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# ENHANCING THE IMPLEMENTATION OF SOLAR PHOTOVOLTAIC SYSTEMS IN COMMERCIAL BUILDINGS

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***Abstract*** — The escalating concerns regarding climate change, such as global warming due to the increase of carbon dioxide in the environment, have called for the urgent need for sustainable energy solutions such as solar energy. This study aims to determine the current adoption of Solar Photovoltaic Systems (SPS) in commercial buildings, identify barriers in the implementation of SPS in commercial buildings and recommend effective strategies for increasing the implementation of SPS in commercial buildings. The study employs the quantitative method using the questionnaire surveys, and the data collected are analysed using SPSS. Findings of the study show that 17 out of 51 commercial buildings in Klang Valley, Malaysia, have implemented SPS in the building, which indicates a low level of SPS uptake among commercial buildings. The most significant barrier hindering the implementation of SPS is found to be the high installation cost, while the most effective strategy for increasing the SPS implementation perceived by the respondents is by increasing the level of awareness on solar PV usage.

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***Keywords*:** Solar Photovoltaic System (SPS), renewable energy, solar energy, commercial buildings, construction

## 1.0 INTRODUCTION

Electrical supply is one of the essential aspects of our lives, playing a pivotal role in various industries. In recent years, the predominant method of generating electricity worldwide has been through the burning of fossil fuels. Many nations still burn fossil fuels to produce electricity [1]. However, this method of electricity generation is releasing harmful gas to the atmosphere and creating global warming due to the trapping of the emitted gas. A greenhouse gas called carbon dioxide causes global warming, and it is released through the burning of fossil fuels, together with other dangerous gases such as carbon monoxide, nitrogen oxides and sulphur dioxide [1]. Thus, it is a crucial matter to resort to a better and sustainable solution for electricity generation to cater for the electricity demand globally without compromising the environment's sustainability. This study aims to investigate the implementation of SPS in commercial buildings by determining the current implementation level of SPS and the barriers in the implementation of SPS. Hence, the recommendation of effective strategies for increasing the implementation of SPS in commercial buildings is vital.

### 1.1. Solar Photovoltaic System (SPS) as an Alternative Electrical Energy Solution

In light of the growing global demand for sustainable energy, the Solar Photovoltaic System (SPS) has emerged as a promising alternative to traditional electrical energy sources. The world is progressing towards the use of renewable energy due to the high demand for energy as well as increasing concern for the environment [2]. Solar energy carries the sustainable energy solution through the technology of the solar photovoltaic system (SPS). Photovoltaic (PV) technology has been discovered to be reliable and has an important potential for electrical generation in a sustainable manner. SPS is getting known more widely as the renewable energy solution, where the solar panels convert the solar energy into electricity, which is cleaner and less noisy than fossil fuels [3]. SPS uses the natural resource sunlight to generate electricity. Typical semiconductor materials are used to produce an electronic device called PV, which converts the sunlight directly into electricity [4].

In Malaysia, buildings consume 48% of the energy generated, with commercial buildings alone utilising up to 38,645 GWh, a notably high amount [5]. Thus, the commercial buildings are considered one of the highest consumers of electrical energy in Malaysia. Given the high demand for electrical energy in commercial buildings, implementing SPS is believed to provide a beneficial solution to various issues, particularly regarding environmental impacts caused by traditional electricity production. Commercial buildings refer to buildings that are intended for any use other than residential, manufacturing, or agricultural purposes; they include schools, hospitals, offices, and grocery stores. (Technology Roadmap for High-Performance Commercial Buildings, 2000) [6]. Therefore, this study aims to determine the current implementation level of SPS in commercial buildings, to identify the barriers in the implementation of SPS in commercial buildings, and to recommend effective strategies for increasing the implementation of SPS in commercial buildings.

## 1.2. Current Implementation Level of SPS

Solar energy price has decreased significantly over the past two decades, causing higher opportunities for its implementation, and it is expected that the residential solar capacity will fluctuate from 58GW in 2018 to 143GW by 2024 globally [7]. The decrease in solar energy production is expected to provide an opportunity to transition towards renewable energy sources like solar energy and shift away from the traditional method of burning fossil fuel in the future for electricity generation [8]. However, the study by the above researchers contradicts another study [9], which states that in Malaysia, despite the country being among the top 10 producers of solar panels, the PV market is still small, which further results in a low level of implementation if compared with other countries. Solar energy in Malaysia has not been widely developed [10]. The growth of solar energy in Malaysia has been slow due to the presence of barriers [11].

