Review on Determinants Influencing Solar PV Adoption in Malaysia: A Conceptual Framework

PAULINE CHOO, JAYARAMAN KRISHNASWAMY, REE CHAN HO,
MOHD FAIZAL BIN FAUZAN
Taylor's Business School,
Taylor's University,
Subang Jaya, Selangor,
MALAYSIA

Abstract: - The aim of the paper is to review extensively the extent of the adoption of solar PV panel installation in residential areas to get an idea of the extraction of the available solar energy. Elaborate content analysis is provided for the extraction of renewable energy and sustainable energy security measures which are the crucial functions of the installation of solar PV panels. The study proposes a research framework with the help of literature by applying the Theory of Planned Behavior model with determinants factors that affect the adoption of solar PV panel installation namely, attitude, subjective norm, availability, affordability of cost, efficiency, and acceptability. The present study is expected to contribute to the literature by shedding light on the identified sustainable energy security practices in the context of solar energy. Further, the study is an eye opener to create awareness of the alternative measures of generating electricity using free natural resources.

Key-Words: - Malaysia Solar PV Adoption, Sustainable Energy Security, Theory Planned Behavior, Attitude, Subjective norm, Availability, Affordability, Efficiency, Acceptability.

Received: June 2, 2022. Revised: November 4, 2022. Accepted: December 4, 2022. Published: December 31, 2022.

1 Introduction

The role of energy in the everyday basis of human extends to body functions, food preparation, and social activities such as agriculture, transportation, industrial activities, communication, and so on. According to [1] the dependency on energy increased through the age of Industrial 4.0, Artificial Intelligence (AI) technology, and Big Data generation. However, the dependency on the energy sourced from depleting resources of fossil fuel components, such as coal, natural gas, and petroleum has its concern. In [2] the authors argued that these high dependencies should pave the road for policymakers to propose alternative approaches to energy generation that also can reduce carbon footprints.

The high energy demand over the supply provides evidence that the discourse around energy security is highly warranted in policymaking, [3]. This is supported by [4] who emphasized that energy security is an issue that is critical to policymakers, businesses, and communities that are dependent on an uninterrupted energy supply. Around the world, China is becoming the world's largest energy consumer at 3381 million tons of oil equivalent (Mtoe) since 2009 due to its vast economic growth and industrialization revolution. In Malaysia, the energy consumption is recorded at 88 Mtoe [5], but the demand is increasing in 2018 which a growth rate of 2.3%.

According to [6] the demand rate surpassing the supply rate led to a high dependence on fossil fuels and imported energy in Malaysia. For example, more than 80% of Malaysia's electricity sources are from coal and natural gas. However, the coal consumed in the processing power plants is mostly imported from South Africa, Australia, and Indonesia [7]. This compels an argument that despite the economic identity of Malaysia as an oil producer, the dependency on foreign resources (import resources) is still higher. Furthermore, the projected lane of Malaysia to become a net energy importer by the end of 2030 will not be realized unless new energy sources are developed within the country to fulfill the demands. Thus, there is a need to propose an alternative to energy consumption especially an electricity-based alternative to ensure the sustainability of energy in a long run.

One of the common alternatives to energy resources is solar energy. Solar energy is a type of energy that is harvested from the sun, [8]. In [9] the authors listed several advantages of solar energy. First, the properties of solar energy are abundant and renewable energy. Secondly, solar energy is a

dependable source of energy due to its function that is not exhaustible thus providing solid and increasing output efficiencies than other sources of energy. The utilization of solar energy also proved to be free from any detrimental impact on the ecosystem. Lastly, the system of solar energy is flexible and can be utilized in village systems, industrial operations, and homes, and is affordable compared to other energy sources. The driving force behind solar energy is the amount of energy it is able to convert into electricity.

However, solar energy is highly dependent on the amount of sun available which is solar radiation. This provides an advantage to Asian countries as the high sunshine duration per year led them to receive higher solar radiation compared to other temperate countries [9]. This relates to the system of solar photovoltaic (PV) applications for electricity generation in Malaysia. Solar PV energy is defined as the direct translation of solar illumination (radiation) into electricity, [10]. The application of PV in tropical countries such as Malaysia with hot and sunny climates is appropriate due to the suitable sun exposure of roughly 4.0-4.9 kWh/m2/day [11]. This prompts the PV application of Large Scale Solar (LSS) and Rooftop Solar in Malaysia.

According to [12] the advantages of solar energy (PV) extend toward wide-range aspects of environmental, economic, technological, distributional, and social impacts. In [13] the authors stated that there is a significant positive correlation between the number of energy efficiency measures and the reduction of household electricity usage. This shows that the PV application also benefits the users economically besides the environmental impact. In [14] the authors listed several benefits of adopting Solar PV. They reported that Solar PV has great security value attributed to the potential of reducing outages, and as the alternative backup power source available during outages. Besides that, they found the role of Solar PV to reduce carbon emissions thus reducing compliance costs or carbon taxes, and lessening the impact of climate change due to ecosystem damage.

The socio-economic implication inclines toward the job opportunity created by the PV system including the installation process. Despite the great benefits of Solar PV, there is a concern about the cost of installation assumed by consumers. According to [15] the low adoption of PV is affected by net economic impacts on both the utilities and retail rates. Hence, the aim of this study is explained in the section below.

