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THE INTENTION OF USING BATTERY ENERGY STORAGE SYSTEM IN MALAYSIA – DEMOGRAPHIC ANALYSIS

Bakhtiar Alrazi (a)*, Amar Hisham Jaaffar (b), Vigna K. Ramachandaramurty (c),
Nofri Yenita Dahlan (d)
*Corresponding author

(a) College of Business Management and Accounting, Universiti Tenaga Nasional, Sultan Haji Ahmad Shah Campus, Muadzam Shah, Pahang, Malaysia, Bakhtiar@uniten.edu.my
(b) Institute of Energy Policy and Research (IEPRe), Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, Kajang, Selangor, Malaysia, AHisham@uniten.edu.my
(c) Institute of Power Engineering, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, Kajang, Selangor, Malaysia, Vigna@uniten.edu.my
(d) UiTM Solar Energy Research Centre, Universiti Teknologi MARA (UiTM) Shah Alam, Selangor, Malaysia, nofriyenita012@uitm.edu.my

Abstract

Climate change is a global phenomenon and will remain as one of the most severe risks facing the world population in the next decade. The 2030 Agenda for Sustainable Development was introduced by the United Nations on 25 September 2015, and it includes goals and targets aiming at reducing annual greenhouse gas emissions, increasing the proportion of renewable energy, and improving energy efficiency in combating climate change. The growing share of global renewable energy brings about a concomitant increase in the trend of energy storage system (ESS). ESS offers various benefits including, but not limited to, cost savings, environmental protection, and improvement in grid resilience and reliability. Malaysia is committed to climate change initiatives and had recently targeted to increase its renewable energy share to 31 percent and introduce 500 MW-capacity battery energy storage system (BESS) from year 2030 onwards. The extant literature emphasises the need to understand the population's demographic profiles as a factor of public acceptance towards a particular technology. This research aims to identify demographic factors influencing the intention to use BESS in Malaysia. Based on a survey of 384 respondents, we found the influence of ethnicity, level of education, monthly income, household size, geographical location, and property type. The findings improve the extant literature on public acceptance towards ESS and offer necessary input for relevant authorities towards greater acceptance of national sustainability agenda.

Keywords: Energy storage, intention to use, demographic profiles, Malaysia

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1. Introduction

On 11 January 2022, the World Economic Forum (WEF) has released its annual Global Risks Report containing the results of 2021-2022 Global Risks Perception Survey. The survey, which had collected views from 1,183 respondents representing various multistakeholder institutions, named climate change failure and extreme weather as the top two most severe risks over the next decade (WEF, 2022). The Intergovernmental Panel on Climate Change (IPCC) in its 2007 report cited the emissions of greenhouse gas (GHG) as the main cause of climate change (IPCC, 2007). Since many years ago, there have been various initiatives to combat climate change, including the United Nations (UN) Framework Convention on Climate Change in year 1992 and the Kyoto Protocol five years later. On 25 September 2015, 193 UN members gathered at the UN Sustainable Development Summit in New York and adopted the 2030 Agenda for Sustainable Development with its 17 goals – famously known as Sustainable Development Goals (SDGs) (United Nations, 2022a).

Of these 17 SDGs, two contain specific targets related to energy and emissions, namely SDG 7 "Affordable and Clean Energy" and SDG 13 "Climate Action". Target 7.2 sets a goal to increase the share of renewable energy (RE) in the total energy consumption by year 2030. In year 2019, the proportion had increased by 1.6 percent from the 2010 level to 17.7 percent (United Nations, 2022b). Furthermore, Target 7.3 aims to improve global energy efficiency rate by double for the same period (i.e., year 2030). Despite a promising trend with 4.7 megajoules (MJ) per US dollar (USD) in year 2019 (from 5.6 MJ/USD in year 2010), more intensive efforts are needed to achieve the targeted level (United Nations, 2022b). Finally, Target 13.2 calls for the integration of climate change measures into countries' policies, strategies and planning including total annual GHG emissions. However, in year 2019, the global GHG emissions (excluding from the land use) increased by 57 percent and 23 percent from the year 1990 (i.e., the base year) and year 2005, respectively (Olivier, 2022).

