MASTER THESIS

Accelerating Solar PV Systems Development in Jakarta, Indonesia: The Role of Technological Acceptance Model

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Abstract:

This research investigates the adoption of solar photovoltaic (PV) systems in Indonesia within the framework of the RPVSS policy. Addressing the energy trilemma of security, affordability, and sustainability, the study assesses key factors influencing adoption. Affordability emerges as a challenge due to high upfront costs and limited energy storage. Expert interviews reveal political and technical concerns regarding grid stability and intermittency. Environmental sustainability is compromised by inadequate solar waste treatment facilities. Public perception reflects positive views on usefulness and ease of use, yet concerns persist about affordability and environmental awareness. Recommendations for policymakers include subsidies, collaboration with property developers, simplifying adoption processes, launching comprehensive awareness campaigns, and establishing waste treatment facilities. The study underscores the relevance of the Technological Acceptance Model (TAM) to enhance solar PV adoption through better affordability, convenience, environmental awareness, and technical understanding. While insights are drawn from Jakarta, future studies could extend findings to broader urban contexts. This research offers a comprehensive analysis of solar PV adoption challenges, public perceptions, and actionable policy recommendations for sustainable energy transition in Indonesia.

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List of Abbreviations

AC	Alternating Current
ASEAN	Association of Southeast Asian Nations
DC	Direct Current
GHG	Greenhouse Gases
GW	Gigawatts
IEEFA	Institute for Energy Economics and Financial Analysis
IESR	Institute for Essential Services Reform
IPP	Independent Power Production
IRENA	International Renewable Energy Agency
MEMR	Ministry of Energy and Mineral Resources
OEC	The Observatory of Economic Complexity
PLN	Perusahaan Listrik Negara
ROI	Return on Investment
RPVSS	Rooftop Photovoltaic Solar Systems
TAM	Technological Acceptance Model
TKDN	Tingkat Komponen Dalam Negri
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action

1. Introduction

1.1 Research Background

Climate change has become a pivotal challenge facing the world in recent decades. This concern leads to the need for energy transition, as fossil fuel consumption was estimated to contribute to more than two-thirds of total greenhouse gas (GHG) emissions globally. In 2020, even though global CO2 emissions from fuel combustion declined by around 6% due to COVID-19 reduced global energy demand, fossil fuel still represented 80% of the total energy supply globally (IEA, 2021)

Regarding the global energy transition challenge, Indonesia plays a vital role as the highest energy consumption country in the Association of Southeast Asian Nations (ASEAN) in total. It is forecasted to keep growing along with economic and population growth (IRENA, 2022). Consequently, the Indonesian Government has stipulated to increase the Renewable Energy mix by 23% and 31% in 2025 and 2050, respectively, through Government Regulation No.79 of 2014 in the National Energy Plan and 2015 Paris Agreement (MEMR, 2019).

Located in the equator, solar energy possessed the highest potential of the other renewable energy options in Indonesia, with an average of 4.8 kWh/m square per day and a total potential of 207,898 MW (see Table 1) (Silalahi et al., 2021; MEMR, 2019). As a country with significant potential to produce solar energy, Indonesia found to have remained underutilizing the solar PV systems[1] (Dang, 2017; Mujiyanto and Tiess, 2013). The realization of solar PV systems adoption in Indonesia constitutes only 0.03% of the total potential (MEMR, 2019). In this sense, Indonesia's untapped solar energy potential could significantly contribute to energy transition and meet the growing energy demand in the following years.

Table 1. Renewable Energy Potential in Indonesia (Source: MEMR, 2019, p.6)

Energy Source	Potential*)
Hydro	94.3 GW
Geothermal	28.5 GW
Bioenergy	Bio PP : 32.6 GW and
	Biofuel : 200 Thousand bpd
Solar energy	207.8 GWp
Wind	60.6 GW
Ocean energy	17.9 GW

[1] Hereafter, the solar PV system refers to a set of hardware that consists of one or more solar panels, an inverter, a network metre, and a grid that can convert solar energy to electricity (Akorede, 2022).

To promote the adoption of solar PV systems, the Government of Indonesia introduced the Rooftop Photovoltaic Solar Systems (RPVSS) policy in 2018 to encourage the public (hereafter, public refers to households) to adopt solar PV systems and reduce reliance on fossil fuels, which are the major contributor to climate change. However, in 2021, Indonesia's energy source is still dominated by fossil fuels, which account for almost 90% of the national energy mix, which illustrates the slow progress of renewable energy adoption in the country (Ritchie, 2022b). In solar PV systems development, policy frameworks that are supportive and favorable to adopting solar PV systems can help accelerate the technology adoption (Kunaifi et al., 2020). In addition, understanding the factors that influence the public as potential adopters of solar PV systems under RPVSS policy is crucial to accelerate the development of solar PV systems. For instance, if the public, as potential adopters of technology, find the maintenance and costs related to solar PV systems problematic, they could be inclined not to install solar PV panels on their rooftops. In this sense, technological acceptance studies offer a framework to analyze the public perception and attitudes toward the intention to use solar PV systems (Yang, 2021). This research will focus on the current situation in Indonesia regarding the adoption of solar PV systems, as the public will perceive the technology based on the current policy.

In Indonesia, solar energy technology has gained popularity recently. Many studies have been published in which focusing on analyzing the technical and economic aspects of solar PV systems in Indonesia (Qamar, 2022; Kristiawan et al., 2018; Sijabat & Mostavan, 2021 and Dwipayana & Herdiansyah, 2021). In addition, there have been publications addressing the public perception of the solar PV systems associated with the challenge of installing solar PV systems in Indonesia (Setyawati, 2020; Qolbi, 2020; and Tarigan, 2020). However, there needs to be more research on technological acceptance's potential impact on the adoption of solar PV systems under specific policy settings. Therefore, the present research focuses on assessing the impact of technological acceptance in solar PV systems under the RPVSS policy.

1.2 Problem Statement

To achieve the energy mix target of 23% in 2025 and 31% in 2050, the development of solar energy is expected to become the backbone as the weather and location of Indonesia are in favorable conditions to generate solar energy. However, the slow development of solar PV systems in Indonesia is strongly linked to political issues rather than technical as Indonesia is still dominated by coal as the energy source, and most coal businesses are owned by the political elites (Setyawati, 2020). In solar PV systems development, the influence of energy policy will determine the technological standard and the technology adoption procedure for the potential customer. Thus, it is relevant to analyze the key components that influence the development of solar PV systems in Indonesia under a specific policy setting.

Since 2018, the Government of Indonesia has implemented the Rooftop Photovoltaic Solar Systems (RPVSS) Policy, encouraging the public to adopt solar PV systems to generate energy. However, the adoption of solar PV systems in Indonesia remained insignificant regardless of the existence of the RPVSS policy. In accelerating the adoption of solar PV technology, the public is considered an important stakeholder and plays a vital role as a potential user (Yang, 2021). In this sense, understanding the public perception of solar PV systems and analyzing the key factors influencing the public intention to adopt the new technology is imperative. The Technological Acceptance Model (TAM) theory offers a framework to understand the determinants of the intention to adopt solar PV systems in Indonesia, which could occur based on four indicators: usefulness, ease of use, environmental awareness, and affordability (Yang, 2021).

1.3 Research Objective and Contribution

There are three objectives of the present research, which are (1) to analyze key factors that influence the public willingness to adopt solar PV systems in Indonesia, (2) to measure current technological acceptance of solar PV systems under RPVSS policy, and (3) to explore the way to utilize the technological acceptance to accelerate solar PV development in Indonesia.

As the existing research has acknowledged the public perceptions towards solar energy systems in Indonesia (Setyawati, 2020), this study aims to contribute to the body of literature that focuses on accelerating the adoption of solar PV systems by analyzing the critical factors in the solar energy development complex systems in Indonesia. In addition, this research aims to support policymakers by exploring the potential impact and solution for accelerating solar PV systems adoption based on public and experts' perceptions towards the solar PV systems under the RPVSS policy. Through combined experts' perception and technology acceptance model, the policymakers could evaluate the potential result of options or the potential impacts of a new policy and analyze the best approaches to accelerate the adoption of solar PV systems under the RPVSS policy.

1.4 Research Question

The main research question of this study is: How can technology acceptance accelerate solar PV systems adoption under RPVSS policy to facilitate Indonesia's energy transition?

To answer this question, the following sub-questions are formulated:

- What is the current situation of solar PV systems under the RPVSS policy in Indonesia to address energy trilemma?
- What are the public perceptions toward usefulness, ease of use, affordability, and environmental awareness regarding solar PV systems addressed by RPVSS policy in Indonesia?
- What recommendations can be formulated to improve the technological acceptance of the public?

1.5 Thesis Outline

The thesis research was structured as follows. Section 1 outlined the introduction, which includes an overview of the study, the problem statement, the aim and objectives, and the research question. Section 2 emphasized the literature review to identify the knowledge gap in the present research. Section 3 elaborated on the conceptual frameworks, which consist of the underlying theory that tailored this study. Section 4 deals with methodologies used to conduct this research, ethical considerations, and research boundaries and limitations. Section 5 showed the findings of data collection from all relevant stakeholders and was followed by a discussion in section 6, which consisted of the results of data analysis from the previous section. Finally, section 7 concluded all the findings by answering the research question and offering recommendations and suggestions for future studies.

2. Literature Review

This chapter elaborates on initial desk research of solar PV systems in Indonesia under RPVSS policy, which covers the situation of solar PV systems development, general understanding of solar PV systems, policy, and policy implementation.

2.1 Solar PV Systems Development in Indonesia

Indonesia is in fourth position in the global population, with 276 million people. It is estimated to reach 335 million in 2050, and electricity consumption is estimated to be 30 times higher than present in 2050 due to the increase in population (IRENA, 2022). The future of Indonesia's energy consumption will have a significant impact on global GHG emissions. In 2021, Indonesia's energy mix derived from oil and gas (51%) and coal (40%), which indicates less than 10% shares of renewable energy sources in Indonesia (see Figure 1) (Ritchie, 2022b). Regarding fossil-fuel procurement, in 2021, Indonesia will still become the 21st largest fossil-fuel importer in the world by spending 6.03B USD in the given year (*OEC*, 2021).

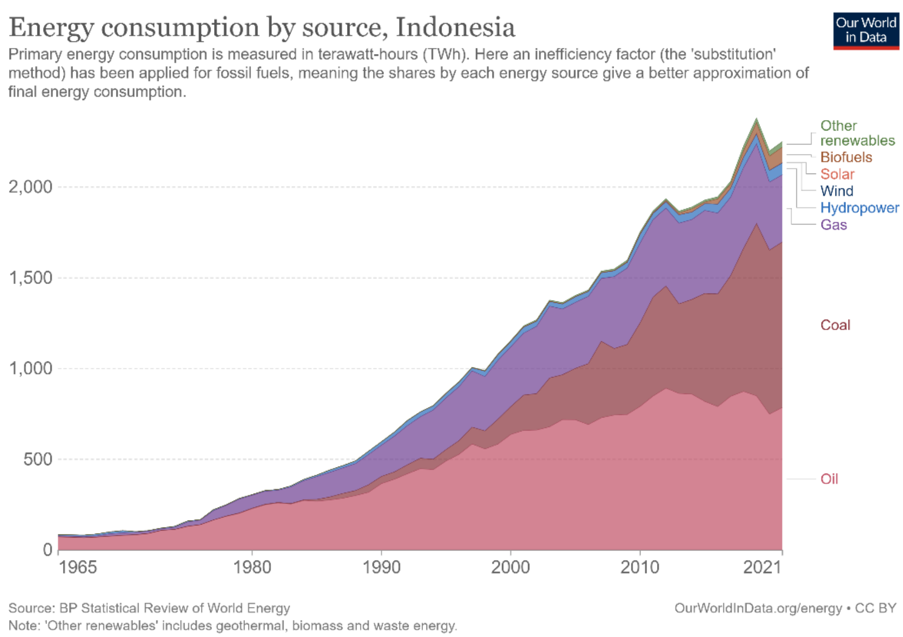

Figure 1. Energy consumption by source, Indonesia (Source: Ritchie, 2022b)

Indonesia possesses a vast potential for utilizing solar energy as an energy resource, and solar energy is identified as Indonesia's highest potential source of renewable energy (MEMR, 2019). Accordingly, solar energy is considered a promising solution to achieving energy transition goals under Government Regulation No. 79.2014 by increasing the shares of renewable energy in the energy mix (MEMR, 2019). According to IRENA[2] (2022), solar energy utilization in Indonesia is

[2] IRENA stands for the International Renewable Energy Agency, an intergovernmental organization comprising more than 170 member countries. This organization is managed by an executive board that includes representatives from each member country.

estimated to reach 47 gigawatts (GW) of installed capacity by 2030, which includes the plan to provide electricity for approximately 1.1 million households in rural areas without electricity access. However, the current situation in Indonesia is in the sixth position regarding the amount of installed capacity (kWh) in Southeast Asia after Singapore, Malaysia, the Philippines, Thailand, and Vietnam (IRENA, 2020).

In Indonesia, regulation support and policy uncertainty related to solar PV systems were found to be the main barriers. Indonesia's electricity business adopted a single-buyer model, which made Perusahaan Listrik Negara (PLN) a state-owned electricity company that could generate, transmit, and supply electricity to the customer (Qolbi, 2020). However, under the energy policy 2014, private enterprises allowed to become contract suppliers of energy generation consider PLN still solely managing the transmission and distribution. While there was evidence of the Government making an effort to create a policy to boost solar PV development, the fluxing policy change was the reason for insignificant progress (Gunawan et al., 2021).

Regulations related to solar PV systems have changed frequently since 2014 by two major policy developers, MEMR and PLN, which include energy pricing, export tariff value, cap of price for PLN, project location, technical standards, and net-metering (Gunawan et al., 2021). The inconsistency and uncertainty of Indonesia's solar energy policy impacted distrust from investors and disadvantageous circumstance for the renewable producer as the price is determined by PLN, which use cheap coal in the operations (IEEFA, n.d.).