1.1 Research Objective

The purpose of this research is to review the current state of solar PV adoption in Malaysia and determine the factors associated with solar PV adoption based on past studies. Then, proceed to propose a conceptual framework relating to the intention of solar PV adoption in Malaysia as a result of this paper. The focus on solar PV centrally lies in maximizing the adoption and reducing the cost of installation, [16]. This paper attempts to review factors associated with solar PV adoption and proceed to propose a conceptual idea according to reviewed studies. The research questions (RQs) identified in this paper stated as follows:

RQ1: What is the current state of solar PV adoption in Malaysia?

RQ2: What are the factors associated with solar PV adoption based on past studies?

2 Literature Review

2.1 The State of Solar Energy in Malaysia

Sustainable Energy Development Authority (SEDA) Malaysia was established in 2011 to administer and manage the implementation of the feed-in tariff (FiT) mechanism mandated under the Renewable Energy Act 2011, [17]. This mechanism under SEDA allowed consumers to sell electricity generated from renewable resources (up to 30MW) to power utility firms through the process known as FiT implementation. Solar PV is among the renewable energy included for FiT eligibility. According to [18] the application for FiT quota of Solar PV was positive due to its familiarity with electricity generation compared to other renewable sources.

Encouragement towards adopting Solar PV is extended after the FiT scheme ended. The Malaysian government introduced the initiative of Net Energy Metering (NEM) through Eleventh Malaysia Plan. The NEM aimed to lower the cost of monthly electricity for consumers through the earned from the excess generated energy. The energy produced by the installed Solar PV system will be utilized first, and the excess energy can be exported and sold to the distribution licensee. Malaysian government limited the solar panel installation of consumers accredited by SEDA approval. Currently, there are 157 registered Solar PV service providers listed on the SEDA official web portal, [19]. These providers are responsible to help consumers with the process of application and installation of solar PV. The role of providers in

supporting the consumers with the process of Solar PV installation and after-support service is emphasized by Qureshi et al., (2017) [20].

The state of solar PV (energy) in Malaysia is improving through the stated initiatives by the Malaysian government. Through each Malaysian Plan, the awareness towards heavy reliance on non-renewable energy resources was identified, thus igniting several plans that open an opportunity for Solar Energy. The adoption of solar PV is crucial from various perspectives including efficiency, economic, environmental, and sustainability. One of the effective actions to encourage adoption is through policies. Local policies towards solar energy exert a substantial impact on its adoption at the household level, [21].

2.2 Renewable Energy Policies in Malaysia

In Malaysia, the New Economic Policy (NEP 1971-1975) of the Second Malaysia Plan paved the way toward sustainable development. Due to the global oil issues causing uncertainty in prices and supply, the Malaysian government initiated an energy efficiency initiative with few policies on hand, [22], [23]. The first policy under National Petroleum Policy (1975) under Third Malaysia Plan (1976-1980) did not cover the electrical sector despite the focus on petroleum resources. The Four Fuel Policy 1981 (4FDP 1981) aimed to balance the usage of oil, gas, coal, and hydroelectricity to address the overdependence on crude oil as primary energy. However, this intervention in new energy resources (hydroelectricity) was lacking in awareness among the mass public.

The policy was revised in the Eight Malaysia Plan (2001-2005) with Renewable Energy Sources (RES) formally presented as the fifth fuel in the energy mix known as Five-Fuel Diversification Policy 2001 (5FDP 2001). Through this policy, the harnessing of solar energy was emphasized among other energy, [11]. The move towards renewable energy was extended in the latest Eleventh Malaysia Plan (2016-2020) which targets to achieve 20% of renewable energy in the energy mix by the year 2025. In this plan, the focus was to increase the solar energy generation capacity which potentially opens new business opportunities for big companies, SMEs, micro businesses, and households, [24], [25].

Despite the efforts, there is a stream of dissatisfaction among consumers of renewable energy due to poor community engagement, and cost-issue with unmatched pricing versus tariff, [26]. The issue with the Solar PV cost and other barriers was cited by scholars in their studies regarding Solar PV presented in the next section.

2.3 Past Studies on Solar PV Adoption

A case study in [20] reported that the barriers to Solar PV adoption included the cost bear by consumers to buy and install, the complexity and difficulty of using multiple appliances at the same time, shortages of vendors and technical support, and lack of financial support by the government at the household level. In [27] they found that concern about electricity increase rates, economic factors, and future planning was the deciding factor for households to adopt Solar PV. They also reported that peer pressure and the solar installation processes are also the determining factors for the adoption.

Also, [27] emphasized the importance of a marketing base to provide information to households on the information relating to solar-generated electricity, future adoption, and solar installers to disseminate more awareness on Solar PV benefits. This is proved by the study conducted by [28] among households in Sweden. Their study focused to establish an information campaign as a medium to encourage Solar PV adoption among households. The result of their study showed that informational campaign significantly drives a positive effect on Solar PV adoption rates with a 29% increase in the submitted application. Another study by [29] identified a list of barriers and motivations to Solar PV adoption to generate factors of the adoption among households in Santiago, Chile. They presented factors such as information that is straightforward to provide a comparison, attractive financial incentives, and installation-aspect as the strategies to encourage Solar PV adoptions.

Qualitative semi-structured interviews among households were used by [30] to identify the case of Solar PV adoption in Finland. They reported that the households that adopted Solar PV had a good satisfaction rate with their PV plant through the pleasure of having a mechanism of pollution-free energy. Most of the adopters were reported to enlarge their Solar PV system. It was also highlighted in the study that the experts and peers-adopters played a big role to provide advice and co-operate with information on the installation process, costs, and energy amount, [30]. A similar qualitative methodology was utilized in [31]. Their study relates to barriers and motivation to Solar PV adoption among Nigerian households. Their findings point to the economical barrier citing a lack of financial commitment and high capital costs

to adopt Solar PV. The motivational aspects were energy saver option, reliance on fewer power outages, and greater financial access.

