JIEE Journal of Industrial Engineering and Education

Barriers to Adoption of Photovoltaic System: A case study from Indonesia

Nurwidiana Nurwidiana *

Department of Industrial Engineering, Sultan Agung Islamic University, Semarang, Indonesia, 50112

ABSTRACT

The transition to renewable energy is increasingly important. Indonesia encourages the use of solar energy through photovoltaic (PV) technology on the roofs of houses and buildings to achieve the renewable energy mix target. However, the diffusion of PV systems has been slow even after the issuance of government regulations regarding PV systems. This research investigates barriers to PV adoption by Indonesian households. A survey was conducted, resulting in responses from 404 households in Indonesia that had yet to use PV. Only complete answers from respondents with the status of their own house and having the authority to make decisions are included in the analysis. Processing 376 data that met the requirements found that high investment costs were the main barrier to PV adoption, followed by access to installation service providers and lack of information available as the next obstacle. The affordability of distribution centers as information service providers, procurement, installation, and maintenance of PV systems is the most technical support respondents need to be willing to adopt PV systems. On the financial aspect, it is hoped that PV system equipment grants for households in remote areas and subsidies for the procurement of PV systems in the regions that have access to electricity from the State Electricity Company (PLN) are expected to be facilitated. Further research on the effect of financial and technical facilitation on PV adoption rates is needed to formulate effective policies.

ARTICLE INFO

Received February 2, 2023
Accepted March 3, 2023
Available online March 19, 2023

***Correspondence**

Nurwidiana Nurwidiana
nurwidiana@unissula.ac.id

Keywords:
renewable energy; transition; photovoltaic system; barriers

1. Introduction

Electricity is the most widely used type of energy in the modern world. Electricity consumption indicates a country's economic development, so the need for electricity overgrows in line with economic growth. However, more than 70% of the world's energy needs depend on fossils, impacting global climate change (Abbasi & Abbasi, 2012). Electricity production must be shifted from conventional energy sources to new sources due to environmental impacts and depletion of fossil fuel reserves. Solar energy is an abundant source of renewable energy.

Indonesia, which is located on the equator, has a solar energy potential of 207.8 GW, or 46.7% of Indonesia's total renewable energy potential (Ministry of Energy and Mineral Resources, 2021). Significant potential with mature technology makes solar energy a renewable energy that is encouraged to use to reduce dependence on fossil energy. In 2017 the Indonesian government promoted photovoltaic (PV) technology for using solar energy on rooftops through the One Million Solar Roof National Movement (GNSSA) program. At the end of 2018, the Ministry of Energy and Mineral Resources issued the Minister of Energy and Mineral Resources No. 49 of 2018, which regulates the use of rooftop PV systems for customers of the State Electricity Company (PLN) (Ministry of Energy and Mineral Resources, 2019). Through this regulation, users of rooftop PV systems connected to the PLN network (PV on grid) can send excess electricity from the PV system to the PLN network and become a deduction from PLN's electricity bill the following month.

To achieve the 23% renewable energy target in the national energy mix in 2025, the Indonesian government, through the National Energy General Plan (RUEN), stipulates the use of solar energy through 3600MW rooftop PLTS in 2025. It is gradually targeted that in 2022 it can be installed up to 450 MW. In 2023, it will be 900 MW, 1800 MW in 2024, and 3600 MW in 2025 (Willis *et al.*, 2011). However, after implementing various programs and policies, as of July 2021, the installed capacity for the new rooftop PV system of 35.56 MW. This achievement shows the low diffusion of PV systems in Indonesia.

Research on the diffusion of PV systems has existed since the 1980s and has increased in the following years. Several studies have studied the influence of various aspects, such as the economy, socio-demographics, psychology, recommendations, and policies, on the intention to use a PV system (Willis *et al.*, 2011; Mundaca & Samahita, 2020; Yang & Timmermans, 2017; Elmustapha *et al.*, 2018; Schelly, 2010; Jannuzy & de Melo, 2013; Reeves & and Rai, 2018). For decades, PV system technology and costs were assumed to be commercially uncompetitive compared to conventional energy sources (Karakaya & Sriwannawit, 2015; Rai *et al.*, 2015). A International Renewable Energy Agency (2019) shows that recently, PV systems have become more competitive due to technological maturity and reduced production costs. However, the adoption of PV systems is still slow. This shows that constraints other than financial aspects hinder the diffusion of PV systems.

Research on barriers to adoption has been of general interest in many research areas into the renewable energy transition. However, only some studies address barriers to implementing PV systems, particularly in Indonesia. To fill this gap, this article investigates the barriers to the diffusion of PV systems in various contexts, especially by household adopters in Indonesia.