Kunaifi et al. (2020) found a correlation between solar PV installed capacity and government policy. From 2013 to 2016, the export tariff value for solar PV systems was desirable for IPP and led to a significant increase in installed solar PV capacity. Under MEMR Regulation no.17/2013, the export tariff ranged from 25 cents USD/kWh – 30 cents USD/kWh, and starting in 2016, the export tariff was reduced to 13.5 cents USD/kWh – 25 cents USD/kWh, which slowing down the progress. The situation was exacerbated in 2017 under a new regulation that capped the export tariff from 7 cents USD/kWh to 17 cents USD/kWh, which is seen as a significant barrier to solar PV development (IESR, 2019). In this sense, the solar PV development was highly dependent on policy related to solar PV technology and the public's perception of the policy as the potential technology adopter. The following section will elaborate on the most recent policy in solar PV systems in Indonesia.

2.2 Rooftop Photovoltaic Solar Systems Policy in Indonesia

In the present research, the studies on solar PV systems development in Indonesia is conducted under RPVSS policy as the policy regulate all the technical and administrational requirement to adopt the technology. Therefore, to analyze the technological acceptance of solar PV systems in Indonesia, the present research focuses on the RPVSS policy.

As mentioned before, under the Ministry of Energy and Mineral Resources (MEMR), the Indonesian Government has stipulated to increase the shares of renewable energy to 23% in 2025 and 31% in 2050 (MEMR, 2019). The Indonesian Government introduced Ministerial

Regulation No. 49/2018, Rooftop Photovoltaic Solar Systems (RPVSS) to support this goal. Related to the RPVSS policy, four core stakeholders were identified: consumers, the national electricity company (PLN), the Central Government of Indonesia, and independent power producers (IPP). The RPVSS policy enables all kinds of customers of the PLN to feed their excessively produced energy into the national grid. Regarding this situation, PLN is considered a pivotal component as this company is a state-owned company responsible for solely providing electricity in Indonesia, known as the market monopoly in electricity (Maulidia et al., 2019). Through this policy, the Indonesian Government plans to encourage the public in Indonesia to adopt solar PV systems to generate their electricity.

In Jakarta, the housing stock comprises a mix of houses and apartments, reflecting the multifaceted nature of the city's urban development. While traditional single-family houses are prevalent, high-rise apartment complexes have become increasingly common, especially in densely populated urban areas. In terms of tenure, owner occupancy remains a significant trend, with many individuals and families aspiring to own their homes as a mark of stability and financial security. This is reflected in the prevalence of homeownership in Jakarta, where many residents prioritize acquiring property.

Thus, the RPVSS policy enables "on-grid PV systems" to PLN customers, allowing them to install photovoltaic panels and connect them to the national grid on residential, governmental, commercial, and industrial buildings (Setyawati, 2020). The visual frameworks of the on-grid PV systems are shown in Figure 2.

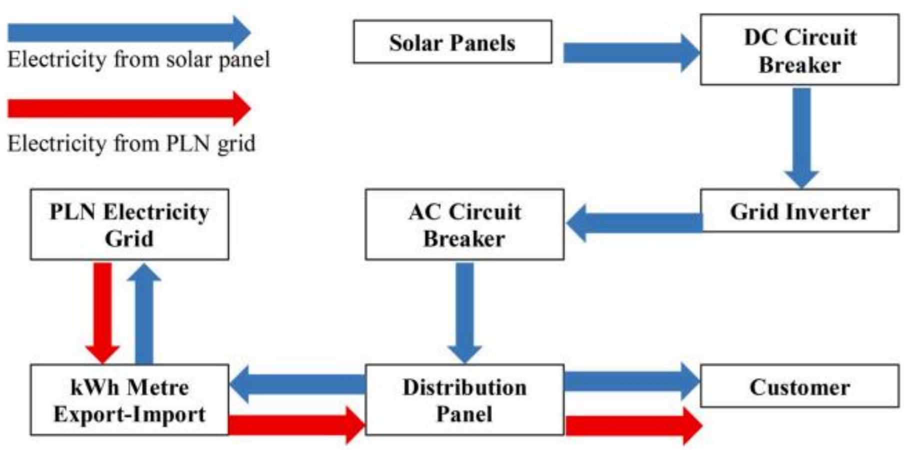

Figure 2. On-grid solar PV electricity systems (Source: Ministry of Energy and Mineral Resources Regulation No. 49/2018). To operate this system, first, the solar panel gathers photovoltaic energy in direct current (DC) form and is transported to the DC Circuit Breaker. Respectively, the Grid Inverter will convert it to alternating current (AC) and transport it to AC Circuit Breaker. Then, the Distribution Panel will distribute it to the customer for daily use and feed the excessive energy to the national grid (PLN owns the national grid and works as the transmission systems network to distribute electricity to the customer). Between the last process, the kWh Metre will calculate and record the amount of consumed or excess electricity export (Setyawati, 2020).

There are several barriers found in solar PV systems development under RPVSS policy settings, including lack of information and promotion of the technology, the expensive upfront cost of technology adoption, long-term payback period or ROI, and considered small value of export rate, and lack of subsidies or financial support scheme. At the same time, some people stated that solar leasing schemes could attract more customers, and there is a lack support from PLN (Setyawati, 2020). Regarding the last barrier, PLN is only authorized to give private entities a "certificate of operation" without offering the installation and maintenance service themselves.

Regarding RPVSS, the customer requires prior approval and verification from PLN to install the technology. This process consists of application submission and administrative requirements such as PLN customer number, the specification of capacity and equipment to install, and the option to install the battery storage. Under the RPVSS policy, the maximum installed capacity of the solar panel is 100% of the existing electricity capacity contract, and the fed-in tariff of excessive exported electricity will be valued at 65% of the standard PLN tariff (around 5.5 cents USD/kWh - 7 cents USD/kWh, based on 2023 electricity prices in Indonesia and March 2023 exchange rate). If the export energy exceeds the import, the excess can be transferred to the following month to offset the monthly bill (maximum of three months). The upfront cost of the kWh net metre device is Rp. 2,000,000, and the cost of installation is around Rp. 17,000,000/kWh (on average, one household may need to install 2kWh of solar panel capacity, approximately Rp. 34,000,000 or US 2210, March 2023 exchange rate). For household customers, the amount needed for 1 kW installation is 8 square metres. The lifespan of solar panels is 20 to 25 years, and the inverter is 10 to 15 years, while the solar panels require maintenance around two to four times a year. According to Tarigan (2020), the average return on investment (ROI) or payback period of rooftop solar PV adoption under the RPVSS policy would be around 9-10 years. These aspects of the RPVSS policy will influence public perception toward the solar PV technology itself as this policy will arrange the terms and conditions to adopt the technology.

As a summary for this section, solar PV development in Indonesia highly depends on regulation and the involvement of stakeholders like the Government, PLN, IPP, and potential consumers. The frequent change in policies related to the adoption of solar PV systems in Indonesia illustrates that these policies must be more attractive for potential users to adopt the technology. Understanding how technological acceptance could accelerate solar PV systems development under specific policy settings is pivotal. Technological acceptance is a critical aspect to address as the intention to adopt solar PV technology under the RPVSS policy is determined by the public perception toward the content of the policy itself (Park et al., 2014). For instance, the technical complexity of adopting solar PV, the price of installment and maintenance, and the economic benefit of solar PV could influence the willingness of the public to adopt solar PV systems on their rooftop.

While a few scholars have already studied the public perception toward solar PV systems in Indonesia (such as Setyawati, 2020; Qolbi, 2020; and Tarigan, 2020), a gap still exists regarding solar PV technological acceptance studies in Indonesia; little is known about how the public perceived solar PV systems under RPVSS policy. Through technological acceptance, the public's needs and preferences as potential users can be identified and used to create policies based on their needs. Therefore, analyzing the factors influencing the acceptance of solar PV systems under RPVSS policy can help policymakers formulate more effective policies encouraging solar PV systems adoption and accelerating solar PV development in Indonesia.

3. Conceptual Framework

This chapter elaborates on an overview challenge related to this research, and the theories that connect each challenge were presented.

3.1 Energy Transition in the Context of Energy Trilemma

Solar PV systems have been a promising sector in Indonesia to achieve an energy transition strategy due to the geo-location and weather characteristics in the given country. The present research refers to energy transition as a policy-driven process that involves a systematic shift towards sustainable, climate-friendly, economically efficient, and secure energy systems (Pastukhova & Westphal, 2020). The "need" for the next energy transition arises because current energy systems are unsustainable regarding all environmental, social, and economic criteria (Grubler, 2012). At the same time, the energy trilemma is defined as the challenge of managing trade-offs between three main energy management objectives: energy security, energy affordability, and environmental sustainability (Gunningham, 2013). Therefore, these two concepts are related as the energy transition aims to address three main aspects of the energy trilemma.

Regarding this view, the energy trilemma concept is relevant to this study as the three pillars of energy trilemma are used as an indicator of the solar PV systems development in Indonesia. The examination of solar PV systems through the lens of the energy trilemma will shed light on the extent to which these systems address the challenges posed by energy security, affordability, and environmental sustainability. This analysis will help inform policymakers and stakeholders about the strengths and areas for improvement in Indonesia's solar PV sector as it aligns with the overarching goals of the energy transition and the energy trilemma. Thus, energy trilemma is the crucial concept to simplify the broad spectrum of the solar PV systems development impact by focusing on three categories, namely, energy affordability, energy security, and environmental sustainability (Weiss et al., 2021)

The energy trilemma is a well-known challenge in governing energy, which involves a trade-off between each pillar, particularly in developing countries. For example, Indonesia's transition from net oil exporter to net oil importer illustrates the challenge of managing energy security while providing affordable energy for the public's needs (Resosudarmo et al., 2019). The Government's effort to balance the need for a reliable and affordable energy supply while avoiding environmental impact has been recognized as a significant challenge in Indonesia's energy policy.

As mentioned before, the electricity market in Indonesia is a single market buyer, and most of the regulation toward energy is influenced by MEMR and PLN. The RPVSS policy aims to promote solar PV technology as a vast energy source in Indonesia to reduce GHG emissions and dependency on fossil fuels. While there will be a broad impact of solar PV development in

Indonesia, this study focused on the energy trilemma's three main aspects, as the emergence of solar PV technology will affect the energy price, energy mix, and environmental impact.

3.1.1 Energy Affordability

There is still a lively debate about energy affordability and the indicator to assess a given concept (Hills, 2012). While that is true, the definition of energy affordability is well elaborated by Miniaci et al. (2014), that the affordability criteria should focus on the supply side, which consists of energy prices, technology cost, and condition of services while at the same time considering the consumers' needs and perceptions. Therefore, this research referred to energy affordability at the scope of the upfront cost of technology purchasing, maintenance cost, and monthly energy bill.

3.1.2 Energy Security

While there is a broad definition of energy security, there seems to be an agreement about energy security linked to risk (Rutherford et al., 2007; Ölz et al., 2007; Wright, 2005; Keppler, 2007; Lieb-Doczy et al., 2003). However, the source of risks in the context of energy security is redundant (Gnansounou, 2008). To simplify the needs of this study, three main categories are introduced, which are derived from technical risk, human risk, and natural disaster risk (Winzer, 2012). Technical risk, as described by (Winzer, 2012), indicates the failure of energy hardware such as transmission lines, power plants, or transformers due to a failure of infrastructure caused by mechanical, thermal, or human error. Second, human risk implies supply and demand instability, political issues, and geopolitical risk (energy import dependency); natural disaster risk deals with extreme natural events such as storms and earthquakes (Winzer, 2012).

3.1.3 Environmental Sustainability

The last aspect of the energy trilemma lies in environmental sustainability, which implies the transition of the energy systems to avoid potential harm to the environment (*World Energy Trilemma Index*, n.d.). This aspect is relevant for developing the solar energy system in Indonesia as the development itself entails positive and negative effects on the environment. For instance, solar PV systems are clean, renewable energy with zero emission of GHG while using it. They are considered a promising technology for increasing energy supply and reducing fossil-fuel dependency (Tawalbeh et al., 2021). However, there are consequences of the manufacturing process for the environment, such as raw material extraction, manufacturing, disposal, and recycling, which can be a potential barrier to development (Dubey et al., 2013).

To specify the potential barriers and consequences of solar PV development, there are several components**:** land use, air pollution and climate change, hazardous material emission, raw material extraction, water usage, and noise and visual impacts (Tawalbeh et al., 2021).

3.2 Technological Acceptance Model

The Technological Acceptance Model theory argues that the person's desire to adopt the technology is significantly influenced by their attitudes toward the content of the technology, which stem from their perception of perceived usefulness and the perceived ease of use of the technology (Ducey & Coovert, 2016). According to Yang (2021b), the Technology Acceptance Model (TAM) is the pivotal framework for technological acceptance created by Davis (1989) and originated from the combination of the theory of reasoned action (TRA) and the theory of planned behavior (TPB). TRA and TPB are theoretical frameworks concerned with individual motivational factors as predictors of the likelihood of engaging behaviors (Montano & Kasprzyk, 2015).

This theory is relevant to the development of solar PV systems in Indonesia as the willingness of people to use technology is heavily determined by people's attitudes towards the technology (Azjer & Gilbert Cote, 2008). Regarding TAM in renewable energy, Yang (2021) introduces two more categories, which result in perceived usefulness, perceived ease of use, environmental awareness, and perceived affordability (see Figure 3). Thus, the present research used these four categories as solar PV technology is considered renewable energy, which is still emerging in Indonesia.

