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A Meta-Analysis of Adopters and Non-Adopters of Rooftop Photovoltaics in Indonesian Households †

Bertha Maya Sopha [1,*] and Sholeh Ma'mun [2]

[1] Industrial Engineering Program, Department of Mechanical and Industrial Engineering, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia
[2] Department of Chemical Engineering, Universitas Islam Indonesia, Yogyakarta 55584, Indonesia; sholeh.mamun@uii.ac.id
* Correspondence: bertha_sopha@ugm.ac.id
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Abstract: Although the Indonesian government has conducted various interventions to escalate the uptake of rooftop PV in Indonesian households, adoption has still been sluggish. Few studies have been conducted to explore the issue, and these studies are scattered. The paper aims to assess generalizations of the previous studies regarding adopters' and non-adopters' characteristics of Indonesian households and their perceptions of rooftop PV attributes using meta-analysis. The findings show that statistically significant differences between the two studies in terms of socio-demographic factors, problem awareness, innovativeness, and perceived qualities of rooftop photovoltaics exist. Despite the differences, the adopters of both studies perceived equally that using renewable energy was important, that rooftop photovoltaics were environmentally friendly, and that they were generally aware of environmental problems. It appears that the non-adopters sample drawn from stratified random sampling demonstrates a similar distribution specified by Diffusion of Innovation. Furthermore, the non-adopters in the two research show a comparable belief regarding the significance of putting renewable energy into practice. Due to inconclusive patterns, an empirical investigation that sufficiently represents both the rooftop PV adopters and non-adopters in Indonesian households is suggested. Other potential future research are also discussed.

Keywords: adopters; non-adopters; rooftop photovoltaics; meta-analysis; Indonesian households

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1. Introduction

The electricity demand increased as a result of population growth and rising economic developments. Fossil fuels including coal, oil, and gas have been the dominating energy sources in Indonesia. The high consumption of fossil energy has led to an increase in CO_2 emissions globally from 32 Gt in 2010 to 37 Gt in 2017 [1,2]. However, the depletion of fossil fuels and increased concerns about environmental problems such as global warming due to CO_2 emissions have triggered the development of renewable energy. Renewable energy has gained prominence and continues to receive attention over the past two decades. Among renewable energies, solar energy has shown to have tremendous potential to be developed [3]. To meet the target of 23% of renewable energy in the national energy mix by 2025 [4], the Government of Indonesia (GoI) is seeking the provision of 45.2 GW of sustainable electricity, of which solar power is expected to contribute as much as 6.5 GW [5]. GoI has supported the construction of solar power stations for both industrial and residential sectors. The target of 3.5 GW of solar power for residential settings has been set. A number of initiatives, including the awarding of a 50 Wp Solar Home System (SHS) grant to homes without access to energy and a rooftop solar scheme for individuals living off the grid have been performed [5]. Nevertheless, the market for PV systems has only spread slowly. The

adopters of rooftop PV in the residential sector were still far from the target; as of mid-2021, they had only reached 4028, with a total capacity of 35 MW [5].

Sluggish diffusion of rooftop PV despite government initiatives indicates the need to better understand the potential adopters of rooftop PV. A number of studies such as Refs. [6–9] have highlighted the necessity to understand the individual factors underlying decision-making on environmentally friendly technology, in addition to technology factors. With respect to rooftop PV, very few studies such as [10–12] have been conducted to understand the characteristics of adopters and non-adopters of the rooftop PV to estimate the future diffusion of PV. For the Indonesian context, two studies, i.e., [10,11], were found. These studies were conducted at different locations, scales, and times. Because it is important to comprehend how Indonesian households as a whole perceive rooftop PV, the objective of the paper is to conduct a meta-analysis to formally assess and identify the general patterns with respect to the characteristics of PV adopters and non-adopters in Indonesian households and their perceptions of PV attributes.

