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Foresight Study on Solar Photovoltaic (PV) Adaptation in Damansara Emas Residential Area

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Abstract

Solar Photovoltaic (PV) is a way to generate renewable energy that is friendly to environment. Many incentives adoption in Malaysia is rather slow in residential area, Net Energy Metering system (NEM) and Feed-in Tariff (FiT) are incentives that are provided by Malaysian Government but the adaptation rate is still rather low and slow. Thus, this research intends to identify the key drivers of rooftop solar PV adaptation among residential in Malaysia or forecast the future trends within the residential area in Malaysia, specifically, Damansara Emas, Malaysia. The approach for this study consisted of foresight analysis on Solar PV adaptation impact-uncertainty analysis, and scenario analysis. This study used STEEPV analysis to examine the issues and drivers related to Solar PV. A total of 180 residents from Damansara Emas were involved in completing the survey. The result of the survey concluded that cost-effective of technology increase the rate of Solar PV adaptation, and secondly the incentives and government policy to resident, these were discovered from scenario building. This research will give benefits to resident in residential area with potential to adapting the technology and government motives to increase the renewable energy sources in country, there fore early precaution and can be taken by stakeholders and adopters.

1. Introduction

The enormous population of Malaysia (about 32.9 million people) has a significant demand for energy, with 90 percent of it coming from fossil fuels (Department of Statistics Malaysia Official Portal, 2023). Coal still accounts for 38% of worldwide electricity production, although Malaysia is increasingly dependent on renewable sources. Coal accounted for 50.6% of the electrical output in 2017. Due to the popularity of natural gas, which accounted for 63.4 percent of total power output 20 years before 1997, coal accounted for just 7.4 percent of total power generation. However, heavy use of fossil fuels has several severe environmental repercussions, such as water and air pollution, as well as direct and indirect public health costs, such as premature mortality from particulates, sulphur dioxide, and nitrogen oxide, and missed workdays (Machol & Rizk, 2013).

Up to 98 percent of Malaysia's coal, which is used in thermal power plants to create around 40 percent of the country's electricity, is imported. The nation was the eighth biggest importer of coal briquettes and the twelfth largest importer of bituminous coal (not agglomerated) in 2018 (The Star Online, 2020, September 15). Since 2001, the Malaysian government has made many initiatives to expand green energy (Mekhilef *et al.*, 2014). However, the government has just recently begun to produce electricity from renewable energy sources. Malaysia has established several energy policies and programmes since 1979, including the National Energy Policy 1979, the National Depletion Policy 1980, the Four-Fuel Diversification Policy 1981, the Fifth Fuel Policy

2000, and the National Renewable Energy Policy 2005. The government has granted several types of green financial incentives to power providers, including Feed-in-Tariff (FiT) and New Energy Metering, to aid in the implementation of the regulations (NEM). Even after enacting all these rules, Malaysia continues to produce power from fossil fuels. The energy balance of Malaysia was mostly relied on fossil fuels.

Energy is necessary for the fulfilment of several basic human requirements, as well as for the industrial, transportation, and agricultural operations that drive global economic growth. Gross domestic product (GDP) is used to measure economic growth, and GDP in Malaysia is virtually perfectly correlated with the country's energy consumption. Malaysia's economic prosperity is contingent upon an uninterrupted energy supply. As a result, any conservation regulations or disruptions in the supply of energy will negatively influence economic growth. In Malaysia, we have both renewable energy (RE) and non-renewable energy (non-RE). However, energy generation from RE sources is nowhere close to non-RE sources due to various factors. Hence, various efforts and policies are being introduced to close the gap between energy generation between RE and non-RE sources.

Renewable Energy (RE) is another source of energy that can change the future of the energy sector in the world. As the current world started making its way to clean energy transition, non-renewable energy is also depleting. Apart from that, unlike non-renewable energy sources such as fossil energy, RE does not produce carbon during its power generation operation. Hence, it is not weird that Malaysia is also another country moving towards a clean energy transition. Not to mention, Malaysia is also one of the largest solar energy generator countries in Asia. However, this only holds for the industrial sector but not the residential area.

GSPARX, focuses investment on residential Solar Photovoltaic (PV). The company also offer a solution that allows the customer (Normal consumer) to sell excess power generated under Net Energy Metering Scheme (NEM). Other private companies such as Solarvest, Ditrolic Solar, Cutech Group and etc are companies that provide services such as installing Rooftop Solar PV on residential buildings in Malaysia. Incentives from the Government significantly reduced the installation cost of Solar PV on the residential houses' rooftop for the 3kWp system, which GSPARX offered is currently set at RM18,900 which will potentially reduce at very least RM90 from the electric bill and can pay back the installation cost is approximately 7-8 years according to GSPARX itself. While the incentives from the company itself seem to be interesting for Malaysian households to get themselves Solar PV systems integrated into their rooftop, surprisingly, the total amount of Solar PV installed in a residential area is only over 1,000 houses. This clearly indicates that the system's adaptation is rather low and slow compared to Malaysia's neighbor countries like Indonesia (GSPARX, 2021).

Renewable energy sources are certainly being focused on by the Malaysian government in order to increase power generation expansion in Malaysia. However, there are several challenges and issues that needed to be first mentioned. Among those issues are limited national energy sources in Malaysia, increasing power consumption, low and expansion rate of RE sector in Malaysia.

Firstly, Malaysia is a country that mainly relies on non-renewable energy sources such as natural gas and coal; the production rate seems to be growing over the last ten years too. However, the power consumption rate in Malaysia is also significantly increasing as demands increase over time (Muhibbullah, 2021). The government has invested nation funds into Renewable Energy (RE) sectors to boost the technology adaptation rate in Malaysia. RE sources such as hydropower, wind turbines, and solar energy, although the campaign's effectiveness and investment seem to be more weighted on the industrial sector than in residential areas (Muhibbullah, 2021). As rooftop Solar PV system integration is the only option for residential spaces, factors that affect the Malaysian decision to adopt the system have become a question that is being asked.