In Malaysia, the state of Solar PV adoption is relatively new. According to [32] the deployment of Solar PV in Malaysia is still in the initial stage. Despite the strong potential of Malaysia for Solar PV adoption due to its equatorial location and the support from the government's initiatives through research projects and programs, increased R&D efforts are required to overcome the economic barrier of high capital investment, [33]. However, few scholars bring attention to the Solar PV adoption state in Malaysia, [34], [35], [36], [37].

[34] conducted a study to determine the public inclination toward adopting Solar PV in Malaysia and utilized a quantitative survey questionnaire to gather data from residents in Peninsular Malaysia. Three factors were found namely, perceived usefulness, perceived ease of use, and attitude to use influenced the residents to adopt Solar PV. In [35] the authors argued that despite the vast basic knowledge regarding science, low-income Malaysians had average awareness of solar energy. However, the respondents had a high level of acceptance of the Malaysian government's plans for solar energy compelled by the increase in their household incomes. In [36] the authors investigated the behavioral intention of non-users in Klang Valley towards their inclination toward Solar PV. They found the aspect of cost has a significantly higher impact compared to knowledge and facilitation.

Through a survey questionnaire methodology to non-solar PV users in Klang Valley, Malaysia by [37] the authors found that the aspect of being aware of the environment-sustainability and knowledge are the biggest contributor to the intention to adopt Solar PV. The aspect of usefulness also mediates the relationship as well. The studies of Solar PV adoption in Malaysia showed that the information relating to Solar PV on the environmental benefit, economic benefit, and usefulness are at the state of needing improvement. They further stressed the need for aggressive Research and Development (R&D) program. To adhere to and reduce the cost of Solar PV, the government is encouraged to improve the R&D and capital investment for integration of solar manufacturing facilities to boost growth, thus, in line with the effective tool for sustainable energy security, [38].

In [32] the authors highlighted that the lack of policy towards suitable renewable energy is one of the factors for the low adoption. The concern on sustainability and depletion of fossil fuel and peak oil issues also addressed the need for energy security. Renewable energy source, solar particularly is warranted to provide energy security, [38]. The policy around energy security revolves around strategic plans to reduce the risk of supply interruptions to an acceptable level. These plans should be addressed and adjusted to ensure a steady supply of inexpensive energy to cater to demand, [6], [39], [40].

Global policymakers and industry players are striving into fostering Solar PV adoption despite the slow growth of consumers' interest. Presented studies by past scholars showed that there are multiple challenges in adopting Solar PV from consumer (household) perspectives. Table 1 summarised the challenges to adopting Solar PV based on past studies.

3 Research Methodology

This study begins by identifying the research gap by conducting reviews from various databases in scholarly literature. Among the selected scholarly sources are Science Direct, Google Scholar, ProQuest, JSTOR, and Research Gate. These sources are the primary sources to review the published manuscripts regarding Solar PV adoption. In addition, information regarding the initiatives and policies of Solar PV in Malaysia was obtained from the government's documents and portal. Next, a thorough review was performed in answering the RQs. Finally, based on the findings from the literature review, this study developed a conceptual research framework on the intention of solar PV adoption in Malaysia.

4 Review Analysis and Findings

After reviewing selected journal articles listed in Table 1, it is found that cost was regularly mentioned by past scholars, [20], [27], [29], [31], [36] as the challenge for households to adopt Solar PV. The perceived higher cost of owning Solar PV led them to believe it is unparallel to their income range compared to traditional electricity-based energy. This is supported by [41] who mentioned that the Solar PV installations scale is not cost-competitive as opposed to fossil-fuel power plants. The growing energy mix of solar power is only attainable through low-cost storage, [42].

Past scholars [20], [27], [29], [30] also cited the installation process of Solar PV as one of the barriers to owning renewable energy. The

installation process is considered a major part of Solar PV due to the need to have a trusted vendor which will provide regular services through the availability of experts and technicians. The perception that the vendors are less familiar with Solar PV led to a lack of interest from the users.

Besides that, there is also a factor of usefulness which is cited by several past scholars, [20], [34], [37]. This includes the adaptation towards Solar PV homes, ease of using the appliances, and the useful factors weighted more than the traditional electricity system. Most past scholars, [27], [28], [29], [35], [37], stressed the importance of information awareness on knowledge of adopting Solar PV. The awareness towards deficiencies of natural resources and the environment can be further improved with the campaign by the government, subsidies incentives, good marketing strategies, and also education from an early age.

This will allow the last challenge which is the attitude, [34], towards Solar PV inherent to a positive adoption. Attitudes play a significant role to form the intentions of households in adopting Solar PV, [43]. The attitude may vary in relation to the financial access linked with knowledge. According to [44] individuals with financial resources tend to adopt Solar PV due to environmental values satisfaction while low-financial resources individuals worried about limited financial access and fear of power outages.

One of the gaps identified was the majority of the researchers are from the perspective of western countries and only a few articles are from the Malaysian perspective, [35], [36], [46]. The usage of solar PV technology in the household context has been studied in certain research. Other studies have looked at the governmental policy, and commercial views, and concluded that PV solar systems are becoming more acceptable and used by people all around the world, [46]. Lacking research analysis and discussion on Malaysian solar PV adoption may be due to the insensitivity of the consumer viewpoint of solar power usage and also a handful of articles might not be published in Scopus-indexed journals, [34].

