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What Drives Residential Consumers Willingness to Use Green Technology Applications in Malaysia?*

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Abstract

The government policies and initiatives to guarantee sustainable energy and clean environmental conditions contributed to the introduction of green technology electricity appliances in the market. This study sought to determine the physiological and socio-economics-demographic factors driving residential electricity consumers to use green technology electricity appliances, mainly solar PV, smart meter, electric vehicle, and battery storage technology. By understanding consumer intention, the investors of solar PV, battery storage, electric vehicle, and smart meter can estimate the demand and upscale the market for the corresponding products. For that purpose, the intention to use the solar PV, smart meter, electric vehicle, and battery storage function is developed by utilizing the combination of the theory of planned behavior, technology acceptance, and reasoning action. A reliable and valid structured online questionnaire and stepwise multiple regression are used to identify the possible factors that drive consumer behavior intention. The results show that the social influence, knowledge on RE, and perceived price significantly influence residential consumers' willingness to adopt the technologies offered. The findings of this study suggest that the involvement of NGOs, public figures, and citizens' cooperation are all necessary to spread information about the government's objectives and support Malaysia's present energy and environmental policies.

Keywords: Intention to Use, Electric Vehicle, Smart Meter, Battery Storage, Solar PV

JEL Classification Code: DO1, D91, Q01, Q28, Q55

1. Introduction

Electricity has been one of the world's most important resources for anthropogenic and economic activities in recent years. Its function becomes rigorous, along with economic development and modernization (Othman et al., 2020). The government needs to ensure an adequate supply of electricity to the Malaysian community by discovering alternative energy and increasing energy efficiency; therefore, the sustainable energy and sustainable development goals can be met. Due to the growing level of consciousness on the above-mentioned issue, the government plays an essential role to implement several policies and initiatives, starting with the National Energy Policy in 1979 (Bekhet & Othman, 2016). Then, the government introduced the Five-Fuel Diversification Policy in 2001 and the Renewable Energy Act in 2011 to encourage the use of renewables in electricity production (Lau et al., 2020). Other government initiatives such as Feed-in-Tariff (FiT) (2011), Net Energy Metering 1.0 (NEM 1.0) (2016), and NEM 2.0 (2019) schemes are correspondingly implemented to support the sustainable energy and sustainable development target (SEDA, 2021).

These initiatives are quite challenging initially because not many Malaysians are alert to the aforementioned scheme (Lau et al., 2020; Muhammad Suki et al., 2012). As the fact on renewable energy (RE) spread, many Malaysians realized

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the advantage from FiT and NEM 1.0 and 2.0. Attributable to the overwhelming response from the PV industry and to boost solar energy usage, the government introduced the NEM 3.0 in 2021(SEDA, 2021). Moreover, through National Green Technology Policy in 2009 and National Energy Efficiency Action Plan (NEEAP) 2016–2025, the government has promoted energy efficiency to safeguard the productive use of energy and minimize waste from energy consumption through energy efficiency appliances. Yet, Malaysia Energy Information Hub (MEIH) data shows electricity consumed by Malaysians and the electricity intensity[1] still rising in the same direction for the 1980–2019 periods (Energy Commission, 2021). This indicates that achieving energy saving from energy efficiency (EE) by 8% in 2025 could be difficult.

Notably, the adoption and success of that particular technology are beyond government control. What is being offered in the market should have feedback from the consumer side. Some consumers find it difficult to adopt new technology appliances because they imply changes in their lifestyles. Adopting a new kind of technology requires knowledge, perceived benefit, perceived cost, and many uncertainties. The new technology application such as smart meters, electric vehicles, solar PV, and battery storage is considered a green product because of its function to support ecological activities, provide a smaller impact on the environment, and minimize the use of fossil fuels; not many know on this fact. Malaysian consumer acceptance and behavior intention to adopt these applications is still questionable. Without consumer willingness to use these applications, the government cannot accomplish its target policies and initiatives. Albeit many empirical studies have been undertaken on behavior intention, the study on consumer behavior intention on these technologies by residential electricity consumers is relatively scant (De Dominicis et al., 2019; Neaimeh et al., 2015; Manjunath et al., 2014; Gyamfi et al., 2013; Ozaki, 2011). Thus, this study intends to fill the gap by investigating the factor driving residential electricity consumers to adopt smart meters, electric vehicles, solar PV, and battery storage. This study is focusing on psychological, socio, economic and demographic aspects. Likewise, the psychological aspects were adapted from the Theory of Planned Behavior (TPB), the Theory of Reasoned Action (TRA), and the Technology Acceptance Model (TAM). This information is beneficial to electricity providers, enabling them to plan the supply for electricity and cater to the demand for electricity mainly from the residential consumers. Also, this information is valuable for the investors to create new business opportunities in the energy market.

The remainder of this paper is structured as follows: Section 2 presents the literature on behavior intention and research framework; Section 3 presents the methodology steps; Sections 4 and 5 illustrate the empirical results and discuss the findings, respectively. Lastly, Section 6 draws the conclusion and policy implication.