Secondly, will current Malaysia energy sources will be enough for Malaysians in the future? The reason behind this question is because of the power consumption rate in Malaysia increased every year as demand increased; the nation needed other energy sources besides natural gas and coal, which were primary energy sources and major income sources (Khairudin *et al.*, 2021). Hydropower and Solar power were renewable energy sources options available and suitable for geolocation in Malaysia. However, up until now, only 2% of energy comes from hydropower and solar power, which is low compared to other mixed energy sources in Malaysia.

Malaysia's government has provided many incentives to boost the RE power generation rate in residential areas, but it is still unclear whether Malaysia will achieve its target. Malaysia has an ambitious target for Renewable Energy (RE) growth, which is set to achieve 20% RE penetration by 2025 (Abdullah, 2019). Many efforts from the Government were made to help achieve the target, including a subsidiary company from Tenaga National Berhad (TNB) known as TNB Renewable Sdn. Bhd. (TRe) and GSPARX Sdn Bhd. Including Feed-in traffic (FIT) and the Net Energy Metering Scheme (NEM), which allow normal consumers that install Solar PV systems in their residentials to sell surplus power generated by Solar PV to the National Grid at specific prices. Based on the issues arise, this study aims to identify the key driver in deciding rooftop solar PV adaptation within the residential area in Malaysia and to determine future trends of solar PV adaptation within the residential area in Malaysia

2. Methodology

This study involved many people and analyses various options for satisfying needs and seizing future opportunities. To collect data for the study, the mixed methods strategy, which combines quantitative and qualitative techniques, was adopted. For this research, the issues, trends, and difficulties of Solar PV adoption in residential structures were studied using a mixed-method foresight approach.

2.1 Research Design

A full examination of the issue description and development of the research goals were provided. Next, the study's scope has been determined to completely recognize which research field has been investigated and to establish its specifications. In addition, the literature review for this investigation has been presented in the next chapter. Consequently, a review of the current research on Solar PV uptake is necessary for Solar PV system cost and knowledge or understanding of the technology from the residents from the journals, books, articles, online materials, and websites will provide a detailed background of the subject matter. Data collected from the study were carried out using quantitative analysis with the Statistical Package of Social Science (SPSS) to verify the validity of the result. Hence, broad discussion and explanation were made to understand further the data collected. Lastly, the study's conclusion has been constructed at the end of the study based on the result analysis. Recommendations for further study has been discussed in the last chapter. Figure 2.1 illustrates the research flowchart.

2.2 Data Collection

2.2.1 Data Designing

Additional readings utilizing journals, publications, and online and offline databases, and the keywords from the job summary have been developed. During the data listing procedure, each keyword has been compiled for examination.

2.2.2 Listing of Data

The data design documentation will be reviewed and listed correspondingly. During the listing process, all data designing notes will be categorized and seen in numerous ways to ensure that no errors in the listed data.

2.2.3 Data Classification

Materials that have been reviewed will be categorized according to STEEPV which refers to Social, Technological, Environmental, Economical, Political, and Value. Data classification was done in such a manner in order to provide a clear view of all collected data.

2.2.4 Data Identification and Theme Comparison

Data collected and classified have been verified to ensure that data will fit with the study's objectives and comparison between primary and secondary themes has been made, with the most appropriate theme has been chosen to continue the research. The theme chosen was used in developing the questionnaire.

2.2.5 STEEPV Analysis

The STEEPV analysis is a method for identifying the possible driving factors of the researched field. The STEEPV research was utilised to identify several issues and drivers, policy suggestions, upcoming initiatives, and crucial locations. This form of study utilises secondary data. Previously collected secondary data can be evaluated for the research. The secondary data utilised for advice and references in this study about the Solar PV technology drivers in recruiting are from scholarly papers and websites (Nazrko & Kuźmicz, 2017).

Nazrko and Kuźmicz, (2017) stated STEEPV is an acronym for Social, Technological, Economic, Environmental, Political and Values. This analysis was used to help identify and classify factors that have or may impact recent environmental innovation. In this way, by using STEEPV analysis, the data will be placed accordingly in the specific contexts. The drivers that emerged from secondary data were tabulated in STEEPV categories as in Table 1.

Table 1 *Area of STEEPV in the research*

Drivers	Related Area
Social	Ways of life (e.g., use of leisure time, family living patterns), demographic structures, social inclusion and cohesion issues (fragmentation of lifestyles, levels of (in)equality, educational trends).
Technological	Rates of technological progress, pace of diffusion of innovations, problems and risks associated with technology (including security and health problems
Economic	Levels and distribution of economic growth, industrial structures, competition and competitiveness markets and financial issues.
Environmental	Pressures connected with sustainability and climate change, more localised environmental issues (including pollution, resource depletion, and associated biodiversity, and welfare concerns).
Political	Dominant political viewpoints or parties, political (in)stability, regulatory roles and actions of governments, political action and lobbying by non-state actors (e.g., pressure groups, paramilitaries).
Values	Attitude to working life (e.g., Entrepreneurialism, career aspirations. deference to authority, demands for mobility (across jobs or places, etc.), preferences for leisure, culture, social relations, etc.

2.2.6 Issues and Drivers Formulation

Formulation of drivers is the primary factor in the microenvironment that underpins significant trends and challenges. It covers the aspects that will shape the organization's future environment. Therefore, STEEPV analysis will be utilized to determine the components that will shape or affect future growth. In this study, the impact-uncertainty analysis will be utilized to examine the formulation's key drivers.

2.3 Data Analysis

2.3.1 Descriptive Analysis

Descriptive analysis employs statistical tools to describe or summarize a data collection. Statistical Package for the Social Sciences' (SPSS) used to evaluate the questionnaire data. The output of the computer-based statistical analysis in numerical form. In addition, it collected data in frequency, percentage, mean, and standard deviation formats. SPSS can analyze enormous amounts of data and is easy to use, especially for data interpretation.