Additionally, Malaysia demonstrates relatively slow progress in implementing solar PV technology when compared to other countries [2]. Malaysia is still far behind in SPS uptake in comparison with other Asian countries, despite being located in the equatorial region, where the use of solar energy is promising [12]. Despite solar energy having enormous potential in Norway, the cumulative solar PV installed capacity is still small in the country [13]. The study conducted by previous researchers concludes that, despite the global decrease in solar PV production costs and the anticipated rise in SPS utilisation, the actual situation contradicts this prediction, as solar PV adoption remains slow. Despite the abundance of solar energy in Nigeria, only a few states have adopted SPS to minimise electricity bills [14].

However, in contrast with other countries, both solar PV and wind power have shown significant growth in the past decade, with yearly increments of 27% and 13%, respectively, in Zimbabwe [15]. Previous studies reveal that most countries, such as Malaysia and Norway, are making slow progress towards adopting SPS.

## 1.3. Barriers in the Implementation of SPS

### *1.3.1. Financial Barrier*

In the financial aspect, the high cost of purchasing and installing the SPS is a burden to many. The cost of solar PV in Thailand is still one of the major barriers that hinders the adoption of SPS, specifically for the small-scale rooftop SPS [16]. In Malaysia, high initial purchase cost is the main barrier to installing solar panels, with 59 out of 91 residential respondents agreeing to the statement [10]. Prior to the study on 225 individuals, more than 80% of the respondents stated their willingness to install solar PV; however, the respondents were startled upon knowing the high cost of installing solar PV, and the later result showed the likelihood of the respondents installing solar PV is shifting towards the “unlikely”, which shows that high purchase cost is the major hindrance to solar PV adoption [11].

A survey conducted by Jaffar et al. [17] also found that the low rate of SPS implementation is caused greatly by the high initial cost of SPS. The initial cost of SPS is the major barrier that affects the growth of SPS in Zimbabwe, since its cost is not affordable for many people [15]. The initial cost of SPS is the major barrier for the SPS growth despite its benefit for the people in urban and rural areas. Therefore, past research [18] suggests that the high initial cost is a major barrier to implementing SPS.

This is due to the high initial cost of SPS and the ongoing maintenance required throughout its operation period. Thus, some studies have shown that the high maintenance cost of SPS is another barrier that causes people to worry

about adopting it. High maintenance cost is the second major barrier after high initial cost that hinders the SPS adoption among 59 out of 91 respondents [10]. The high maintenance cost of solar panels can prevent the user from adopting the SPS [17]. One cannot abandon the need for maintenance of SPS since the system is operating and requires maintenance in the aspects of repairing, replacement and cleaning. According to Tarigan [19], the cost of rooftop SPS basically depends on several factors, such as system size, component quality and the location of installation, and further highlighted some of the main components of a typical rooftop SPS which the cost should cover, namely, solar panels, inverter, mounting and racking system, electrical wiring and safety equipment, and monitoring system, as well as operating and maintenance.

Some countries offer financial support for those who are willing to install SPS in their property. However, the financial support is limited and insufficient, thus hindering the SPS adoption. The International Energy Agency (2018), as cited in Xue et al. [13], stated that in Norway, although the public institution Enova covers a portion of the SPS cost for citizens, this coverage is relatively low, ranging from 10% to 30%. Consequently, citizens must pay between 50,000 and 105,000 NOK to install SPS in a single home, which is considered high. Jaffar et al. [17] also agreed that financial support for accessing capital is another barrier for SPS.

### *1.3.2. Government's Policy and Regulation Barrier*

Policy uncertainties are the barrier to SPS growth in Thailand, where the support for solar PV initiated in 2007 was disturbed along the three years from 2010 until 2013, and a brief support was introduced between October and November 2013 [16]. The uncertainties on the policy may cause certain investors to lose interest and confidence in investing in and utilising the SPS. The barrier to solar PV is also caused by the policy and regulatory instability where the cost-effective storage system does not exist and hinders solar from becoming the primary source of energy [15]. In addition to that, the absence of proper regulation in controlling the solar panels' quality has made the solar market in Zimbabwe to have been flooded with poor-quality solar panels that fail within 5 years of operation against the 25-year manufacturer warranty.