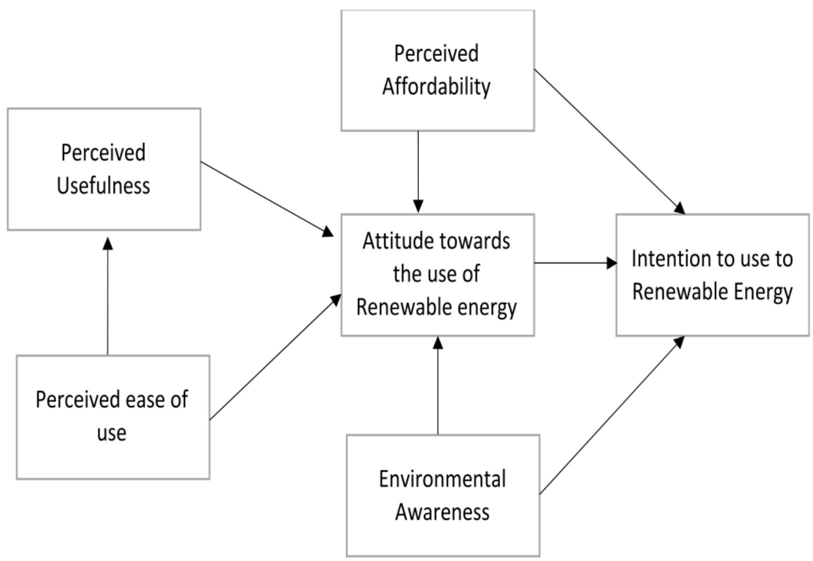

Figure 3. Technological Acceptance Model Framework (Yang, 2021)

This theory framework could measure the public perception of solar PV technology under the RPVSS Policy. The content of the RPVSS policy was examined, and the key indicators that correspond with each category of TAM were identified. The main idea of the TAM theory application in this research is that the public perception of RPVSS policy regarding the four categories of TAM will positively or negatively affect people's intention to use rooftop solar PV.

In the context of the energy transition, applying the TAM theory helps to understand and facilitate the acceptance and adoption of new technologies that support the energy transition and address the challenges of the Energy Trilemma. The TAM theory helps assess the perceived usefulness, ease of use, affordability, and environmental awareness of new energy technologies by individuals, which can influence their acceptance and adoption. By understanding the factors that affect technology acceptance, policymakers, researchers, and energy companies can design strategies and interventions to promote the adoption of sustainable energy technologies, thereby contributing to the energy transition and addressing the goals of the Energy Trilemma.

3.2.1 Perceived Usefulness

Perceived usefulness is defined as the extent of work performance improvement when a person implements the technology based on that person's belief (Davis et al., 1989). In the context of RPVSS policy, the indicator of perceived usefulness is related to lowering electricity bills when adopting the given technology or meeting daily electricity needs without extensive effort (Ahmad et al., 2017). Regarding the energy trilemma, this indicator relates to energy security and affordability as the electricity bill relates to the monthly bill in energy affordability and providing electricity connected to energy security.

3.2.2 Perceived Ease of Use

Perceived ease of use is defined as the extent of convenience or minimum effort while a person uses the technology based on that person's perspective (Davis et al., 1989). In the context of RPVSS policy, this indicator is related to the compatibility of the building as the installment of technology requires some building specification, frequency of interaction while using the technology, frequency of maintenance, and complexity for technology installation (Ahmad et al., 2017; Bandar & Amarasena, 2018). Regarding the energy trilemma, this indicator is related to energy security as the compatibility and technical obstacle connected with technical and human risk. For instance, the increase of solar PV in Indonesia could reduce energy dependency, and the compatibility of the infrastructure (grid system) in Indonesia imposes the risk of hardware failure or error.

3.2.3 Perceived Affordability

This category is the extension of TAM theory, which was introduced by Yang in 2021 to adjust the needs of research in renewable energy technology. Related to the RPVSS policy, this indicator is related to the rate of return on investment (payback calculation), monthly electricity bill, upfront cost for installation, and maintenance cost. Regarding the energy trilemma, this indicator is strongly connected to energy affordability, which deals with finance-related components.

3.2.4 Environmental Awareness

Besides the perceived affordability, environmental awareness is also considered an extension of the TAM theory introduced by Yang, 2021. The adoption rate of solar PV depends on the potential user perception, affecting the willingness to adopt the technology. As potential users, the public needs to be informed of the environmental aspect of the given technology, which might increase their acceptance of the technology. Respectively, this indicator relates to all kinds of rooftop solar PV systems' positive and negative environmental impacts. In the context of RPVSS policy, the indicator includes raw material extraction, material disposal, waste treatment, and reduced GHG emissions. Related to the energy trilemma, this indicator is firmly associated with environmental sustainability.

3.2.5 TAM Indicator

To summarize this section, 15 indicators of TAM were formulated to address public perception for each category towards solar technological acceptance under RPVSS policy. These indicators were used in surveys to measure technological acceptance from the public (see Table 2).

Table 2. TAM indicator (Own data: 21 March 2023)

Category	Indicator
Perceived Usefulness	Provide daily needs of electricity
	Lower electricity bill
	Enable tasks without extensive efforts
Environmental Awareness	Manufacture impact
	Reduce GHG emissions
	The existence of solar panel waste treatment
	Reduce dependence on fossil fuels
Perceived Affordability	The upfront cost to adopt solar PV
	Maintenance cost
	Return on Investment
Perceived Ease of Use	The initial process to adopt solar PV
	House compatibility
	Frequency of maintenance
	Frequency of interaction
	Technical obstacle

4. Methodology

This chapter elaborates on the step-by-step procedure and methods used to achieve the research objectives and answer the research question of the present research. First, background research and a literature review were conducted to find the knowledge gap and formulate the research objective and question. This study aims to analyze how the technological acceptance of solar PV systems under the RPVSS policy could accelerate solar PV system development in Indonesia. Understanding the public perception toward solar PV systems could help policymakers formulate a better policy that corresponds with public needs, thus accelerating the development of given technology.

To create recommendations for policymakers, this study combined expert opinion from interview results and public perception toward solar PV systems under RPVSS policy from survey results. The interview results were analyzed to identify the current situation regarding solar PV systems under RPVSS policy in Indonesia from policy content to practice and explore the potential solution for the barriers that challenged the acceleration of solar PV systems adoption, considering the three dimensions of the energy trilemma: energy security, affordability, and environmental sustainability. Respectively, the survey results were analyzed to understand better the current public perception of perceived usefulness, environmental awareness, affordability, and ease of use. This research aims to identify which aspects can be improved to improve public perception of solar PV systems under the RPVSS policy. The visualization of the research strategy is shown in Figure 4.

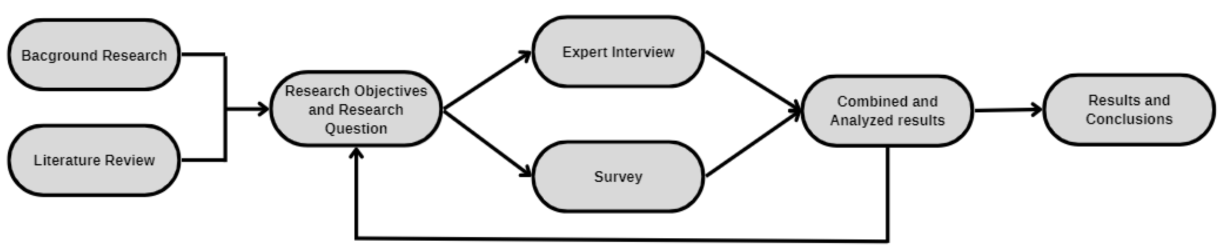

Figure 4. Visual diagram of research strategy

4.1 Content Analysis

The present research data collection starts with background research and a literature study to find the critical components of dynamic solar PV systems in Indonesia. The articles were identified in the Scopus database and Google Scholar, using the combination of the following keyword “Solar PV development”, “Solar PV adoption”, “RPVSS Policy”, “Public Perception”, and “Indonesia”. While selecting the paper, there were two criteria: writing in English and focusing on Indonesia's solar PV development under the RPVSS Policy.

After getting a comprehensive understanding of the issues of RPVSS Policy in Indonesia, the research was limited to focusing on the public perception and technology acceptance toward solar PV technology. During the content analysis, frequently mentioned challenges and critical stakeholders, considered very important for comprehending the technological acceptance of solar PV technology in Indonesia, were identified.

4.2 Interview Design

After a literature review, an interview with experts in the solar PV systems and RPVSS policy was conducted to answer the first sub-research question, "What is the current situation of solar PV systems under the RPVSS policy in Indonesia to address energy trilemma?". In the interview process, eight respondents consisting of a researcher, a mid to high-level management position in the solar PV industry, a regulation institution, and a solar PV systems adopters were chosen and agreed to do the interview (see Table 3).

The targeted participants consisted of representatives of the regulatory institution, researchers, business entities, and non-governmental organizations considered experts (working for more than two years related to solar PV systems). After careful consideration, the number of interview targets was eight respondents due to the data sufficiency purpose and time limitation, and these numbers are based on two respondent targets for each category. Before the interview, the targeted participants were contacted via LinkedIn and personal connections and asked to participate as the informant.

Table 3. Interviewee profile

Code	Interview Dates	Institution	Institution Remarks	Experience
Interviewee 1	10-April-23	Just Transition Network	An independent policy and research institute.	4 years
Interviewee 2	26-April-23	General Electric Indonesia	Power generation company	3 years
Interviewee 3	26-April-23	Ministry of Energy and Mineral Resource Indonesia	An Indonesian ministry responsible for the field of energy and mineral resource	6 years
Interviewee 4	27-April-23	SUN Energy	Solar project developer	5 years
Interviewee 5	13-May-23	Perusahaan Listrik Negara (PLN)	State own electricity company	2 years
Interviewee 6	26-Mar-23	Ministry of Energy and Mineral Resource Indonesia	An Indonesian ministry responsible for the field of energy and mineral resource	4 years

Interviewee 7	15-May-23	Customer	Solar PV systems adopters	2 years
Interviewee 8	20-May-23	Perusahaan Listrik Negara (PLN)	State own electricity company	3 years

The interview was conducted in a semi-structured interview with a set of predetermined questions and distributed online through email and WhatsApp applications. Complete interview questions were provided in Annex 1. All the interviews were conducted via Microsoft Teams with an average time duration of around 1 hour for each interview in Indonesian. At the beginning of the interview, each interviewee asked permission to record the interview verbally. The interview questions consist of the experts' backgrounds and opinions about the current situation of solar PV systems in Indonesia. For example, the interviewee was asked about their experience and affinity related to solar PV systems in Indonesia. Then, their perspective toward current conditions of solar PV systems adoption under RPVSS policy was asked as the opening question. The rest of the questions aimed to explore their opinions on specific topics, such as the key factors that influence solar PV systems adoption, the importance of public acceptance, barriers and opportunities of the RPVSS policy, and suggestions for the policymakers. Each interview was always closed with an open-ended question like "Is there anything else that you would like to add to this topic?" which aimed to allow the interviewee to express something that they missed during the interview or clarifications about their previous statement. In addition, based on the expert background, some questions were adjusted to correspond with the respondents' backgrounds.

After the interview, all the results were analyzed by extracting keywords and essential components in qualitative data. While extracting keywords, the process involved highlighting parts of a statement from the interview session and translating it from Indonesian to English. When analyzing the results, the analysis was focused on identifying the barriers and opportunities from the predetermined challenge of solar PV systems and their connection with energy trilemma.

4.3 Survey Design

This study uses survey methods to define public perception towards the RPVSS policy based on four TAM indicators. Respectively, the survey results were analyzed to understand the public perception toward solar PV systems under the RPVSS policy. In this way, public perception could contribute to exploring the challenge and opportunity for policymakers to accelerate the adoption of solar PV systems in Indonesia.

The survey consisted of 19 questions related to the TAM indicator. The answer option consists of a Likert scale answer, and the participants must live in Jakarta, as shown in Annex 2. A Likert scale answer is a response a respondent gives to indicate their level of agreement or disagreement with a statement, ranging from strongly disagree to strongly agree. The Likert scale was created by Rensis Likert in 1932 to measure the attitudes and beliefs of a study population (Stratton, 2018). The Likert scale helps determine a valid and trustworthy way to quantify subjective preferential thoughts, feelings, and behaviors reliably (Joshi et al., 2015). When using Likert-like data, researchers frequently want to quantify "fuzzy" attitude data so that traditional statistical methods can be applied (Stratton, 2018).

The first section of the survey included the identification questions of the respondents, such as age and city of residence. The second section consisted of TAM indicators-related questions and Likert scale answers.

As shown in Table 2, there were four categories for TAM, and each category has specific indicators to measure public perception of solar PV systems. On the survey form, some information was provided for each category to guide respondents to answer the questions. Each question has the option of numerical value 1 to 5, which indicates no useful perception with a minimum of 1 to very high usefulness with a maximum number of 5 (see Table 4).

Table 4. Likert scale value

Numerical Value	*Perception Value*
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

.

The choice to focus on this location was because Jakarta is the capital city of Indonesia with a strong economic situation compared to other cities. In this sense, developing solar PV systems under RPVSS policy will happen in Jakarta first, rather than in other cities, due to the economic situation.

In addition, the survey respondents must be above 18 years old due to consideration of potential technology users in the future and presumed to have prior knowledge about solar PV technology. The survey was created using QUALTRICS software and distributed through online media such as WhatsApp, email, and Instagram. The targeted number of respondents in the present research is based on the Slovin formula with a margin error of 5% and a 95% confidence level (See Figure 5). In 2022, Jakarta had more than 10.000.000 population in the city, which resulted in 385 respondents.

$$n = \frac{N}{1 + N\,e^2}$$

$$n = no.\,of\ samples$$

$$N = total\ population$$

$$e = margin\ of\ error$$

Figure 5. Slovin formula

After data collection, the results were analyzed using simple statistical methods to enable quantification measures. In data analysis, the mean value for each indicator, category, and total was calculated by dividing all the values by the total number of respondents. This approach was essential to identify which aspects or categories in TAM have a negative result, which indicates low public perception.

4.5 Research Material and Accessing method

The data required, and the collection method were adjusted with the research sub-question of the present research, as shown in Table 5.

Table 5. Research material and accessing method.