SPSS software was used to evaluate the data received from the questionnaire about the foresight research on rooftop solar PV adaptation in Damansara Emas residential area. The acquired mean score will be utilized to interpret the study. Therefore, the meaning of the mean score is shown in Table 2.

Table 2 *Mean score interpretation*

Mean Score	Interpretation
1.00 - 1.80	Very Low
1.81 - 2.60	Low
2.61 - 3.20	Medium
3.21 - 4.20	High
4.21 - 5.00	Very High

2.3.2 Impact-Uncertainty Analysis

The result obtained from the descriptive analysis will be used for the impact-uncertainty analysis. This investigates the uncertainty in identifying the purpose of using Solar PV in the residential area. List of variables derived according to importance, impact, and uncertainty to construct the impact-uncertainty analysis. The main drivers for the impact-uncertainty analysis are the variables with the highest impact and level of uncertainty, which can be explained in Fig. 1.

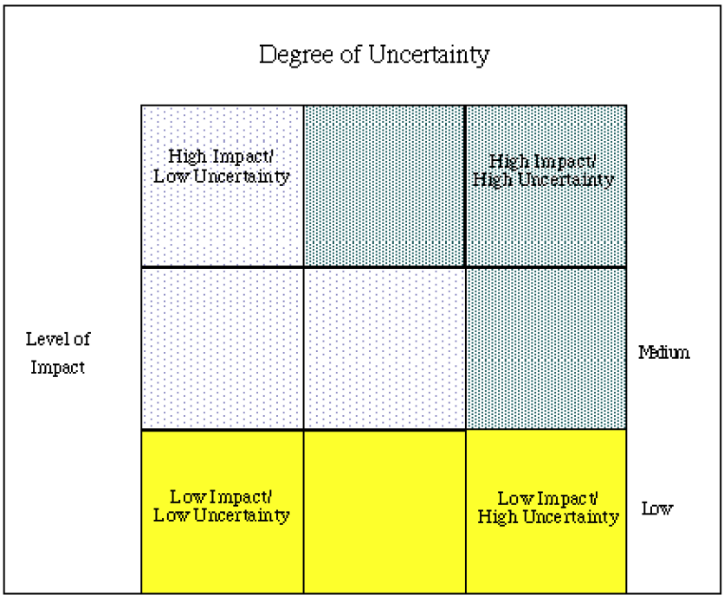

Fig. 1 *Impact-uncertainty analysis*

2.3.3 Scenario Analysis

Using the two primary drivers identified during the impact-uncertainty study, a scenario analysis will be constructed. It aims to outline prospective outcomes such as future issues, trends, strategy, and future-related development. To depict the future implications of Solar PV difficulties and trends in the residential sector of Malaysia, four potential scenarios were developed. These scenarios illustrate four potential outcomes between 2021 and 2031. The scenario assessment is visualized in Fig. 2.

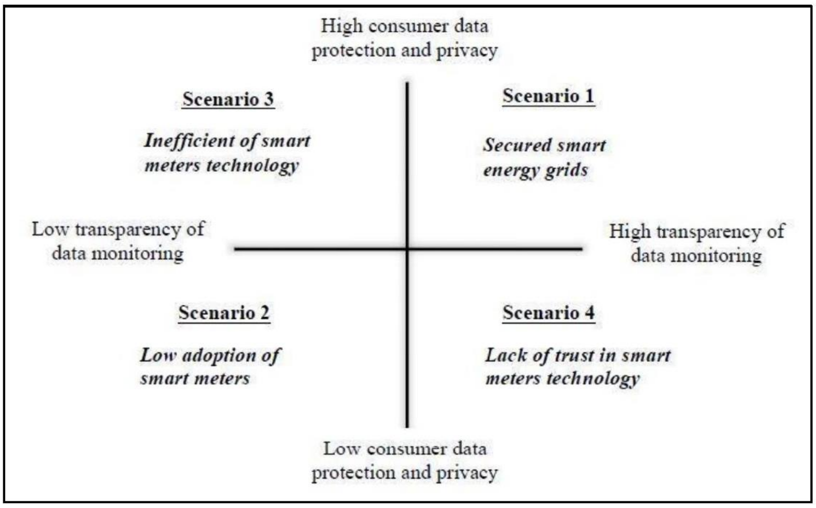

Fig. 2 *Scenario analysis*

3. Literature Review

3.1 STEEPV Analysis

Using Social, Technological, Economic, Environmental, Political, and Values (STEEPV) research, the challenges, and drivers of Solar PV in residential areas were found. The concerns and motivations for this study were extracted from secondary data sources such as journals, papers, books, and reports.

3.1.1 Issues and Challenges Related to Social

According to Table 3, list of issues and challenges, using "Social" factor from STEEPV analysis, there were six drivers that could be found and identified through Solar Photovoltaic related literature review process.

Table 3 *List of issues and challenges for social*

No	Drivers	Related Area
1	Financial feasibility for both domestic and commercial buildings to install Solar PV system its buildings based on electricity consumption profile (Wei & Saad, 2020).	Investment return
2	Net energy metering (NEM) which supposed to help reduce customer monthly electricity but to what extent does it benefit customers with different sizes of PV sizes under the NEM scheme (Razali *et al.*, 2020).	Solar PV benefits
3	More job created with expansion of Solar energy sectors (Zhang *et al.*, 2017).	Job opportunity
4	Promotion of Low Carbon Cities Framework (LCCF) which act as a socioeconomic booster to push the development and expansion of environmentally friendly technology such as solar energy (Muhibbullah, 2021).	Sustainability life
5	Malaysia provides substantial solar insulation suitable for Solar Photovoltaic (PV) implementation to fulfill the national energy demand (Muhibbullah, 2021).	Strategic Location
6	Financial feasibility for both domestic and commercial buildings to install Solar PV system its buildings based on electricity consumption profile (Wei & Saad, 2020).	Investment return

3.1.2 Issues and Challenges Related to Technological

There were twelve drivers that have been detected and recognized through the process of reviewing the literature on solar photovoltaics, as shown in Table 4, which lists issues and challenges using the "Technological" factor from STEEPV analysis.

