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Public acceptance of residential solar photovoltaic technology in Malaysia

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Abstract

Purpose – Gaining independence from fossil fuels and combating climate change are the main factors to increase the generation of electricity from renewable fuels. Amongst the renewable technologies, solar photovoltaic (PV) is believed to have the largest potential. However, the number of people adopting solar PV technologies is still relatively low. Therefore, the purpose of this paper is to examine the household consumers' acceptance of solar PV technology being installed on their premises.

Design/methodology/approach – To examine the solar PV technology acceptance, this study uses technology acceptance model (TAM) as a reference framework. A survey was conducted to gather data and to validate the research model. Out of 780 questionnaires distributed across Malaysia, 663 were returned and validated.

Findings – The analysis revealed that perceived ease of use, perceived usefulness and attitude to use significantly influenced behavioural intention to use solar PV technology.

Research limitations/implications – This study contributes by extending the understanding of public inclination towards the adoption of solar PV technology. Also, this study contributes in identifying the areas which need to be examined further. However, collecting data from urban peninsular Malaysian respondents only limits the generalization of the results.

Practical implications – On the policy front, this study reveals that governmental support is needed to trigger PV acceptance.

Originality/value – This paper uses TAM to analyse the uptake of solar PV technology in Malaysian context.

Keywords Malaysia, Renewable energy, Technology acceptance, Solar photovoltaic

Paper type Case study

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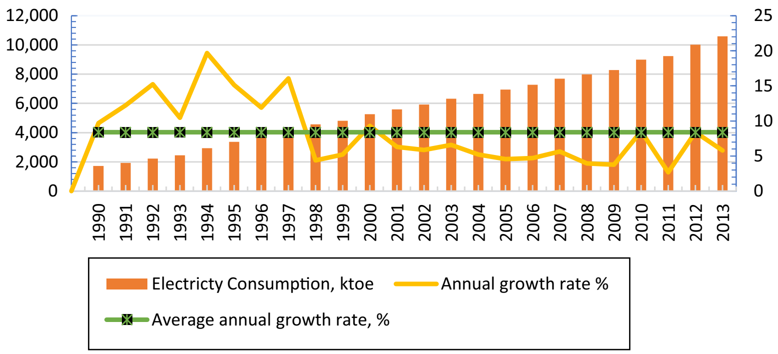
1. Introduction

Decisions regarding fuels to be used for the generation of electricity have their ramifications in the global economy as well as the environment (Ahmad and Tahar, 2014a). Electricity producing technologies draw criticism for their reliance on the use of fossil fuels. These fossil fuels are not only environmentally harmful but are also unsustainable. To mitigate the drawbacks of using fossil fuels, Intergovernmental Panel on Climate Change (IPCC) recommends renewable fuels for the generation of electricity (IPCC, 2011). Besides being environmentally benign, renewable fuels can also play a major role in fulfiling rising energy demand (Von Borgstede *et al.*, 2013).

Among various technologies using renewable fuels, solar photovoltaic-based electricity production is dubbed as the most environmentally friendly and sustainable for electricity productions. During the last decade, a widespread deployment of solar PV systems, ranging from kilowatts (kW) to hundreds of megawatts (MW), demonstrated the viability of PV technology as a major sustainable power source. In an industrialized country like Germany, 4 per cent of the total electricity demand is met by photovoltaic, with a total of 32 gigawatts (GW) of installed capacity in 2013 (IEA-PVPS, 2013). Globally, in 2013, approximately 39 GW of solar PV capacity was installed, adding to a total of 139 GW capacity (REN21, 2015). On the economic side, a sharp drop in costs of solar modules and substantial financial support polices indicates a global shift towards renewable technologies for the generation of electricity. Specifically, a drop of 60 per cent in the cost of solar PV systems was observed for the period 2008-2010 (REN21), while around a total of \$214bn was sanctioned in financial support in 2013 for renewable technology (UNEP, 2014).