Next, the Norway authorities are lacking in providing efficient financial incentives to promote the PV market, which has become the barrier in SPS implementation [13]. It is further stated in Xue's study [13] that among the current incentives offered by the country's authority are subsidies for the initial cost. However, looking at the initial cost subsidy of 10 to 30%, the remaining cost is still considered high for people to invest in. The growth of solar energy has been slow due to a lack of consistency and promotion policies to develop renewable energy projects [20].

### *1.3.3. Technical Barrier*

The survey shows the lack of solar panel providers and lack of experienced technicians for maintenance and support for SPS are the barriers for SPS adoption among individuals in the northern region of Malaysia [10]. Additionally, Xue et al. [13] noted that the limited number of solar PV projects in Norway prevents people from learning due to a lack of opportunities for project reference, which has contributed to the slow growth of PV in the country.

### *1.3.4. Knowledge Barrier*

The lack of knowledge and awareness regarding the return on investment for solar power systems (SPS) and their benefits are major challenges that hinder the growth of the solar industry [21]. This barrier is also supported by Xue et al. [13], which stated many residents in Norway have no idea of the possible benefits of the SPS since there is a limited number of PV projects in the country. The lack of awareness and education about the financial benefits that SPS adoption brings can halt people's intentions to adopt a solar system [17]. This is understandable because people focus solely on the significant upfront cost of SPS, which causes them to overlook the long-term benefits and the shared advantages that everyone can enjoy.

The convenient application process is absent for people to sign up due to a lack of awareness of solar technology [21]. Additionally, financial institutions, such as banks, do not offer reasonable loan interest rates because they lack awareness of solar-PV-related financing options. In a study conducted by Florez & Ghazali [10] in Malaysia, they found that the lack of awareness of available financial incentives as well as the lack of knowledge about the Feed-in Tariff (FiT) programme were the barriers to SPS implementation. Besides that, Jaffar et al. [17] found that the lack of awareness of the alternative source of electricity generation is also the barrier to the SPS implementation.

*1.3.5. User's Perspective Barrier*

In the aspect of users themselves, Xue et al. [13] mentioned that the potential users, such as people and private entities, are having thoughts of uncertainty about surrounding risks, such as how much is the electricity that they will generate using the SPS, how long is the payback period and what are the potential risks that may come in the future, which become the barriers to the adoption of SPS. Besides, the researcher also mentioned the lack of communication among different stakeholders like bankers, construction companies, consulting companies and industry players that are involved in the PV project may hinder the SPS adoption by potential users. When communication does not exist among them, the knowledge transfer, understanding and acceptance of solar PV may not be established correctly, further becoming the barrier for solar PV adoption.

1.4. Strategy to Increase the Implementation of SPS

*1.4.1. Financial Aspect*

Looking back at the barriers to the implementation of SPS in the previous study, the most highlighted barrier comes from the aspect of finance, where many are expecting some sort of financial support and incentives from relevant parties to purchase the solar PV. To enhance the household intention in Malaysia to utilise solar PV, the stakeholders in the solar PV industry should cooperate effectively with each other on offering financial incentives as well as long-term financial support for those who purchase the solar PV [2]. Similarly, Guno [22], through their study in 2021, suggested that the government in the Philippines should offer subsidies to those who adopt cleaner technology like solar PV. This act from the government may give encouragement to the public, given that they will enjoy the subsidies and also get the return of investment in the long run. However, in the similar study by Guno [22], they also recommend the government impose a carbon tax for those who are using the electricity from the burning of fossil fuels. This act does look strict if being imposed by the government since it portrays the public as being forced into purchasing solar PV technology.

Guno [22] also recommends another strategy to increase SPS adoption, where the financial institutions, like banks, should provide more affordable payment terms to capture the interest of the low- to medium-income households to purchase solar PV. Besides, to grow the solar PV implementation in Malaysia, the financial support must be properly made available [9]. In other words, a previous study recommends offering long-term financial support as a strategy to boost SPS adoption.