Table 4 *List of issues and challenges for technological*

No	Drivers	Related Area
1	Solar energy is proposed as an alternative solution to the rise in electricity consumption that affects climate change in Malaysia (Wei & Saad, 2020).	Alternative energy solution
2	Floating Solar PV system as cooling system for large scale solar system without incurring water consumption (Choi, 2014).	Solar PV cooling solution
3	Lack of expertise in optimization of biomass residue has slowed down RE generation in Malaysia (Khairudin *et al.*, 2021)	Renewable Energy Transition
4	Development of perovskite solar cells (PSCs) which increase the efficiency in absorbing solar energy and its life cycle (Carneiro *et al.*, 2022)	Solar PV Technology development
5	Replacement of MAPbI3 perovskites type solar cells with alternatives that are more efficient in solar energy harvest (Hussain *et al.*, 2018).	Solar PV cells development
6	Consideration of Fiber-shaped perovskite solar cells for alternatives of rigid-shaped perovskite solar cells for other usage (Hussain *et al.*, 2018).	Integration of Solar energy in portable device
7	Solar PV combination with grid electric for hot water and space heating in domestic sector can reduce energy consumption from grid significantly (Datas *et al.*, 2019).	Energy consumption reduction for heating system
8	Water cool Solar PV panel to increase its performance and efficiency while producing hot water helps reduce electric bill (Arefin, 2019).	Utilization of Solar PV for house water heating system
9	Economic burden reduction through government policy which including subsidy from purchase, installation and maintenance of Solar PV (Poruschi *et al.*, 2018).	Incentivized Solar PV adoption

10	Integration of lithium-ion battery with Solar PV system to store excess energy generated during peak hours (O'Shaughnessy *et al.*, 2018).	Utilization of lithium-ion battery with Solar PV
11	Photovoltaic (PV) integration with Electric Vehicle (EV) with battery technology development has popularized renewable energy uses for automotive (Ghosh, 2020).	PV catalyst of development of EV
12	Photovoltaic (PV) act as standalone energy supply to EV Charging station which does independently from national grid and does not cause carbon emission (Ghosh, 2020).	Vehicle with zero carbon emission

3.1.3 Issues and Challenges Related to Economic

Fifteen drivers were detected and identified through a process of literature review connected to solar photovoltaics, as shown in Table 5 list of issues and challenges utilizing the "Economical" component from STEEPV analysis.

Table 5 *List of issues and challenges for economic*

No	Drivers	Related Area
1	Financial feasibility for both domestic and commercial buildings to install Solar PV system its buildings based on electricity consumption profile (Wei & Saad, 2020).	Solar PV incentives
2	Net energy metering (NEM) which supposed to help reduce customer monthly electricity but to what extent does it benefit customers with different sizes of PV sizes under the NEM scheme (Razali *et al.*, 2020).	Return of investment with NEM for Solar PV
3	Implementation of Solar energy as new energy resource requires huge amount of investment values (Abdullah *et al.*, 2019).	Solar PV adaptation cost
4	Feed-in-Tariff (FiT) are not worth the investment after consideration on all other risks (Abdullah *et al.*, 2019).	Solar PV incentives
5	Differences in cost between Solar Photovoltaic (PV) with fossil fuel is incomparable (Teoh *et al.*, 2020).	Cost Performance versus fossil fuel-based energy source
6	Demand for energy from domestic increased the favorability in energy sector (Keleher & Narayanan, 2019)	Economic upturn
7	Solar PV combination with grid electric for hot water and space heating in domestic sector can reduce energy consumption significantly (Datas *et al.*, 2019).	Energy consumption reduction in heating system.
8	Utilization of water heating with thermal collector system to reduce electric bill while also reducing carbon emission (Arefin, 2019).	Energy consumption reduction.
9	The effectiveness and value of incentives such FiT or NEM has decline over time (Solangi *et al.*, 2011).	Ineffective incentives
10	Strategic location in Malaysia suitable for LSS (Large Scale Solar) as solar generation at Perlis was generally high (Daut *et al.*, 2011).	Strategic location for Solar PV adaption
11	High level of uncertainty and complexity plus huge investment requires to implement Solar PV (Qian *et al.*, 2021).	Uncertainty and complexity to adapt with Solar PV

12	Integration of lithium-ion battery with Solar PV system to store excess energy generated during peak hours and use stored energy (Qian *et al.*, 2021).	Store excess energy from Solar PV in
13	Adding battery will increase the savings but not cost effective as the cost is double of what consumer saved from implementing it (Green & Staffell, 2017).	Solar PV plus cost effectiveness
14	Rapid battery deterioration influences the profitability of PV with battery systems, particularly for large-load families (Truong *et al.*, 2016).	Lifecycle of battery determine Solar PV cost effectiveness
15	Integration of battery, both lithium and lead-acid into Solar PV system, neither does not prove to be cost effectives, especially at low-rate electricity countries (Parra & Patel, 2016).	Cost effectives of Solar PV various on country

3.1.4 Issues and Challenges Related to Environmental

Through utilization of factor "Environmental" from STEEPV analysis, there were twelve drivers were identified and categorized from review on precedence literature which were shown in Table 6.