2. Previous Literature and Research Framework

A stream of existing studies has discussed household intention and behavior with a variety of perspectives. A review of the literature found some of the previous scholarly work on behavioral intention on energy-efficient (EE) usage (Apipuchayakul & Vassanadumrongdee, 2020; Ali et al., 2019; Alam et al., 2019), energy-saving behavior (Akroush et al., 2019; Tan et al., 2017), purchasing electric vehicle behavior (Tu & Yang, 2019) and public intention to use solar energy (Kim et al., 2014). Accordingly, numerous researchers applied the Theory of Planned Behavior (TPB), Theory of Reasoned Action (TRA), and Technology Acceptance Model (TAM) as a theoretical basis for their study. However, several studies attempted to improve the explanatory power of TPB, despite the general usefulness of the theory in predicting behavioral intention, by adding additional constructs within the TPB model. For example, Tan et al. (2017) extended the TPB research by adding the items in the survey that consist of moral norms, environmental concerns, and environmental knowledge to understand consumers' intention toward purchasing energy-efficient household appliances. However, the items or variables highlighted in their study are not much different from one study to another, such as attitude, subjective norms, perceived behavioral control, environmental knowledge, and the intention to use renewable energy (Table 1).

Furthermore, another study discussed developing an effective and cost-efficient intervention to promote building energy-saving options in the Singapore residential sector (Xu et al., 2021a) and further discussed household energy-saving intention (Xu et al., 2021b) using the conceptual framework of Household Energy-Saving Option (HESO). On the other hand, Nie et al. (2021) evaluated the efficiency of the Chinese current energy-efficient household appliance subsidy policy and enlightened the government's redesign of the subsidy policy to improve efficiency. Thus, Table 1 shows the constructs used in different countries, years, and contexts of the study.

However, this study aims to assess the factors that drive residential electricity consumer intention to adopt solar PV, smart meter, electric vehicle, and battery storage by considering the theory of TPB, TRA, and TAM as implemented by previous research. These theories will cover the psychological determinants of consumer intention.

Table 1: Past works of Literature and the Constructs used

Author	Constructs	Theory / Model
Nie et al. (2021)	Energy efficiency, energy-saving, subsidy policy	Combination of net present value (NPV) difference method and Conversion Method of Electrical Engineering Coefficient
Xu et al. (2021a)	Theoretical foundation (T), Integrated interventions (I), Market premises (M), energy sustainability (E), and stakeholders (S)	Conceptual Framework - Household Energy Saving Option (HESO)
Xu et al. (2021b)	Environmental attitude, personal norm, perceived behavioral control, behavioral intention, and household energy-saving behaviors, and household risk preference	Conceptual Framework - Household Energy Saving Option (HESO)
Nguyen et al. (2021a)	Corporate greenwashing behavior, Consumers'green trust, Consumers'green word-of-mouth, Consumers'green purchase intentions	Theory of reasoned action (TRA)
Nguyen et al. (2021b)	Perceived usefulness, perceived ease of use, perceived enjoyment, attitude, behavior intention, knowledge sharing factors, social influence factors	Technology Acceptance Model (TAM)
Hamundu et al. (2020)	Perceived compatibility, perceived complexity, owner-manager knowledge on accounting, organization size, competitive pressure, informal network, and government intervention.	Technological, organizational, and environmental (TOE) model
Wibowo et al. (2020)	Perceptions of maqashid sharia, perceptions of economies of scale, perceptions of market structure, perceptions of technology procurement costs, and behavioral intention	Technology Acceptance Model (TAM)
Apipuchayakul and Vassanadumrongdee (2020)	Attitude, Subjective Norms, Perceived Behavioral Control, Behavioral intention	Theory of Planned Behavior (TPB)
Akroush et al. (2019)	Energy Awareness, Perceived Benefits, Perceived Price, Consumers' Attitudes, Purchasing Intention	Theory of Planned Behavior (TPB), Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM)
Tu and Yang (2019)	Perceived Usefulness, Perceived Ease of Use, Compatibility, Personal Innovativeness, Interpersonal Influences, External Influences, Self-efficacy, Facilitating Conditions, Perceived Behavioral Control	Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), Innovation Diffusion Theory (IDT)
Ali et al. (2019)	Optimism, Innovativeness, Insecurity Discomfort, Attitude, Subjective Norms, Perceived Behavioral Control, Intention to Buy	Theory of Planned Behavior (TPB), Technology Readiness Index (TRI)
Alam et al. (2019)	Purchasing Intention of Energy-efficient Product, Attitude, Subjective Norm, Perceived Control, Knowledge, Price	Extended Theory of Planned Behavior (TPB)
Kardooni et al. (2018)	Intention to Use of Renewable Energy, Knowledge, Trust, Cost	Conceptual Framework
Wang et al. (2017)	Attitude, Subjective Norm, Perceived Behavioral Control, Residual Effect	Theory of Planned Behavior (TPB)

Table 1: Continued

Author	Constructs	Theory / Model
Tan et al. (2017)	Attitude, Subjective Norm, Perceived Behavioral Control, Moral Norms, Environmental Concern, Environmental Knowledge	Theory of Planned Behavior (TPB)
Park and Kwon (2017)	Intention to Use, Perceived Benefits, Perceived Trust, Satisfaction, System Quality, Perceived Cost, Attitude	Theory of Planned Behavior (TPB)
Kim et al. (2014)	Intention to Use, Perceived Benefits, Perceived Trust, Satisfaction, System Quality, Perceived Cost, Attitude	Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM)
Ha and Janda (2012)	Attitude, Subjective Norm, Belief about Energy Efficient Product, Knowledge about Energy Efficient Product, Environmental Awareness, Confidence of Consequence, Eagerness of Environmental Engagement	Theory of Reasoned Action (TRA)

