.067
226	2.000	1.667	3.000	3.333	4.500	5	0	0.076	−0.076	0.015
227	3.333	4.000	3.000	3.667	3.750	3	1	0.209	.791	.070
228	2.667	3.667	3.000	3.000	4.250	3	0	0.114	−0.114	.038
229	4.667	2.333	3.000	3.000	4.500	3	0	0.364	−0.364	0.121
230	3.333	2.333	3.000	3.000	4.250	3	1	0.129	0.871	0.043
231	3.333	3.000	2.000	2.667	3.500	4	0	0.085	−0.085	0.021
232	3.667	3.667	3.000	4.000	3.750	2	0	0.181	−0.181	0.091

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
233	1.667	1.000	3.000	3.000	4.250	2	0	0.012	−0.012	0.006
234	4.667	5.000	3.000	2.667	4.000	2	1	0.323	0.677	0.161
235	2.333	2.667	3.000	3.000	3.500	5	0	0.065	−0.065	0.013
236	2.000	5.000	3.333	3.000	2.000	4	0	0.037	−0.037	0.009
237	4.000	4.667	3.000	4.000	3.500	2	1	0.255	0.745	0.127
238	4.000	1.000	3.000	2.000	2.000	4	0	0.029	−0.029	0.007
239	4.000	3.333	3.000	3.667	4.000	3	0	0.309	−0.309	0.103
240	3.000	4.000	3.667	3.000	3.000	3	0	0.101	−0.101	0.034
241	4.333	3.333	4.333	2.667	4.750	4	1	0.677	.323	0.169
242	4.000	4.333	3.000	2.667	3.000	4	0	0.227	−0.227	0.057
243	1.667	1.000	2.000	2.000	1.500	3	0	0.001	−0.001	0.000
244	4.333	3.000	3.000	4.000	3.500	2	0	0.211	−0.211	0.105
245	2.667	3.667	3.000	3.000	4.250	3	0	0.114	−0.114	0.038
246	4.667	3.667	2.000	2.000	3.750	4	1	0.257	0.743	0.064
247	4.333	4.000	3.000	3.000	4.000	3	1	0.355	0.645	0.118
248	3.333	4.667	3.000	3.333	4.000	2	0	0.165	−0.165	0.083
249	3.000	4.000	3.000	3.000	3.750	5	0	0.208	−0.208	0.042
250	4.333	5.000	3.000	3.000	3.750	4	0	0.536	−0.536	.134
251	5.000	5.000	5.000	5.000	3.250	3	1	1.148	−0.148	0.383
252	4.333	3.333	3.000	4.000	4.250	2	0	0.311	−0.311	0.156
253	4.333	3.667	2.000	3.000	3.500	4	1	0.265	0.735	0.066
254	3.333	1.667	2.333	3.667	2.750	4	0	0.062	−0.062	0.015
255	3.333	4.333	3.667	3.667	3.750	3	0	0.274	−0.274	0.091
256	2.333	3.667	3.000	2.667	3.000	3	0	0.034	−0.034	00.011
257	2.000	2.333	3.667	2.667	3.500	2	0	0.018	−0.018	0.009
258	4.333	3.333	3.667	3.000	3.500	5	0	0.477	−0.477	0.095
259	3.000	1.667	4.000	3.000	3.500	3	0	0.072	−0.072	0.024
260	2.333	5.000	2.000	3.667	4.000	4	0	0.149	−0.149	0.037
261	4.000	4.000	3.000	4.000	3.750	2	0	0.243	−0.243	0.121
262	5.000	5.000	5.000	5.000	2.750	2	1	0.669	0.331	0.335
263	3.000	3.667	3.000	3.333	3.500	3	0	0.113	−0.113	0.038
264	4.000	3.667	3.333	3.667	4.000	3	0	0.364	−0.364	0.121
265	3.000	2.333	2.000	2.333	3.000	3	0	0.022	−0.022	0.007