The present study has two distinct underlying motivations. First, it identifies conflicts or agreements of the previous findings with respect to the characteristics of the adopters and non-adopters of rooftop PV in Indonesian households. This helps to understand the variations among Indonesian households. As confirmed by Ref. [13] in a more general context, the challenges in developed countries differ from those in developing countries. Second, the study analyses the general patterns of characteristics of PV adopters and non-adopters to assist GoI in designing effective and efficient interventions to support the diffusion of rooftop PV in Indonesian households to meet the national energy mix target.

2. Theoretical Background

Diffusion of innovation (DoI) [14] has been long and widely used to categorize the potential adopters in various applications. According to DoI, the adoption of innovation is a process in which certain individuals are more likely to accept an invention than others. It does not happen all at once. An innovation spreads over time to a group of people who are part of the social system through particular routes in which perceived quality of innovation, communication channels, time, and social system are the four primary components that make up the dissemination of innovation. Furthermore, Rogers [14] categorizes the population into five groups: innovators, early adopters, early majority, late majority, and laggards. Innovators are the first to use the innovation because they are drawn to the newness of the technology. Another group that embraces technology early is the early adopters, who do so in an effort to stay ahead of the curve. Decisions made by the early majority group are influenced by the innovation's usefulness and potential advantages. While adopting, the late majority is more thoughtful than the early majority. The final category is known as laggards; they are slow to adopt new concepts or technology and usually only do so when compelled to or because others in their group are already doing so. The heterogeneity in terms of characteristics of individuals in a social system, combined with social interactions among the individuals, leads to the dynamics of adoption and diffusion. It is henceforth essential to recognize the heterogeneity among individuals.

Within the context of environmentally-friendly innovation, it is also imperative to address attitudes toward the environment. To determine whether or not individuals take environmental issues into account when making adoption decisions on environmentally-friendly innovation, it is necessary to carefully assess their awareness of environmental problems. The present study examines problem awareness. In addition, the perceived importance of using renewable energy in dealing with environmental issues is also considered.

DoI also addresses that the attributes of the innovation influence adoption decision-making, explaining 49–87% of adoption variance [14]. According to DoI theory [14], the attributes of innovation involve relative advantage, compatibility, complexity, trialability, and observability. Based on Ref. [9]—which conducted an initial investigation on rooftop PV in Indonesia—ease of use, incurred costs, environmental benefit, social symbol, and autarky benefit are selected to be analyzed in the study. In summary, based on the aforementioned

parameters, the present study conducts a meta-analysis with respect to socio-demographic factors (i.e., age, gender, education), individual factors (i.e., innovativeness, problem awareness, perceived importance of using renewable energy), and perceived attributes of rooftop PV—including technical, economic, environmental, and social aspects.

3. Methodology

A meta-analysis based on the two previous studies of rooftop PV in Indonesian households, i.e., [10,11], was conducted. The two studies were selected because they focus on rooftop PV in Indonesian households and provide necessary data in relation to the aforementioned parameters in Section 2. Table 1 presents a brief profile of the two studies.

Table 1. The profile of the two studies on rooftop PV in Indonesian households.

Parameter	Ghassani [10]	Nurwidiana [11]
Year of empirical survey	2019	2021
Survey location	Yogyakarta city	Eight regions: Sumatera, Java, Kalimantan, Sulawesi, Bali, Nusa Tenggara, Papua, Maluku
Sampling method	Purposive	Stratified random
Number of respondents	152	450
Adopters	51	46
Non-adopters	101	367
Unit of analysis	Household	Household

A statistical approach was deployed for comparison analysis. For interval data, the comparison analysis was analyzed using *t*-tests; for nominal data, chi-squared tests were employed to ascertain whether any significant differences existed between the groups being analyzed.

4. Results and Discussion

This section is divided into four parts following the parameters to be analyzed—socio-demographic factors, innovativeness, problem awareness, and perceived importance of using renewable energy—as well as perceived attributes of rooftop PV.

4.1. Socio-Demographic Factors

Table 2 presents the comparison analysis of the respondents' socio-demographic factors. With respect to age, a significant difference between the two studies is observed. Ref. [10] demonstrated a significant age difference between the adopters and the non-adopters, whereas Ref. [11] showed otherwise. The older adopters from Ref. [10] can be due to the targeted households with rooftop PV being selected purposively in upper-middle-class housing.