Secondly, it is found that energy security is purely used as an assessment with indicators to evaluate a country's availability of energy sources at an affordable price with a scoring system, [6], [45]. Only a few research journal articles are available on sustainable energy security (SES), [53], [61]. This paper profoundly used sustainable energy security as the determinant or factor that explains the influence of adopting solar PV in Malaysia presented in the next section.

4.1 Proposed Conceptual Framework of Solar PV Adoption in Malaysia

This study integrates the socioeconomics (attitude, subjective norms) and sustainability concerns (sustainable energy security dimensions) to relate to the attitudes and behaviors of Malaysian households in adopting Solar PV. These variables align with the past studies that cited households' behavior and attitudes as one of the adoption factors [36] towards Solar PV adoption. This study proposes the importance of Sustainable Energy Security (SES) as well as the determinants to evaluate society's awareness. Energy security is commonly used to evaluate a country's uninterrupted availability of energy sources at an affordable cost with a scoring system [6, 45]. The concept of SES was first introduced by [61] to highlight the emerging trends in energy security and sustainability for India with a view to answering the question 'Is Sustainable Energy Security (SES) in India increasing or decreasing?'. [61] defined SES as the "provisioning of uninterrupted energy services in an affordable, equitable, efficient in an environmentally benign manner".

According to [40] the concept of Energy Security follows four dimensions, namely Affordability, Accessibility, Acceptability, and Availability. The affordability dimension refers to the cost of energy in relation to the energy tariff and electricity tariff for different sectors. This speaks to whether the price of owning energy is equitable or cheaper than traditional electrical energy. For the accessibility dimension, the concept refers to good access to energy for all parts including rural and developed areas. The acceptability dimension relates to the acceptance of people and the government toward achieving renewable energy. The last dimension of the Energy Security concept is Availability. This dimension refers to the availability of resources (natural and renewable) in each country to serve the people and economies.

To provide a framework for this study, the Theory of Planned Behavior (TPB) is applied as proposed by [46] to explore the Solar PV system at the household level. Previous literature review reveals that various determinants that reflect and influence behavioral intention to use solar PV systems that will lead to actual behavior, include intention, willingness, and plan to use solar PV systems in the near future. Hence, determinants such as pricing, technology advancement, and financial soundness of the households from previous studies captured the behavioral intention

to use solar PV systems by applying TPB, [28], [36], [47].

TPB explained a perception based on a person's thoughts or feelings towards using solar PV, [48]. Previous experience can influence individual attitudes and therefore help or hinder individual intentions to purchase. This study also brings the definition of solar PV security from an energy security perspective where it refers to the continuous availability of energy sources at an affordable price, [45].

The Sustainable Energy Security (SES) dimensions proposed by [61] were also identified as determinants for Solar PV adoption which consisted of four dimensions that are availability, affordability, efficiency, and acceptability (environment). Fig.1 shows the proposed conceptual research framework of this study. The following section explained the determinants from the perspective of solar PV adoption.

4.1.1 Attitude

Attitude is defined as an individual's evaluation of a particular behaviour as favourable or unfavourable, [48]. It is considered as consumers' positive or negative opinions towards solar PV use. These optimistic and pessimistic opinions are based on the advantages and consequences of solar PV from the perspective of social, environmental, and economic. A study by [49] revealed that consumers' intention and willingness to pay for RE are positively associated with attitude. This is due to opinions ranging that prevailing energy and climatic problems (dependence on fossil fuel, global warming, poor air quality, and climate change) could be minimized by deploying RE. [46] also reveals that attitude has a strong positive effect on the intention to use PV solar technology in the household.

4.1.2 Subjective Norm

Subjective norm is defined as the degree to which an individual perceives that most people who are important to him think he should or should not use the system, [50], [51]. The subjective norm, which is the social factor, refers to the social pressure for performing and not performing the behavior. The subjective norm can be academically defined in a way that it refers to the degree to which an individual perceives that he should or should not use the system based on the thought of the people who are very important to the individual refer as significant others (e.g., parents, spouse, friends, teachers, neighbors), [50], [51]. A study by [52] found that the value belief norm theory positively affects behavioral intention.

4.1.3 Availability

Government policies, political factors, and geopolitical factors can affect the availability of the solar PV system in a country. Sustainable energy practices vary significantly due to the variation in population size, availability of natural resources, as well as the level of industrialization and urbanization, [53], [54]. The availability of compatible infrastructure systems is vital for providing stable and uninterrupted solar PV systems. The infrastructure system includes supply and distribution facilities, technical facilities, training, and developing awareness about the solar PV system. Findings from past scholars, [20], [27], [29], [30], emphasized these availabilities as an adoption factor for Solar PV.

4.1.4 Affordability of Cost

The cost has been widely cited as the major contributor to the adoption of Solar PV. Past scholars, [20], [27], [29], [31], [36], provided empirical evidence that cost is one of the challenges. The high solar cost works as a barrier to solar adoption while the low cost works as the driver of solar adoption, [55], [56]. The price of a solar PV system determines its affordability of solar PV, thus there are several factors for instance price of solar PV, price volatility, supply, demand, decentralization, and market competition of solar PV systems. Therefore, measuring the relevance of investment and cost of solar systems is important to consider. This is important as the magnitude of the cost and investment behind the installation of solar PV systems plays a crucial role to influence the behavioral intention of an individual. Thus, this study refers to affordability as the ability to pay for a unit of energy for a particular energy service that is a function of the retail price of energy and consumers' ability to pay for it.