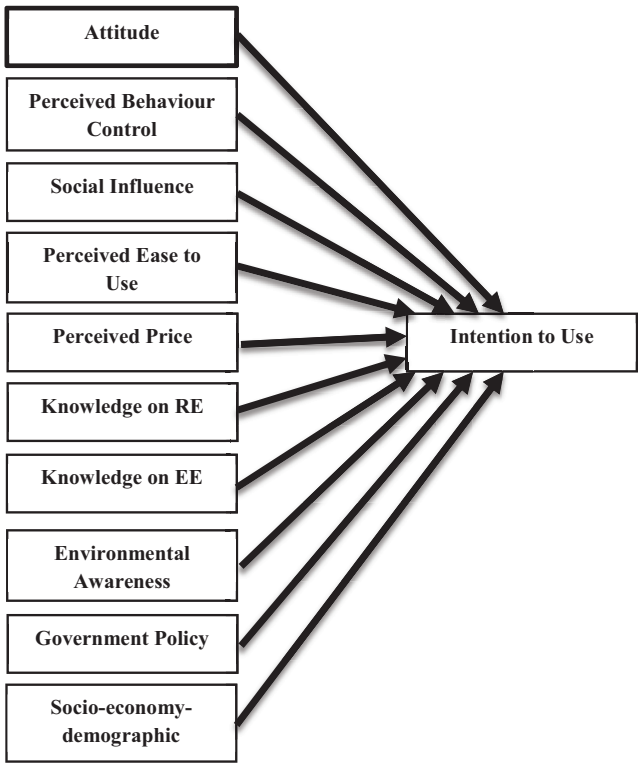

Figure 1: Proposed Research Framework

In addition, the role of social-demographic factors such as income, monthly bill, consumer age, and the number of households are highlighted to increase the credibility of this study. The research framework is presented in Figure 1. Then, Appendix 1 presents the definition of each construct employed in the current study. This study hypothesizes the significant role of psychological, socio-economic, and demographic aspects in influencing consumer behavior intention to use solar PV, smart meter, electric vehicle, and battery storage.

3. Data Sources and Methodology

A survey inquiry was constructed and developed to collect empirical data to investigate the predictors that will influence the intention to use the electric vehicle, smart meter, battery storage, and solar panel by residential households in Malaysia. This study employed quantitative data collection via a structured online questionnaire. Table 2 summarized the details of the source from where the questionnaire was adapted with minor alterations. Before the data collection, the questionnaire was reviewed and examined by an expert in the energy field and an expert in methodology (mainly the art of developing the questionnaire) to ensure the analyses quality, reliability, and validity. Later the pilot test was conducted on 104 residential consumers in Peninsular Malaysia, and it covers consumers in the East Coast, Southern Region, Northern Region, and Central Region. Due to the COVID-19 pandemic, this questionnaire is distributed online via the Google Forms mechanism, and simple random sampling is employed.

The questionnaire was structured as follows: Section A: To assess the socio-demographic aspects and the electricity consumption; Section B: To measure consumer behavior intention to use the electric vehicle, smart meter, battery storage, and solar panel. The measurement items used a 10-point Likert-type scale that array from 1 = strongly disagree to 10 = strongly agree as suggested by Hoque et al. (2017). The survey was conducted within two months, which started in January 2021 and ended in February 2021.[2] Appendix 2 contains the questionnaire.

Table 2: Instrumentation Source

Constructs	Items	Source
Intention to use electricity vehicle	3	Nguyen et al. (2021); Lau et al. (2020); Apipuchayakul and Vassanadumrongdee (2020); Kaffashi and Shamsudin (2019); Kim et al. (2014)
Intention to use smart meter	3	
Intention to use battery storage	3	
Intention to use the solar panel	3	
Attitude	7	Apipuchayakul and Vassanadumrongdee (2020); Kaffashi and Shamsudin (2019)
Perceived Usefulness	6	Nguyen et al. (2021b); Tu and Yang (2019)
Perceived ease of use	6	Nguyen et al. (2021b); Tu and Yang (2019)
Government Policy	4	Kaffashi and Shamsudin (2019); Wang et al. (2017)
Perceived Price	4	Lau et al. (2020)
Environmental Awareness	8	Sang et al. (2019); Wang et al. (2017)
Knowledge of energy efficiency	6	Lau et al. (2020); Alam et al. (2019)
Knowledge of renewable energy	6	
Perceived behavior Control	10	Apipuchayakul and Vassanadumrongdee (2020); Alam et al. (2019); Kaffashi and Shamsudin (2019)
Subjective Norms/Social influence	6	Lau et al. (2020); Apipuchayakul and Vassanadumrongdee (2020); Kaffashi and Shamsudin (2019); Ha and Janda (2012)

The collected data was analyzed using IBM SPSS Statistics. The descriptive statistic is employed to describe the demographic attributes of the respondents. Then, the multiple regressions via stepwise technique are applied to examine the hypotheses and evaluate the factor influencing the intention to use the electric vehicle, smart meter, battery storage, and solar panel.