With respect to gender and education, both studies showed a similar trend in which significant differences between the adopters and the non-adopters exist. However, it is interesting to note that the two studies have statistically significant differences with respect to the distribution of gender and education of the adopters and the non-adopters.

It appears that the adopters are dominated by males with university-level education. The results are supported by the DoI [14] in which the adopters are characterized with advanced education.

Table 2. Comparison analysis of the respondents' socio-demographic profile.

Socio-Demographic Factors	Ghassani [10]	Nurwidiana [11]	Significance Test Between [10] and [11]
Age	*Mean (SD)*	*Mean (SD)*	
Adopters	45.3 (9.4)	40.2 (7.6)	$t(97) = -2.883$; $p < 0.01$ **
Non-adopters	35.5 (10.4)	40.7 (8.3)	$t(505) = 5.349$; $p < 0.001$ ***
Adopters vs. Non-adopters	$t(152) = 5.657$; $p < 0.001$ ***	$t(450) = 0.211$; $p = 0.617$	
Gender	*N (%)*	*N (%)*	
Adopters			
Male	26 (51%)	41 (89.1%)	$\chi^2 = 149.467$; $df = 1$; $p < 0.001$ ***
Female	25 (49%)	5 (10.9%)	
Non-adopters			
Male	40 (40%)	259 (64%)	$\chi^2 = 25$; $df = 1$; $p < 0.001$ ***
Female	61 (60%)	145 (36%)	
Adopters vs. Non-adopters	$\chi^2 = 5.042$; $df = 1$; $p < 0.05$ *	$\chi^2 = 27.344$; $df = 1$; $p < 0.001$ ***	
Education	*N (%)*	*N (%)*	
Adopters			
Elementary school	2 (4%)	0 (0%)	
Junior high school	1 (2%)	1 (2.2%)	$\chi^2 = 16.266$; $df = 4$; $p < 0.01$ **
Senior high school	4 (8%)	12 (26.1%)	
Undergraduate	31 (61%)	22 (47.8%)	
Post-graduate	13 (25%)	11 (23.9%)	
Non-adopters			
Elementary school	0 (0%)	0 (0%)	
Junior high school	0 (0%)	1 (0.2%)	$\chi^2 = 148.727$; $df = 4$; $p < 0.001$ ***
Senior high school	35 (35%)	27 (6.7%)	
Undergraduate	57 (56%)	197 (48.8%)	
Post-graduate	9 (9%)	179 (44.3%)	
Adopters vs. Non-adopters	$\chi^2 = 49.719$; $df = 4$; $p < 0.001$ ***	$\chi^2 = 24.79$; $df = 4$; $p < 0.001$ ***	

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

4.2. Innovativeness

According to DoI, innovativeness is attributed to innovators and early adopters. Both groups are open to new ideas and willing to take risks to implement technology in society. Based on empirical evidence, DoI suggests that the typical composition of the population according to their innovativeness is 2.5% of innovators, 13.5% of early adopters, 34% of the early majority, 34% of the late majority, and 16% of laggards. The composition was then compared against both studies which were drawn from the non-adopters. The non-adopters were designated because the non-adopter group is more representative of the general Indonesian population than the adopter group.

Table 3 shows that there is a significant difference between the distribution based on DoI [14] and that of Ref. [10], and a non-significant difference between DoI [14] and that of Ref. [11]. It can be argued that the purposive sampling method used by Ref. [10] leads to a limited representation of Indonesian households. On the other hand, the non-adopters of [11] represent the general distribution of innovativeness in the society. Furthermore, the differences on innovativeness in the population was also observed by Ref. [15] in potential photovoltaic adopters in Germany.

Table 3. Comparison analysis of the innovativeness category.

Innovativeness Category	Rogers [14]	Ghassani [10]	Nurwidiana [11]
Innovators	2.5	0	4.4
Early adopter	13.5	13.9	17.1
Early majority	34	64.4	28.3
Late majority	34	15.8	37.9
Laggards	16	5.9	12.3
Significance test between [14] and the respective study		$\chi^2 = 45.635$; $df = 4$; $p < 0.001$ ***	$\chi^2 = 4.663$; $df = 4$; $p = 0.323$

Note: *** $p < 0.001$.