Research sub-question	**Desired information to answer the question**	**Source of data**	**Accessing data**	**Method of analysis**
What is the current situation of solar PV systems policy in Indonesia to address energy trilemma?	The general components of solar PV systems	<u>Primary data</u> Literature review	Content analysis	Qualitative- Analyzing the general component of solar PV systems
	Experts' opinion of the components in solar PV systems development under RPVSS policy (related to energy trilemma).	<u>Primary data</u> Various Stakeholders	Interview	Qualitative- Identifying the key components of solar PV systems development under RPVSS policy

	The possible impact of increasing attitudes toward solar PV technology under RPVSS policy (related to energy trilemma).	<u>Primary data</u> Various Stakeholders	Interview	Qualitative- Analyzing the possible impact of technological acceptance in solar PV technology under RPVSS policy
What are the public perceptions toward usefulness, ease of use, affordability, and environmental awareness regarding solar technology under the RPVSS policy in Indonesia?	The public perception of perceived usefulness in RPVSS policy	<u>Primary data</u> Citizens of Jakarta older than 18 years old	Surveys	Qualitative and Quantitative- Translating the quantitative data from the survey to qualitative data.
	The public perception of perceived ease of use in RPVSS policy	<u>Primary data</u> Citizens of Jakarta older than 18 years old	Surveys	Qualitative and Quantitative- Translating the quantitative data from the survey to qualitative data.
	The public perception of affordability in RPVSS Policy	<u>Primary data</u> Citizens of Jakarta older than 18 years old	Surveys	Qualitative and Quantitative- Translating the quantitative data from the survey to qualitative data.
	The public perception of environmental awareness in RPVSS Policy	<u>Primary data</u> Citizens of Jakarta older than 18 years old	Surveys	Qualitative and Quantitative- Translating the quantitative data from the survey to qualitative data.
What recommendations can be formulated for RPVSS policymakers to improve the technological acceptance of the public?	Combined analysis from experts' interviews and public perception of perceived usefulness, environmental awareness, affordability, and ease of use.	<u>Primary data</u> Various Stakeholders and citizens of Jakarta older than 18 years old	Interview and Surveys	Qualitative and Quantitative- Combining interview results and translating (from quantitative to qualitative) survey results to create recommendations

The visualization of the relation between desired information, research sub-questions, and data analysis is shown in Figure 6.

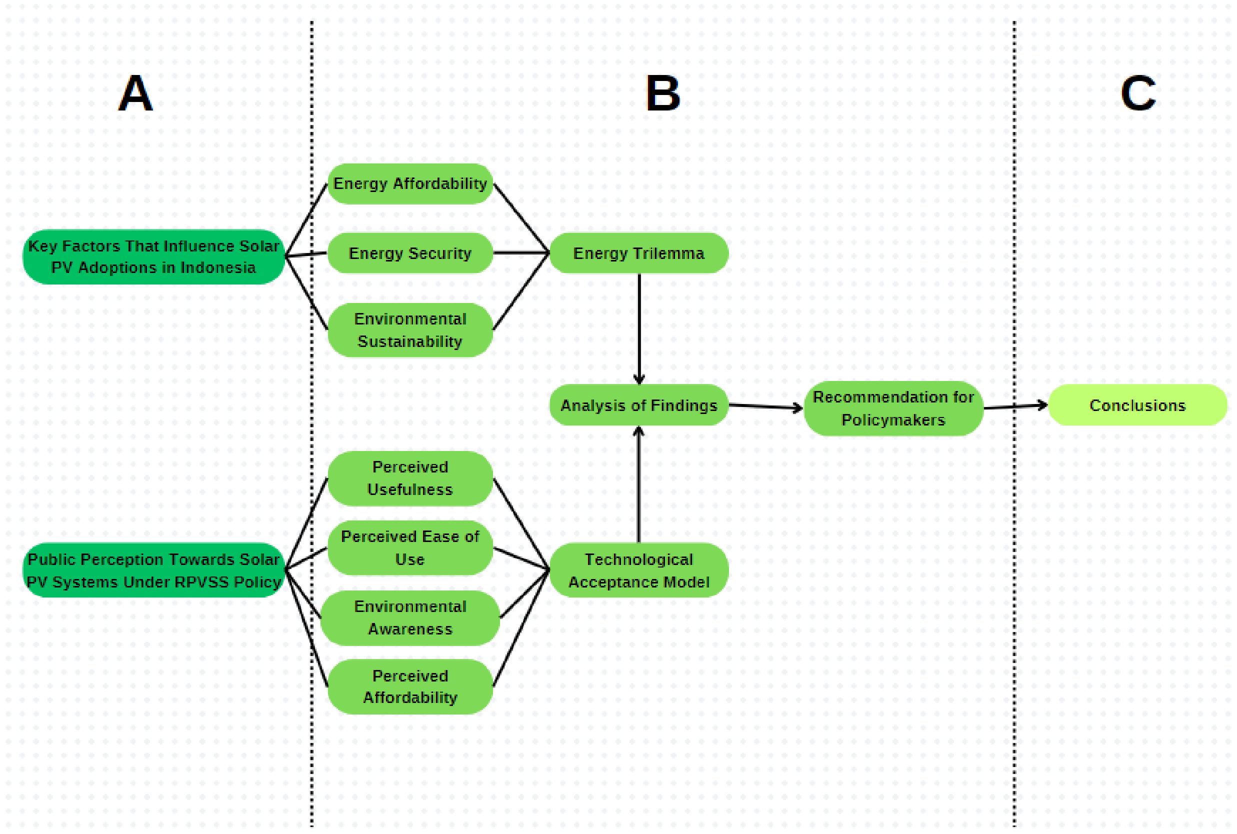

Figure 6. Visual diagram of data collection and data analysis. A) Desired data for data collection, B) Data analysis, and C) Conclusion.

4.6 Ethical Consideration

Ethical reflections were made and submitted since the present research involves human behavior. Regarding the confidential issue, consent was asked of the potential interviewee before the interview session, and the first section of the survey form consists of the consent form. This research uses the principles of consent, data use privacy, and the nature of the participants in this research was voluntary. The present research only considers the data collection results that have the consent from the participants. Due to the anonymity, the potential respondent of the interview has the right to choose anonymously at their will. In addition, QUALTRICS software was used as the media to create the survey form to comply with data privacy usage.

4.7 Research Boundaries and Limitations

To ensure the research objective could be achieved within the time limit given by the University of Twente, several boundaries of the present research are elaborated. The present study only focused on the impact of the technology acceptance model in solar PV development under the RPVSS policy in Jakarta, Indonesia. In this sense, regardless of the type of solar cell and the technology specification, different stakeholders of solar PV systems in Indonesia were asked to participate for a specific purpose. In the same context, the present study also focuses on age and residency without considering other aspects like income, gender, and housing situation (owner vs. tenant), which could affect the outcome and insight of the research. In addition, as the solar PV development possessed a broad range of complex systems, this research focused solely on implementing the RPVSS policy dimension.

There was also a possibility of bias regarding the survey as the respondents might need to answer the question correctly due to their beliefs about the expected answer. The assumption about the expected answer and perception as the correct answer might lead respondents to have a non-conscious biased answer. Furthermore, due to online distribution, only people with social media access could participate. The uneven distributions of respondents' age were anticipated as more young people used social media than older people. However, due to geographical limitations (the author was staying in the Netherlands while the targeted respondents were in Indonesia) and time, online distribution was the best option for conducting the present research. In addition, due to the conditions of solar PV systems as an emerging technology that is still in the early phase of development, there was a possibility that the survey respondents were not familiar with the technology and were giving random answers.

Regarding the limitations in the present research, several measures were found to be effective in addressing the limitations. First, to prevent biased answers from respondents, both interview and survey questions were formulated as neutral as possible to avoid stimulation that might influence respondents' answers. Then, in the interview session, if there were contradictory answers to the same question, further literature analysis on the topic was conducted to sort out the subjective answers from the respondents. On the other hand, the questions in the survey were structured in random order to prevent the respondents from unconsciously being affected by the question order, segmented category, and the position of answer options. Additionally, the survey targeted as diverse as possible respondents to cover different answers from different backgrounds.

5. Findings

This chapter will elaborate on the results of data collection through interviews and surveys. The interview questions and survey questions can be found in Appendix 1.

5.1 Solar PV Systems Implementation Under RPVSS Policy

This section will elaborate on the current conditions of solar PV adoption under the RPVSS policy in Indonesia. The interview results were organized by extracting the keywords of pivotal information on the policy content, practical implementation, and experts' opinions of current barriers and opportunities in solar PV adoptions. While analyzing the results, all the findings were focused on connecting the pivotal information to the corresponding energy trilemma pillars.

5.1.1 Energy Affordability

In general, the energy affordability aspect of solar PV systems is derived from several components, such as upfront cost, export tariff, maintenance cost, and ROI. To summarize the energy affordability aspect, the upfront cost to adopt solar PV systems under RPVSS policy was Rp. 34,000,000 on average, the export tariff was 65% of installed capacity, and the maintenance cost was Rp. 700,000 – Rp 1,000,000, and combining these three components, the payback period or ROI was calculated for 8-10 years (Interviewee 4).

According to experts, the upfront cost of solar PV systems under the RPVSS policy was a challenge in accelerating the adoption of solar PV systems in Indonesia. While adopting solar PV systems under RPVSS policy offers long-term savings through reduced electricity bills, the upfront cost is a barrier for low-income people.

> "… on average, one household need 2kWh installed solar panel capacity which cost around Rp.34,000,000. From my experience, most adopters were only high-income people interested in reducing their electricity bill."

(Interviewee 4)

In addition, *tingkat komponen dalam negri (*TKDN policy) or domestic component level is known as a factor that increases the technology price (Interviewee 5). The TKDN policy obliged the minimum percentage of local content to be incorporated into products or projects. This policy resulted in a higher price of solar PV systems as Indonesia still lacks solar PV material and technology to manufacture solar panels (Interviewee 4).

To address this challenge, different financing options could accelerate the adoption. For example, the solar leasing option may attract more potential adopters, and the lack of subsidies for solar PV also means only high-income people could afford the technology (Interviewees 1 & 6). In addition, property developers also possessed an excellent opportunity to accelerate the adoption rate of solar PV systems in Indonesia. Building an in-house solar PV system in a new residential area could solve the upfront cost affordability. The upfront cost of the solar PV systems was included in the property price and paid with a mortgage (Interviewee 3).

On the other hand, increasing solar PV systems adoption could reduce the price of technology. The effect is caused by several reasons, such as the economy of scales theory, which is related to the decreasing average cost per unit as the production quantities increase. Then, increased technology adoption could attract more players in the market and foster market competition. Finally, as technology adoption increased, the supply chain could be more efficient and established (Interviewee 3).

5.1.2 Energy Security

As mentioned in section 3.1.2, there are three categories of energy security risks: technical risks, human risks, and natural disaster risks. Regarding technical risks, solar PV systems pose a limitation due to the nature of solar PV, which depends on sunlight availability and is known as an intermittency issue. To mitigate the limitation, various approaches such as energy systems (e.g., batteries), demand response programs that incentivize consumers to reduce electricity usage during peak times, and integration of other energy sources via smart grid were employed (Interviewee 2). In Jakarta, integrating other energy sources was more common in practice than using batteries due to the current unaffordable price of battery technology. Most adopters in Jakarta were using electricity from solar PV systems in the afternoon and switching to other energy sources from the national grid at night (Interviewee 5).

Solar PV systems also pose a risk to national grid stability as there was a rapid fluctuation in the supply and demand of electricity in midday and evening. In short, there will be less electricity demand at midday as most people leave their homes to do activities and a high electricity supply due to the high availability of solar energy. Conversely, in the evening, there will be a rapid fluctuation in high electricity demand, which poses a challenge for grid operators to meet the rising demand (Interviewee 2). Failing to address this challenge could result in a blackout. Rapid fluctuation in supply and demand is also the reason for PLN to cap the solar capacity installment to 100% of capacity and the export tariffs to 65% to balance the supply and demand (Interviewee 5).

Regarding human risks, political issues were found to be the main challenge in accelerating solar PV adoption under the RPVSS policy. Ideally, the MEMR is responsible for formulating energy policies and regulations in Indonesia while the PLN implements the policy. However, based on an interview with a representative from MEMR, PLN was found to be not following the predetermined policy from MEMR due to different interests from both parties, which resulted in policy inconsistency and bad policy implementation. Consequently, the RPVSS policy in Indonesia has been revised numerous times due to different interests between both parties and is considered to hinder investors from investing in Indonesia (Interviewee 1 and Interviewee 8). There was also speculation that if a private solar PV company tried to appeal at the policy formulation meeting with different interests from PLN, this private company would be ostracized in the tender stage by PLN (Interviewee 6).

The last risk in energy security was natural disasters. Even though natural disaster risk rarely occurred, there was evidence of storms destroying solar panels in several locations in Indonesia (Interviewee 6).

5.1.3 Environmental Sustainability

The environmental sustainability aspect of solar PV systems consists of several components, categorized into positive and negative impact components. The solar PV system was considered clean energy, which emits zero GHG emissions when using it. In this sense, the first positive impact of environmental sustainability was reducing GHG emissions (Interviewee 1, Interviewee 3, and Interviewee 8).

Conversely, the negative impact of solar PV systems was derived from the manufacturing and at the end of the life span. The solar PV system manufacturing process involves extracting raw materials (such as silicon, silver, and tellurium), using chemicals, and an energy-intensive manufacturing process (Tawalbeh et al., 2021). Solar PV systems at the end of the life span contain hazardous materials that require proper waste treatment to avoid environmental harm (Interviewee 1). Even though solar PV waste is considered not to pose significant toxicity compared to other electronic waste, soil, and waste source contamination is possible if solar panels end up in landfills.