In addition, this study identifies the expected facilitation so that non-adopters are willing to adopt the PV system. The research results will provide information on barriers to PV adoption and provide input regarding facilitation that the government and industry must provide to encourage further PV adoption, especially in Indonesia.

This research contributes to the literature on the transition to renewable energy, specifically barriers to adoption and the technical and financial facilitation needed to encourage further adoption of PV systems in Indonesia. Furthermore, the remainder of this paper consists of 4 parts. The literature review is presented in Section 2, and our methodological steps are outlined in Section 3. In Section 4, we discuss our findings, and finally, our conclusions are presented in Section 5.

2. Literature Review

Although PV technology has advanced rapidly in recent decades, many publications indicate that there are still some barriers to adoption (Curtius, 2018; Wolske, 2020; Schelly, 2014). Economic barriers are usually related to the high cost of PV modules because potential adopters have to choose between PV systems and conventional energy sources (Saryznski *et al.*, 2012). Karakaya & Sriwannawit (2015) conducted a literature review of PV adoption in 28 countries, finding that the high initial investment cost was the main obstacle. If the prices of competing energy sources are low, this can become a barrier to PV adoption.

Due to their high cost, PV systems are usually unprofitable without policy support. The right policies are essential for rapidly deploying green energy, including PV systems. Currently, most countries have various policy measures to support renewable energy. Inadequate and ineffective policy support has often been cited as a barrier in several studies in different contexts, for example, in Italy and the US (Palmer *et al.*, 2015; Zhao *et al.*, 2011). Vasseur & Kemp (2015) point to the influence of the inconsistent national subsidy scheme in the Netherlands, discouraging entrepreneurs from investing in PV systems.

PV system performance is another essential consideration in the adoption decision. This is influenced by the local conditions of the user's environment and the availability of services (Joshi & Kumar, 2019). Lack of adequate knowledge is another obstacle. Lack of knowledge can result in improper use and inability to maintain the PV system (D'Agostino *et al.*, 2011). This can create negative perceptions and prevent potential customers from adopting the PV system. The transition to PV systems requires campaigns and education to communicate more information about investments in PV systems, their environmental impact, and feed-in tariffs. Otherwise, the low technology awareness barrier cannot be overcome (Islam & Meade, 2013).

In developing countries, the existing technical capacity and national infrastructure influence the diffusion of PV systems. Governments need to build technical capacity to promote broad adoption. Limited PV companies and technicians in Ghana resulted in slower PV adoption than in Kenya and Zimbabwe (Bawakyillenuo, 2012). Indonesia's national supply chain is complex because of the vast archipelago. This leaves remote areas unserved, and the PV market is concentrated in big cities (Nurwidiana et al., 2021). A study comparing Japan and the Netherlands shows that Japan has a better technological innovation system to support the PV industry (Vasseur & Kemp, 2015). On the other hand, the Netherlands needs more collaboration and knowledge exchange between researchers, policymakers, and adopters. The Dutch case also needs more human and financial resources to stimulate the PV market.

Finally, the fact that fossil fuels are far more mature than PV technologies in the electricity market prevents PV systems from being an attractive option for customers. However, government-imposed renewable energy tariffs can help overcome barriers to this immature market.

3. Methodology

The survey was chosen as a household data collection method because of its ability to obtain information that describes the characteristics of a large population. An online survey is the preferred alternative to facilitate the distribution of questionnaires, given the broad area of research. Data collection was carried out using a questionnaire consisting of three parts: explanation, approval, and content. The explanatory section describes the PV system, the purpose and benefits of the survey, the intended respondents, and guarantees of data confidentiality from respondents. The consent contains a statement of the respondent's willingness to participate in the research. The contents of the questionnaire are designed to be composed of four parts, each part containing several closed-ended and open-ended questions.

Part A questions about socio-demography. The information asked included gender, age, income, education, residence location, home ownership status, access to electricity, and authority to make decisions. Part B consists of questions about perceived barriers to using the PV system. Respondents were presented with some factors which, based on previous research, were found to be barriers to PV adoption in several countries. Furthermore, respondents were asked to choose three main barriers to implementing PV systems. Respondents were also allowed to provide answers other than the factors already mentioned. Part C is a questionnaire to identify the level of importance of technical and financial facilitation expected from the government and/or the PV industry so that they are willing to use PV. This section presents findings from previous PV adoption studies regarding the technical and financial facilitation that households often expect to be willing to adopt PV. Respondents were asked to assess the level of importance of these facilities for the decision to adopt PV. Answers are provided on a Likert scale where a value of 1 means very unimportant and a scale of 5 means very important. Part D asks about the intention to use PV in the future, expressed by asking when to install the PV system. In this section, five answer options are provided, namely installing PV as soon as possible, in the next three years, in the next five years, in the next ten years, and not going to install a PV system.