4.1.5 Efficiency in Technology

Technology plays a crucial role in evaluating the sustainability of energy. Whereas, the cost of technology, greenhouse gas emission reduction target and production target influence the selection of technology. Moreover, the environmental policy by the government also affects the selection of technology such as government tax policy for fossil carbon. Non-user believe that the quality of the solar PV system is also very important to reap higher utility, [57], [58], [59]. The existing technical capacity and infrastructure system can

affect the diffusion of the solar PV system, [58]. This is because adopting highly reliable and effective technology is essential, [60].

4.1.6 Acceptability of Environment

Acceptability links to environmental aspects, and social and cultural barriers that shows the environmental compatibility of the energy product considering the neighboring territory and environmental science, [61]. Environmental indicators highlight the reduction or decrease of carbon emissions, biodiversity, noise pollution, air pollution, usage of the land, and exhaustion of natural resources, [62], [63], [64]. Consumer perception of environmental concerns affects the acceptance of solar adoption, [65]. The households' willingness to adopt Solar PV is potentially due to the environmental factor, [66]. This is evidenced by [37] the authors found that awareness of the environment is a substantial indicator for consumers to adopt Solar PV.

5 Conclusion

Through reviewing the state of solar energy in Malaysia encompassing policies and government intervention, it is found that Malaysia has enormous potential in adopting Solar PV, especially with the positive reaction towards the quota released for Solar PV installation, [18]. This shows that there is demand for Malaysians to use Solar PV to generate electricity, but the adoption rate is relatively low, [36]. This led to answering the first RQ on what hinders this. What are the factors that affect the Solar PV adoption rate in Malaysia?

From the literature review, this study successfully constructed a conceptual framework for Solar PV adoption in Malaysia from the findings which answered the second RQ. The proposed conceptual research frameworks took account of the findings from past studies conducted on Solar PV adoption presented through various international geographical locations including Malaysia. This study adopts the Theory of Planned Behaviour (TPB) to explore the Solar PV system at the household level. It also discovered the importance of the Sustainable Energy Security (SES) concept used as the determinant to reflect and influence behavioral intention to use solar PV systems, including intention, willingness, and plan to use solar PV systems in the near future. Therefore, six variables were included presenting the influence factor towards the adoption of Solar PV among Malaysians. These variables namely Attitude, Subjective Norm, Availability, Affordability, Efficiency, and Acceptability (Environment) were derived from past scholars' theoretical statements and also based on their empirical evidence of research.

This study has instigated the updated discussion and reviews on Solar PV adoption globally. Next, statistical data is needed to verify the relevancy of the conceptual research framework for future work. Further work is recommended to present a follow-up framework to support the understanding of how each of the variables are interacting through statistical evidence. This will also provide a robust statement on why these variables are the contributor to Solar PV adoption in Malaysia.

This paper may support the Malaysian government to implement stronger policies based on the principal aim of the Solar Energy program. The policies would complement the contributor factors such as cost, and availability inherent by future users of Solar PV. The six variables suggested will also inform the government on the practical aspects that influence the adoption reasons for the consumers. This study will also create awareness and commercialization value to the community and Solar PV providers on the influential aspects pointed towards Solar PV adoption.

References:

[1] Meira, Jorge Augusto, and Patrick Glauner. (2017). "Distilling Provider-Independent Data for General Detection of Non-Technical Losses."

[2] Ahmad M, Zhao ZY, Irfan M, Mukeshimana MC (2019) Empirics on influencing mechanisms among energy, finance, trade, environment, and economic growth: a heterogeneous dynamic panel data analysis of China. *Environ Sci Pollut* Res 26(14):14148–14170

[3] Seng, Koh Kai, and Ammar Syafi Bin Mohd Fauzi. (2019). "An Overview of Renewable and Non-Renewable Energy Demand as Well as Development Status in Malaysia." *Chemical Science and Biomolecular Engineering* 1(1):1–6.

[4] Ang, B. W., Choong, W. L., & Ng, T. S. (2015). Energy security: Definitions, dimensions and indexes. *Renewable and Sustainable Energy Reviews*, 42, 1077–1093.

[5] Enerdata. (2020). "Total Energy Consumption 2018." *Global Energy Statistical Yearbook 2019*. Retrieved May 14, 2020

(https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html).

[6] Sahid, E. J. M., & Sin, T. C. (2019). Energy security in ASEAN region: A case study of Malaysia energy security performance with renewable energy implementation. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, 61(2), 190–201.

[7] Energy Commission of Malaysia. (2019). *Malaysia Energy Statistics Handbook 2018.*

[8] Itskos, G., Nikolopoulos, N., Kourkoumpas, D. S., Koutsianos, A., Violidakis, I., Drosatos, P., & Grammelis, P. (2016). *Chapter 6 - Energy and the Environment*. In S. G. Poulopoulos & V. J. Inglezakis (Eds.), Environment and Development (pp. 363-452). Amsterdam: Elsevier.

[9] Kannan, N., & Vakeesan, D. (2016). Solar energy for future world: - A review. *Renewable and Sustainable Energy Reviews*, 62, 1092-1105. doi:https://doi.org/10.1016/j.rser.2016.05.022

[10] Brooks, A. E. (2014). *Chapter 18 - Solar Energy: Photovoltaics.* In T. M. Letcher (Ed.), Future Energy (Second Edition) (pp. 383-404). Boston: Elsevier

[11] Abdullah, Wan Syakirah Wan, Miszaina Osman, Mohd Zainal Abidin Ab Kadir, and Renuga Verayiah. (2019). "The Potential and Status of Renewable Energy Development in Malaysia." *Energies* 12(12):2437

[12] Schelly, C., Lee, D., Matz, E., & Pearce, J. M. (2021). Applying a Relationally and Socially Embedded Decision Framework to Solar Photovoltaic Adoption: A Conceptual Exploration. *Sustainability*, 13(2). doi:10.3390/su13020711

[13] Havas, L., Ballweg, J., Penna, C., & Race, D. (2015). Power to change: Analysis of household participation in a renewable energy and energy efficiency programme in Central Australia. *Energy Policy*, 87, 325-333.