4.3. Problem Awareness and Perceived Importance of Renewable Energy

This sub-section explores the perception of the respondents regarding their awareness of environmental problems and the perceived importance of implementing renewable energy to deal with the problem. Table 4 reports the results of the comparison analysis. Ref. [10] indicated that the adopters and the non-adopters are significantly different with respect to problem awareness in which the adopters have a higher awareness of environmental problems than the non-adopters. However, Ref. [11] showed non-significant differences between the adopters and the non-adopters with respect to problem awareness and the perceived importance of using renewable energy.

Table 4. Comparison analysis of the problem awareness and importance of renewable energy.

Parameters [a]	Ghassani [10]	Nurwidiana [11]	Significance Test Between [10] and [11]
Problem Awareness	*Mean (SD)*	*Mean (SD)*	
Adopters	4.46 (0.30)	4.54 (0.55)	$t(97) = 0.949$; $p = 0.345$
Non-adopters	4.18 (0.41)	4.57 (0.70)	$t(505) = 5.392$; $p < 0.001$ ***
Adopters vs. Non-adopters	$t(152) = 4.206$; $p < 0.001$ ***	$t(450) = -0.290$; $p = 0.772$	
Importance of using renewable energy	*Mean (SD)*	*Mean (SD)*	
Adopters	4.63 (0.56)	4.47 (0.75)	$t(97) = -1.111$; $p = 0.269$
Non-adopters	4.59 (0.60)	4.57 (0.69)	$t(505) = -0.363$; $p = 0.716$
Adopters vs. Non-adopters	$t(152) = 0.329$; $p = 0.742$	$t(450) = -0.818$; $p = 0.414$	

[a] The parameters were measured using a five-point Likert scale with 1 representing strongly disagree and 5 representing strongly agree. Note: *** $p < 0.001$.

It appears that the problem awareness of the adopters between the two studies is in agreement. On the other hand, the problem awareness of the non-adopters is dissimilar. It is also interesting that both the adopters and the non-adopters of the two studies are not statistically different, indicating a similar perception of the importance of using renewable energy. Giving the high mean value (out of the maximum scale of 5) indicates strong agreement with the high importance of using renewable energy as an option to deal with environmental issues.

4.4. Perceived Attributes of Rooftop PV

Table 5 reports the perceived attributes of rooftop PV. Ref. [10] highlighted that a significant difference exists between the adopters and the non-adopters with respect to the perceived environmental friendliness of PV. Rooftop PV is perceived by the adopters as more environmentally friendly than by the non-adopters. Ref. [11] indicated significant differences exist in perceived ease of use and autarky benefit between the adopters and the non-adopters. The adopters perceived higher ease of use and autarky benefits than the non-adopters. The findings imply that higher perceptions of environmental friendliness of

innovation, ease of use, and autarky benefit are attributable to the adopters. Henceforth, appropriate interventions can be focused on the areas.

Table 5. Comparison analysis of problem awareness and responsibility.