A pilot study was conducted to test and refine the questionnaire. Furthermore, to test the validity and reliability of the questionnaire, the questionnaire was distributed to 30 homeowners before being sent and disseminated to respondents. A validity test is carried out to test whether the question items can measure the perception of technical and financial facilitation in solar PV adoption. Testing is carried out through the correlation calculation between each question with a total score. The value of the R count will be compared with the value of the R table, where at a significance level of 0.05 and the amount of data (n) 30, the r table is 0.361. The test results show that all question items have an r count > r table value, then declared valid. Cronbach Alpha is used to indicate the value of reliability. From the survey data, Cronbach's Alpha Coefficient for the perception of technical facilitation and financial facilitation of 0.807, shows the variables in this study are reliable. Due to the high initial investment costs, the intention to use PV is generally driven by knowledge of the benefits PV systems generate both financial and environmental benefits (Karakaya *et al.*, 2015). So the PV system is often targeted at educated households who have access to PLN electricity. The research sample is respondents from a group of households that have yet to use a PV system with a coverage area covering the entire territory of Indonesia.

The analysis was conducted to identify the most significant barriers that respondents who had not yet adopted the PV system felt. In addition to aggregate analysis, a study was carried out for each household group based on the installed PLN electricity capacity. This analysis is intended to determine whether there are differences in barriers to adoption in different household groups. Next, an investigation was carried out on the importance of technical and financial facilitation to the PV adoption decision. A more detailed analysis to determine whether there are differences in the importance of technical and financial facilities in different household groups uses Analysis of Variance (ANOVA).

4. Results

4.1 Demographic characteristics of the respondents

The questionnaire was sent in early November 2020, and after five weeks, responses were obtained from 404 respondents who had yet to use the PV system. The 404 responses received were sorted based on the answers' house ownership status, decision-making authority, and completeness. After filtering, 367 responses remained for analysis.

Of the 367 respondents, the majority of respondents (91%) live in the Java region. The ages of the respondents ranged from 21 years to 60 years, with an average of 39 years. Meanwhile, the average income of the respondents was Rp. 10,000,000. A bachelor's degree is the highest educational attainment for most respondents (48%), and even 44.4% achieved post-graduate. Based on the installed electricity capacity, respondents were dominated by households with an installed PLN electricity capacity of 1300VA.

The Chi^2 test was used to test whether there is a significant difference between the sample and the population concerning education level, area distribution, and household access to electricity (0). The test results at a significance level of 0.05 showed $p > 0.05$ in the distribution of areas and access to household electricity, indicating no significant difference between the sample and the population data. In contrast, testing at the level of education gives a p-value <0.001. The population is dominated by elementary school level, while the majority of the sample has undergraduate education. This indicates a concordance between the sample and the target users of the PV system, namely educated people, so the survey results are expected to represent the answers of the target households.

Table 1. Demographic characteristics of the respondents

Variables	Samples (N= 367)	Populations	Chi^2 test		
			Chi^2	***df***	***p***
Education			692,54	3	< 0,001
1 = elementary school	1 (0.3%)	55,7%			
2 = high school	25 (6,8%)	34,7%			
3 = university	177(48,2%)	9,0%			
4 = postgraduate	164 (44.7%)	0,6%			
Region			4,692	5	0,455
1 = Java & surrounding islands	274 (74.7%)	58,8%			
2 = Sumatra & surrounding islands	36 (9.8%)	20,7%			
3 = Kalimantan & surrounding islands	14(3.8%)	6,0%			
4 = Sulawesi & surrounding islands	19 (5.2%)	6,7%			
5 = Bali & Nusa Tenggara	12 (3.3%)	5,4%			
6 = Maluku, Papua & surrounding islands	12 (3.3%)	2,4%			
Electricity Access			3,742	2	0,587
1 = No electricity	2 (0,5%)				
2 = PLN 900 VA	20 (5.4%)				
3 = PLN 1300VA	214 (58,3%)	93,7%			
4 = PLN 2200VA	91 (24,8%)				
5 = PLN 5500 VA	37 (10,1%)	5,9%			
6 = PLN 6600 VA or more	3 (0,8%)	0,4%			

4.2 Intention to install a PV system

This section compares respondents' responses to the question, "What are your plans regarding the PV system?" Figure 1 shows that only 11% of respondents intend to install a PV system immediately. Most respondents (24%) put it off for the next 5 years.