*1.4.2. Policy Aspect*

In each country, the government's policy, regulation and uptake play a crucial role in the successful delivery and implementation of any project. Government policy plays a crucial role in encouraging the public to adopt cleaner energy through the use of solar PV. The formulation and implementation of effective government policies are paramount in shaping the success of a nation's pursuit of specific objectives, in which case the objective is to encourage more adoption of solar PV. To further enhance the solar PV utilisation in Malaysia, well-crafted policies and strategies that directly focus on decreasing the installation cost of solar PV must be made [11]. Besides, Alam [2] suggested in their study that the Malaysian government should establish consistent, standardised and uniform policies involving the adoption of solar PV technology. Consistency in policies is essential to provide stability and predictability in governance. It means that the government's actions and regulations should be steady and unwavering, avoiding abrupt changes that could create confusion or uncertainty among citizens, businesses, and other stakeholders.

Apart from that, more effective policies regarding solar PV utilisation must be put in place. The environmental awareness among users must be enhanced by creating more effective policy targeting towards a more environmentally friendly living, like encouraging people to stop using single-use plastics, which in the end shall improve the public's awareness [23]. The public with improved environmental awareness would be adopting SPS, as its utilisation is benefiting the environment since it promotes clean energy. Besides, Husain [9] recommends that Malaysia should improve its policies on solar PV implementation since the available policies still have their limitations, and the most successful program run by the government is FiT since it is the most profitable. Thus, policymakers must work hand in hand with the relevant party to come up with the most effective policy on solar energy, which triggers the people to utilise solar PV.

*1.4.3. Knowledge Aspect*

Having the right information and sufficient knowledge on solar PV are very essential in driving the public towards SPS adoption. With the information provided by relevant parties, the public can reason and critically evaluate their investment in cleaner energy through SPS. Alam [2] agreed that conducting an informative campaign to educate the citizens on the solar PV utilisation by the Malaysian agency, like the energy commission, is crucially needed. This is further supported by Cheam [23] in their study, where they recommend the collaborative effort by the Malaysian Energy Commission and solar PV vendors is needed in providing the accurate information regarding solar PV to Malaysians. This shall help the public and private entities to be well equipped with the genuine information regarding the cleaner energy adoption using SPS, like the benefits it brings not only to the user in the aspect of finance but also, crucially, to the environment. The knowledge on solar PV is crucial for the public sector, private sector and the community, thus suggesting the establishment of an online and offline data-sharing platform regarding solar PV [13]. Through this platform, government and business entities can provide relevant information on solar PV usage to the public. Online data sharing may be accessed through the website, where offline information sharing can be done by conducting workshops and presentations to the public.

There is a need to enhance the awareness level among citizens of Malaysia regarding the advantages of solar PV adoption in order to boost the rate of solar PV usage [11]. Training programmes for residents on solar PV usage as well can help to educate and further increase the adoption of solar PV among residents in Malaysia [2]. The awareness of solar PV adoption towards energy saving in mosques should be done in the form of training and education programmes [17]. Delivering the right amount of information to people is crucial because solar PV is a cleaner technology that requires users to understand it in order to be well-equipped with knowledge.

## 2.0 METHODOLOGY

This chapter outlines the research methods adopted to achieve the objectives of the study. A quantitative research approach is employed to ensure a systematic and objective analysis of the data. To gather the necessary information, questionnaire surveys are used as the primary data collection tool. This approach allows for the efficient collection of data from a diverse group of respondents, ensuring the reliability and validity of the findings. Figure 1 below shows the flow of the activities involved in the research process.

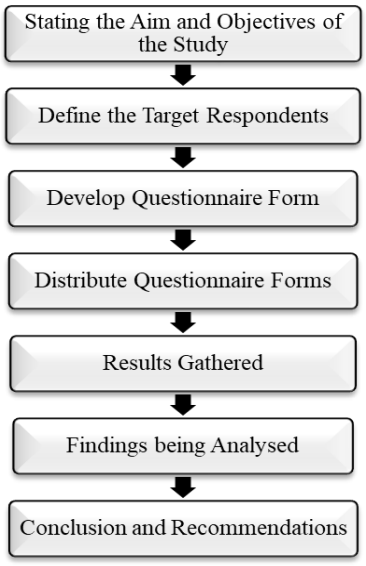


**Figure 1:** Flow of the research process

2.1. Questionnaire Design

The questionnaire distributed to the respondents consists of four (4) parts which cover the objectives of the study. Part A of the questionnaire comprises questions intended to identify the respondent's demographic background, such as the years of working experience, job position of the respondent, location of the commercial buildings, as well as the type of commercial building the respondents are managing. Part B covers the questions dedicated to determining the current level of SPS implementation in the commercial buildings managed by the respondents.