Within the renewable technologies for electricity production, solar PV and wind go side by side. However, in 2013, the growth rate of solar PV technology was recorded at 39 per cent compared to wind technology which stood at a rate of 25 per cent (REN21). Despite the impressive track record of solar PV technology, there are societal barriers to mass acceptance of this technology (Solangi *et al.*, 2015; Kaldellis *et al.*, 2012). In Malaysia, like many other developing countries, electricity demand has been on the rise. The increase in demand is presented in Figure 1. This represents an average annual growth rate of 8.38 per cent for the period 1990-2013.

Likewise, fossil-fuels have been used to meet the growing demand. Fuel mix for the generation of electricity is presented in Figure 2. Though a shift from oil and diesel is visible, fossil fuels such as natural gas and coal dominate the fuel mix with minimal contribution



Source: National Energy Balance (NEB) (2013)

Figure 1. Electricity consumption and annual growth rate

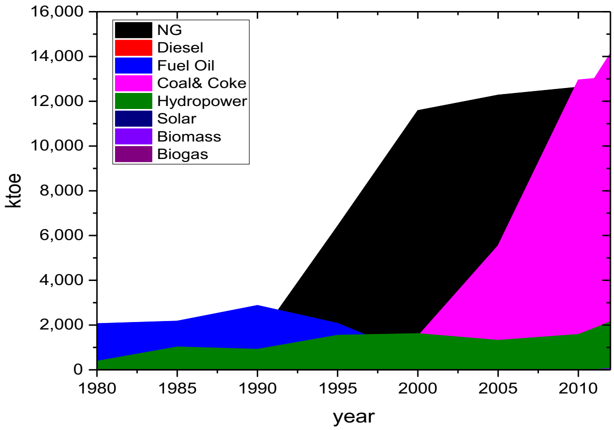


Figure 2.
Fuel mix for various power plants

Source: Malaysia Energy Statistics Handbook (2014), National Energy Balance (NEB) (2013)

from renewable fuels, except hydropower. Hydropower contributed 294 GWh (8.7 per cent) of the total fuel mix for the generation of electricity in 2012 (NEB, 2013).

On the policy front, in Malaysia, renewable technologies for the generation of electricity were introduced in the fifth-fuel policy under the 8th and 9th Malaysian plans (Hashim and Ho, 2011). The main reason for this inclusion is owing to the achievable potential of renewable energy sources in the country. Table I summarises the estimated renewable potential in Malaysia.

Since December 2011, the financial support mechanism of feed-in tariff has also been in place (Ahmad and Tahar, 2014b; Muhammad-Sukki *et al.*, 2014). Though various studies have discovered that the general public in Malaysia is in favour of renewable technologies (Ahmad, *et al.* 2015; Ahmad and Tahar, 2014c; Alam *et al.*, 2014; Lim and Lam, 2014), there is a lack of understanding on the public attitudes and motivation to use renewable technologies, particularly solar PV technology (Solangi *et al.*, 2015; Muhammad-Sukki *et al.*, 2011). There are numerous studies available from developed counties evaluating the prospects of solar PV technology from the public's perspective (Musall and Kuik, 2011; Park and Oh, 2014; Schelly, 2014), but for developing countries, such as Malaysia, these studies

Table I.
Estimate of renewable energy potential in Malaysia

Renewable source	Potential (MW)
Large-hydro	29,000
Mini-hydro	500
Solar photovoltaics	6,500
Biomass	29,000
Biogas	250
Municipal solid waste	400
Wind	No reliable data available

Source: Kardooni *et al.* (2016), Ahmad and Tahar (2014a) are limited in number and are more focused on technical and policy considerations (Chua and Oh, 2012; Lau *et al.*, 2009; Maulud and Saidi, 2012; Mekhilef *et al.*, 2012; Murni *et al.*, 2013; Nor *et al.*, 2014). Moreover, research findings from developed countries cannot be applied to developing countries owing to their specific social, economic and political setup (Dewan and Kraemer, 2000). Therefore, it is vital to know the perceptions, attitudes and intention of the future use of solar PV technology from the Malaysian perspective. The main objective of this study is to evaluate the factors that influence the adoption of solar PV technology in Malaysia. Therefore, the technology acceptance model (TAM) is leveraged in this empirical research.