4. Results

The total number of respondents in this survey is 1064, and their demographic characteristics are presented in Table 3. In terms of gender perspective, the majority were females, which consists of 59.1%, while males made up the remaining 40.9% of the total respondents. Most of the participants were within the age group of 20–30 (34.7%), followed by the age group of 31–40 (30.9%). The majority of the respondents were well-educated, 75.9% of them being university graduates and postgraduates. Regarding marital status, 62.3% of the respondents were married, and 36.7% were identified as single. As for occupation, 38.3% of the respondents worked in government sectors, followed by 34.9% in the private sector. In terms of monthly income, 42.7% of the respondents were categorized as the B40 group, 38.5% were the M40 group, and the remainder were from the T20 group.

Reliability was evaluated by measuring the Cronbach's α coefficient to check the internal consistency among the items. In this study, the Cronbach's α value for the overall scale of each predictor was within 0.854–0.951, advocating good consistency among the items for each variable (Table 4).

Table 5 shows the results of the multiple regression analysis for electric vehicles, smart meters, battery storage, and solar PV. Based on Table 5, the *F*-value ranged from 50.00–61.00, with a significance value of less than 5%. Based on these results, it can also be interpreted that all the suggested variables/constructs in Table 5 simultaneously and significantly affect the intention of residential electricity consumers to use an electric vehicle, smart meter, battery storage, and solar panel.

Furthermore, the results revealed that all the suggested factors in the battery storage model significantly explain 23% of the variance in consumer intention to use battery storage. All the suggested factors in the smart meter model significantly explain 23% of the variance in consumer intention to use a smart meter. While electric vehicle and solar panel models show all the listed factors in the respective column significantly change 22% and 28% of consumers' intention to use the electric vehicle and solar panel, respectively.

Thoroughly, perceived behavior control, perceived price, environmental awareness, good knowledge on RE, and social influence positively affected the consumer intention to use battery storage. Conversely, the consumer age was found to negatively influence the consumer intention to use the battery storage. However, the perceived price, good knowledge on RE, social influence, perceived ease to use,

Table 3: Demographic Attributes of the Respondents

Respondents' Profile		Frequency	Percentage (%)
Gender	Male	435	40.9
	Female	627	59.1
Age Group	20–30	369	34.7
	31–40	329	30.9
	41–50	252	23.7
	51–60	99	9.3
	>60	15	1.4
Education	SPM	84	7.9
	Diploma	173	16.3
	Bachelor Degree	428	40.2
	Master / PhD	207	19.5
	PhD	156	14.7
	Others	16	1.5
Marital Status	Single	391	36.7
	Married	663	62.3
	Others	10	9.0
Occupation	Private	371	34.9
	Government	408	38.3
	Self-Employed	67	6.3
	Student	66	6.2
	Others	152	14.3
Monthly Income	<RM2499	233	21.9
	RM2500 – RM4849	221	20.8
	RM4850 – RM7099	221	20.8
	RM7100 – RM10959	188	17.7
	RM10960 – RM15039	127	11.9
	>RM15039	74	7.0

perceived usefulness, and government policy were identified to positively influence the consumer intention to use the smart meter.

For the case of the electric vehicle, the perceived behavior control, environmental awareness, good knowledge on RE, and social influences positively impact consumer behavior intention. Whereas consumer income has negatively

Table 4: Reliability Analysis

Constructs	Cronbach *α*
Intention to use electricity vehicle (ITU-EV)	0.912
Intention to use the smart meter (ITU-SM)	0.965
Intention to use battery storage (ITU-BS)	0.943
Intention to use solar panel (ITU-S)	0.908
Attitude (AT)	0.938
Perceived Usefulness (PU)	0.894
Perceived ease of use (PEU)	0.951
Government Policy (GP)	0.796
Perceived Price (PP)	0.887
Environmental Awareness (EA)	0.854
Knowledge of EE (KEE)	0.894
Knowledge of RE (KRE)	0.944
Perceived behavior Control (PBC)	0.935
Subjective Norms (SN)/Social influence	0.877

influenced consumer intention to use an electric vehicle. Also, perceived price, environmental awareness, good knowledge on RE, social influence, perceived usefulness, attitude, and monthly bill were identified to positively influence the consumer intention to use the solar panel. Only the income was found to negatively impact the consumer intention to use the solar panel. The findings from this study were found to support the previous literature. Despite the fact that not all previous studies were conducted on the same research topic, empirical analysis has revealed that these predictors are applicable and significant in this study.