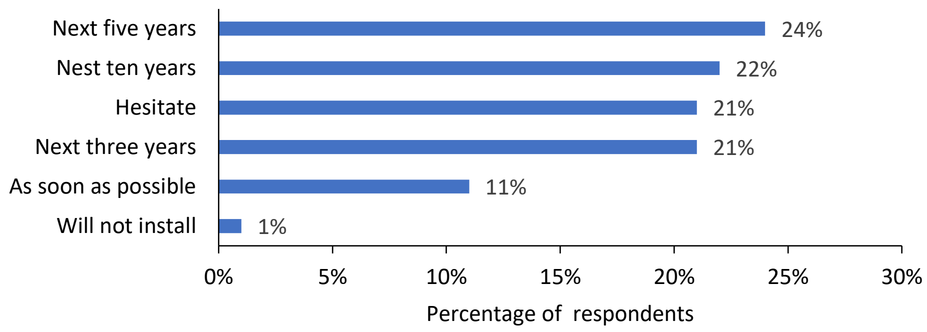

Figure 1. Respondents' intentions in installing PV systems

Furthermore, an analysis was carried out on the answers to households which were grouped based on the installed PLN electricity capacity (0). However, the intention to install PV for households with different installed power capacities is the same. Similar to the results in the aggregate analysis, respondents who intend to use PV as soon as possible have the smallest percentage compared to other choices in all household groups.

Table 2. Intentions to install PV systems across household group-based PLN electricity capacity installed

Plans to install a PV system	Household group-based PLN Electricity Capacity Installed				
	900VA	1300 VA	2200 VA	5500VA	6600VA
As soon as possible	9%	11%	12%	7%	20%
Next three years	17%	19%	23%	31%	20%
Next five years	13%	28%	20%	24%	20%
Next ten years	39%	22%	24%	10%	40%
Hesitate	13%	19%	29%	29%	0%
Will not install	9%	1%	1%	0%	0%

Interesting findings here. In aggregate, there are 21% of respondents have yet to be able to provide an answer. Households still need to figure out the courage to decide when to use PV for various reasons. Some of the reasons mentioned are as follows:

- Installing if the break-even point is not too long.
- Install if the price is low.
- Waiting for an affordable distributor.
- Need more information.
- Install if infrastructure facilities are easily accessible.
- Install a PV system if required by the government.
- Install if the government provides subsidies at the beginning of the installation.
- Install if the operation is easier and more efficient.
- Waiting for regulations from the government.

From the answers above, it appears that some respondents are still in a waiting position until they receive clear information, affordable PV prices, and support from distributors and regulations. This finding is in line with Setyawati (2020) regarding the community's response to ministerial regulation No. 49 of 2018 concerning Rooftop PV. The results show that the majority of respondents (71%) expressed an interest in PV systems but preferred to wait for another scheme before installing PV systems, implying that the respondents either did not think the current scheme was good enough or were expecting a better scheme proposed soon.

4.3 Barrier to PV systems adoption

These respondents were asked closed-ended questions and asked to choose their top three barriers to installing a PV system. Most respondents cited "high initial investment costs" as their primary obstacle to PV system installation. The second most popular answer is "difficulty access to installation services." It is followed by barriers to information availability (See Figure 2). These responses indicate that financial factors are the most significant barrier behind people's reluctance to acquire PV systems, followed by the availability of installation services and information availability.

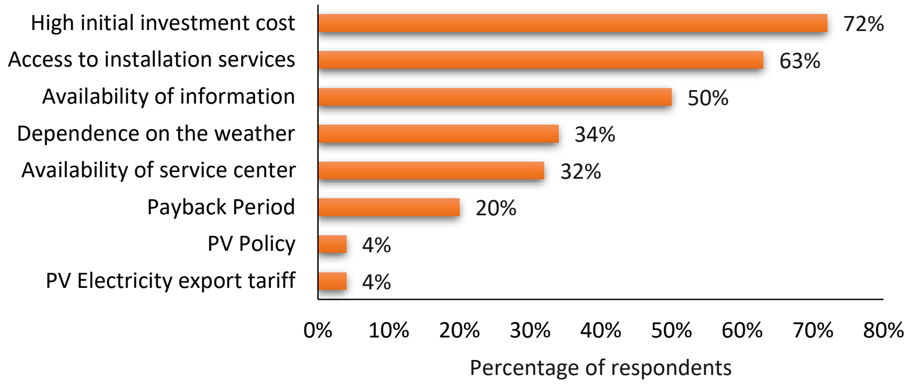

Figure 2. Respondent barriers to using PV system

An in-depth analysis was conducted to investigate barriers to adoption in each household group based on the installed PLN electricity capacity. Figure 3 shows that high initial investment cost is the main barrier for all household groups. Access to installation services was the next barrier for all groups except for the 2200 VA group, and the next obstacle was the availability of information. On the other hand, for the 2200 VA household group, the availability of information was a problem for fewer respondents than access to installation services.