2. Materials and methods

2.1 Conceptual framework of the study

Novel technologies for the generation of electricity, such as solar PV technology, has raised questions on the adoption of this technology by the general public. In particular, there is a need to find out which factors shape the decision-making of the target group to adopt this technology. Besides the motivation, there is also a need to find out why an individual accepts the solar PV technology. Likewise, there is a need to find out the determinants that influence solar PV acceptance. These questions are the driving force behind our endeavour. This study focuses on the factors governing solar PV technology acceptance and its usage among users. The conceptual model of the research is shown in Figure 3. The main theme of this research is to find users' intention to use solar PV technology based on attitudes towards technology, its usefulness and ease of use. The model used in this study has been inspired from Davis (1989). Beside this conceptual inspiration, our study has its empirical lineage to Alam *et al.* (2014) and Tsantopoulos *et al.* (2014).

Social scientists have developed a number of models to examine and comprehend the factors affecting the acceptance of an innovative technology. These approaches include the following: the theory of reasoned action (TRA) (Ajzen and Fishbein, 1980) and its successor, the theory of planned behaviour (TPB) (Ajzen and Fishbein, 1980), the TAM (Davis, 1989) and the diffusion of innovation (DOI) (Rogers, 1962) theory. The current research focuses on the TAM as its core. The reason for choosing TAM is mainly because of the very nature of the study. Solar PV technology is at its initial phase of introduction in Malaysia. This warrants solar PV technology adoption to be assessed. Furthermore, this assessment needs to be done not only from the technical and economic side but also must include the social and environmental aspect of the said technology. In this regard, this study aims to seek an understanding of the relationship between the public's perceptions and the future intent to adopt the solar PV technology. Though perceptions and attitude towards a particular technology is considered to be a weak measure of individuals' attitude (Schelly, 2014; Siegrist *et al.*, 2014), public attitude to renewable technologies is, nevertheless, an important factor to be considered in large scale acceptance (Heras-Saizarbitoria *et al.*, 2013). The

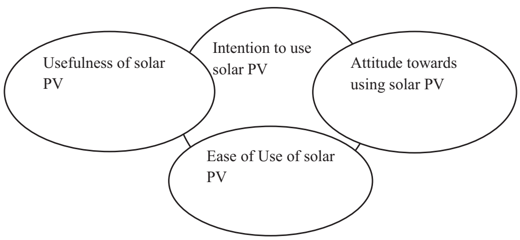


Figure 3. Conceptual framework of the study

importance of attitude has also been verified by Frewer *et al.* (1998) in their research. Furthermore, the existing literature indicates that individuals' attitude towards a particular technology is one of the best predictors of individuals' intention to use the technology (Ajzen and Gilbert Cote, 2008). Likewise, Islam and Meade (2013) established their research only on the individual intentions, and they gathered data to determine if households will adopt solar panel installation.

Besides the societal aspect, research into renewable energy technology is needed from the sustainability perspective. As Palanisami *et al.* (2014) say:

> Whether or not fossil fuel sources run out or not, alternative energy sources are likely to be used to reduce environmental pollution and solar energy is the most promising substitute for fossil fuel.

In this backdrop, it becomes imperative to discover the public acceptance of a new technology.

2.2 Research model and hypotheses

As mentioned in Section 2.1, the conceptual framework is based on the TAM. The hypotheses regarding the core TAM relationships have been formulated as:

H1. A user's attitude towards using solar PV technology positively affects the behavioural intention.

H2. A user's perceived usefulness of the solar PV technology positively affects the attitude towards using the solar PV technology.

H3. A user's perceived ease of use of the solar PV technology positively affects the attitude towards using the solar PV technology.

H4. A user's perceived ease of use of the solar PV technology positively affects the perceived usefulness of the solar PV technology.

Figure 4 summarizes the research model and hypotheses of this study.