5. Discussion

The results obtained from the previous section indicate that social influence and knowledge on RE can increase the consumer behavior intention to use the battery storage, smart meter, electric vehicle, and solar PV. This implies that information from friends, family members, mass media, and internet information is able to increase consumer willingness to use battery storage, smart meters, electric vehicles, and solar PV. This result in-lined with Alam et al. (2019) and Ha and Janda (2012), who found a positive relationship between social influence and consumer intention for the case of energy-efficient household appliances. With this kind of finding, Kaffashi and Shamsudin (2019) suggested the involvement of NGOs and citizens' cooperation to spread the information on the government agenda. Also, the role of social media, socially recognized people (such as celebrities), and cross-ministry cooperation is significant to create the consumer positive behavior towards the function of battery

Table 5: Measurement Models

Measurement Models/ intention to use	Constructs/Variables	Standardized Coefficient	*t*-value	VIF
Model 1: Battery Storage	Constant	–	3.840	–
	PBC	0.107***	2.377	2.753
	PP	0.195***	5.969	1.458
	Age	–0.131***	–4.790	1.019
	EA	0.085***	2.447	1.658
	KRE	0.090***	2.667	1.569
	SN	0.101***	2.410	2.381
	Adj R^2 = 23%, F = 52.073 (0.00), DW = 1.956			
Model 2: Smart Meter	Constant	–	–0.001	–
	SN	0.120***	3.328	1.785
	PEU	0.098***	2.376	2.313
	PP	0.162***	4.887	1.517
	KRE	0.094***	2.898	1.441
	GP	0.093***	2.702	1.632
	PU	0.078**	2.030	2.030
	Adj R^2 = 23%, F = 52.523 (0.00), DW = 1.989			
Model 3: Electricity Vehicle	Constant	–	0.480	–
	PBC	0.146***	3.266	2.705
	KRE	0.199***	5.875	1.558
	SN	0.120***	2.909	2.302
	Income	–0.096***	–3.472	1.028
	EA	0.101***	2.891	1.652
	Adj R^2 = 22%, F = 59.955 (0.00), DW = 1.857			
Model 4: Solar PV	Constant	–	–	–
	EA	0.172***	0.172	1.908
	KRE	0.212***	0.212	1.397
	SN	0.127***	0.127	1.985
	Income	–0.117***	–0.117	1.194
	AT	0.105***	0.105	1.906
	Monthly Bill	0.077***	0.077	1.169
	PP	0.065**	0.065	1.426
	Adj R^2 = 28%, F = 60.760 (0.00), DW = 1.911			

Note: *p-value < 0.1; **p-value < 0.05; ***p-value < 0.001. Dependent variable = intention to use.

storage, smart meter, electric vehicle, and solar PV. Likewise, the information shared through social media, schools, and universities curriculum is able to enrich the knowledge on RE, including RE's roles, benefits, and potential, and all this effort potentially creates a positive behavior towards battery storage, smart meter, electric vehicle, and solar PV. This argument is supported by Alam et al. (2019), who revealed a significant positive relationship between knowledge and behavior intention to purchase energy-efficient products.

Second, the results show the positive impact of perceived price on consumer behavior intention to use battery storage, smart meter, and solar PV is consistent

with Alam et al. (2019). They discovered a significant positive effect of price on energy-efficient household products. Typically, the consumer becomes sensitive when dealing with a price; when the price increases, the quantity demanded will decrease vice versa. The same goes for Malaysian consumers; the study by Tan et al. (2017) showed the Malaysian consumers were more likely to buy inefficient products (rather than efficient one) because they are relatively cheaper. In this case, the best strategy to create behavior intention on battery storage, smart meter, and solar PV is by providing rebates, subsidies, or tax exemption for those who spend on battery storage, smart meter, and solar PV. Unfortunately, for the case of the electric vehicle, consumer perception of price was found not significant to influence their behavioral intention. But their intention to use is driven by income level, where those with middle income and below are much more interested in electric vehicles than those with high-income level.

Third, this study revealed the significant role of environmental awareness in determining the consumer behavior intention to use battery storage, electric vehicle, and solar PV. This finding is contrary to Tan et al. (2017) and Ramayah et al. (2010). This study indicated that environmental awareness is necessarily a precondition for the occurrence of behavior intention to buy the abovementioned tools. Without environmental awareness, the willingness to consume the product could be less. Again, the government's role, through relevant ministries, non-governmental organizations, and policymakers, is required to disseminate information about the current state of the environment and the consequences for the rest of the world if ignored.

Fourth, aligned with the previous study by Alam et al. (2019) and Ali et al. (2019), this study found the consumer perceived behavior control has significantly influenced their behavior intention to use battery storage and electric vehicles, but insignificantly influenced behavior intention to use the smart meter and solar PV. With available resources (i.e., time, money, support, etc.) in hand, this indicates consumers' confidence to use battery storage and electric vehicles. Continuous support by the government is required to maintain public confidence in battery storage and electric vehicles. However, government and electricity providers should hand in hand rebuild consumer confidence in smart meters and solar PV by highlighting the function and benefits consumers could gain through the use of the smart meter and solar PV.

Fifth, instead of knowledge on RE, social influence, and perceived price, the consumer behavior intention to use the smart meter depends on their perceived ease of use, perceived usefulness, and government policy. The perceived usefulness via consumer anticipation on the positive outcome that they obtain from the smart meter usage is consistent with Akroush et al. (2019). In other words, the residential consumer in Malaysia believes the smart meter can be used to solve their current problem related to electricity consumption.

Another interesting finding of the study is the significant interaction between socio-demographic characteristics with the consumer behavior intention. First, the consumer behavior intention to use solar PV is predetermined by their monthly bill and income level. The higher the monthly bill, the higher the encouragement to employ solar PV. However, the lower and middle-income levels are significantly interested in solar PV as compared to high-income levels. Surprisingly, the lower-income group is more likely than the higher-income group to use electric vehicles. And the consumer of younger age has more intention to use battery storage rather than an older consumer.