Due to its intermittent nature, renewable energy requires energy storage system (ESS) for support services and saving excess energy to be used later (Sani et al., 2020). The ESS comes in various technologies, including pumped hydro storage, flywheels, compressed air, super-capacitor, and lithium-ion batteries, to name but a few (; Jones et al., 2018; Gaede et al., 2020; Sani et al., 2020). According to the International Energy Agency (IEA), battery energy storage system's (BESS) installed capacity was at 17 gigawatts (GW) at the end of year 2020 and remains the dominant technology due to increasing deployment of electric vehicle (EV) (IEA, 2022). The annual energy storage additions had increased from a mere 0.7 GW in year 2015 to 5.2 GW in year 2020. Of this amount, China contributed about 31 percent of total additions in year 2020, followed by the US with 29 percent, while Europe and South Korea represented about 13 and 15 percent, respectively (IEA, 2022). The benefits offered by ESS include cost savings for both grid operators and consumers, environmental protection, supporting renewable energy sources, improvement in grid resilience and reliability, and promoting transport storage (Sani et al., 2020).

Malaysia is committed towards sustainable development agenda, particularly on matters related to climate change mitigation and adaptation. In year 2020, RE represented 23 percent of the national installed capacity mix (Sustainable Energy Development Authority (SEDA), 2022). On 21 June 2021, the Ministry of Energy and Natural Resources (or Kementerian Tenaga dan Sumber Asli, KeTSA) announced the country's aim to increase the RE share to 31 percent in year 2025 and subsequently to 40 percent in year

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2035 (KeTSA, 2021). Additionally, to support solar as the RE technology with the highest potential in Malaysia, the Ministry expected the introduction of 500 megawatt-capacity utility scale BESS during the 2030-2034 period (KeTSA, 2021). As the concept/technology of BESS is new in Malaysia, there is a need to gauge the public opinion and factors contributing to their acceptance prior to its implementation in order to avoid potential resistant delay or, even worse, cancellation of the project (Ambrosio-Albala et al., 2020; Emmerich et al., 2020; Huijts et al., 2012; Thomas et al., 2019). One of the factors found to be significant in the extant literature on energy consumption and renewable energy technologies adoption is the population's demographic profiles (Hayn et al., 2014; Nelson et al., 2021). However, prior literature examining public perceptions of ESS did not discuss the role of variations in respondents' demographic profile greatly.

Therefore, the aim of this research is to investigate the demographic variables influencing the intention of Malaysians to use BESS. This research is significant due to its focus on an area which has not much been investigated in the past and is related to climate change which becomes a major social concern at present. The analysis also provides timely and necessary input to relevant authorities in designing suitable mechanisms to enhance public awareness and knowledge of ESS to increase its acceptance and usage in the future.

The remaining sections of the paper are being structured as follows. Section 2 reviews related literature. Section 3 discusses the research methods. Section 4 presents the findings. Section 5 concludes the paper.

2. Literature Review

The basic concept of ESS is to store energy produced which will be used later (Sani et al., 2020; Aneke & Wang, 2016). The growing interest towards ESS stems from the need to increase the share of renewable energy in the total energy consumption and to address the climate change issue. This is due to the intermittent nature of the electricity generated from renewable energy (Sani et al., 2020) which could lead to loss of revenues, dissatisfaction among consumers resulting from disrupted services and delay in achieving the climate change target (Devine-Wright et al., 2017). In this regard, ESS contributes to operational cost savings for both grid operators and consumers, positive environmental impacts, enhancing renewable energy sources, improvement in grid resilience and reliability, and the promotion of transport storage (Aneke & Wang, 2016; Argyrou et al., 2018; Sani et al., 2020). Large-scale ESS refers to the method of storing large amounts of energy in the order of 10's to 100's of megawatt-hour (MWh) from a grid level perspective (Hameer & van Niekerk, 2015). By contrast, small-scale ESS is limited to rural and residential settlements ranging from 50 watt-hour to 20 kilowatt-hours (kWh) (Hameer & van Niekerk, 2015). At the household level, EES can also be installed at home and/or vehicles (Devine-Wright et al., 2017). ESS is available in many forms which can be grouped into mechanical, chemical, electrochemical, electrical, and thermal (Dehghani-Sanij et al., 2019). The comparison of each type of technology has been well discussed in the literature (see, for example, Aneke & Wang, 2016; Argyrou et al., 2018; Faisal et al., 2018; Luo et al., 2015) Of these technologies, battery (BESS) is the most dominant (IEA, 2022) due to its efficiency, convenience, reliability, and ease of use (Dehghani-Sanij et al., 2019).