Table 6 *List of issues and challenges for environmental*

No	Drivers	Related Area
1	Solar energy being proposed as the most suitable energy source alternative as rising of energy consumption in Malaysia caused climate change (Wei & Saad, 2020).	Energy sources alternatives
2	Legislation challenges in getting quick approval from authorities for Solar Photovoltaic (PV) construction project (Abdullah *et al.*, 2019).	Legislation challenges
3	Gold layer (mesoporous layer) in perovskite solar cells (PSCs) dominant factor for carbon footprint from the energy required for manufacturing (Carneiro *et al.*, 2022).	Carbon footprint from solar cells manufacturing
4	Temperature required to manufacture perovskite solar cells (PSCs) needed to be lowered in order to reduce the carbon footprint from the manufacturing process (Carneiro *et al.*, 2022).	Power consumption during manufacturing
5	Gold in mesoporous layer needed to be replaced with lower environmental impact material (Carneiro *et al.*, 2022).	Environmental Impact
6	Association of carbon emission with enormous energy demand which corresponded to growth of domestic sector (Keleher & Narayanan, 2019).	Association with carbon emission
7	Utilization of water heating with thermal collector system to reduce electric bill while also reducing carbon emission (Arefin, 2019).	Reduction of carbon emission
8	Malaysia is strategic location has the highest potential for solar irradiation rate which affect effectiveness of Solar PV system (Mekhilef *et al.*, 2014).	Strategic location for Solar PV adaptation
9	During Solar PV panels operations, it does not produce any noise to residents of the house unlike energy generation from other (Mekhilef *et al.*, 2014).	Noise pollution
10	Efficient in making use of degraded land for Solar PV implementation without land-use conflict with agricultural purposes land (Shiraishi *et al.*, 2019).	Utilization of degraded land
11	Frequent maintenance and cooling method for Solar PV consume significant of water, corresponding to size of solar PV system (Conceição *et al.*, 2022).	Water consumption for maintenance
12	EV that powered with PV integrated charging station can significantly reduce greenhouse gas (GHG) emission compared to fossil fuel powered vehicle by 50-60% (Conceição *et al.*, 2022).	GHG emission reduction

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3.1.5 Issues and Challenges Related to Political

Through utilization of factor "Environmental" from STEEPV analysis, there were twelve drivers were identified and categorized from review on precedence literature which were shown in Table 7.

Table 7 *List of issues and challenges for political*

No	Drivers	Related Area
1	Policymaker providing attractive incentives to users to help boost the energy generation from renewable energy (Parliament of Malaysia, 2011).	Incentives establishment
2	Net energy metering (NEM) which does not shows any significant assist to reduce the cost of implementation (Razali *et al.*, 2020).	Solar PV incentive re-consideration
3	Public awareness and implement policies and initiatives is essential in boosting Solar PV implementation in Malaysia that directly target the decrease of installation costs (Teoh *et al.*, 2020).	Education syllabus on Solar PV
4	Policy and national scale plan to boost development of affordable energy resources while reducing dependency of fossil fuel (Economic Planning Unit, 2015).	Development of Renewable Energy policy

3.1.6 Issues and Challenges Related to Values

Through utilization of factor "Environmental" from STEEPV analysis, there were twelve drivers were identified and categorized from review on precedence literature which were shown in Table 8.

Table 8 *List of issues and challenges for values*

No	Drivers	Related Area
1	Solar PV technology advancement act as catalyst to Low Carbon Cities Framework (LCCF) to provide green technology culture among Malaysian (Muhibbullah, 2021).	Sustainability Life
2	Net energy metering (NEM) which supposed to help reduce customer monthly electricity but to what extent does it benefit customers with different sizes of PV sizes under the NEM scheme (Razali *et al.*, 2020).	Solar PV Return of Investment (ROI) to consumers
3	Development of significant energy-saving features building which include efficient cooling and heating system, utilization of highly efficient A/C and Solar water heater system (Wilkinson & Boehm, 2005).	Sustain energy-saving life
4	Solar PV plays a big role in Zero Energy Building concept to bring net zero electric bill and carbon emission free buildings (Wilkinson & Boehm, 2005).	Independent building with zero carbon emission

3.2 Merged Issues and Drivers

According to issues and drivers gathered, the highest number of drivers is economic factor that is the most important, followed up by technological, environmental, Social, Political and Values. Therefore, with the several drivers found with 53 drivers, all can be merged according to the related issues and drivers of categories. Hence, in Table 9, a list of drivers found in the STEEPV analysis based on Table 3 to Table 8. All the drivers will be used in the development of questionnaire.

Table 9 *List of merged issues and drivers*

No	Drivers	Related Area
1	Existing policy and incentives were not favorable or shows significant benefits to consumers or resident.	Incentive and government policy
2	Initial cost of investment in Solar PV is huge for normal consumer in residential area to adapt with the technology, additionally consideration about uncertainty and complexity of technology to people in residential area.	Solar PV cost effectiveness

3	Malaysia has strategic location to adapt Solar PV as it provides solar irradiation higher than other Western countries.	Strategic location
4	Development of energy sector industry will open more job opportunity in Malaysia.	Energy sector development
5	Solar PV will act as catalyst to lifestyle that will encourage more environmental perseverance.	Sustainability life
6	Play a big role in introducing renewable energy to consumer while boosting the transition process	Role in Renewable Energy transition
7	Charging station for Electric Vehicle can be installed at domestic house and work independently from national grid and unlike gas station that requires transportation of gas.	PV for charging
8	Application of PV to power household and vehicle also devices, significantly reduce GHG and Carbon emission while at the same time also reduce noise pollution.	Environmentally friendly technology

4. Results and Discussion

4.1 Response Rate

A total of 217 respondents participated in this study. The online questionnaire has been distributed through social media. Table 10 shows that 180 out of 217 questionnaires has been collected which yield the response rate of 82.95%.

Table 10 *Respondents demographic*

Sample Size	Returned (Valid) Questionnaires	Response Rate (%)
217	180	82.95

4.2 Respondent's Demographic Information

The overall result of the respondent's demographic was shows in the Table 11 that includes the frequency and percentage. The information consists of gender, age, ethnicity, income classification, education, level of perceived awareness of solar panel applications in Malaysia and which approach of energy generation that the respondent prefer. A total of 180 respondents' responses were collected from the survey. Based on Table 4.2, female respondents dominate the sample as compared to male respondents. The respondents were divided into five categories of age group as such below 30 years old, 31-35 years old, 36-40 years old, 41-45 years old, 46 years old or above. Majority of the respondent were from age group of below 30 years old and majority of the respondent were Chinese. Besides that, respondent's income classification data were collected which as well ranged from RM4,850 to RM10,970, and most of the respondents coming from B40 (<RM4,850). Plus, survey reported majority of respondents' have Bachelor of Degree, and when questioned about their awareness about application of Solar Photovoltaic technology in Malaysia, most of respondents reported a moderate level of awareness. Lastly, almost all respondents responded that they prefer renewable energy as energy sources such as Solar panel.