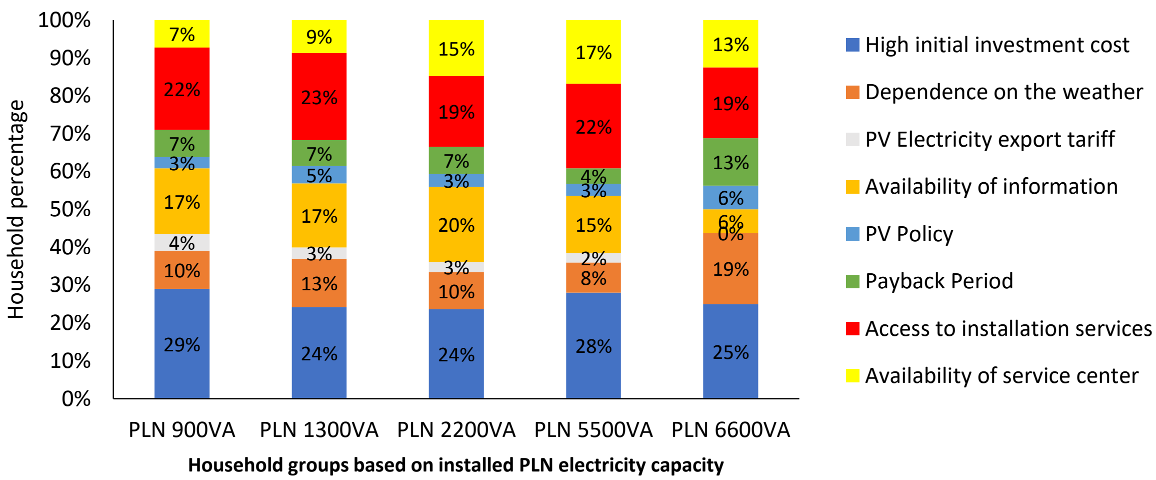

Figure 3. Barriers to installing PV systems across household group-based PLN electricity capacity installed

These results confirm that high initial investment cost, access to installation services, and information availability are the three main obstacles to PV system adoption in any household group. This is in line with previous findings that the high cost of PV is the main factor for household reluctance to use PV (Karakaya & Sriwannawit, 2015; *Rai et al., 2015*). The next hurdle is the industry support factor in providing installation and information services. Without sufficient information, the complexity of PV technology raises the perception that PV systems are complicated and complex, making it an obstacle to adoption (Vasseur & Kemp, 2015; Karakaya *et al*., 2015; Korcaj *et al*., 2015).

4.4 Technical and financial facilitation

Several studies have identified the financial and non-financial support needed for PV adoption in Indonesia and several other countries. This section examines respondents' perceptions of the financial and technical support for PV adoption decisions. Respondents were asked to provide a statement of the level of importance of the facilitation to support the use of the PV system. The answers are given in the form of a Likert scale with a value of 1 (very unimportant) to a value of 5 (very important). 0 presents the expected support from both aspects in order of importance.

Table 3. Technical facilitation and financial facilitation

No	Facilitations	Importance Rating
1	Service center in an affordable location (Joshi & Kumar, 2019)	4.53
2	The vendor or distribution center location is affordable (Joshi & Kumar, 2019)	4.44
3	PV system maintenance training program (Joshi & Kumar, 2019)	4.44
4	Provision of PV from within the country (Dehghani *et al*., 2018)	4.43
5	Community empowerment for system maintenance (Joshi & Kumar, 2019)	4.35
6	PV system grant for the remote area (Sovacool, 2018)	4.35
7	Subsidies for purchasing a PV system (Setyawati, 2020)	4.22
8	Electricity export rates to PLN (Setyawati, 2020)	4.12
9	PLN electricity tariff discount (Sommerfeld *et al*., 2017)	4.02
10	Facilitation of PV purchase cost loans (Setyawati, 2020)	3.85

The essential requirement is the affordability of service center and distribution center facilities as technical facilitation. This relates to the role of the facility as a provider of PV information, installation, and maintenance services. The existence of a distribution center will increase trust and reduce the complexity of using PV systems. The most critical financial facilitation is PV system equipment grants for areas without a PLN electricity network. For areas connected to the PLN network, the need for subsidies and the determination of export tariffs is a demand from the respondents.