Based on an interview with solar PV companies' representatives, most solar PV hardware was imported from China, meaning Indonesia needs to experience the manufacturing impact directly (Interviewee 4). Regarding the challenge of managing waste, Indonesia still lacks waste treatment facilities, which indicates a tangible threat at present. An opportunity to address the environmental challenge of the solar PV manufacturing process lies in technology efficiency, as the more efficient the technology, the less raw material is needed to manufacture the technology (Interview 3). There was a fast development of solar technology efficiency. For example, in 2020, a typical solar panel usually has a 330-watt peak. In 2023, the advanced solar panel has a 650-watt peak, the same size as the previous model, making it more efficient.

5.2 Public Acceptance of Solar PV Systems under RPVSS Policy

After identifying the current situation of solar PV systems under RPVSS policy, the survey sought to gauge public perception to measure technology acceptance, such as perceived usefulness, environmental awareness, affordability, and ease of use. The results of this measure imply the current public perception toward solar PV systems' technological acceptance, which illustrates their desire to adopt solar PV systems. This section is structured as follows: Profile respondents, perceived usefulness result, environmental awareness result, perceived affordability result, and perceived ease of use result.

5.2.1 Respondents' Profile

Of 429 respondents that finished the surveys, 390 respondents live in Jakarta, Indonesia (see Fig. 7). Hereafter, all the data analysis only used respondents from Jakarta, which gave the total number of samples 390. Of 390 respondents, there are 56.4% of respondents aged range from

18-25 years old, 39.5% range from 26-35 years old, 3.1% range from 36-45 years old, and only 1% older than 46 years old (See fig. 8). The results were expected as the surveys were distributed via social media and not many people use social media. However, based on interview results, young people younger than 35 years old pose great potential as solar PV systems adopters since they are at the age where they want to buy permanent residential.

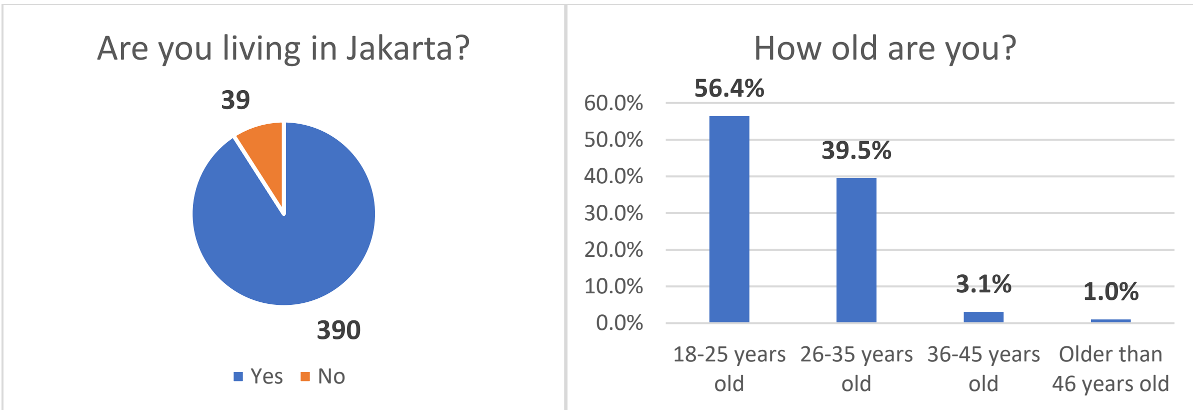

Figure 7. Respondents profile

The respondents were provided with a short introduction to solar PV systems and the policy that regulates solar PV adoption in Indonesia (RPVSS) policy. After that, the respondents were asked about their awareness of the RPVSS policy. The results showed that less than 20% of the respondents were aware of the policy, 34.1% had only heard about the policy but did not understand the content, and 46.4% were not aware of the existence of the RPVSS policy before reading the introduction (see Fig. 8). The results illustrate that the awareness of people in Jakarta of the RPVSS policy is still low given more than 80% of people are not aware or only heard about it without a proper understanding of the content.

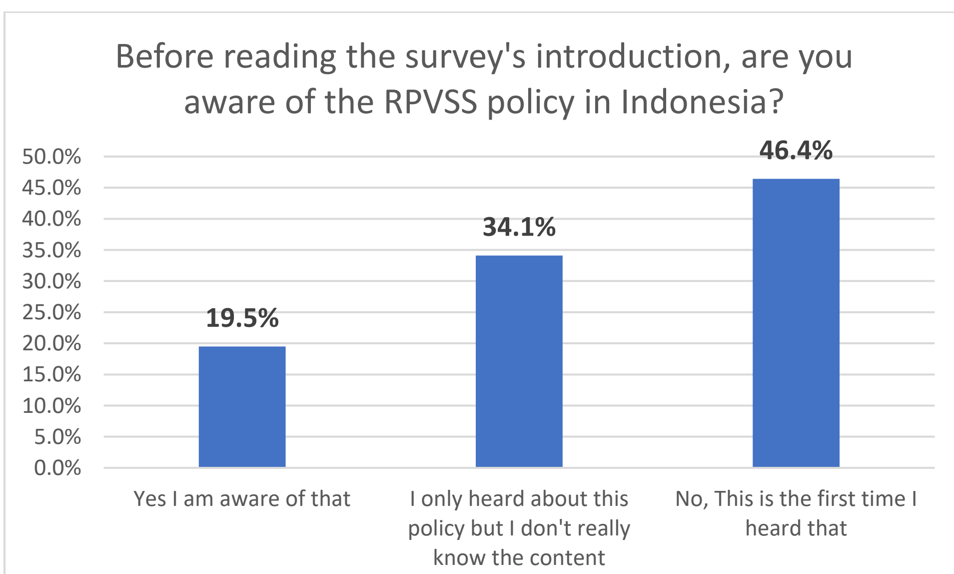

Figure 8. Respondent's awareness result

5.2.2 Perceived Usefulness

This section will elaborate on the results of the first TAM indicator, perceived usefulness. Information on the usefulness of adopting solar PV systems under the RPVSS policy was provided as a guide to answer the following questions. The information is shown in Annex 2.

In Q.5, the question is related to the function of solar PV systems to provide electricity. As shown in Figure 9, around 83% of respondents answered agree or strongly agree, around 3% answered strongly disagree or disagree, and around 14% answered neutral. This result indicates that most respondents believe solar PV is a reliable source of electricity generation.

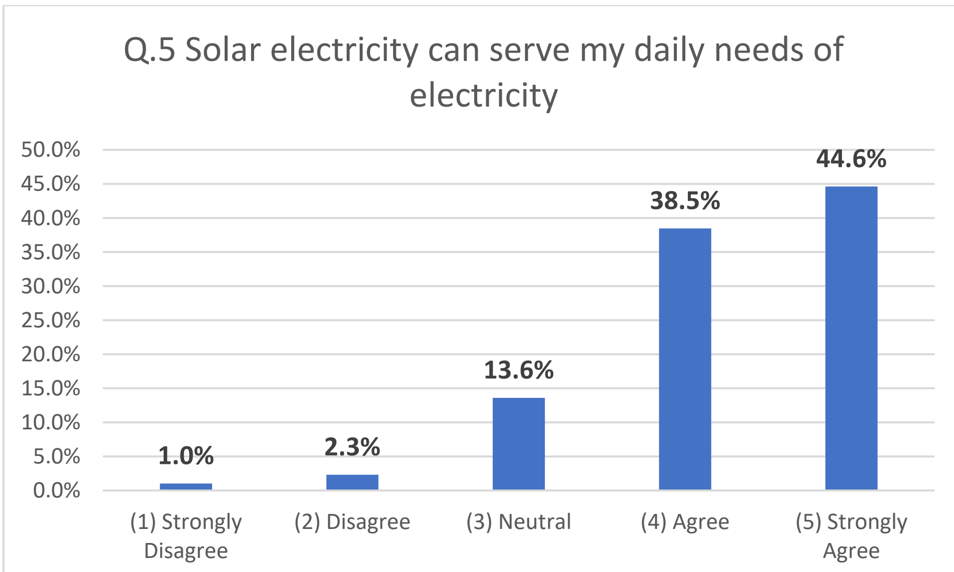

Figure 9. Result of Q.5

In Q.6, the question is related to the financial incentive, which could save 65% cost by exporting excessive electricity from adopting the solar PV systems under the RPVSS policy. As shown in Figure 10, around 83% of the respondents answered agree or strongly agree, less than 3% answered strongly disagree or disagree, and around 14% answered neutral. This result indicates that most of the respondents agree that adopting the solar PV systems under the RPVSS policy is useful as it could lower their electricity bill every month.

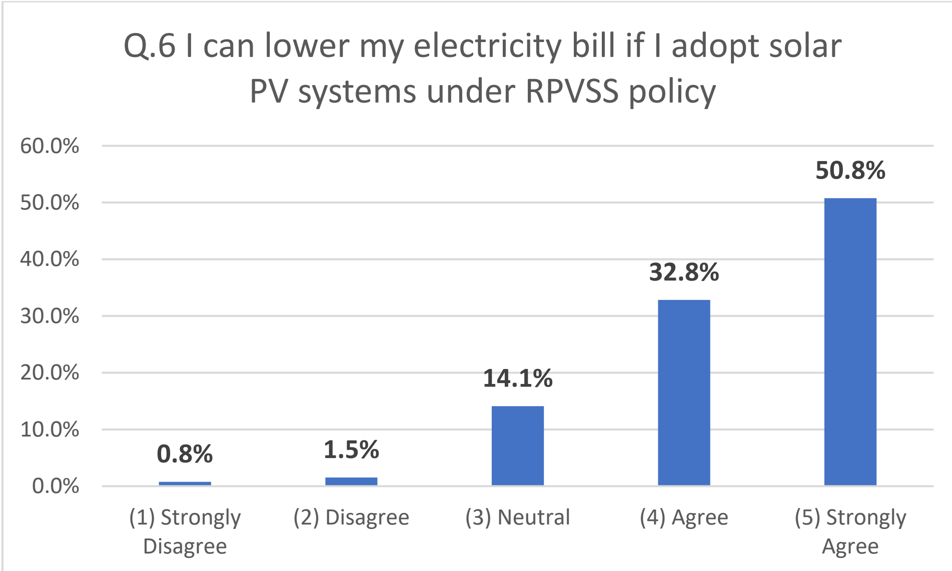

Figure 10. Result of Q.6

In Q.7, the question was related to public perception of the practical use of solar PV systems. For instance, As shown in Figure 11, around 65% of respondents answered agree or strongly agree, less than 5% answered strongly disagree or disagree, and 31% answered neutral. This result indicates that more than half of the respondents believe they could complete the task without extra effort if they adopt solar PV systems.

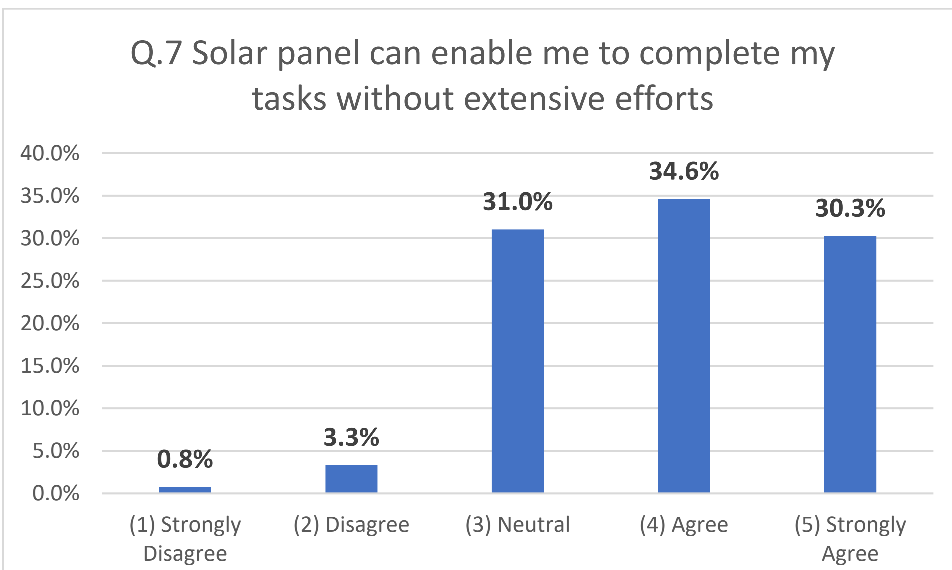

Figure 11. Result of Q.7

5.2.3 Environmental Awareness

This section will elaborate on the results of the second TAM indicator, environmental awareness. Environmental awareness was an essential aspect of TAM theory as the perception of the public toward the environmental aspect of the technology will affect their willingness to adopt the technology. For example, suppose the public believes the lack of waste treatment facilities or the impact of manufacturing solar panels will harm the environment. In that case, the public willingness to adopt the technology might be affected. Text information provided prior to answering the question is shown in Annex 2.

In Q.8, the question was related to the impact of manufacturing solar PV. Based on the information given in the survey, there were consequences of solar panel manufacture, such as raw material extraction, which could significantly impact the environment. As shown in Figure 12, around 57% of the respondents answered agree or strongly agree, while around 11% of respondents answered strongly disagree or disagree, and around 32% answered neutral. This indicates that more than half of the respondents believe that the positive effect of using solar PV systems outweighs the manufacturing consequences.