Table 11 *Respondents demographic*

Demographic		Frequency *(f)*	Percentage *(%)*
Gender	Male	84	46.7
	Female	96	53.3
	Total	180	100
Age	Below 30 years old	76	42.2
	31 – 35 years old	54	30.0
	36 – 40 years old	38	21.1
	41 – 45 years old	4	2.2

	46 years old and above	8	4.4
	Total	180	100
Ethnicity	Malay	52	28.9
	Chinese	90	50.0
	Indian	38	21.1
	Total	180	100
Income Classification	B40 (< RM 4,850)	120	66.7
	M40 (RM 4,851 – RM 10, 970)	48	26.7
	T20 (> RM 10,971)	12	6.7
	Total	180	100
Education	Highschool graduate	24	13.3
	Diploma	52	28.9
	Bachelor's degree	84	46.7
	Master's Degree	18	10
	PHD	2	1.1
	Total	180	100
Level of perceived awareness of Solar Panel applications in Malaysia	High awareness	42	23.3
	Moderate awareness	92	51.1
	Low awareness	36	20.0
	No awareness	10	5.6
	Total	180	100
Would you prefer the conventional approach to generate energy or renewable energy source like solar energy generated from solar panel?	Yes	42	23.3
	No	92	51.1
	Total	180	100

4.3 Importance Analysis

The overall result of the importance analysis was shown in Table 12, in which include both means and standard deviations for each of eight drivers are shown. Based on the analysis, all driver scored a high level of importance but driver "Environmentally friendly technology", come at first place, which scored 4.02 mean with standard deviation of 0.818. The second highest score is driver "Strategic location" reported 3.97 mean score with 0.852 standard deviation. The third placed driver falls on "Incentive and Government Policy" with 3.97 mean score and 0.782 standard deviation. Followed by third place, "Energy sector development", fourth place scored 3.89 mean score with 0.962 standard deviation. Fifth and sixth placed were achieved by "Photovoltaic for charging" and "Role in Renewable energy transition", these two drivers reported mean score of 3.71 (0.948 of standard deviation) and 3.69 (1.010 of standard deviation). The last two driver, "Solar PV cost effectiveness" and "Sustainability life", both reported the same mean score of 3.68 but reported 0.919 and 1.010 in standard deviation.

Table 12 *Importance descriptive analysis*

No	Driver	Mean (μ)	Standard Deviation (σ)
1	Incentive and government policy	3.94	0.782
2	Solar PV cost effectiveness	3.68	0.919
3	Strategic location	3.97	0.852
4	Energy sector development	3.89	0.962
5	Sustainability life	3.68	1.034

6	Role in Renewable energy transition	3.69	1.010
7	Photovoltaic for charging	3.71	0.948
8	Environmentally friendly technology	4.02	0.818

4.4 Impact Analysis

Table 13, which includes both means and standard deviations for each of the eight drivers, displays the overall results of the importance analysis. According to the research, every driver had a high level of impact, but the driver "Incentive and government policy" came out on top with a mean score of 4.02 and a Standard Deviation (SD) of 0.791. The driver with the second-highest score, "Environmentally friendly technology," had a mean score of 3.92 and a standard deviation of 0.838. The third-placed driver has a 3.91 mean score and a 0.905 standard deviation, falling under the category of "Strategic location". Followed by third ranked driver, the fourth falls under two drivers which referred to "Solar PV cost effectiveness" and "Energy sector development", where both score 3.88 mean score but standard deviation of 0.843 and 0.747 respectively. The fifth rank driver, "Sustainability life" had a mean score of 3.83 and a standard deviation of 0.903. The second last ranked driver, "Role in Renewable energy transition" reported 3.74 in mean score and 0.989 standard deviation. Lastly, driver "Photovoltaic for charging" scored only 3.68 mean score but highest in standard deviation, 1.037.

Table 13 *Impact descriptive analysis*

No	Driver	Mean (μ)	Standard Deviation (σ)
1	Incentive and government policy	4.02	0.791
2	Solar PV cost effectiveness	3.88	0.843
3	Strategic location	3.91	0.905
4	Energy sector development	3.88	0.747
5	Sustainability life	3.83	0.903
6	Role in Renewable energy transition	3.74	0.989
7	Photovoltaic for charging	3.68	1.037
8	Environmentally friendly technology	3.92	0.838

4.5 Uncertainty Analysis

The overall findings of the importance analysis are shown in Table 14, which contains averages and standard deviations for each of the eight drivers. Every driver reported a high level in uncertainty; however, "Incentive and government policy" had the most impact, with a mean score of 3.94 and a Standard Deviation (SD) of 1.021. "Solar PV cost effectiveness," the driver with the second-highest score, with a mean score of 3.87 and a standard deviation of 1.008. The third-placed driver, who falls under the category of "Strategic location", has a 3.70 mean score and a 0.854 standard deviation. Fourth place was "Sustainability life " had a mean score of 3.68 and a standard deviation of 0.970. "Energy sector development" and "Role in Renewable energy transition" came in fifth and sixth, respectively, with mean scores of 3.67 (0.924 standard deviation) and 3.67 (1.049 of standard deviation). Driver "Photovoltaic for charging", which was placed second-to-last, with a mean score of 3.56 and a standard deviation of 1.143. Finally, the driver "Photovoltaic for charging" had a mean score of only 3.52 but the biggest standard deviation of 1.300.