2.3 Participants and procedure

The survey research gathered information for scientific purposes from a sample of the population using standardized instruments. The aim of the study was to get a more

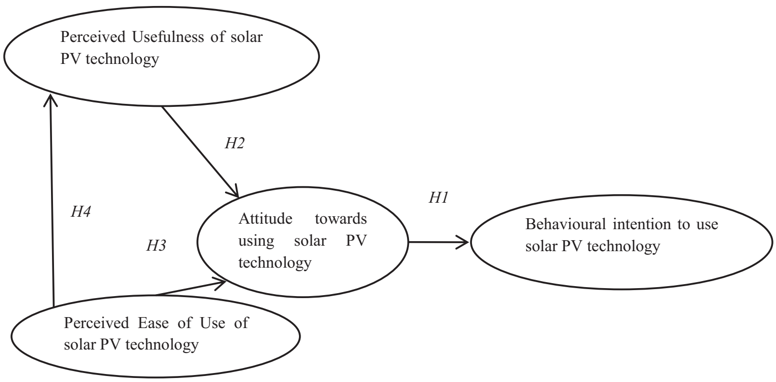


Figure 4.
The research model

comprehensive and broader view of the factors that determine the acceptance of solar PV technology for general public usage. At first, the questionnaire was distributed among faculty members and graduate students of Industrial Management, Universiti Malaysia Pahang, to establish the face validity of the items. Based on their feedback, a revised questionnaire was developed. In June 2013, data were collected using the personal administrated method. A non-probability convenience sampling was used following Halder *et al.* (2016) and Alam *et al.* (2014). This approach fulfiled the cost and convenience of obtaining the sufficient respondents for the survey. A total of 780 questionnaires were administered among the residents of peninsular Malaysia only. The reason behind this geographic focus is because of its higher population density and level of urbanisation. Besides this reason, peninsular Malaysia has modern information and technological facilities as compared to East Malaysia. Therefore, we assumed that the peninsular Malaysian population would be more appropriate.

2.4 Questionnaire development

The questionnaire developed consisted of questions following the TAM. Based on the insights gained from practical experiences and the literature review, a survey questionnaire was developed. A five-point Likert scale, where 1 being strongly disagree and 5 being strongly agree, was used for each question. The paper-based questionnaire first provided information on solar PV technology to familiarise the respondents with the topic. Later, demographic questions were asked. The questions related to perceived usefulness of the technology were presented next, followed by perceived ease of use, attitude towards use and behavioural intentions at the end.

2.5 Measures

A three-step approach was adopted in this study. The first step, "problem focus and literature review", was conducted through direct observation of the solar PV market in the country and by reading past literature published in the area. The second step consisted of organising a public survey, while the third step focused on testing the TAM on the gathered data. The final step of the study consisted on verifying the hypotheses made by using regression analysis.

3. Data analysis

In this research, data were coded and later analysed using statistical package for the social sciences (SPSS) 16.0. A number of statistical tests were applied to analyse the data. The first phase of analysis consisted of descriptive analysis, normality test, single mean *t*-test, reliability analysis and confirmatory factor analysis. The second phase consisted of the inferential analysis. This analysis aimed to explore the relationships between the independent variable (IV) and the dependent variable (DV) through correlation analysis and regression analyses to test the proposed research hypotheses and to identify the most influential factors in the whole system. The following subsections provide the details of data analysis performed.

3.1 Respondents' demographics

The demographic characteristics of the respondents are as follows: male respondents comprised 45.6 per cent and female were 54.4 per cent. In terms of race, 67.3 per cent of the respondents were Malay, followed by 31.4 per cent Chinese, while Indians and other ethnicities comprising only 0.6 per cent. The majority of the respondents (73 per cent) were between 21 and 50 years of age, while below 20 years and above 60 years form a small proportion. A total of 43 per cent of the respondents were university graduates and the monthly income of the 43 per cent was in the 2,001-4,000 Malaysian ringgit (MYR) range. Finally, only 2.6 per cent of respondents were high electricity users, i.e. those having a monthly bill from MYR400 and above. The demographic characteristics of all the effective respondents are presented in Table II.