Statistical tests with ANOVA were conducted to investigate differences in the level of importance of each factor in different household groups. Of the ten factors examined, significant differences were only found in the affordability factors for service center locations and distribution center locations between the 900VA household group and the 2200VA and 5500VA groups. These findings are in table 4. In the 2200VA and 5500 VA groups, the affordability of the vendor or distribution center location has the highest level of importance. In contrast, the 900VA is only worth 3.87, making the location of the vendor distribution center the least important factor for this group. The 900VA group tends to have more importance on financial support factors.

Table 4. Importance rating of technical and financial facilitating across the household group

	Factor	Household group-based PLN Electricity Capacity Installed					Significance test (ANOVA)	
		900 VA	1300 VA	2200 VA	5500 VA	6600 VA	*F*	*p*
1	Service center in an affordable location	4,13	4,53	4,58	4,62	4,40	2,514	0,041
2	The vendor or distribution center location is affordable	3,87	4,44	4,56	4,52	4,20	4,920	0,001
3	PV system maintenance training program	4,30	4,43	4,51	4,38	4,60	0,636	0,637
4	Provision of PV from within the country	4,04	4,47	4,42	4,40	4,40	2,075	0,083

	Factor	Household group-based PLN Electricity Capacity Installed					Significance test (ANOVA)	
		900 VA	1300 VA	2200 VA	5500 VA	6600 VA	*F*	*p*
5	Community empowerment for PV system maintenance	4,17	4,40	4,36	4,12	4,40	1,589	0,176
6	PV system grant for remote area	4,43	4,42	4,17	4,33	4,20	2,088	0,082
7	Subsidies for purchasing a PV system	4,43	4,26	4,12	4,19	3,80	1,035	0,389
8	PV electricity export rates to PLN	4,09	4,15	4,15	3,93	3,60	1,170	0,323
9	PLN electricity tariff discount	4,39	4,26	4,17	4,10	4,40	0,817	0,515
10	Facilitation of PV purchase cost loans	4,26	3,80	3,81	3,95	4,20	1,268	0,282

Furthermore, demands were analyzed by asking about expectations regarding the location of the distribution center and location of the service center, expected payback period, expected subsidies, and expected electricity export tariffs to PLN.

Table 5. Technical and financial facility expectations

Variables	*All Respondent (n = 376)*	Household group-based PLN Electricity Capacity Installed					Significance test (ANOVA)	
		900 VA	1300 VA	2200 VA	5500 VA	6600 VA	*f*	*p*
The expectation of the location of the distribution and or service center (in terms of the respondent's residence)								
In similar province	91,8%	91%	93%	94%	88%	100%	0,584	0,674
In the same region	3,3%	9%	2%	1%	2%	0%		
In the country	4,9%	0%	5%	5%	10%	0%		
Expected subsidy rate (%)	54,71	59,78	54,19	55,13	57,38	27	2,211	0,067
Expected Payback Period (years)	8,35	8,52	8,36	8,52	7,64	8,4	0,819	0,514
Expected PV electricity export tariffs to the PLN grid (%)	63,95	64,13	64,06	62,98	62,26	68	0,245	0,913

0 shows that almost all respondents demanded distribution center and service center facilities in the province where they live as a form of industry support to ensure ease of installation and maintenance of PV systems. As financial facilitation, the average respondent wants a 54.74% subsidy to be willing to use the PV system. Regarding the payback period, 8.35 years is the value expected by the respondents. Interesting findings on the expected electricity export tariffs from the PV system to PLN. Respondents gave an expected value of export tariffs of 64% lower than the currently set (65%). This was triggered by a lack of understanding of the applicable PV regulations, indicating a lack of socialization of regulations regarding PV systems.

A partial analysis of each household group was carried out abo financial and technical facilitation expectations. An ANOVA test was carried out, and the results showed no significant differences between household groups in the expectations of vendor locations, PV system purchase subsidies, payback periods, and electricity export tariffs from the PV system to PLN.

5. Conclusion

This paper succeeded in identifying the factors that hinder the adoption of PV systems in Indonesian households. The high initial investment cost is the biggest obstacle for households to use PV systems, followed by access to PV installation service providers and availability of information. The results show that the barriers to the diffusion of PV systems in Indonesia are influenced by financial factors and the need for support from the industry in providing PV system infrastructure. This finding is significant for accelerating the diffusion of RPV in Indonesia.