6. Conclusion and Policy Implications

This study aims to identify the factors affecting intention to use battery storage, smart meter, electric vehicle, and solar PV, specific to residential electricity consumer point of view. Instead, this study considered the role of physiological, socioeconomic, and demographic characteristics to discover more potential determinants of behavioral intentions on battery storage, smart meters, electric vehicles, and solar PV. It is expressed in four different models. The combination of stepwise multiple regression, theory of planned behavior, theory of technology acceptance, and theory of reasoning action is used to complete the research goals. In addition, the stepwise multiple regression analyses revealed the following: First, the intention to use battery storage is significantly determined by social influences, knowledge in RE, environmental awareness, perceived price, level of confidence on battery storage, and consumer age. The younger customer tends to have a better intention to use battery storage compared to the older age. Second, the intention to use smart meters is significantly determined by social influence, environmental awareness, perceived price, perceived ease of use, perceived benefit or usefulness, and government policy. The socio-economic-demographic characteristics insignificantly influence the residential consumer to use the smart meter. Third, the intention to use an electric vehicle is significantly determined by social influences, knowledge in RE, environmental awareness, the confidence level in electric vehicles, and consumer income. However, the middle to lower-income had shown more intention to use the electric vehicle as compared to the high-income group. Fourth, the intention to use solar PV is significantly determined by social influence, knowledge in RE, environmental awareness, perceived price, consumer positive attitude towards new technology, monthly bill, and consumer income. Accordingly, consumers with high

monthly bills show more interest in installing solar PV than those with lower monthly electricity bills.

Concerning social and practical implications, this study provides relevant information for governmental institutions and other organizations interested in the distribution of battery storage, smart meters, electric vehicles, and solar PV. Gaining insights into what motivates people to invest in the above-mentioned technologies may help design policy instruments and marketing/financial programs to increase the number of users and market share of battery storage, smart meters, electric vehicles, and solar PV.

As the study points out, social influence significantly influences the residential electricity consumers' intention to adopt battery storage, smart meters, electric vehicles, and solar PV; the involvement of NGOs, public figures, and citizens' cooperation to spread the information on the government agenda is highly recommended. Also, the role of social media such as Facebook, Instagram, Twitter, Tick-Tok, Youtube, along with traditional social media (television, newspaper, bulletin, magazine, etc.), must be considered by policymakers to highlight the importance of energy and environmental sustainability to the Malaysian society. With an appropriate content, strategy, and communication channel, the consumer's positive behavior towards battery storage, smart meter, electric vehicle, and solar PV can be shaped.

Furthermore, the policymakers (Ministry of Education, Ministry of Energy and Natural Resources, Ministry of Environment and Water, Sustainable Energy Development Authority, Energy Commission) should work hand in hand to educate Malaysian society through environmental campaigns or the tools of informal education (e.g., brochures, exhibitions, or seminars) to create environmental awareness and RE knowledge among Malaysian society. To the best of the author's knowledge, the Energy University (UNITEN) aggressively educates people on energy and environmental-related matters by offering Energy Management and Sustainability as part of the program syllabus and offering Bachelor's Degree in Energy Economics and a Master in Energy Management. This type of effort is in line with Malaysia's Sustainable Energy and Development agenda.

Malaysia residential electricity consumers perceived the price of battery storage and solar PV as one of the factors of their behavioral intention. Consistent with Tan et al. (2017), who revealed Malaysian residential electricity consumers preferred to use an inefficient product rather than an efficient product to avoid paying more (because it can increase the cost of living). In a similar vein, the monthly electricity bill is also one of the reasons consumers tend to adopt solar PV. Concerning that, policymakers (through Sustainable Energy Development Authority) had introduced Feed-in-Tariff (FiT) in 2011, Net Energy Metering 1.0 (NEM 1.0) in 2016, and NEM 2.0 in 2019 schemes, and recently, NEM Rakyat 3.0 to encourage Malaysia's Renewable Energy (RE) uptake among residential consumers. Residential electricity consumers will favor the above-mentioned scheme through its ability to save consumer electricity bills. This condition is in line with the consumer motive to adopt solar PV. Also, this initiative could help Malaysia to reduce GHG emissions by 45 percent by 2030 to its 2005 GDP (Bekhet and Othman, 2018).

Furthermore, a study by Zekeri et al. (2021) showed that the pairing of solar PV and battery storage will benefit the residential consumer in the future. So far, the global residential solar PV has grown significantly, with an annual average growth rate of about 50% between 2010 and 2020 (Zekeri et al., 2021). The successful story of solar PV will be followed by market penetration of battery storage in the future with an appropriate pricing and promotion strategy. Moreover, the policymaker should also provide policies to encourage residential electricity consumers through subsidies such as price advantage, extending guarantee on battery life, etc. This initiative will significantly decrease the burden of adopting battery storage and solar PV.

While the current research has shed some light on several significant issues, some limitations reveal opportunities for future studies. First, the current study did not classify customer groups by consumer settlement area and job attachment (energy vs non-energy industry), while previous studies showed that consumer behaviors tend to differ based on some characteristics of the customer. Second, the comparison between consumer intention and actual usage is also beyond current research coverage. Thus, for future extension, a study can consider the above-mentioned issues and advance methodologies such as Structural Equation Modeling (SEM) or Artificial Neural Network (ANN) to produce more comprehensive policy implications.