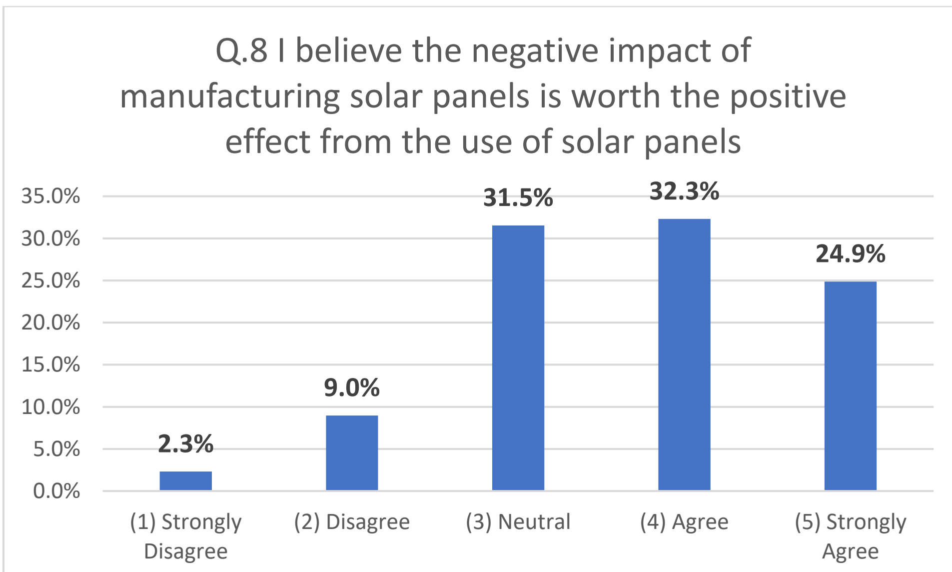

Figure 12. Result of Q.8

In Q.9, the question was related to public perception toward the possibility of reducing GHG emissions if they adopt solar PV systems. As shown in Figure 13, around 83% of respondents answered agree or strongly agree, while less than 3% answered strongly disagree or disagree, and around 14% answered neutral. This result indicates that most of the respondents believe that adopting solar PV systems on their rooftops can contribute to reducing GHG emissions.

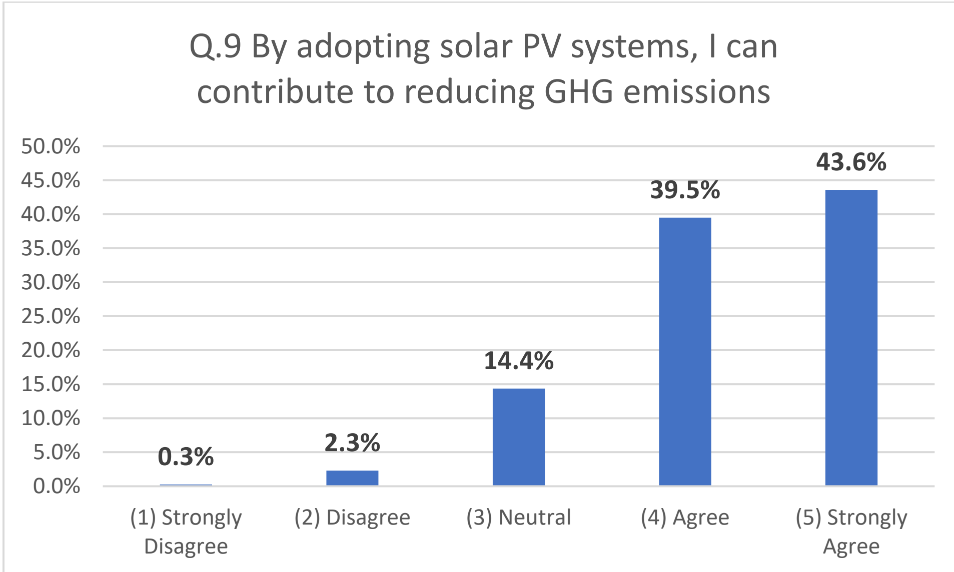

Figure 13. Result of Q.9

In Q.10, the respondents were asked about their feelings about Indonesia still lacking solar panel waste treatment. As shown in Figure 14, around 72% of the respondents answered strongly disagree or disagree, while only 9% answered agree or strongly agree, and around 19% answered neutral. This result indicates that most respondents were unwilling to adopt solar PV systems due to the lack of solar panel waste treatment facilities.

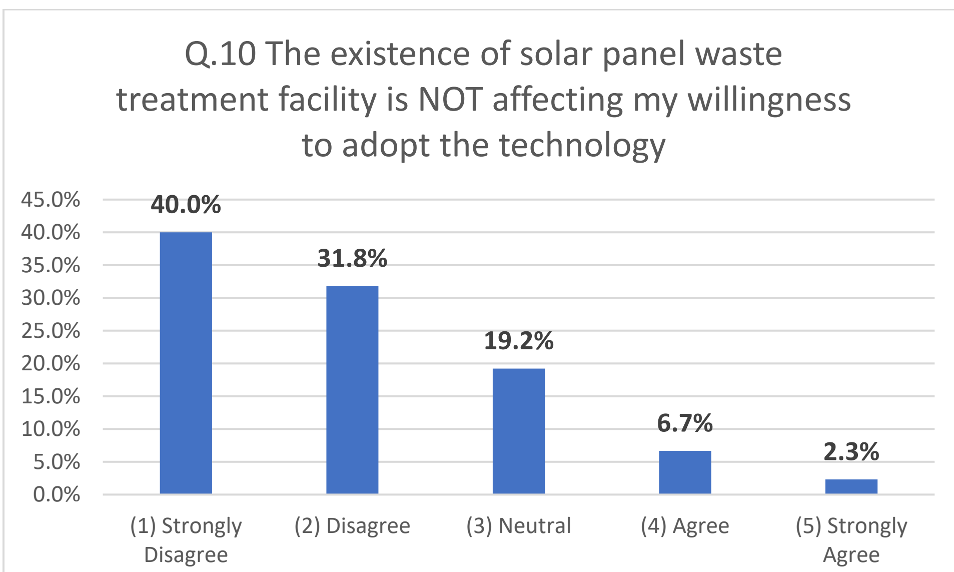

Figure 14. Result of Q.10

In Q.11, the question was related to public perception toward the potential of solar PV systems to replace fossil fuels as an energy source. Even though it was widely known that solar PV helps reduce the dependence on fossil fuels, this question aims to find out clear affirmation of respondents' beliefs on the matter after they were provided with information about the current solar PV systems situation in Indonesia. As shown in Figure 15, around 83% of the respondents answered agree or strongly disagree, only around 4% answered strongly disagree or disagree, and 13% answered neutral. This result indicates that most respondents believe adopting solar PV could help reduce dependence on fossil fuels and address climate change.

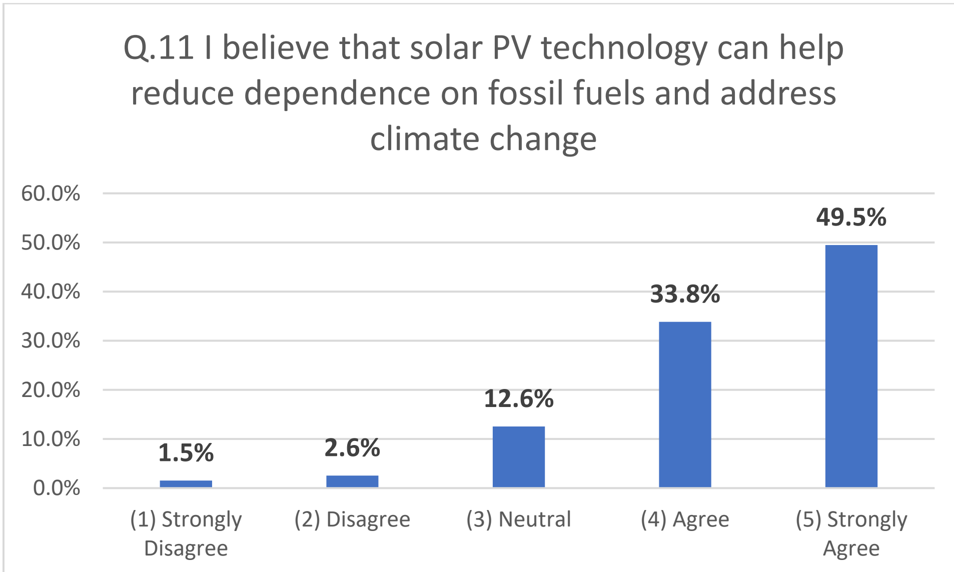

Figure 15. Result of Q.11

5.2.4 Perceived affordability

Perceived affordability is the third TAM indicator related to the public perception of technology affordability. The main idea of this TAM indicator was that the public perception of technology affordability could affect their willingness to adopt solar PV systems. For instance, if the public feels that the upfront cost, maintenance cost, and ROI were not affordable or not financially benefitted them, the public willingness to adopt solar PV systems might be affected. Before answering questions in the survey, brief information about the affordability of solar PV systems under RPVSS policy was given, as shown in Annex 2.

In Q.12, the question was related to the respondents' perception of the upfront cost of adopting solar PV systems under the RPVSS policy. Based on the text on the survey form, the upfront cost to adopt solar PV systems was Rp. 34,000,000 or US 2210. As shown in Figure 16, around 40% of the respondents answered agree or strongly agree, while 29% answered strongly disagree or disagree, and 31% answered neutral. This result indicates that the upfront cost to adopt solar PV systems under RPVSS policy only affordable for 40% of the respondents, while around 60% were either could not afford it or could afford it but still had doubts as it was not financially beneficial for them.

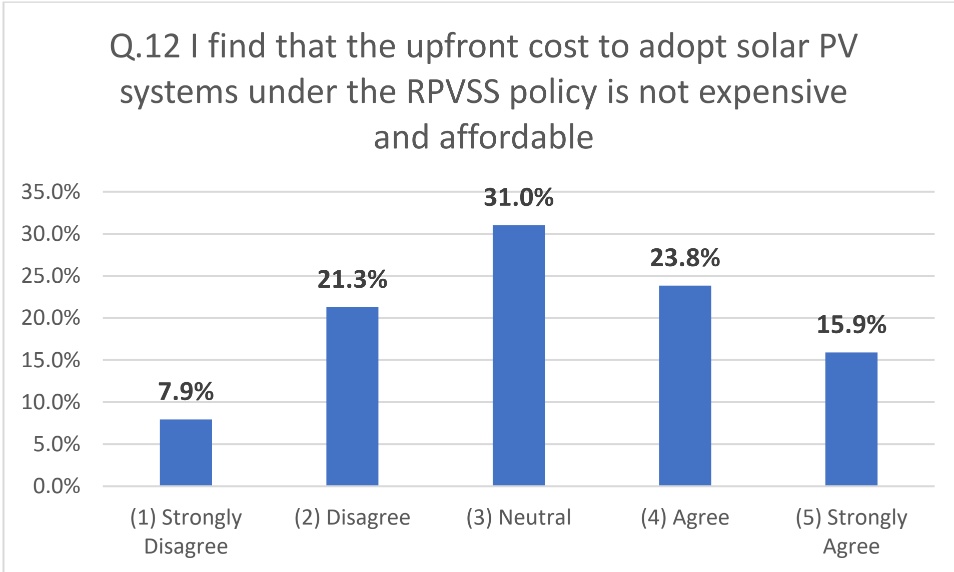

Figure 16. Result of Q.12

In Q.13, the question was related to the public perception of the maintenance cost of solar PV systems. Based on the information in the survey form, one-time maintenance will cost around Rp. 700,000 to Rp. 1,000,000, and the adopters need to do two maintenance each year. As shown in Figure 17, around 51% of the respondents answered agree or strongly agree, while around 20% answered strongly disagree or disagree, and 29% answered neutral. This result indicates that only around half of the respondents found the maintenance cost affordable, while the rest felt it was expensive or did not financially benefit the adopters.

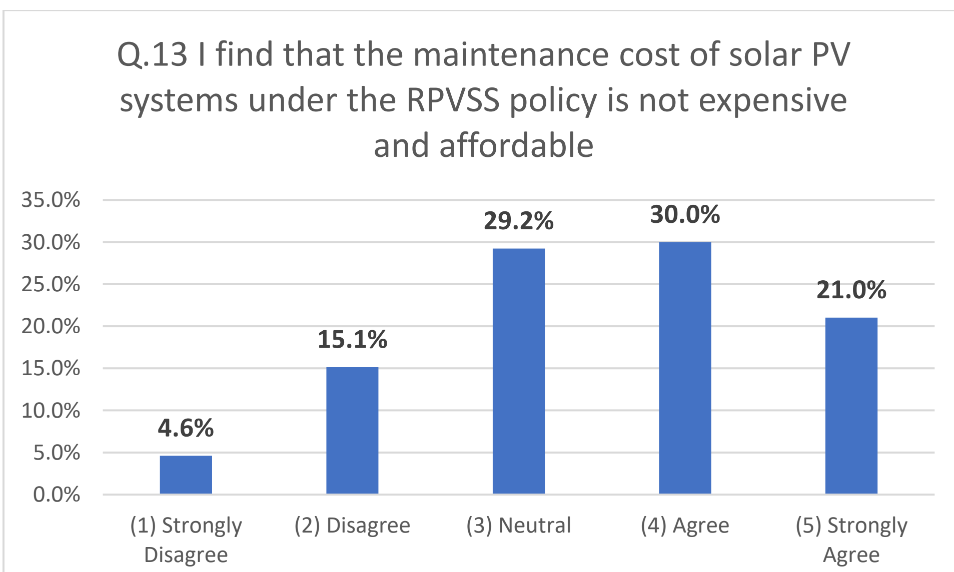

Figure 17. Result of Q.13

In Q.14, the question related to the public perception of Return on Investment (ROI) from adopting solar PV systems under RPVSS policy. Based on the information from the survey form, the ROI rate was 9-10 years. As shown in Figure 18, around 61% of the respondents answered agree or strongly agree, 17% answered strongly disagree or disagree, and 22% answered neutral. This result indicates that under RPVSS policy, 9-10 years ROI for most respondents using solar PV systems is good enough.