There have been limited literature examining the public acceptance towards ESS (Devine-Wright et al., 2017), with most of them using European settings, particularly the UK. Thomas et al. (2019) conducted

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a series of workshop to understand the social acceptability of ESS in the UK. They found a low level of awareness, and salience attached, towards ESS while perceived risks and benefits were the most important factor influencing their acceptance. Moreover, fairness, independence, and control as well as convenience were the three evaluative criteria for economic and governance aspects of ESS. The finding on low level of awareness among the UK public is also noticed by Ambrosio-Albala et al. (2020, 2019). Based on focus group discussions with residents in Leeds, Ambrosio-Albala et al. (2019) found that public acceptance was a function of cost-effectiveness, Government's subsidy, perceived benefits, ability to perform daily routines without interruption, trust in local authority, appearance and aesthetics, property ownership, and type of battery. Using questionnaire survey among a broader UK sample, Ambrosio-Albala et al. (2020) observed the importance of perceived benefits and public funding to support the installation of BESS. They also found the influence of demographic profiles, namely age, gender, and educational background on the acceptance level. Jones et al. (2018) found a preference for pumped hydro storage among the UK residents. Moreover, intention to support ESS was influenced by several psychological factors, namely positive affect, attitude, awareness, perceived benefits, belief on the justification of investment, trust in developers, environmental values, and perceived problems.

Emmerich et al. (2020) examined public acceptance of energy technologies in Germany, including BESS. Perceived effects had a direct effect, while trust in industry and municipality as well as perceived problems had an indirect effect towards the acceptance. In another Germany-based study, Hoffmann and Mohaupt (2020) found a high level of interest among the photovoltaic (PV) systems users towards ESS. Profit motive dominated the main reason for investment in ESS. In essence, ESS could help them increase self-consumption, which in turn, lead to cost savings and reducing their reliance on energy suppliers. In Canada, Gaede et al. (2020) found almost half of the respondents have not heard of ESS, indicating a low level of awareness. Despite that, the level of intention to use ESS was positive with means ranging between 3.49 and 3.62 (out of 5.00) across the five regions. Significant factors were positive affect, perceived benefits, social norms, attitude, costs, knowledge, and perceived problems.

Public perception towards ESS in Asia has been investigated in few studies. Abe et al. (2015) found a low level of awareness and use (or intention to use) ESS in the PV system in Japan. In a later study, Abe and Ishida (2022) examined the level of Japanese public satisfaction towards ESS leasing. More than half of the respondents claimed that they were satisfied while another 18 percent were very satisfied. Subjective financial benefits, satisfaction with having new technical equipment, and understanding ESS were associated with the satisfaction level. Finally, using technology acceptance model, Jaaffar et al. (2022) found the significant influence of attitudes, social norms, and perceived behavioural control on the intention to use BESS among residential consumers in Malaysia. Furthermore, consistent with Jones et al. (2018), trust in developers became the factor for the respondents' perception towards the costs, benefits, and anticipated effects of BESS.

Except for Ambrosio-Albala et al. (2020), there is no other studies examining the role of demographic profiles on the acceptance towards ESS. This however was not the case for other literature on energy consumption and general renewable energy behaviour. Understanding the customers' demographic profiles enables market segmentation which can help companies to better serve the customers' diverse demands (Hayn et al. 2014). Hayn et al. (2014) found household size, net income, and employment status as the factors influencing energy consumption among the European consumers. Nelson et al. (2021)

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conducted a review of the renewable energy technologies adoption (electric vehicles, PV, solar water heaters, and smart home technology) in China. The adoption was influenced by respondents' culture, gender, income, education, age, and residential area. While majority of prior literature found the influence of educational and income levels (e.g., Elmustapha et al., 2018; Li et al., 2020; Tabi et al., 2014; Wee et al., 2020; Zhang et al., 2019), there are also studies found significant influence of property type (Maxim et al., 2022) and ethnicity (Bennett et al., 2020).