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Endnotes

[1]Electricity intensity is the amount of electricity consumed divided with GDP. The higher the electricity intensity, the lower the level of efficiency.

[2]Prior to the field study, the pilot test was conducted in December 2020 with 104 samples.

Appendix 1:

The constructs employed in this study and its definition:

a) Intention to use (ITU)
The intention to use (ITU) refers to the extent to which consumers think they are willing to purchase or use such products. The TPB proposed by Ajzen stated that the behavior of individuals is determined by their 'behavioral intention'. Therefore, this study utilized TPB to determine residential consumer behavior toward solar PV, smart meter, electric vehicle, and battery storage.

b) Attitude (A)
Attitude refers to consumer psychological evaluation of a certain product. According to Apipuchayakul and Vassanadumrongdee (2020), attitude is a determinant of purchase intention. The consumer with positive attitudes towards solar PV, smart meters, electric vehicles, and battery storage tends to have an intention to purchase it as well.

c) Perceived behavior control (PBC)
According to Ali et al. (2019) and Tu and Yang (2019), the perceived behavior control (PBC) is an individuals' degree of control over the execution of certain behavior. Tan et al. (2017) defined the PBC refers to people's perceptions of their ability to perform a given behavior. This study concluded the PBC as a consumer's confidence to perform a given behavior with available resources (i.e., time, money, support, etc.) in hand.

d) Subjective Norms (SN)
The Subjective norms (SN) refer to consumers' perceived peer pressure, which dictates that they behave in a certain way to meet social expectations (Apipuchayakul & Vassanadumrongdee, 2020). Ali et al. (2019) stated the SN as the influential degree of peers' opinion and perceptions while performing a specific behavior. Based on previous literature, this study defines the SN as a consumer performance resulting from peers' opinions (friends, family, mass media, and internet information) about solar PV, smart meter, electric vehicle, and battery storage.

e) Government policy (GP)
The government policy (GP), in this case, refers to any related energy and environmental policies that are used to sway purchase, retail stocking, and production decisions towards solar PV, smart meter, electric vehicle, and battery storage. The study by Wang et al. (2017) had classified government policy as one of the subjective

norm indicators. In the current paper, the GP purposely measures the influence of government policies and initiatives towards SN and consumer behavior.

f) Perceived ease to use (PEU)
The perceived ease to use (PEU) refers to consumers' ability to learn the operation of solar PV, smart meter, electric vehicle, and battery storage and use them without much effort.

g) Perceived usefulness (PU)
The perceived usefulness (PU) refers to consumers' perception of the efficiency of solar PV, smart meter, electric vehicle, and battery storage functions.

h) Perceived price (PP)
Many researchers have examined the effect of the perceived price (PP) on consumer attitude and intention to buy, and the results were found to contradict one another. The PP, in this case, is referring to consumers' perception of the price of solar PV, smart meter, electric vehicle, and battery storage — either affordable or unaffordable.

i) Knowledge on EE (KEE) and Knowledge on RE (KRE)
The knowledge is used to understand its influence on ITU and explain the gap between the consumers' attitudes and orientation towards energy conservation and their actual behavior (Akroush et al., 2019). This study anticipates the better the knowledge on EE and RE, the higher ITU on solar PV, smart meter, electric vehicle, and battery storage.

j) Environmental awareness (EA):
Similar to KEE and KRE, environmental awareness (EA) is used to understand its influence on behavioral variables and explain the gap between the consumers' attitudes and orientation towards energy conservation and their actual behavior (Akroush et al., 2019; Kaffashi & Shamsudin, 2019). This study anticipates that the higher the degree of consciousness on environmental issues, the higher the ITU on solar PV, smart meters, electric vehicles, and battery storage.

Appendix 2:

Sample of the questionnaire:

Section A: Socio-demographic

This section intends to identify the demographic profile of each respondent. Please answer/tick the boxes that are related.

1.	Gender	
	Male	Female
2.	Age	
	20–30	31–40
	41–50	51–60
	> 60	
3.	Marital status	
	Single	Married
	Others:	
4.	Race	
	Malay	Chinese
	Indian	Others (please specify):
5.	Education level	
	SPM	Diploma
	Bachelor	Masters
	PhD	Others (please specify):
6.	Occupation sector	
	Government	Private
	Retired	Self-employed
	Others (please specify):	
7.	Income group	
	< RM2,499	RM2,500–RM4,849
	RM4,850–RM7,099	RM7,100–RM10,959
	RM10,960–RM15,039	> RM15,039
8.	Number of households	
	1–2	3–4
	5–6	7 and above
9.	Monthly electricity bill	
	< RM43.60	RM43.60–RM77.50
	RM77.60–RM180	RM181–RM286
	RM287–RM396	RM397–RM1,024
	>RM1,024	
10.	Monthly electricity consumption (kWh)	
	<200	201–300
	301–500	501–700
	701–900	> 900

Section B

This section intends to understand consumer perception of new technology appliances. The example of new technology appliances such as an electric vehicle, battery storage, solar photovoltaic, prepaid/smart meter or any electrical appliances that have energy-efficient functions.