Meanwhile, questions contained in Parts C and D were intended to gain insight on the barriers and effective strategies of SPS implementation in commercial buildings.

2.2. Sampling and Population

The study focuses on the implementation of rooftop SPS on three types of commercial buildings, which are shopping malls and supermarkets/hypermarkets in Klang Valley. The study targeted the respondents who manage commercial buildings where the scope of work is across the areas of project management, building management, and facility and maintenance management of the particular commercial building. Based on the data obtained from the National Property Information Centre (NAPIC), as shown in Table 1, there are a total of 892 commercial buildings comprising corporate offices/office buildings, shopping malls and supermarkets/hypermarkets in Klang Valley.

**Table 1** Number of Commercial Buildings in Klang Valley (NAPIC, 2024)

| Location | Shopping mall | Supermarket/Hypermarket | Corporate Office/Office Building |
|---|---|---|---|
| **A) Kuala Lumpur** | 76 | 7 | 417 |
| **B) Selangor** | 88 | 51 | 253 |
| **Subtotal** | 164 | 58 | 670 |
| **Total Commercial Buildings** | | 892 | |

The sampling and population for this study were determined based on the objectives of evaluating the implementation of solar photovoltaic systems (SPS) in commercial buildings. The target population comprised professionals managing or involved with commercial buildings, including facility managers, engineers, and other relevant stakeholders. The sampling method employed aimed to capture diverse perspectives within the targeted demographic.

However, due to time constraints and challenges in reaching the target respondents, the study distributed 124 questionnaire surveys. Out of these, 51 completed surveys were returned, resulting in a response rate of 41.12%. Although the response rate is moderate, it is sufficient for quantitative analysis, as it aligns with acceptable thresholds in survey-based research, where response rates between 30% and 50% are often considered adequate. This response rate reflects the accessibility and willingness of the target population to participate within the limitations of the data collection period.

2.3. Data Analysis

The data gathered within this study is analysed using IBM SPSS, where the two types of data analysis are employed using the software, namely frequency analysis and descriptive analysis. In this study, the frequency analysis is employed on the data gathered, referring to the demographic background of respondents such as the location of commercial buildings, job positions and types of commercial buildings, as well as regarding the implementation level of SPS in commercial buildings. Meanwhile, the descriptive analysis is applied to the data gathered, where the barriers and effective strategies of SPS implementation in commercial buildings were explored, with the mean value being the indicator.

## 3.0 RESULTS AND DISCUSSION

3.1. Demographic Survey

Referring to Tables 2, respondents from shopping malls made up 52.90% of the total respondents and are dominating the types of commercial buildings which participated in the survey. It is then followed by 31.40% of

respondents representing Corporate Office/Office Building and 15.70% of respondents representing Supermarket/Hypermarket.

The commercial buildings participating in this survey are mostly located in Kuala Lumpur, which made up 35.30% of the total percentage. Petaling is the second dominant area of the commercial building, with a percentage of 23.50%, followed by Klang, with a percentage of 17.60%. Gombak and Hulu Langat, on the other hand, are the areas with the fewest commercial buildings, located at a total percentage of 11.80% each, which is equivalent to 6.

The respondent's designation in the commercial building varies from project management, building management, facility and maintenance management, and operation management, just as intended by the researcher. The respondent's background is classified according to the managerial and executive level. Most of the respondents are designated as the Facility & Maintenance Manager, which makes up 43.10% of the total respondents.

The working experience of the respondents who participated in the questionnaire survey shows a diverse range of experience levels. The largest group of respondents, which made up 43.10% of total respondents, has less than 5 years of experience. It is then followed by those with 5 to 10 years of experience, which made up 25.50% of the sample. Respondents with 11 to 15 years of experience account for 21.60%, while those with 16 to 20 years and more than 20 years of experience represent 5.90% and 3.90%, respectively.

The data regarding the level of familiarity of SPS is also collected to understand the state of knowledge of the targeted respondents. The question basically asked how much the respondents know or understand about SPS and whether they have knowledge, information or experience with SPS. The largest group of respondents, making up 41.20% of the total percentage, is neutral regarding their familiarity level. A moderate level of 29.40% of respondents are familiar with SPS, followed by those who are not familiar, which make up 21.60% of the total percentage. This table shows that while a significant portion of respondents have a certain level of familiarity with SPS, there is also a notable portion of respondents who lack familiarity, while a large segment is maintaining a neutral stance.