[14] Hansen, L., Lacy, V., & Glick, D. (2013). A review of solar PV benefit & cost studies. *Rocky Mountain Institute*.

[15] Chaianong, A., Bangviwat, A., Menke, C., & Darghouth, N. R. (2019). Cost–Benefit Analysis of Rooftop PV Systems on Utilities and Ratepayers in Thailand. *Energies*, 12(12), 2265.

[16] Nemet, G. F., Lu, J., Rai, V., & Rao, R. (2020). Knowledge spillovers between PV installers can reduce the cost of installing solar PV. *Energy Policy*, 144, 111600. doi:https://doi.org/10.1016/j.enpol.2020.111600

[17] SEDA. (2011). "History of FiT in Malaysia." *SEDA PORTAL*. Retrieved November 5, 2017 (http://dual.seda.gov.my/feed-in-tarif-fit/history-of-fit-in-malaysia/)

[18] SEDA. (2019). *SEDA Annual Report 2018.*

[19] SEDA. (2020). 2020 Registered PV Service Provider Directory. *SEDA PORTAL*. http://www.seda.gov.my/directory/registered-pv-service-provider-directory/

[20] Qureshi, T. M., Ullah, K., & Arentsen, M. J. (2017). Factors responsible for solar PV adoption at household level: A case of Lahore, Pakistan. *Renewable and Sustainable Energy Reviews*, 78, 754-763.

[21] Groote, O. D., Pepermans, G., & Verboven, F. (2016). Heterogeneity in the adoption of photovoltaic systems in Flanders. *Energy Economics*, 59, 45–57. https://doi.org/10.1016/j.eneco.2016.07.008

[22] Abdul-Manan, Amir F. N., Azizan Baharuddin, and Wei Chang Lee. (2015). "Ex-Post Critical Evaluations of Energy Policies in Malaysia from 1970 to 2010: A Historical Institutionalism Perspective." *Energies* 8(3):1936–57.

[23] Dharfizi, Awang Dzul Hashriq, Ahmad Bashawir Haji Abdul Ghani, and Rabiul Islam. (2019). "Evaluating Malaysia's Fuel Diversification Strategies 1981–2016." *Energy Policy* 137:111083

[24] Energy Commission of Malaysia. (2020). *Peninsular Malaysia Electricity Supply Industry Outlook 2019.* Putrajaya, Malaysia.

[25] Lokman, Tasnim. 2017. "PM: Malaysia on Course to Reduce Carbon Emissions by 40 Pct by 2020." *New Straits Times*, 3–7.

[26] Alam, S. S., Hashim, N. H. N., Rashid, M., Omar, N. A., Ahsan, N., & Ismail, M. D. (2016). Small-scale households renewable energy usage intention: Theoretical development and empirical settings. *Renewable Energy*, 68, 255-263

[27] Rai, V., Reeves, D. C., & Margolis, R. (2016). Overcoming barriers and uncertainties in the adoption of residential solar PV. *Renewable Energy*, 89, 498-505. doi:https://doi.org/10.1016/j.renene.2015.11.080

[28] Palm, A., & Lantz, B. (2020). Information dissemination and residential solar PV adoption rates: The effect of an information campaign in Sweden. Energy Policy, 142, 111540.

doi:https://doi.org/10.1016/j.enpol.2020.111540

[29] Walters, J., Kaminsky, J., & Gottschamer, L. (2018). A Systems Analysis of Factors Influencing Household Solar PV Adoption in Santiago, Chile. *Sustainability*, 10(4), 1257.

[30] Karjalainen, S., & Ahvenniemi, H. (2019). Pleasure is the profit - The adoption of solar PV systems by households in Finland. *Renewable Energy*, 133, 44-52. doi:https://doi.org/10.1016/j.renene.2018.10.011

[31] Ugulu, A. I. (2019). Barriers and motivations for solar photovoltaic (PV) adoption in urban Nigeria. *International Journal of Sustainable Energy Planning and Management*, 21. https://doi.org/10.5278/ijsepm.2019.21.3

[32] Ahmad, N. A., & Byrd, H. (2013). Empowering Distributed Solar PV Energy for Malaysian Rural Housing: Towards Energy Security and Equitability of Rural Communities. *International Journal of Renewable Energy Development*, 2(1).

[33] Mekhilef, S., Safari, A., Mustaffa, W. E. S., Saidur, R., Omar, R., & Younis, M. A. A. (2012). Solar energy in Malaysia: Current state and prospects. *Renewable and Sustainable Energy Reviews*, 16(1), 386-396. doi:https://doi.org/10.1016/j.rser.2011.08.003

[34] Ahmad, S., Mat Tahar, R. b., Cheng, J. K., & Yao, L. (2017). Public acceptance of residential solar photovoltaic technology in Malaysia. *PSU Research Review*, 1(3), 242-254. doi:10.1108/PRR-11-2016-0009

[35] Malik, S. A., & Ayop, A. R. (2020). Solar energy technology: Knowledge, awareness, and acceptance of B40 households in one district of Malaysia towards government initiatives. *Technology in Society*, 63, 101416. doi:https://doi.org/10.1016/j.techsoc.2020.101416

[36] Lau, L. S., Choong, Y. O., Wei, C. Y., Seow, A. N., Choong, C. K., Senadjki, A., & Ching, S. L. (2020). Investigating nonusers' behavioural intention towards solar photovoltaic technology in Malaysia: The role of knowledge transmission and price value. *Energy Policy*, 144, 111651.