Table 14 *Uncertainty descriptive analysis*

No	Driver	Mean (μ)	Standard Deviation (σ)
1	Incentive and government policy	3.94	1.021
2	Solar PV cost effectiveness	3.87	1.008
3	Strategic location	3.7	0.854
4	Energy sector development	3.67	0.924
5	Sustainability life	3.68	0.970
6	Role in Renewable energy transition	3.67	1.049
7	Photovoltaic for charging	3.56	1.143
8	Environmentally friendly technology	3.52	1.300

4.6 Impact-Uncertainty Analysis

Impact-uncertainty was analysed by plotting the mean of variables impact and uncertainty in a graph. Two drivers with the highest mean value of variables impact and uncertainty will be used for determining the future scenario. The mean of impact and uncertainty variables is displayed in Table 15. Using data in Table 14, a scatter plot was plotted as per illustrated in Fig. 3, and two drivers were chosen to generate future scenario. The highest plot in graph will be picked the two main driver.

Table 15 *Impact-uncertainty descriptive analysis*

No	Driver	Impact	Uncertainty
D1	Incentive and government policy	4.02	3.94
D2	Solar PV cost effectiveness	3.88	3.87
D3	Strategic location	3.91	3.7
D4	Energy sector development	3.88	3.67
D5	Sustainability life	3.83	3.68
D6	Role in Renewable energy transition	3.74	3.67
D7	Photovoltaic for charging	3.68	3.56
D8	Environmentally friendly technology	3.92	3.52

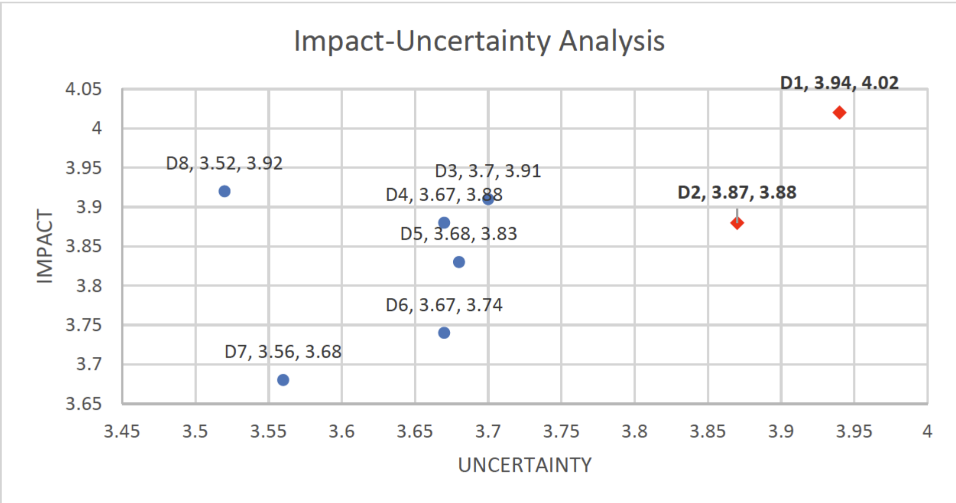

Fig. 3 *Impact-uncertainty analysis*

As illustrated in Fig. 3, the top two drivers were identified to have the highest impact and uncertainty for future trends of Solar Photovoltaic (PV) adaptation in Damansara Emas residential area. A high incentives and government policy (D1) can accelerate the adaptation rate of Solar Photovoltaic (PV) technology and have highest impact while cost-effectiveness of Solar Photovoltaic (PV) (D2) will be chosen as second driver for future scenario building as its second highest uncertainty after D1 and scenario building required two different drivers. These two drivers (D1 and D2) were used to build a scenario analysis in exploring the future trends of Solar Photovoltaic (PV) adaptation in Damansara Emas residential area.

5. Discussion

5.1 Issues and Drivers of Solar Photovoltaic (PV) Adaptation in Damansara Emas Residential Area

This section of the research reviews the literature in relation to solar photovoltaic systems using prior research as a guide. The conundrum and key factors in STEEPV analysis have been covered. The Social, Technological, Economic, Environmental, Political, and Values concerns would be examined using STEEPS analytical methodologies. The analysis covers all needs for implementing solar photovoltaic technology in Damansara Emas Residential Area as well as concerns and obstacles. By using secondary data as a source of knowledge, the researcher was able to pinpoint all of the major problems. All of the readings for this study came from online articles, journals, or newspapers where the data were divided into several categories (Social, Technological, Economic, Environmental, Political, and Values). The level of relevance, influence, and uncertainty was then determined by basing a questionnaire on the identified drivers and issues. The survey was given to residents of the Damansara Emas residential neighborhood using a Google Form, and the outcome was reached. As a result, the researcher discovered that all the factors that were identified as drivers for this study's adoption of solar photovoltaic (PV) technology were largely dependent on economic and political factors via the effectiveness of the technology and incentives, as well as government policy for Malaysians.

5.2 Future Trends of Solar Photovoltaic (PV) Adaptation in Damansara Emas Residential Area

The two main terms from the impact-uncertainty analysis were employed to create the scenario space and influence the narrative production as well as predetermined components to recognize the strategic issues that must be tackled in all scenarios. The alteration in the trajectory will be along the positive and negative planes. The right side will have positive polarity, while the left will have negative polarity. Therefore, these two factors—incentive and government policy (D1) and solar photovoltaic (PV) cost-effectiveness (D2)—are the study's two main driving forces. The four scenarios created for this research are shown in Fig. 4.