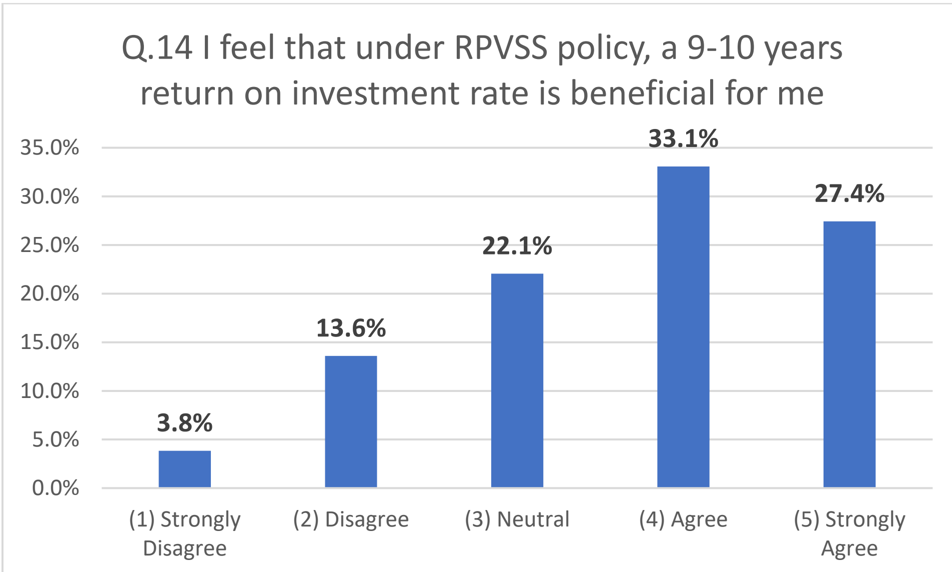

Figure 18. Result of Q.14

5.2.5 Perceived Ease of Use

The last TAM indicator was perceived ease of use, which related to the public perception of practical context while using solar PV systems or in the installation process. The main idea of this indicator was that public perception toward the ease of use of technology could affect their willingness to adopt the technology. For example, if the public perceived the initial process to install the technology was too complex, or the maintenance requirement was too redundant, the public might not want to adopt the technology. Before answering the survey question, brief information on the practical context of solar PV systems under RPVSS policy was given, as shown in Annex 2.

In Q.15, the question was tailored to assess public perception toward the initial process of adopting solar PV systems under RPVSS policy. To adopt the solar PV systems, the potential adopter must apply for submission along with administrative requirements and capacity specifications for solar PV. As shown in Figure 19, around 56% of the respondents answered agree or strongly agree, while 14% answered strongly disagree or disagree, and 30% answered neutral. This result indicates that more than half of the respondents believe the initial process to adopt solar PV systems was convenient enough.

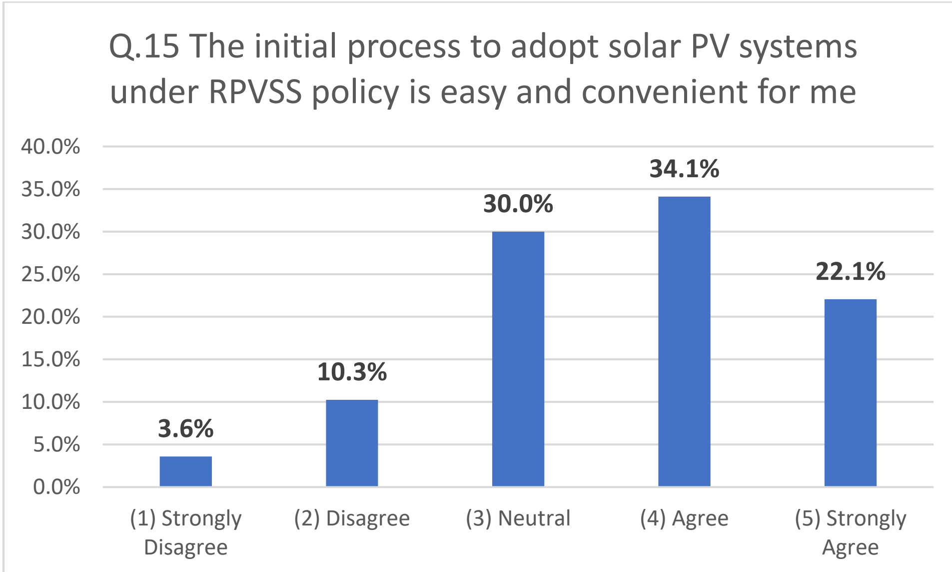

Figure 19. Result of Q.15

In Q.16, the question related to public perception about the compatibility of their building (in this case, the strength of their rooftop) and the capacity of solar PV installation. As shown in Figure 20, around 77% of the respondents answered agree or strongly agree, only around 6% answered strongly disagree or disagree, and 21% answered neutral. This result indicates that most respondents believe their home would be compatible with solar PV installation.

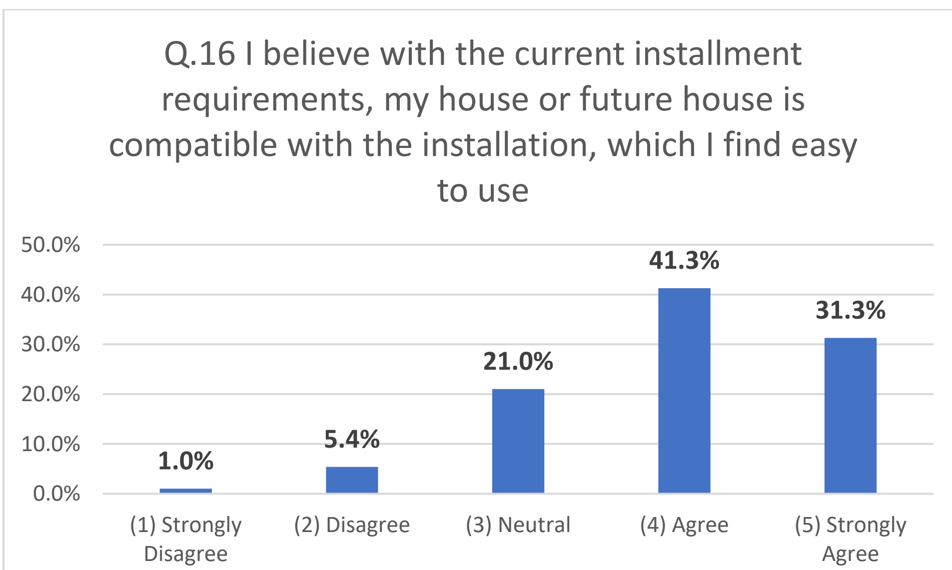

Figure 20. Result of Q.16

In Q.17, the respondents were asked about their feelings toward the frequency of solar PV maintenance under the RPVSS policy. Based on information from the survey form, all the solar PV systems adopters were obligated to do at least two maintenance each year. As shown in Figure 21, around 69% of the respondents answered agree or strongly agree, 7% answered strongly disagree or disagree, and 24% answered neutral. This result indicates that most respondents found that the frequency of maintenance at least two times each year was not redundant.

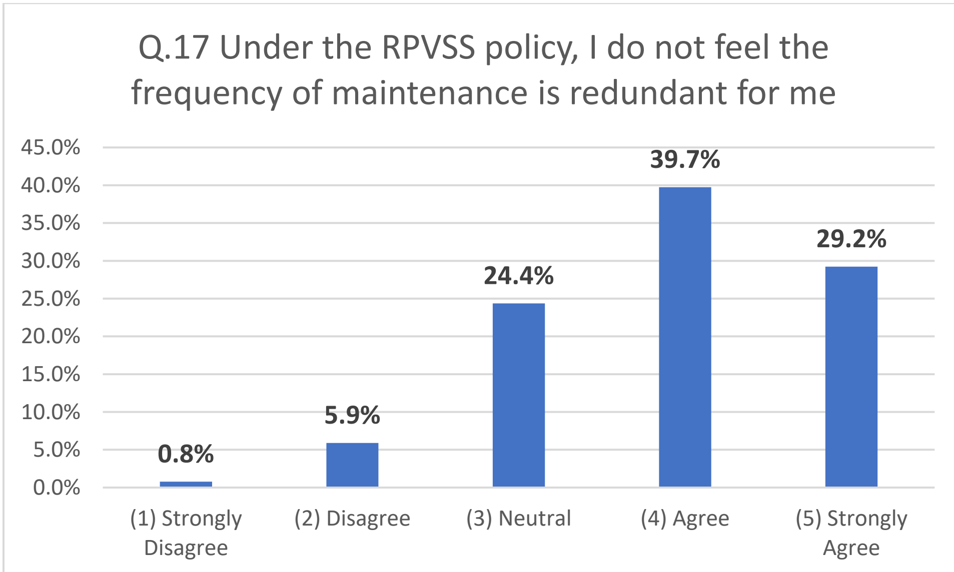

Figure 21. Result of Q.17

In Q.18, the respondents were asked about their perception of the frequency of interaction with the technology. The question means assessing the respondents' convenience level after knowing the information about how they interact or engage with solar PV systems in their daily lives. Based on information from the survey form, all adopters only need to monitor their electricity production without interacting with the technology. As shown in Figure 22, around 76% of the respondents answered agree or strongly agree, 6% answered strongly disagree or disagree, and 18% answered neutral. This result indicates that most respondents agreed that the frequency of interaction while using the solar PV systems was convenient for them.

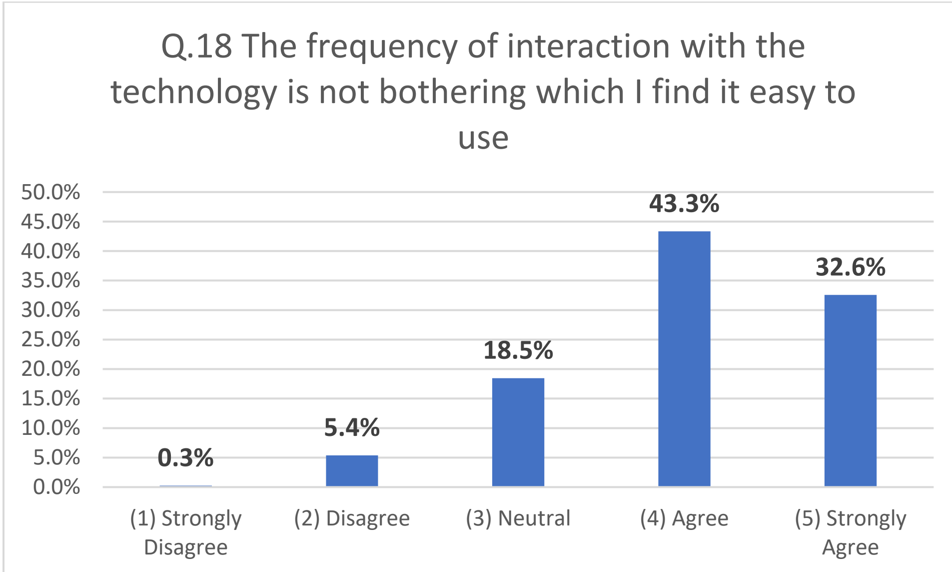

Figure 22. Result of Q.18

In Q.19, the question assessed the public perception of solar PV systems' performance. Even though there was no information about the technical obstacle shown in the survey, this question was essential to assess the public perception of the ease-of-use aspect of technology. While the survey may not have explicitly presented specific technical obstacles in its information, it aimed to capture respondents' subjective understanding and expectations as potential adopters regarding technical challenges or obstacles they might anticipate while adopting or using solar PV systems under the RPVSS policy. As shown in Figure 23, around 56% of the respondents answered agree or strongly agree, while 16% answered strongly disagree or disagree, and 27% answered neutral. This result indicates that around half of the respondents believe there will be only a little technical obstacle while using solar PV systems.

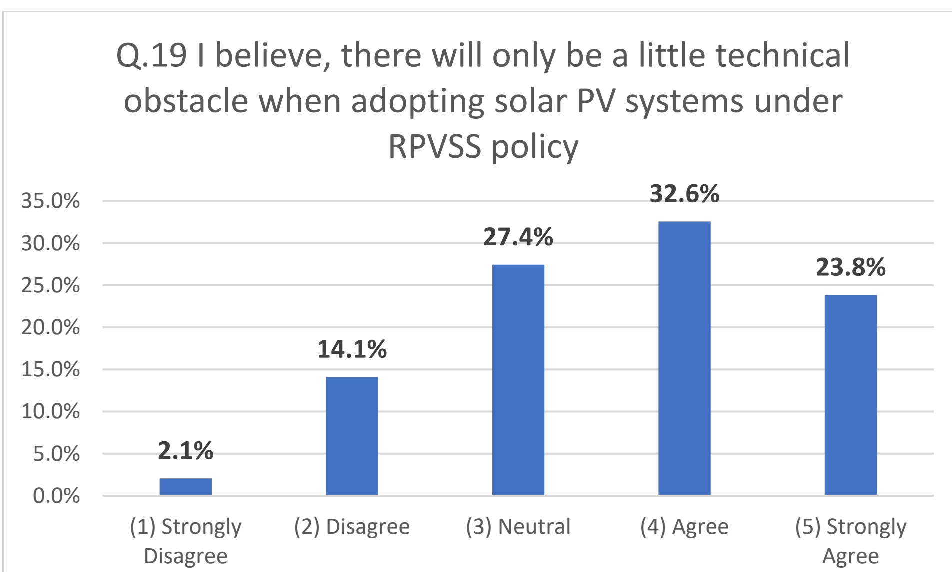

Figure 23. Result of Q.19

To better understand the public perception of solar PV systems under RPVSS policy, the present research used a simple statistical approach by calculating the mean value. The mean value is a commonly used measure of central tendency that provides an average data representation. In this case, the research aimed to assess public perception of solar PV systems under the RPVSS policy using a simple statistical approach.

As shown in Table 4, the survey result consists of two different values: numerical value and perception value. In this sense, the present research aims to calculate the mean value from numerical value (scale between 1 to 5) from the results from each question. This approach allows for a concise representation of the collective perception and summarizes the respondents' perception of each specific aspect associated with solar PV systems under the policy.

The mean value from the result of each question was created by adding all the values and dividing the result by the total number of respondents. In this sense, the values for each question ranged between 1 and 5, as shown in Table 6, and the total number of respondents was 390. There were three different mean values; first was the mean value for the question, which calculated the mean value for each question; the mean value for the indicator, which calculated the mean value for each TAM indicator; and the mean value for total perception which calculate the total mean value for solar PV systems under RPVSS policy in general. The result is shown in Table 6.