3. Methods

As mentioned in the earlier section, the concept of energy storage is new in Malaysia. According to Sekaran and Bougie (2016), a non-probability sampling technique is appropriate if the researcher intends to obtain quick feedback from the respondents about topics which are not very familiar to them. Furthermore, it is not the intention of this research to generalise the findings to the population. Therefore, the samples were taken conveniently from the academics and students of higher educational institutions (HEIs), representatives from the industry players and regulators, and the public. For the higher educational institutions, they consisted of a government-linked university and three public universities. These institutions were selected for several reasons. Firstly, this research is a part of a broader research programme involving researchers from three different institutions. It is perceived that academics and students from these institutions would be more familiar with ESS, hence would be able to provide fair assessment on the technology. Secondly, another university was added based on prior research collaboration in a similar topic. The representatives from industry players and regulators comprised the management and personnel of Tenaga Nasional Berhad (the national utility company), Energy Commission Malaysia, and other energy-related organisations. Moreover, to obtain a more balanced representation of respondents, we also collected data from the public, who did not fall under the two categories of respondents described earlier.

The full set of questionnaires was designed based on prior literature (Gaede et al., 2020; Jones et al., 2018) and consisted of several sections, namely prior knowledge about battery energy storage system (BESS), understanding of BESS application in power generation, industries and residences; demographic profiles; attitude and perception towards BESS; and contact details. Intention of using BESS was assessed in the attitude and perceptions section, comprising the following statements: (1) I am willing to support the use of BESS in my neighbourhood; (2) I would not support the use of BESS in my neighbourhood if asked; and (3) If asked, I would actively endorse the use of BESS in my neighbourhood. The respondents were asked to rate the items between 1 and 5 (1= strongly disagree, 2= disagree; 3= neutral; 4= agree; 5= strongly agree. For demographic profiles, the respondents were asked about their gender, age, ethnicity, educational level, position in current employment, industry, monthly income, household size, geographical location of residence, current settlement area, and type of residence.

The questionnaire was distributed via online platforms, namely emails, Facebook posts and WhatsApp messages between June and September 2021. We received 331 responses from the HEI/public group and 53 responses from the industry player/regulator group, leading to a total of 384 respondents. For further analysis, the mean score for intention was calculated for each respondent, while the demographic factors were divided into general demographic profiles, socioeconomic profiles, and residential profiles. Using IBM SPSS Statistics 22, independent-Samples *t*-test (for two samples) and One-Way ANOVA with Post Hoc Multiple Comparisons (for *k* samples) tests were conducted to examine any significant difference

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in the intention across demographic profiles. Additionally, the equivalent non-parametric tests, namely Mann Whitney U test and Kruskal Wallis 1-Way ANOVA were conducted to establish consistency in the results.

4. Findings

Table 1 presents the findings of the research. Although not tabulated, the average score for intention (*INTENT*) was 3.60 (median=4.000) suggesting a medium-to-high level of intention of using BESS among the Malaysians. There was a balanced representation of gender among the respondents with male made up 51 percent, while female 49 percent. In addition, majority of them were between 31 to 40 years old (35%) and Malay/Bumiputra (74%), holding a bachelor's degree (50%), working as professionals (36%) in the non-education industries (64%), representing public at large (86%), in the middle-income group (43%) and having four to six members in a family (60%). In terms of residential characteristics, most respondents were residing in the central region (i.e., Kuala Lumpur, Putrajaya, and Selangor, 67%), urban area (64%) and landed properties (72%).

Table 1. Descriptive statistics and bivariate analysis

No	Demographic	Categories	*n*	%	*INTENT*	*p*-value
		Panel A: General demographic profiles				
1	Gender	Male	196	51.0	3.64	0.363
		Female	188	49.0	3.56	
2	Age (years)	Below 20	4	1.0	3.75	0.340
		20-30	119	31.0	3.67	
		31-40	133	34.6	3.52	
		41-50	97	25.3	3.56	
		51 and above	31	8.1	3.77	
3	Ethnicity	Malay/Bumiputra	285	74.2	3.66	0.089*
		Chinese	61	15.9	3.43	
		Indian	35	9.1	3.43	
		Others	3	0.8	3.67	
		Panel B: Socioeconomic profiles				
1	Level of education	Secondary school	8	2.1	3.63	0.005***
		Certificate/Diploma	28	7.3	3.46	
		Bachelor's degree	192	50.0	3.47	
		Master's/PhD degree	153	39.8	3.77	
		Others	3	0.8	4.00	
2	Employment	Professionals	138	35.9	3.66	0.509
		Top/middle mgmt./supervisory	84	21.9	3.48	
		Administrative/technical	53	13.8	3.49	
		Retiree	5	1.3	3.60	
		Housewife	5	1.3	3.70	
		Full-time student	85	22.1	3.69	
		Others	14	3.6	3.61	
3	Industry	Education	139	36.2	3.66	0.237
		Other industries	245	63.8	3.57	
4	Role	Industry player/regulator	53	13.8	3.72	0.234