Parameters [a]	Ghassani [10]	Nurwidiana [11]	Significance Test Between [10] and [11]
Ease of use	*Mean (SD)*	*Mean (SD)*	
Adopters	4.71 (0.54)	3.95 (1.15)	$t(97) = -4.278$; $p < 0.001$ ***
Non-adopters	4.01 (0.61)	3.43 (0.85)	$t(505) = -12.405$; $p < 0.001$ ***
Adopters vs. Non-adopters	$t(152) = 1.601$; $p = 0.112$	$t(450) = 3.832$; $p < 0.001$ ***	
High cost	*Mean (SD)*	*Mean (SD)*	
Adopters	4.25 (0.52)	3.52 (1.05)	$t(97) = -4.278$; $p < 0.001$ ***
Non-adopters	4.40 (0.95)	3.50 (0.93)	$t(505) = -8.659$; $p < 0.001$ ***
Adopters vs. Non-adopters	$t(152) = -0.987$; $p = 0.325$	$t(450) = 0.149$; $p = 0.882$	
Environmentally friendly	*Mean (SD)*	*Mean (SD)*	
Adopters	4.53 (0.73)	4.48 (0.75)	$t(97) = -0.339$; $p = 0.735$
Non-adopters	4.08 (0.78)	4.29 (0.72)	$t(505) = 2.579$; $p < 0.05$ *
Adopters vs. Non-adopters	$t(152) = 3.420$; $p < 0.001$ ***	$t(450) = 1.675$; $p = 0.095$	
Social symbol	*Mean (SD)*	*Mean (SD)*	
Adopters	2.39 (0.72)	3.11 (1.29)	$t(97) = -3.424$; $p < 0.001$ ***
Non-adopters	2.45 (1.11)	2.83 (1.14)	$t(505) = 3.063$; $p < 0.01$ **
Adopters vs. Non-adopters	$t(152) = -0.312$; $p = 0.756$	$t(450) = 1.542$; $p = 0.124$	
Autarky benefit	*Mean (SD)*	*Mean (SD)*	
Adopters	4.67 (0.48)	3.98 (0.83)	$t(97) = -5.073$; $p < 0.001$ ***
Non-adopters	4.59 (0.62)	3.69 (0.83)	$t(505) = -10.246$; $p < 0.001$ ***
Adopters vs. Non-adopters	$t(152) = 0.734$; $p = 0.464$	$t(450) = 2.214$; $p < 0.05$ *	

[a] The parameters were measured using a five-point Likert scale with 1 representing strongly disagree and 5 representing strongly agree. Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

It is worthwhile to note that the two studies indicate significant differences in the perceptions of all attributes of rooftop PV except for the perceived environmental friendliness of rooftop PV by the adopters of both studies given the fact that the satisfaction of the attributes of technology influence the continuous adoption [16]. Significant differences in perceived ease of use between the two studies indicate that the spatial analysis such as addressed in some studies, e.g., Ref. [16] is required because Ref. [3] indicated that different regions have different PV-supporting infrastructures, leading to different perceived ease of use. Ref. [3] further indicated that a robust supply chain of PV maintenance highly influenced the adoption and diffusion of PV. Hence, an optimal supply chain is required, indicating the required further study to explore the optimized supply chain as well as to develop the approach in supporting the optimal supply chain of PV, e.g., Ref. [17].

Summarizing, the findings indicate discrepancies are observed between the two studies. This could be due to differences in terms of the scope and sampling method. It implies that the findings have limited generalization. Henceforth, due to inconclusive findings, it implies that further studies that sufficiently represent both groups, the adopters and the non-adopters of the Indonesian population still have to be carried out for future research.

5. Conclusions

The present study aims to evaluate generalizations on the characteristics of the adopters and the non-adopters and their perceived attributes of rooftop PV in Indonesian households. A meta-analysis based on the two empirical studies of rooftop PV in Indonesian households was conducted. Findings indicate that significant differences were observed between the two studies with respect to socio-demographic factors (i.e., age, gender, education), innovativeness, problem awareness, and perceived attributes of rooftop

PV (i.e., ease of use, rooftop PV cost, social symbol, and autarky benefit). It is worth emphasizing that the adopters of the two studies have similar degrees of environmental problem awareness, perceived importance of using renewable energy, and perceived environmental friendliness of rooftop PV. It appears that the non-adopters following stratified random sampling follow the theoretical distribution of innovativeness following DoI. Moreover, the non-adopters of the two studies indicate similar perceptions of the importance of implementing renewable energy. The overall findings imply that the existing studies need to be enhanced by conducting an empirical study which adequately illustrates the adopters and the non-adopters of rooftop PV in Indonesian households.

The paper has contributed to better understand the variations among Indonesian households when it comes to rooftop PV adoption by exploring the general pattern of characteristics of PV adopters and non-adopters using meta-analysis approach. However, this study has a limitation in which the analysis was only based on two empirical PV studies due to data accessibility. Using more empirical studies in the analysis would help to improve the generality of the findings and hence is suggested as future research.

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