[37] Cheam, W.-Y., Lau, L.-S., & Wei, C.-Y. (2021). Factors influencing the residence's intention to adopt solar photovoltaic technology: a case study from Klang Valley, Malaysia. *Clean Energy*, 5(3), 464-473. doi:10.1093/ce/zkab021

[38] Rathore, P. K. S., Chauhan, D. S., & Singh, R. P. (2019). Decentralized solar rooftop photovoltaic in India: On the path of sustainable energy security. *Renewable Energy*, 131, 297-307. doi:https://doi.org/10.1016/j.renene.2018.07.049

[39] Khattak, M. A., Lee, J. K., Khairul, A. B., Tan, X. H., Amirul Syafiq, O., Afiq Danial, A. R., Lailatul Fitriyah, A. S., & Kazi, S. (2018). Global Energy Security and Malaysian Perspective: A Review. *Progress in Energy and Environment*, 6, 1–18.

[40] Shadman, S., Hanafiah, M. M., Chin, C. M. M., Yap, E. H., & Sakundarini, N. (2021). Conceptualising the Sustainable Energy Security Dimensions of Malaysia: A Thematic Analysis through Stakeholder Engagement to Draw Policy Implications. *Sustainability*, 13(21), 12027.

[41] Reichelstein, S., & Yorston, M. (2013). The prospects for cost competitive solar PV power. *Energy Policy*, 55, 117-127. doi:https://doi.org/10.1016/j.enpol.2012.11.003

[42] Comello, S., Reichelstein, S., & Sahoo, A. (2018). The road ahead for solar PV power. *Renewable and Sustainable Energy Reviews*, 92, 744-756. doi:https://doi.org/10.1016/j.rser.2018.04.098

[43] Abreu, J., Wingartz, N., & Hardy, N. (2019). New trends in solar: A comparative study assessing the attitudes towards the adoption of rooftop PV. *Energy Policy*, 128, 347-363. doi:https://doi.org/10.1016/j.enpol.2018.12.038

[44] Alipour, M., Salim, H., Stewart, R. A., & Sahin, O. (2021). Residential solar photovoltaic adoption behaviour: End-to-end review of theories, methods and approaches. *Renewable Energy*, 170, 471-486. doi:https://doi.org/10.1016/j.renene.2021.01.128

[45] IEA. (2018). What is energy security? *IEA PORTAL*. https://www.iea.org/topics/energysecurity/whatisenergysecurity/

[46] Alam, S. S., Ahmad, M., Othman, A. S., Shaari, Z. B. H., & Masukujjaman, M. (2021). Factors affecting photovoltaic solar technology usage intention among households in Malaysia: Model integration and empirical validation. *Sustainability* (Switzerland), 13(4), 1–20.

[47] Lundheim, S. H., Vesely, S., Nayum, A., & Klöckner, C. A. (2021). From vague interest to strong intentions to install solar panels on private homes in the North–An analysis of psychological drivers. *Renewable Energy*, 165, 455-463.

[48] Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckman (Eds.), *Action-control: From cognition to behavior* (pp. 11–39). Heidelberg: Springer.

[49] Irfan, M., Zhao, Z. Y., Li, H., & Rehman, A. (2020). The influence of consumers' intention factors on willingness to pay for renewable energy: a structural equation modeling approach. *Environmental Science and Pollution Research*, 1-15.

[50] Fishbein, M., & Ajzen, I. (1975). Belief, attitude, intention, and behavior: *An introduction to theory and research*. In Reading, Mass. Addison-Wesley Pub. Co.

[51] Venkatesh, V., & Davis, F. D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science*, 46(2), 186–204.

[52] Fornara, F., Pattitoni, P., Mura, M., & Strazzera, E. (2016). Predicting intention to improve household energy efficiency: The role of value-belief-norm theory, normative and informational influence, and specific attitude. *Journal of Environmental Psychology*, 45, 1–10. https://doi.org/10.1016/j.jenvp.2015.11.001

[53] Narula, K., & Reddy, B. S. (2015). Three blind men and an elephant: The case of energy indices to measure energy security and energy sustainability. *Energy*, 80, 148-158.

[54] Gunnarsdóttir, I., Davidsdottir, B., Worrell, E., & Sigurgeirsdóttir, S. (2020). Review of indicators for sustainable energy development. *Renewable and Sustainable Energy Reviews*, 133, 110294.

[55] Bouhal, T., Agrouaz, Y., El Rhafiki, T., Kousksou, T., Zeraouli, Y., & Jamil, A. (2018). Technical assessment, economic viability and investment risk analysis of solar heating/cooling systems in residential buildings in Morocco. *Solar Energy*, 170, 1043-1062.

[56] Egli, F. (2020). Renewable energy investment risk: An investigation of changes over time and the underlying drivers. *Energy Policy*, 140, 111428.

[57] Palit, D. (2013). Solar energy programs for rural electrification: Experiences and lessons from South Asia. *Energy for Sustainable Development*, 17(3), 270-279.

[58] Karakaya, E., & Sriwannawit, P. (2015). Barriers to the adoption of photovoltaic systems: The state of the art. *Renewable and Sustainable Energy Reviews*, 49, 60-66.