### 3.2. Current Implementation Level of SPS in Commercial Buildings

Table 3 below shows the result where it was found that 34 commercial buildings have not implemented SPS yet, which makes up 66.70% of the total percentage. The remaining 17 commercial buildings have implemented SPS in the building rooftop or car park, equivalent to 33.30% of the total percentage. By referring to this result, it suggests that there is a relatively low level of SPS implementation in commercial buildings that have been surveyed. This result aligns with the literature review conducted previously by Husain et al. [9], as cited in [2, 10, 11], where it was suggested that the growth and implementation level of SPS are still low and slow in progress.

**Table 2** Demographic Survey

| **Types of Buildings** | **Items** | **Frequency** | **Percent** |
|---|---|---|---|
| Type of Commercial Buildings | Corporate Office / Office Building | 16 | 31.40 |
| | Shopping mall | 27 | 52.90 |
| | Supermarket/Hypermarket | 8 | 15.70 |
| | Total | 51 | 100.00 |
| Location of Commercial Buildings | Kuala Lumpur | 18 | 35.30 |
| | Gombak | 6 | 11.80 |
| | Petaling | 12 | 23.50 |
| | Klang | 9 | 17.60 |
| | Hulu Langat | 6 | 11.80 |
| | Total | 51 | 100.00 |

**Table 2** Demographic Survey (cont'd)

| Types of Buildings | Items | | Frequency | Percent |
|---|---|---|---|---|
| Respondent's Designation in the Commercial Building | Project Manager | | 2 | 3.90 |
| | Building Manager | | 7 | 13.70 |
| | Facility & Maintenance Manager | | 22 | 43.10 |
| | Operation Manager | | 4 | 7.80 |
| | Assistant Building Manager | | 1 | 2.00 |
| | Senior Operation Executive | | 2 | 3.90 |
| | Building Executive | | 4 | 7.80 |
| | Facility & Maintenance Executive | | 9 | 17.60 |
| | | Total | 51 | 100.00 |
| Respondent's Experience Undertaking Current Job Scope | Less than 5 Years | | 22 | 43.10 |
| | 5 to 10 Years | | 13 | 25.50 |
| | 11 to 15 Years | | 11 | 21.60 |
| | 16 to 20 Years | | 3 | 5.90 |
| | More than 20 Years | | 2 | 3.90 |
| | | Total | 51 | 100.00 |
| Respondent's Level of Familiarity on SPS | Not Very Familiar | | 2 | 3.90 |
| | Not Familiar | | 11 | 21.60 |
| | Neutral | | 21 | 41.20 |
| | Familiar | | 15 | 29.40 |
| | Very Familiar | | 2 | 3.90 |
| | | Total | 51 | 100.00 |

**Table 3.** Current Implementation Level of SPS in Commercial Buildings

| Current Implementation Level of SPS in Commercial Building | Frequency | Percentage |
|---|---|---|
| No (Not Implemented) | 34 | 66.70 |
| Yes (Implemented) | 17 | 33.30 |
| Total | 51 | 100.00 |

3.3. Barriers for SPS implementation in Commercial Buildings

The overall result, as shown in Table 4 below, indicates that the most significant barrier suggested by respondents in the implementation of SPS in commercial buildings is the high cost of installation (4.1373). This finding aligns with previous studies that have discussed the high cost of installation as the major barrier to SPS implementation [10, 13, 15, 16, 17, 18]. The mean score of this barrier leaves quite a gap with the second-ranked barrier, which indicates that the cost of purchasing and installing is still a burden to many commercial buildings.

3.4. Effective Strategy for Increasing the Implementation of SPS in Commercial Buildings

The overall result of effective strategies suggested to respondents is ranked as per Table 5 below. It was found that respondents perceived increasing levels of awareness on solar PV usage, with the mean score of 4.2353 as the most effective strategy out of the 10 strategies. This finding is aligned with the strategies suggested by previous research, which crucially pointed out that enhancing the awareness level among citizens of Malaysia regarding the advantages of using SPS is needed for boosting the SPS implementation. Respondents believe in the accurate information and knowledge delivered to them regarding the SPS as the alternative energy solution and the benefits it brings not only to the user but also to the environment.