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		Public at large	331	86.2	3.58	
5	Monthly income	RM4,849 and below (B40)	127	33.1	3.59	0.126
		RM4,850 – RM10,959 (M40)	166	43.2	3.53	
		RM10,960 and above (T20)	91	23.7	3.74	
6	Household size	1 to 3	101	26.3	3.74	0.012**
		4 to 6	229	59.6	3.50	
		7 and above	54	14.1	3.74	
		Panel C: Residential profiles				
1	Geo. location	Central region	259	67.4	3.65	0.000***
		Northern region	72	18.8	3.17	
		Southern region	21	5.5	3.69	
		East Coast/Malaysia region	32	8.3	4.09	
2	Settlement area	Rural area	62	16.1	3.68	0.211
		Suburban area	76	19.8	3.70	
		Urban area	246	64.1	3.55	
3	Property type	Landed	275	71.6	3.68	0.002***
		High-rise	109	28.4	3.41	

INTENT is the intention of using large-scale BESS. The *p*-value is based on Independent-Samples t-test (for two samples) and One-Way ANOVA with Post Hoc Multiple Comparisons (for *k* samples) tests. Results from the equivalent non-parametric tests produced similar findings, hence are not reported here. It is a two-tailed test. *** is significant at the 0.01 level. ** is significant at the 0.05 level. * is significant at the 0.10 level.

Table 2. Post Hoc tests

Group (I)	Group (J)	Mean Difference (I-J)	Std. Error	*p*-value
Ethnicity				
Malay/Bumiputra	Chinese	.23167	0.10784	0.032**
	Indian	.22932	0.13692	0.095*
	Others	-0.00877	0.44366	0.984
Level of education				
Master's/PhD degree	Secondary school	0.14951	0.27454	0.586
	Certificate/Diploma	0.31022	0.15660	0.047**
	Bachelor's degree	0.30055	0.08204	0.000***
	Others	-0.22549	0.44131	0.610
Monthly income				
RM10,960 and above	RM4,849 and below	0.14571	0.10518	0.167
	RM4,850 – RM10,959	0.20313	0.09989	0.043**
Household size				
4 to 6	1 to 3	-0.23821	0.09091	0.009***
	7 and above	-0.23637	0.11513	0.041**
Geographical location				
East Coast/Malaysia	Central	0.44124	0.13719	0.001***
	Northern	0.92708	0.15555	0.000***
	Southern	0.40327	0.20561	0.051*
Northern	Southern	-0.52381	0.18157	0.004***
	Central	-0.48584	0.09754	0.000***

It is a two-tailed test. *** is significant at the 0.01 level. ** is significant at the 0.05 level. * is significant at the 0.10 level.

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Based on the bivariate analysis, the level of intention (*INTENT*) is a factor of respondents' ethnicity, level of education, household size, geographical location, and property type. Ethnicity is the only significant factor under the general demographic profiles category (*p*=0.089). Table 2 presents selected Post Hoc tests indicating significant difference across multiple groups. Malay/Bumiputra respondents (mean: 3.66) had a greater *INTENT* than both Chinese and Indian counterparts (mean: 3.43). The role of ethnicity in renewable energy has also been found by Bennett et al. (2020).