[59] Müggenburg, H., Tillmans, A., Schweizer-Ries, P., Raabe, T., & Adelmann, P. (2012). Social acceptance of PicoPV systems as a means of rural electrification—A socio-technical case study in Ethiopia. *Energy for Sustainable Development*, 16(1), 90-97.

[60] Bhattacharyya, S. C. (2010). Shaping a sustainable energy future for India: Management challenges. *Energy policy*, 38(8), 4173-4185.

[61] Narula, K. (2014). Is sustainable energy security of India increasing or decreasing? *International Journal of Sustainable Energy*, 33(6), 1054–1075.

[62] Neves, A. R., & Leal, V. (2010). Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework. *Renewable and Sustainable Energy Reviews*, 14(9), 2723-2735.

[63] Jay, S. (2010). Strategic environmental assessment for energy production. *Energy Policy*, 38(7), 3489-3497.

[64] Rosso, M., Bottero, M., Pomarico, S., La Ferlita, S., & Comino, E. (2014). Integrating multicriteria evaluation and stakeholders analysis for assessing hydropower projects. *Energy policy*, 67, 870-881.

[65] Zhai, P., & Williams, E. D. (2012). Analyzing consumer acceptance of photovoltaics (PV) using fuzzy logic model. *Renewable Energy*, 41, 350-357.

[66] Kwan, C. L. (2012). Influence of local environmental, social, economic and political variables on the spatial distribution of residential solar PV arrays across the United States. *Energy Policy*, 47, 332–344. https://doi.org/10.1016/j.enpol.2012.04.074

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Pauline Choo carried out the research and paper writing.
Jayaraman Krishnaswamy support in funding acquisition and provide theoretical content.
Ree Chan Ho has supervision and review paper writing.
Mohd Faizal Bin Fauzan has provide the literature content.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

This research was supported by **Ministry of Education (MOE) Malaysia** through **Fundamental Research Grant Scheme (FRGS/1/2019/SS01/TAYLOR/01/1).** We also want to thank to the Government of Malaysia which provide MyBrain15 program for the sponsoring this work under the self-fund research grant and L00022 from Ministry of Science, Technology and Innovation (MOSTI) Malaysia.

Creative Commons Attribution License 4.0 (Attribution 4.0 International, CC BY 4.0)

This article is published under the terms of the Creative Commons Attribution License 4.0
https://creativecommons.org/licenses/by/4.0/deed.en_US

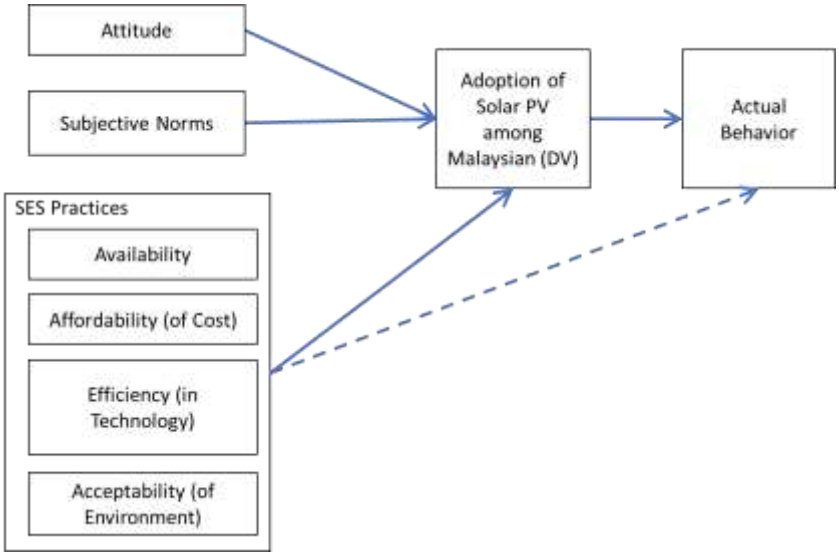

Fig.1: Conceptual Research Framework - Sustainable Energy Security Practices in extended Theory of Planned Behavior

Table 1. Summary of Selected Past Studies on Solar PV Adoption

Authors	**Methodology and Sample**	**Geographical Location**	**Challenges to Adopt Solar PV**
Rai, Reeves, and Margolis (2016) [27]	Quantitative Survey / Households	United States of America	• Marketing Factor • Cost • Ease of Installation
Qureshi, Ullah, and Arentsen (2017) [20]	Quantitative Survey / Consumers	Pakistan	• Cost • Complexity to Adapt • Shortages of Vendors and Technicians • Lack of Financial Support
Ahmad, Mat Tahar, Cheng and Yao (2017) [34]	Quantitative Survey / Residents	Malaysia	• Perceived Usefulness • Perceived Ease of Use • Attitude
Walters, Kaminsky, and Gottschamer (2018) [29]	Qualitative Interview / Households	Chile	• Information • Cost • Ease of Installation
Karjalainen and Ahyenniemi (2019) [30]	Qualitative Interview / Households	Finland	• Experts' availability • Peers Influence
Ugulu (2019) [32]	Qualitative Interview / Households	Nigeria	• Cost
Palm and Lantz (2020) [28]	Qualitative Interview / Households	Sweden	• Informational Campaign
Malik and Ayop (2020) [35]	Qualitative Interview / Households	Malaysia	• Awareness towards solar energy
Lau et al. (2020) [36]	Qualitative / Non-Users	Malaysia	• Cost
Cheam, Lau, and Wei (2021) [37]	Qualitative Interview / Non-PV users	Malaysia	• Awareness towards environment • Knowledge-Factor • Perceived usefulness