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
266	5.000	3.667	5.000	5.000	3.000	4	1	1.165	−0.165	0.291
267	2.333	5.000	3.000	2.333	2.750	4	0	0.052	−0.052	0.013
268	3.333	3.000	4.000	3.000	4.250	5	0	0.349	−0.349	0.070
269	2.667	3.667	3.000	3.000	4.250	4	0	0.152	−0.152	0.038
270	2.667	3.000	2.667	3.000	3.000	3	0	0.038	−0.038	0.013
271	4.667	5.000	3.333	4.667	3.000	4	1	0.853	.147	0.213
272	3.333	4.000	3.000	3.000	4.000	3	0	0.183	−0.183	0.061
273	5.000	5.000	2.667	5.000	3.750	4	1	1.218	−0.218	0.304
274	3.333	1.667	2.333	3.667	2.750	2	0	0.031	−0.031	0d.015
275	4.000	3.333	3.000	4.000	5.000	3	0	0.520	−0.520	0.173
276	3.667	1.333	2.000	2.000	3.500	3	0	0.034	−0.034	0.011
277	4.667	3.333	3.667	3.000	4.000	2	1	0.290	0.710	0.145
278	5.000	4.000	3.000	4.000	4.750	4	1	1.168	−0.168	0.292
279	4.667	2.333	3.000	3.000	4.500	2	0	0.243	−0.243	0.121
280	4.000	4.667	3.000	3.000	4.000	5	1	0.564	0.436	0.113
281	4.000	3.000	3.667	3.000	3.500	5	1	0.350	0.650	0.070
282	5.000	3.667	2.000	4.000	3.000	5	1	0.585	0.415	0.117
283	4.333	4.333	5.000	4.333	4.500	6	1	1.962	−0.962	0.327
284	1.333	5.000	3.000	3.000	3.000	3	0	0.025	−0.025	0.008
285	4.333	2.333	3.000	3.000	5.000	2	0	0.246	−0.246	0.123
286	3.333	3.000	2.333	3.000	3.000	4	0	0.082	−0.082	0.021
287	3.000	2.333	2.333	3.000	4.250	2	0	0.053	−0.053	0.026
288	1.333	4.333	2.333	3.000	5.000	3	0	0.0580	−0.058	0.019
289	5.000	5.000	5.000	5.000	3.000	3	1	1.075	−0.075	0.358
290	3.667	4.000	3.333	3.000	3.750	4	0	0.299	−0.299	0.075
291	4.333	3.667	2.000	4.333	4.500	2	1	0.327	0.673	0.163
292	5.000	4.000	4.000	2.333	4.250	4	1	0.774	0.226	0.194
293	3.000	3.000	3.000	3.000	3.000	3	0	0.058	−0.058	0.019
294	2.667	3.000	2.000	3.000	2.000	5	0	0.024	−0.024	0.005
295	1.667	3.000	3.000	3.000	3.750	2	0	0.018	−0.018	0.009
296	5.000	4.333	3.000	3.000	3.750	4	1	0.676	.324	0.169
297	5.000	5.000	3.000	5.000	5.000	4	1	1.774	−0.774	0.443
298	2.000	5.000	3.333	3.000	2.000	2	0	0.018	−0.018	0.009

Table 11 (continued)

Number	Awareness	Environmental_ concern	Household_ innovativeness	Household_ Attitude	Government_ incentive	Number of Subjects	Observed Responses	Expected Responses	Residual	Probability
299	3.333	2.333	3.000	3.000	4.250	3	1	0.129	.871	0.043
300	2.333	3.000	4.000	2.333	3.750	2	0	0.035	−0.035	0.018

Abbreviations
FIT: Feed-in-tariff; KM: Kilometre; SG: Smart grid; PVs: Photovoltaic System; EVN: Vietnam Electricity; TPB: Theory of planned behaviour; VIFs: Variance inflation factors; FEA: Exploratory Factor Analysis; WTP: Willing to pay.

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Authors' contributions
KT and SJ designed the paper framework and research questions. LDN provided valuable research insights into the analysis. LDN provided valuable research insights into the analysis. LDN and TTL designed the questionnaire, did the survey, wrote and edited the paper; KT and sent the paper to the English Edited Group (RDO-Prince of Songkla University). All authors read and approved the final manuscript

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