Financial and non-financial policies are needed to promote PV technology. The study results provide an overview of the support required to guide households in PV adoption decisions. Financial support in the form of subsidies at a value of 54.74% of the initial cost is expected to overcome the barrier of high investment costs of PV systems which could trigger further diffusion. Evaluation of current policies also needs to be carried out to ensure PV system investment can reach payback in year 8.35, as the average Indonesian household expects. The active participation of the PV industry as a provider of information services, procurement, installation, and maintenance of PV systems is required through the provision of service facilities such as distribution centers and/or service centers in each province. The availability of service facilities at affordable locations will increase the perceived relative advantage and reduce the perceived complexity of the PV system. The presence of PV companies also fosters a peer effect by disseminating information through formal social networks involving the role of highly motivated adopters. Networked information and communication can increase the understanding of households initially disinterested or ignorant about the PV system. These findings are helpful for policymakers and stakeholders as practical recommendations to promote PV adoption in Indonesia. To accelerate PV adoption, it is recommended that government support is in the form of subsidising the purchase of PV system equipment by at least 55% to overcome the high investment cost constraints. On the other hand, the PV industry supports distribution centers in each province as service providers for information, purchase, installation and maintenance of PV systems. Further research is needed to investigate the impact of various technical and financial facilitation on PV diffusion to formulate effective policies. This study is limited to the financial and technical aspects. Studies from other aspects, such as socio-demographic, environmental and peer effects, also are future research opportunities for adopting PV systems in Indonesia.

Declaration of Conflicting Interests. The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Abbasi, T., & Abbasi, S.A. (2012). Is the use of renewable energy sources an answer to the problems of global warming and pollution?. *Critical Reviews in Environmental Science and Technology*, 42, 99–154. doi:10.1080/10643389.2010.498754.

Bawakyillenuo, S. (2012). Deconstructing the dichotomies of solar photovoltaic (PV) dissemination trajectories in Ghana, Kenya and Zimbabwe from the 1960s to 2007. *Energy Policy*, 49, 410–42. doi:10.1016/j.enpol.2012.06.042.

Curtius, H.C. (2018). The adoption of building-integrated photovoltaics: barriers and facilitators. *Renewable Energy*, 126, 783–790. doi:10.1016/j.renene.2018.04.001.

D'Agostino, A.L., Sovacool, B.K., & Bambawale, M.J. (2011). And then what happened? A retrospective appraisal of China's Renewable Energy Development Project (REDP). *Renewable Energy*, 36, 3154–3165. doi:10.1016/j.renene.2011.03.017.

Dehghani, E., Jabalameli, M.S., & Jabbarzadeh, A. (2018). Robust design and optimization of solar photovoltaic supply chain in an uncertain environment. *Energy*, 142, 139–156, doi:10.1016/j.energy.2017.10.004.

Elmustapha, H., Hoppe, T., and Bressers, H. (2018). Consumer renewable energy technology adoption decision-making; comparing models on perceived attributes and attitudinal constructs in the case of solar water heaters in Lebanon. *Journal of Cleaner Production*, 172, 347–357. doi:10.1016/j.jclepro.2017.10.131.

Elmustapha, H., Hoppe, T., and Bressers, H. (2018). Consumer renewable energy technology adoption decision-making; comparing models on perceived attributes and attitudinal constructs in the case of solar water heaters in Lebanon. *Journal of Cleaner Production*, 172, 347–357, doi:10.1016/j.jclepro.2017.10.131.

IRENA (2019). *Renewable Power Generation Cost in 2019*.

Islam, T., & Meade, N. (2013). The impact of attribute preferences on adoption timing: The case of photo-voltaic (PV) solar cells for household electricity generation. *Energy Policy*, 55, 521–530. doi:10.1016/j.enpol.2012.12.041.

Jannuzzi, G. de M., & de Melo, C.A. (2013). Grid-connected photovoltaic in Brazil: Policies and potential impacts for 2030. *Energy for Sustainable Development*, 17, 40–46. doi:10.1016/j.esd.2012.10.010.

Joshi, L., & Kumar, P. (2019). Adoption of solar photovoltaic lighting in rural India: Role of localization strategy. *Energy and Buildings*, 202, 109370. doi:10.1016/j.enbuild.2019.109370.

Karakaya, E., Hidalgo, A., & Nuur, C. (2015). Motivators for adoption of photovoltaic systems at grid parity: A case study from Southern Germany. Renew. *Renewable and Sustainable Energy Reviews*, 43, 1090–1098. doi:10.1016/j.rser.2014.11.077.

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. doi:10.1016/j.rser.2015.04.058.

Korcaj, L., Hahnel, U.J.J., & Spada, H. (2015). Intentions to adopt photovoltaic systems depend on homeowners' expected personal gains and behavior of peers. *Renewable Energy*, 75, 407–415. doi:10.1016/j.renene.2014.10.007.