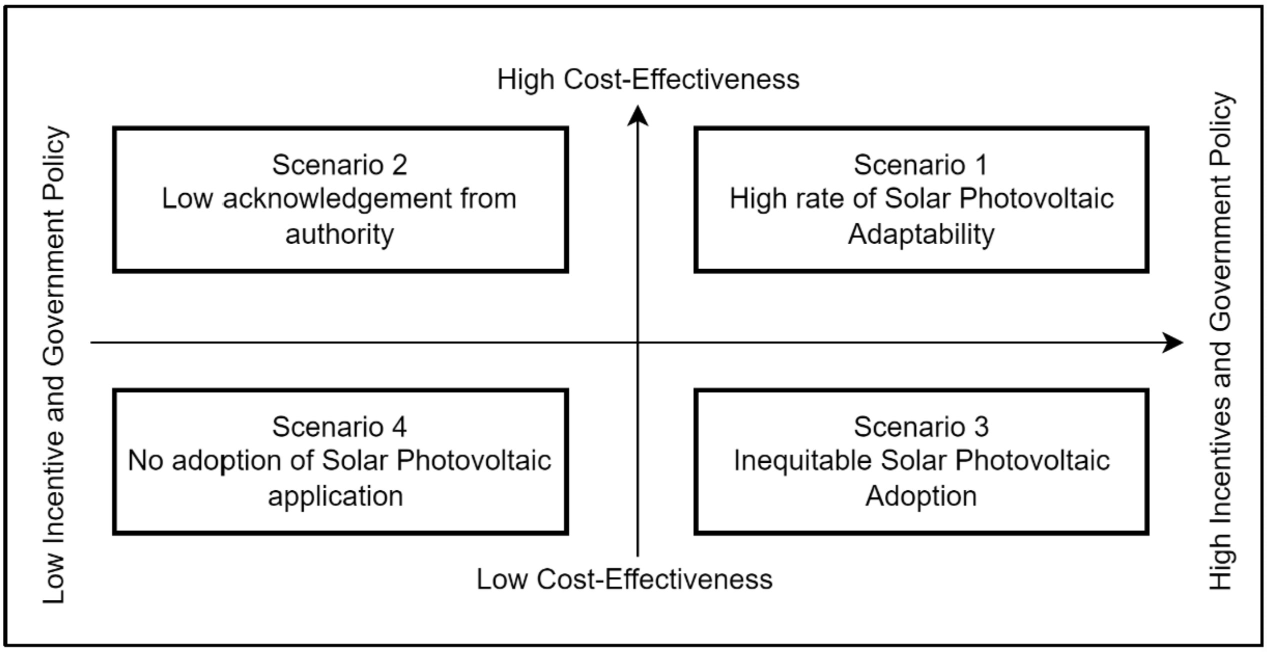

Fig. 4 *Scenario building*

In Scenario 1, the future where Solar Photovoltaic (PV) technology received support from local authority or government and the technology development has advanced to the point it become higher cost-performance, as the technology has matured and widely acknowledged for benefits it brought to adopters. The intention or desired to develop energy sector in Malaysia become more advance through countless effort by establishing policy and incentives for adopters bore fruit. A comprehensive analysis of emerging technology for energy generation and sustainability life with renewable energy source. To this end, an adoption rate of one technology mainly depends on financial status and the benefits that the technology able to provides. As for Malaysia, the research in this emerging technology has been conducted by many researchers to find the potential that Solar Photovoltaic holding. Financial support such as tax incentive or subsidy on the installation of Solar PV that currently only available for commercial adopters will increase the adoption rate (Lau *et al.*, 2022). With support from policy maker such as project Smart Putrajaya where most of building have solar panel to power the building, the development happens due to support and incentives from government. Besides that, the advancement of technology itself also level up its viability, along with its energy conversion that increased up to 20 percent and the priced of its system that reduced more than half over the past five years (A1A Solar Team, 2017, September 25).

Scenario 2 depicts low acknowledgement from authority. This due to low incentive and government policy to support the adoption rate or perhaps the process to acquiring the technology itself to installation process. With low incentives and government policy, it also means that the existence or application of the technology is not widely spread in Malaysia. Low acknowledgment could also come from rational that the technology is not necessary for the country yet, such as the country already possessed of another energy sources that pose a better solution for the country renewable energy sector and development. Even if the technology is high cost effective but it means nothing if the public awareness is low as the application of technology was not in the consideration in the first place.

In Scenario 3, Inequitable Solar Photovoltaic (PV) adoption, due to low cost-effectiveness, but high incentive and government policy, this outlined that the technology is still at its early stage of technology life cycle, and it also indicated that the output from technology is not comparable with the initial large sum investment. Thus, not every individual considered Solar Photovoltaic to be beneficial technology especially Low- and moderate-income (LMI) house, which leads to others variables such as g cash constraints, lower rates of home ownership, low level of awareness on Solar PV (Ardani, 2021). However, with high incentives and government policy will benefits the adopters of Solar PV not to those not capable of adopting it. This Inequitable PV adoption reflects to historical pattern of PV deployment that cause PV systems to cluster in high-income areas.

Lastly, Scenario 4 portrayed the worst scenarios and outcome as the researcher pointed out towards no adoption of Solar PV for residential rooftop application because of low incentives and government policy as well as the low cost-effectiveness. These two factors have become the reason for potential adopter to avoid the technology completely as there is no benefits from adopting the technology. In this scenario, it also depicted that the technology is low cost-effectiveness thus it justified that the technology cannot generate enough Return of Investment (ROI) that the adopter invested. This could be happening due to the technology is still at early stage of its Technology life cycle (TLC). Hence the performance is not that very favorable to the investor. Technology with low level of public acknowledgement will lead to low level of incentives and government policy to support its adaptation. In short, it is considered as impractical technology to adopt nor invest at all as it does not pose any significant benefits to adopter.

6. Conclusion

In conclusion, the first objective which is to identify issues and drivers that related to Solar Photovoltaic (PV) adaptation in Damansara Emas residential area. Therefore, the two key drivers with the highest impact and uncertainty mean were chosen from impact-uncertainty analysis. The first chosen key driver was Incentives and Government Policy and the second was Solar PV cost-effectiveness. Additionally, the second objective is to examine future trends of solar PV adaptation in Damansara Emas residential area. There are four scenarios on the future trends that were discovered from scenario building, which are “High rate of Solar Photovoltaic Adaptability”, “Low acknowledgement from authority", “Inequitable Solar Photovoltaic Adoption”, and “No adoption of Solar Photovoltaic application”. Through all these scenarios, it helps future researcher, market player, government, and resident to understand the foresight of Solar Photovoltaic adaptation in residential area.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** B.H.L. and S.A.R.; **data collection:** B.H.L.; **analysis and interpretation of results:** B.H.L.; **draft manuscript preparation:** B.H.L. and S.A.R. All authors reviewed the results and approved the final version of the manuscript.

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