Construct	Items
Perceived usefulness	I am able to complete my task quickly by using the new technology.
	I can reduce my electricity bill by using the new technology.
	I am able to increase productivity in my task by using the new technology.
	I am able to increase the effectiveness of my task by using the new technology.
	I am able to perform my task by using the new technology.
	I would find the new technology useful in my daily activity.

This part intends to understand the degree of consumer belief that using new technology will take less human effort/energy.

Construct	Items
Perceived ease of use	I think it would be easy for me to learn the new technology.
	I would find it is easy to get the new technology to do what I want.
	I think the function of new technology is clear and understandable.
	I would find the new technology to be flexible to interact with.
	It would be easy for me to become an expert at using the new technology.
	I would find the new technology easy to use.

This part intends to understand consumer attitudes towards new technology appliances.

Construct	Items
Attitude	I find that buying new technology appliances is a good idea.
	I believe it is a wonderful idea to employ new technology appliances.
	I would have positive feelings towards new technology appliances in general.
	I believe it is better for me to employ new technology appliances compared to conventional technologies.
	It is important to me whether the product is energy-saving or not.
	I have a positive attitude about buying new technology appliances.
	Energy efficiency is important to me when making purchases.

This part intends to understand how policy could affect the consumer intention to use new technology.

Construct	Items
Government policy	I have heard of relevant government incentive programs in the process of purchasing household appliances before.
	Domestic advertising and media encourage people to buy energy-efficient appliances.
	The energy-efficient label encourages people to buy new technology appliances.
	Government incentives will affect my decision in being a more careful person in using new technology appliances.

This part intends to understand the consumer intention of using new technology such as electric vehicles, solar photovoltaic systems, prepaid/smart meters & battery storage.

Construct	Items
Intention to use	I would rather use an electric vehicle than a conventional vehicle.
	I intend to use an electric vehicle as soon as possible.
	I will use an electric vehicle in the future.
	I would rather use a solar photovoltaic system rather than purchase from the existing electricity provider.
	I intend to use a solar photovoltaic system as soon as possible.
	I will use a solar photovoltaic system in the future.
	I would rather use a prepaid/smart meter than conventional meters.

	I intend to use a prepaid/smart meter.
	I will use a prepaid/smart meter in the near future.
	I would rather use battery storage instead of selling the electricity surplus to the electricity provider.
	I intend to use battery storage in a large capacity.
	I will use battery storage in the near future.

This part intends to understand the perception of consumers towards new technology appliances prices.

Construct	Items
Perceived price	I think that the price of new technology appliances is reasonable.
	I think that the price of new technology appliances is not higher than that of the conventional one.
	I think that the price of new technology appliances is not higher than my expectation.
	I think that the price of new technology appliances is affordable.

This part intends to understand consumer perception towards environmental awareness

Construct	Items
Environmental awareness	I am worried about the environmental conditions for future generations.
	I think that if people continue the current lifestyle, environmental disasters will be unavoidable.
	The reports on environmental issues on TV, newspaper, or the Internet often make me uncomfortable and irritated.
	I think that the government's investment in environmental protection is sufficient.
	I think that people are not fully aware of the seriousness of environmental and energy issues.
	I think everyone should contribute to environmental protection.
	Helping relieve global warming by using new technology appliances means an intrinsic reward for me.
	Environmental protection is important to me when I purchase new technology appliances.

This part intends to identify consumer knowledge about energy efficiency and renewable energy.

Construct	Items
Knowledge of energy efficiency	I have sufficient knowledge of energy-efficient appliances.
	I have knowledge of energy-efficient appliances based on previous experience.
	I have a positive impression of energy-efficient appliances.
	I know what energy efficiency is.
	I know the difference between energy efficiency and energy saving.
	I know that energy efficiency is beneficial to humankind.
Knowledge of renewable energy	I have sufficient knowledge of renewable energy.
	I have knowledge about renewable energy based on previous experience.
	I have a positive impression of renewable energy.
	I know what renewable energy is.
	I know the difference between renewable energy and non-renewable energy.
	I am aware that renewable energy resources are beneficial to humankind.

This part intends to understand the degree of consumer belief of their capabilities to use/buy new technology.

Construct	Items
Perceived behavior control	I will buy new technology appliances, even my friends advise me not to.
	I am confident that I would use new technology appliances even if another person advises me not to.
	I can control my decision to buy new technology appliances.

	I have resources and the ability to buy new technology appliances.
	I am confident that I can afford to buy new technology appliances in the future.
	I think I will buy new technology appliances because it is readily available in my town.
	I think the decision to buy new technology appliances helps society and the environment.
	I am confident that I would use new technology appliances even it is slightly more expensive.
	I am sure that I can make a difference by using new technology appliances.
	I am confident that in the future, I would use new technology appliances.

This part intends to understand the degree of consumer belief that an important person or group of people will approve and support towards use/buy of new technology.

Construct	**Items**
Subjective norms	People who influence my behavior would think that I should buy new technology appliances.
	Advice from others influences my decision to use new technology appliances.
	Everyone is responsible for contributing to environmental protection by purchasing new technology appliances.
	I feel morally obligated to refrain from buying conventional cost-saving appliances.
	I get a bad conscience if I choose conventional instead of new technology appliances.
	Most people who are important to me would want me to purchase new technology appliances.