3.2 Normality test

Skewness and kurtosis statistics were used to determine the normality of the collected data. Perceived usefulness, with a mean value of 3.703, had skewness and kurtosis values of −0.370 and −0.408, respectively. Likewise, perceived ease of use, with a mean value of 3.257, had skewness and kurtosis values of −0.408 and 0.798. Attitude towards

Table II. Respondents' demographic characteristics

Profile	Description	Frequency	(%)
Gender	Male	303	45.6
	Female	360	54.4
Race	Malay	446	67.3
	Chinese	208	31.4
	Indian	4	0.6
	Others	4	0.6
Age	Below 20	67	10.1
	21-25	16	2.4
	26-30	165	24.9
	31-35	99	14.9
	36-40	102	15.4
	41-45	54	8.1
	46-50	50	7.5
	51-55	38	5.7
	56-60	51	7.7
	61 and above	21	3.2
Monthly income	Less than 900	151	22.8
	1,000-2,000	162	24.4
	2,001-4,000	269	40.6
	4,001-5,000	45	6.8
	5,001 and above	36	5.4
Monthly electricity bill	Lesser than 50	142	21.4
	51-100	245	37
	101-150	155	23.4
	151-200	75	11.3
	201-300	0	0
	301-400	29	4.4
	401-500	8	1.2
	500 and above	9	1.4
Level of education	*SPM	197	29.7
	**STPM	50	7.5
	Vocational	125	18.9
	University	290	43.7
	Other	1	0.2

Notes: Total sample = 663; * Secondary school; ** Higher secondary school using variable had a mean value of 3.611 with skewness value of 0.437 and kurtosis value of −0.382. Finally, behavioural intention had a mean value of 2.941 with skewness and kurtosis values of −0.285 and −0.048, respectively. Skewness and kurtosis values lying between −2 and +2 implies that the data for all the variables are normally distributed. Thus, further empirical analysis can be performed following a parametric way.

3.3 Reliability test

The reliability of data was determined using Cronbach's alpha for all the independent variables and the dependent variables. The Cronbach's alpha for perceived usefulness (0.843), perceived ease of use (0.716), attitude towards using (0.872) and behavioural intention (0.659) were found to be greater than 0.6, implying the measurement system to be reliable.

3.4 Correlation analysis

Table III shows the results of the correlation analysis. It can be seen that the correlation coefficients between perceived usefulness and attitude towards using (0.710), perceived ease of use and attitude towards using (0.710), attitude towards using and behavioural intention (0.733) are positive at the significance level of 99 per cent. Moreover, the absolute value range between 0.3 and 0.8 implies that correlation is practically acceptable.

3.5 Factor analysis

Confirmatory factor analysis was performed to group statements/variables into the TAM theme. Table IV summarises the output of the rotated component matrix using principal component analysis with varimax rotation. The varimax values of the surveyed items were found to be higher than 0.5. Thus, all the items were retained. Besides this, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was found out to be 0.945, and Bartlett's test of sphericity (BTS) was also found to be significant.

Looking at the mean scores, perceived usefulness was found to be the most important factor, followed by attitude towards using, while perceived ease of use and behavioural intention rank third and fourth, respectively.

3.6 Regression analysis

The regression analysis was carried to test the hypothesis of this study.

Factors	Perceived usefulness	Perceived ease of use	Attitude towards using	Behavioural intention
Perceived usefulness	1			
Perceived ease of use	0.613**	1		
Attitude towards using	0.710**	0.710**	1	
Behavioral intention	0.586**	0.677**	0.733**	1

Notes: **Correlation is significant at the 0.01 level (2-tailed); N = 663

Table III. Correlation analysis between independent variables

Factors	Statements/variables	Factor loading	Alpha	Mean	Mean rank
Perceived usefulness	Solar electricity can serve my daily needs of electricity	0.815	0.843	3.70	1
	By using solar electricity, I can lower my electricity bill	0.799			
	Solar electricity can enable me to complete my tasks with same ease as normal	0.722			
	I am confident that solar power can be source of electricity of future	0.706			
Perceived ease of use	I find solar electricity easy to use as source of electricity	0.618	0.716	3.37	3
	I find learning to use solar energy easy to use	0.653			
	It is easy for me to become skilful in using solar electricity	0.730			
	I find solar technology to be an easy and flexible technology to use	0.756			
	My house is suitable for solar installations?	0.659			
	I think there are many technical obstacles in using solar electricity?	0.807			
Attitude towards using	I find solar electricity to be a major source of electricity in future	0.630	0.872	3.61	2
	I believe it is good (or right time) to use solar electricity in my house	0.667			
	I like the idea of using clean source of electricity in my house	0.571			
	Overall I think I will enjoy solar technology as a source of electricity in my house	0.656			
Behavioural intention	I intend to use solar electricity for my house	0.640	0.659	2.94	4
	I plan to have some RE technology for my house for generation of electricity	0.583			
	I am planning to have solar electricity for my house in: 3-4 years; 2-3 years; before 1 year	0.628			