Consistent with findings of prior literature, the level of education plays an important role in influencing the respondents' intention to use products promoting environmental protection (e.g., Bennett et al., 2020; Elmustapha et al., 2018; Fang et al., 2021; Fraser & Chapman, 2020; Karytsas & Theodoropoulou, 2014; Li et al., 2020; Rai et al., 2020; Wee et al., 2020; Tabi et al., 2014; Zhang et al., 2019). In essence, respondents with a postgraduate degree (mean: 3.77) had greater *INTENT* than those with a certificate/diploma (mean: 3.47) and a bachelor's degree (mean: 3.46). Another significant variable under the socio-economic profiles category is the household size. Households with members between four and six had significantly lower *INTENT* than the other groups. Specifically, the mean average for this group was 3.50 while both '1 to 3' and '7 and above' showing greater inclination of using BESS with an average rating of 3.74. The influence of household size is also evident in a study by Elmustapha et al. (2018) who found an average household size for residents adopting solar heating system was much higher than those who did not. Similarly, Bohdanowicz (2021) found a positive association between the number of children and support for climate change mitigation. Finally, Li et al. (2020) observed the influence of household size on time-shifting of energy use for showering activity. It is also interesting to note that although the result in Table 1 does not indicate a significant *p*-value for monthly income, the corresponding Post Hoc test in Table 2 demonstrates that the level of *INTENT* among the T20 group (mean: 3.74) is significantly greater than the M40 group (mean: 3.53) at the 0.05 level. T20 group represents households with monthly income of more than RM10,959, while the monthly income for the M40 group is between RM4,850 and RM10,959 (Department of Statistics Malaysia (DOSM), 2021). This provides further support to prior literature on the relationship between income and pro-environmental behaviour (e.g., Bennett et al., 2020; Bohdanowicz, 2021; Elmustapha et al., 2018; Fang et al., 2021; Makoenimau & Farizal, 2018; Wee et al., 2020; Stephanides et al., 2019; Tabi et al., 2014; Zhang et al., 2019)

Residential profiles section in Table 1 indicates the significant difference in *INTENT* across geographical location and property type. It is rather surprising that given the level of economic development in the East Coast and East Malaysia regions, respondents from this area were more forthcoming in using BESS. This is evident from the mean of 4.09 as compared to the other groups. Specifically, there is a significant difference between East Coast/Malaysia and Northern region (mean: 3.17; *p*-value: 0.000), Central region (mean: 3.65; *p*-value: 0.001), and Southern region (mean: 3.69, *p*-value: 0.051). In fact, the *INTENT* for Northern is significantly different from Southern (*p*=0.004) and Central regions (p=0.000). Finally, there is a significant difference in *INTENT* across the property type with respondents residing in landed properties (mean: 3.68) attached greater intention to use BESS than those living in high-rise buildings (mean: 3.41). This is also consistent with Li et al.'s study (2020) who found the influence of region and house type on time shifting of energy use for showering and heating, respectively. Moreover,

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Maxim et al. (2022) found residential location and dwelling type were factors of willingness to pay for renewable energy among the population in Romania's north-east region.

5. Conclusion

The climate change problem has intensified the efforts to increase the share of energy from renewable sources. ESS has the capacity to reduce the disruption of electricity supply from renewable energy. Of these technologies, BESS is the most dominant and offering the most benefits. The paucity of research examining the acceptance towards ESS and consumers' demographic profiles associated with it has motivated the researchers to conduct this study. Based on the survey and bivariate analysis, consumers' ethnicity, level of education, household size, geographical location, and property type influenced the intention of using BEES. We also found the significant difference between the T20 and M40 groups, suggesting the importance of income level.

For a new technology to be accepted by the public, it is of great importance to understand the perception of public and the related factors, including demographic factors. This could pre-empt any possible public resistance while at the same time help relevant parties to serve the demands of the stakeholders involved more effectively. The Malaysian Government had announced the plan to build a large-scale BESS to support PV systems in Malaysia. In order for the idea to penetrate the public, there should be mechanisms by the Ministry (in this case, KeTSA) and other related organisations to promote the importance of BESS. The demographic analysis in this research could provide timely input to these authorities on the market segments to focus on to ensure the proposed project will run smoothly. For example, there was a lower level of intention among the Chinese and Indians. Hence, those with the authority may want to hold awareness campaigns among these ethnic groups to enhance their understanding of BESS. The significant influence of educational level may indicate the need to integrate fundamentals of BESS into the existing curriculum. The findings on geographical location and property type hint at the most suitable areas for the placement of BESS. Finally, household size and income level suggest the need for developing appropriate financial model that would offer win-win situation between the regulators, industry players, and consumers.

The findings of this research need to be interpreted with caution. Firstly, the sample size is small in comparison to the whole population. It is recommended for future studies to include more respondents to enhance the representativeness of the sample. Secondly, the conclusion is made based on bivariate analysis without any attempt to analyse the demographic profiles simultaneously. A multivariate analysis will provide more robust findings and be able to identify a set of significant demographic factors. Thirdly, the findings are purely from questionnaire survey. Data collected from interview with the consumers, industry players, and regulators will shed better insights on factors influencing the intention to use BESS.

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