**Table 4:** Findings on Barriers Hindering the Implementation of SPS in Commercial Buildings

| Code | List of Barriers | Mean | Std. Deviation | Rank |
|---|---|---|---|---|
| BF1 | High Cost of Installation | 4.1373 | 0.66392 | 1 |
| BK1 | Lack of Awareness on Feed-in Tariff | 3.6275 | 0.72002 | 2 |
| BK2 | Unavailability of Easy Application Process and Reasonable Loan Interest due to Lack of Awareness | 3.6275 | 0.77358 | 3 |
| BU1 | Lack of Communication Among Different Stakeholders | 3.5882 | 0.87582 | 4 |
| BK3 | Limited Information and Awareness of Possible Benefits | 3.5686 | 0.85452 | 5 |
| BU2 | Uncertainty on Surrounding Risks | 3.5294 | 0.83314 | 6 |
| BK4 | Lack of Knowledge on Financial Support | 3.5098 | 0.70349 | 7 |
| BP1 | Lack of Consistent and Promotive Policies | 3.4902 | 0.78416 | 8 |
| BK5 | Lack of Knowledge on Alternative Source of Energy | 3.4902 | 0.90272 | 9 |
| BK6 | Lack of Knowledge on Solar PV Financial Return | 3.4510 | 0.87895 | 10 |
| BP2 | Lack of Efficient Incentives | 3.4314 | 0.83078 | 11 |
| BF2 | Limited Access to Capital | 3.3725 | 0.72002 | 12 |
| BF3 | Limited Financial Support | 3.3529 | 0.82033 | 13 |
| BF4 | High Cost of Maintenance | 3.3333 | 0.73937 | 14 |
| BT1 | Lack of Experienced Technician for Maintenance and Support | 3.2745 | 0.93975 | 15 |
| BP3 | Policy Uncertainties | 3.2549 | 0.86817 | 16 |
| BP4 | Lack of Government Incentives Programme | 3.2549 | 0.86817 | 16 |
| BT2 | Limited Solar PV Projects | 3.2549 | 0.93473 | 17 |
| BT3 | Lack of Solar Panel Providers | 3.0784 | 0.89091 | 18 |

**Table 5:** Findings on Effective Strategy to Increase the Implementation of SPS in Commercial Buildings

| Code | List of Effective Strategy | Mean | Std. Deviation | Rank |
|---|---|---|---|---|
| SK1 | Increasing Level of Awareness on Solar PV Usage | 4.2353 | 0.61930 | 1 |
| SK2 | Offer Training Program | 4.2160 | 0.6104 | 2 |
| SK3 | Providing Accurate Information and Knowledge on Solar PV to Public | 4.1961 | 0.63308 | 3 |
| SF1 | Providing Financial Incentives to SPS User | 4.1373 | 0.63308 | 4 |
| SP1 | Creating More Effective Policy | 4.1176 | 0.55307 | 5 |
| SP2 | Standardizing Policies by the Government | 4.0588 | 0.58006 | 6 |
| SF2 | Providing Bonuses or Awards to SPS User | 3.9608 | 0.74728 | 7 |
| SF3 | Providing Long-Term Financial Support | 3.9412 | 0.58006 | 8 |
| SP3 | Establishing Policy on Reduction of Solar Installation Cost | 3.9412 | 0.70461 | 9 |
| SF4 | Providing Interest-Free Loan | 3.8235 | 0.91007 | 10 |

## 4.0 CONCLUSION

In conclusion, this study presents key findings on the current implementation level of solar photovoltaic systems (SPS) in commercial buildings, revealing that adoption remains low. A major barrier identified is the high perceived cost of SPS installation, which discourages widespread implementation. Additionally, the study highlights that increasing awareness of the benefits and potential of solar PV usage is the most effective strategy for boosting adoption. To address these issues, future research should focus on conducting financial analyses of SPS investments to better understand cost-benefit dynamics, undertaking comparative studies of SPS policies and programmes across different regions to identify best practices, and exploring the potential for SPS implementation in various types of commercial buildings. These efforts will contribute to overcoming current challenges and accelerating the integration of SPS, ultimately supporting a sustainable energy transition in the commercial sector.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.


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