Ministry of Energy and Mineral Resources. (2019). Kebijakan, regulasi dan inisiatif pengembangan energi surya di Indonesia.

Ministry of Energy and Mineral Resources. (2021). Laporan Kinerja DitJen EBTKE Tahun 2021.

Ministry of Energy and Mineral Resources. (2021). Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2021-2030. Rencana Usaha Penyediaan Tenaga List. 2021-2030 2021, 2019–2028.

Mundaca, L., & Samahita, M. (2020). What drives home solar PV uptake? Subsidies, peer effects and visibility in Sweden. *Energy Research & Social Science*, 60, 101319. doi:10.1016/j.erss.2019.101319.

Nurwidiana, N., Sopha, B.M., & Widyaparaga, A. (2021). A Behavioral Factors Underlying Households ' Intention Toward Solar Photovoltaic Adoption. *In Proceedings of the Proceedings of the Second Asia Pacific International Conference on Industrial Engineering and Operations Management*; IEOM: Surakarta.

Palmer, J., Sorda, G., & Madlener, R. (2015). Modeling the diffusion of residential photovoltaic systems in Italy: An agent-based simulation. *Technological Forecasting and Social Change*, 99, 106–131. doi:10.1016/j.techfore.2015.06.011.

Rai, V., Reeves &, D.C., & Margolis, R. (2015). Overcoming barriers and uncertainties in the adoption of residential solar PV. *Renewable Energy*, 89, 498–505. doi:10.1016/j.renene.2015.11.080.

Reeves, D.C., & Rai, V. (2018) Strike while the rebate is hot: Savvy consumers and strategic technology adoption timing. *Energy Policy*, 121, 325–335. doi:10.1016/j.enpol.2018.06.045.

Sarzynski, A., Larrieu, J., & Shrimali, G. (2012). The impact of state financial incentives on market deployment of solar technology. *Energy Policy*, 46, 550–557. doi:10.1016/j.enpol.2012.04.032.

Schelly, C. (2014). Residential solar electricity adoption: What motivates, and what matters? A case study of early adopters. *Energy Research & Social Science*, 2, 183–191. doi:10.1016/j.erss.2014.01.001.

Schelly, C. (2010). Testing residential solar thermal adoption. *Environment and Behavior*, 42, 151–170. doi:10.1177/0013916508327867.

Setyawati, D. (2020). Analysis of perceptions towards the rooftop photovoltaic solar system policy in Indonesia. *Energy Policy*, 144, 111569, doi:10.1016/j.enpol.2020.111569.

Sommerfeld, J., Buys, L., & Vine, D. (2017). Residential consumers' experiences in the adoption and use of solar PV. *Energy Policy*, 105, 10–16. doi:10.1016/j.enpol.2017.02.021.

Sovacool, B.K. (2018). Success and failure in the political economy of solar electrification: Lessons from World Bank Solar Home System (SHS) projects in Sri Lanka and Indonesia. *Energy Policy*, 123, 482–493. doi:10.1016/j.enpol.2018.09.024.

Vasseur, V., & Kemp, R. (2015). The adoption of PV in the Netherlands: A statistical analysis of adoption factors. *Renewable and Sustainable Energy Reviews*, 41, 483–494. doi:10.1016/j.rser.2014.08.020.

Willis, K., Scarpa, R., Gilroy, R., & Hamza, N. (2011). Renewable energy adoption in an ageing population: Heterogeneity in preferences for micro-generation technology adoption. *Energy Policy*, 39, 6021–6029. doi:10.1016/j.enpol.2011.06.066.

Wolske, K.S. (2020). More alike than different: Profiles of high-income and low-income rooftop solar adopters in the United States. *Energy Research & Social Science*, 63, 101399. doi:10.1016/j.erss.2019.101399.

Yang, D., & Timmermans, H. (2017). Households transport-home energy conservation strategies in response to energy price policies: A stated adaptation experiment based on portfolio choices and cross effects designs. *International Journal of Sustainable Transportation*, 11, 133–147. doi:10.1080/15568318.2016.1212442.

Zhao, J., Mazhari, E., Celik, N., & Son, Y.J. (2011). Hybrid agent-based simulation for policy evaluation of solar power generation systems. *Simulation Modelling Practice and Theory*, 19, 2189–2205. doi:10.1016/j.simpat.2011.07.005.

To Cite This Article: Nurwidiana, N. (2023). Barriers to adoption of photovoltaic systems: A case study from Indonesia. *Journal of Industrial Engineering and Education*, 1(1), 80-89.