Notes: KMO = 0.948, significance of BTS = 0.000 principal component, varimax rotation

Table IV.
Varimax analysis, mean score and rank of surveyed data

3.6.1 Regression on behavioural intention to use solar PV technology. Attitude to use explains 57.3 per cent of the variance of behavioural intention. The model is robust (Sig. = 0.000). Attitude to use significantly and positively contribute to behavioural intention to use solar PV technology. Hence, *H1* is verified.

3.6.2 Regression on attitude towards using solar PV technology. Both perceived usefulness and perceived ease of use explain 62.4 per cent of the variance of attitude to use. The model is robust (Sig. = 0.000). Both perceived usefulness and perceived ease of use significantly and positively contribute to attitude towards using solar PV; the strength of perceived ease of use ($\beta = 0.603$; $p < 0.001$) is stronger than perceived usefulness ($\beta = 0.468$; $p < 0.001$).

Based on the regression results, *H2* and *H3* are accepted.

3.6.3 Regression of perceived ease of use on perceived usefulness of solar PV technology. Regression shows that perceived ease of use explains 37.6 per cent variance in the dependent variable, perceived usefulness. The regression confirms a positive relationship between the independent and dependent variables at a significance level of 0.000. The results, thus, lead to the acceptance of *H4*. The regression results corroborate with past literature by Kardooni *et al.* (2016) and Alam *et al.* (2014).

4. Discussion

The study applied widely recognised and robust framework of TAM to explain peninsular Malaysia's household intention to solar PV technology for the generation of electricity. According to the research findings, certain areas are identified as the most crucial regarding adoption of solar PV technology. These identified areas must be thoroughly considered by the policymakers for scaling up of solar PV technology. Owing to the fact that solar PV technology is relatively new in the country, and taking this survey as a test case, it can be inferred that the general public is still sceptical about using the technology. Therefore, at this stage, it is imperative to create awareness about, and familiarize general public with, the usage of solar PV technology and its benefits. A key finding of the research is that the public perception of solar PV technology plays a major role in its adoption process. Therefore, it can be concluded that it is vital for the public acceptance of solar PV that both usefulness and ease of use be highlighted. The findings further indicate that R&D firms need to develop user friendly technology, thus elevating and forming a positive attitude towards future adoption of technology. The study supports the hypothesis that attitude to use has the most significant and strong impact on behaviour intention to use PV technology. Perceived usefulness of technology and the perceived ease of use play a major role in defining the attitude for using solar PV technology. Results show a weak positive relationship between perceived ease of use and perceived usefulness.

4.1 Limitations and suggestions for future work

The study has some limitations. These limitations should be considered while interpreting its findings. The first limitation is the use of correlation data only and not the causal inferences. Second, the cost of technology was not included on assumption that a number of financial support mechanisms are in place. Third, the survey considered individuals only and not organizations dealing with the technology, especially at the supply side. Finally, the government's perspective on technology adoption was not considered. Despite these limitations, the study is one of the first attempts to apply TAM to explain intentions to use solar PV technology. Future research is going to address the aforementioned limitations.

5. Conclusion

Renewable technologies are deemed to play a major role in diversifying fuel mix for the generation of electricity. Therefore, it becomes very important to assess which technology is better- accepted in society. In this context, TAM was leveraged in this study to find the level of public acceptance for solar PV technology. It was found that the general public is more concerned with the ease of use of PV technology as compared to usefulness of the technology. Consequently, both these factors play an important role in affecting the intention to use solar PV technology. These findings augment our understanding of the impediments to developing a large capacity base for solar PV technology, in Malaysia.

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