Table 6. Summary of mean value results

<table>
<tr><th>Question</th><th>Indicator</th><th>Mean Value (Indicator)</th><th>Mean Value (Category)</th><th>Mean Value (Total)</th></tr>
<tr><td>Q.5</td><td>Perceived Usefulness</td><td>4.2</td><td rowspan="3">4.1</td><td rowspan="15">3.7</td></tr>
<tr><td>Q.6</td><td>Perceived Usefulness</td><td>4.3</td></tr>
<tr><td>Q.7</td><td>Perceived Usefulness</td><td>3.9</td></tr>
<tr><td>Q.8</td><td>Environmental Awareness</td><td>3.7</td><td rowspan="4">3.6</td></tr>
<tr><td>Q.9</td><td>Environmental Awareness</td><td>4.2</td></tr>
<tr><td>Q.10</td><td>Environmental Awareness</td><td>2.0</td></tr>
<tr><td>Q.11</td><td>Environmental Awareness</td><td>4.3</td></tr>
<tr><td>Q.12</td><td>Perceived Affordability</td><td>3.2</td><td rowspan="3">3.4</td></tr>
<tr><td>Q.13</td><td>Perceived Affordability</td><td>3.5</td></tr>
<tr><td>Q.14</td><td>Perceived Affordability</td><td>3.6</td></tr>
<tr><td>Q.15</td><td>Perceived Ease of Use</td><td>3.6</td><td rowspan="5">3.8</td></tr>
<tr><td>Q.16</td><td>Perceived Ease of Use</td><td>4.0</td></tr>
<tr><td>Q.17</td><td>Perceived Ease of Use</td><td>3.9</td></tr>
<tr><td>Q.18</td><td>Perceived Ease of Use</td><td>4.0</td></tr>
<tr><td>Q.19</td><td>Perceived Ease of Use</td><td>3.6</td></tr>
</table>

Looking at Table 6, public perception toward the usefulness of the solar PV systems under the RPVSS policy was very positive, with a total mean value (category) of 4.1. The results illustrate that the public feel that adopting solar PV systems under the RPVSS policy could be useful to their life by saving monthly electricity bill as the most useful feature, followed by providing electricity and completing the task as usual. The highest mean value (indicator) for each indicator was from Q.6, which related to reducing electricity bills with a mean value (indicator) of 4.3, followed by Q.5, which related to serving daily needs of electricity and the least mean value was Q.7 which related to the solar PV function to complete the task without extensive efforts with a mean value (indicator) of 3.9.

The last indicator of TAM was perceived ease of use, which scored the second highest compared to other categories with a mean value (category) of 3.8. The highest mean value (indicator) was Q.18, which related to the frequency of interaction while using the technology, and Q.16, which related to building compatibility, scored 4.0 for each question. Q.17, related to the frequency of maintenance per year, scored second highest with a mean value (indicator) of 3.9. Q.15, which related to the initial process of adopting the technology, and Q.19, which related to obstacles while using the technology, scored lowest in perceived ease of use indicators with a mean value (indicator) of 3.6. The results illustrate that the respondents' perception of the ease-of-use indicator was still positive, with several opportunities for improvement. For instance, under the RPVSS policy, the initial process to adopt solar PV systems could be simplified and increase public trust in the technology by enhancing the solar PV systems campaign.

Regarding environmental awareness as the second TAM indicator, this category has a mean value (category) of 3.6, the second lowest compared to other category scores. As shown in Table 6, Q.11, which is related to reducing the dependence on fossil fuel, and Q.9, which is related to reducing GHG emissions, have the highest mean value (indicator) in this category, 4.3 and 4.2, respectively. On the other hand, Q.10, which related to the lack of existence of solar PV waste treatment, scored the lowest with a mean value (indicator) of 2.0 for the question, and Q.8, which related to the impact of raw material extraction scored relatively low in this category with a mean value (indicator) of 3.7. The results illustrate that the public perception of solar PV's environmental effect is positive, as the public believes that adopting solar PV could contribute to reducing GHG emissions while reducing dependence on fossil fuels. Even though manufacturing solar panels requires raw material extraction, most respondents still feel that the positive effect of adopting solar panels outweighs the manufacturing impact. However, the lack of solar panel waste treatment was affecting the public's willingness to adopt the technology.

In perceived affordability, this indicator has the lowest scores compared to the other indicators, with a mean value (category) of 3.4. In this indicator, the highest mean value (indicator) was Q.14, which related to ROI with a mean value (indicator) of 3.6, followed by Q.13, which related to maintenance cost with a mean value (indicator) of 3.5, and Q.12 which related to upfront cost has the least mean value (indicator) of 3.2. The results illustrate that the public perception toward the affordability of solar PV systems under the RPVSS policy was relatively low compared to other categories. The overall mean value (category) was 3.4, indicating that most respondents agreed that reducing upfront and maintenance costs could increase public acceptance of solar PV systems.

Considering the nature of this research was qualitative, which measured public perception toward solar PV systems under RPVSS policy, mean value (total) was used to act as a benchmark to identify which indicator (reflected in each survey question) needs to be improved (see table 7).

Table 7. Mean value (indicator) analysis, order from the lowest mean value to the highest mean value

Question	Indicator	Category	Mean Value (Indicator)	Mean Value (Total)
Q.10	The existence of solar panel waste treatment	Environmental Awareness	2.0	3.7
Q.12	The upfront cost to adopt solar PV	Perceived Affordability	3.2	
Q.13	Maintenance cost	Perceived Affordability	3.5	
Q.14	Return on investment (ROI)	Perceived Affordability	3.6	
Q.15	The initial process to adopt solar PV	Perceived Ease of Use	3.6	
Q.19	Technical obstacle	Perceived Ease of Use	3.6	
Q.8	Solar PV manufacturing impact	Environmental Awareness	3.7	
Q.7	Enable tasks without extensive efforts	Perceived Usefulness	3.9	
Q.17	Frequency of maintenance	Perceived Ease of Use	3.9	
Q.16	House compatibility	Perceived Ease of Use	4.0	
Q.18	Frequency of interaction	Perceived Ease of Use	4.0	
Q.5	Provide daily needs of electricity	Perceived Usefulness	4.2	
Q.9	Reduce GHG emissions	Environmental Awareness	4.2	
Q.6	Lower electricity bill	Perceived Usefulness	4.3	
Q.11	Reduce dependence on fossil fuels	Environmental Awareness	4.3	

After comparing the mean value (question) with the mean value (total), seven indicators are considered to need improvement (shown in red), such as the existence of solar panel waste treatment, upfront cost, maintenance cost, ROI, the initial process to adopt solar PV, technical obstacle, and solar PV manufacture impact.

6. Discussions

6.1 Indonesia's Current Situation of Solar PV Systems.

The RPVSS policy aims to promote solar PV systems adoption and ultimately address the energy trilemma challenge. Thus, the present research uses three energy trilemma pillars as boundaries to the key factors influencing solar PV adoption under the RPVSS policy in Indonesia. According to Gunningham (2013), energy trilemma is a challenge in managing trade-offs between energy security, affordability, and environmental sustainability.

Energy affordability was found to be challenging in Indonesia's current states. Most experts agree that affordability is critical in accelerating solar PV systems adoption. Regarding the RPVSS policy, two main aspects influencing the public willingness to adopt solar PV systems were the upfront cost and export tariffs as financial incentives. Currently, the upfront cost to adopt solar PV systems under the RPVSS policy is still considered expensive by the experts. The TKDN policy obliges technology or projects to have a minimum percentage of local content, which was the main reason for the high upfront cost. This policy leads to higher upfront costs due to the need for raw materials required for manufacturing solar panels in Indonesia. Moreover, energy storage technology like batteries is still considered unaffordable and unpractical for residential use. Therefore, regarding energy affordability, cooperation or investment from foreign countries was found to be pivotal to creating subsidies or better incentives to attract more adopters.

Regarding energy security, based on interviews with experts, the most significant challenges lie in intermittency issues from the nature of solar power and political rather than technological-related issues. Intermittency issues also pose a technical threat as they could disturb the stability of the national grid due to rapid fluctuation in the evening, which could lead to blackouts. These challenges were connected as intermittency issues found to be why PLN and MEMR have different political interests. PLN was more focused on maintaining the stability of the national grid while maintaining business activity by calculating the amount of installed capacity and export tariff for solar PV systems adoption. On the other hand, MEMR focused more on achieving national renewable energy mix goals of 23% by 2025 and 32% by 2050. The different goals or interests of both parties led to policy inconsistency, which impacted and hindered investors from investing in solar PV systems projects in Indonesia. The lack of investment could lead to a low solar PV systems adoption rate due to a lack of financial subsidies or incentives.

Environmental sustainability also faces a significant challenge in Indonesia's current situation. While it is true that solar PV systems are considered clean energy and do not emit CO_2 emissions when using them, manufacturing processes and waste from solar PV are still found to harm the environment. Based on the results of interviews with experts, the main challenge comes from the need for solar waste treatment facilities. Thus, the situation in Indonesia poses a future issue in soil and water contamination from unused solar panels. Regarding environmental sustainability, public awareness of the environmental aspect must be improved. Most of the adopters only adopt solar PV systems if it is beneficial for them in financial terms rather than in environmental terms. In this case, this situation can be an opportunity for a different approach for the Government to attract more adopters by increasing public awareness.

6.2 Public's Solar Technological Acceptance under RPVSS Policy.

Energy affordability is a significant challenge in Indonesia, with the upfront cost of adopting solar PV systems still being considered expensive. This challenge was supported by the survey results, which indicated that the perceived affordability of solar PV under the RPVSS policy scored the lowest among other TAM indicators. From the survey results, the respondents found that upfront cost, maintenance cost, and ROI needed to be more affordable and beneficial for them, which could decrease public intention to adopt solar PV systems. Some experts believe subsidies from cooperation or investment from foreign countries, better incentives, and different financing options like leasing or loans could address this challenge.

There was an unexpected result from survey results: while solar PV systems are considered clean energy, the environmental awareness indicator scored the second lowest among other TAM indicators. This result was derived from the fact that Indonesia still lacks solar waste treatment facilities, which raises concerns about soil and water contamination from unused solar panels. In addition, the environmental impact of solar PV manufacture also scored relatively low based on the survey results. The survey provided respondents with information highlighting raw material extraction as the primary concern in solar PV manufacture. While some experts state that Indonesia still imports solar PV from China and is not impacted by manufacturing impact, the public still raised concerns. Thus, establishing solar waste treatment facilities and increasing technology efficiency could address these challenges and improve public perception of the environmental sustainability of solar PV systems.

The overall perception of the ease of use of solar PV systems is positive, but there are areas for improvement. Respondents rated the frequency of interaction and house compatibility as the highest indicators of ease of use. However, the initial process to adopt solar PV systems and technical obstacles were identified as areas that need improvement to increase public trust and acceptance of the technology. Some experts believe that to make the public more convenient when adopting solar PV systems, PLN could provide installation and maintenance services to the adopters. Regarding the technical obstacles, the low scores illustrate that the subjective understanding of the respondents was negative. While some experts stated that solar PV systems were secure and reliable technology that infrequently encountered an error, the public still expects some obstacles while using or adopting solar PV systems under RPVSS policy. This result was anticipated because the respondents' awareness of the policy content was low. To increase public perception of the technical obstacles, policymakers should create more educational campaigns on solar PV systems to improve public awareness and understanding of the technology.

The public perception of the usefulness of solar PV systems under the RPVSS policy is positive. Respondents believe that adopting solar PV systems can save monthly electricity bills and provide electricity for daily needs. However, some experts believe that Indonesia still faces a challenge in managing the stability of the national grid, considering the emergence of solar PV adoption. Based on the interview with experts, more solar PV adopters mean a higher chance of rapid fluctuations in electricity supply and demand from midday to evening. Efforts to manage this challenge include energy storage systems, demand response programs, and integration of other energy sources.

6.3 Recommendation for RPVSS policymakers.

Policymakers can use the Technological Acceptance Model (TAM). This theoretical framework helps understand and predict people's acceptance and adoption of new technologies to direct their decision-making processes and develop more effective policies promoting the acceptance and adoption of solar PV. The present research used survey results of TAM indicators as a tool for identifying the opportunities to accelerate solar PV adoption under the RPVSS policy. After analyzing the findings, there were several recommendations for policymakers.

First, based on survey results of TAM indicators, perceived affordability holds the lowest score compared to the other categories. These results emphasize the need for more affordable financing options. For example, subsidies by the government or leasing and loan schemes by PLN. In this way, more potential adopters might be attracted to more affordable upfront costs, which leads to accelerating solar PV systems adoption in Indonesia. In addition, the subsidy could also impact a better ROI rate as it could decrease the upfront cost. Thus, a better ROI rate could attract more potential adopters as it means that they could have more financial benefits and view solar PV systems as an investment rather than just adopting new technology.

Second, establish cooperation with property developers. Property developers are considered vital in accelerating the adoption of solar PV systems in Indonesia. Cooperating with property developer impose a different approach to solving the upfront cost issue. As mentioned before, upfront cost was recognized as a pivotal barrier, which ranked second in the survey. By building pre-installed solar PV systems for new residential areas, the potential customer could pay the upfront cost of solar PV in mortgage installments.

Third, the TAM theory also emphasizes the importance of individuals' perception of the ease of using technology (Yang, 2021). Policymakers can focus on simplifying the adoption process and reducing entry barriers for solar PV systems. Therefore, PLN should provide more support to potential adopters. As mentioned before, the initial process to adopt solar PV systems under RPVSS policy is still considered inconvenient based on the survey. In RPVSS policy, potential adopters must apply to PLN and receive prior consent before adopting solar PV systems in their homes. However, PLN needed to provide the installment service themselves; the potential adopter needs to find a private company that provides the product and service to adopt the technology. In this sense, some experts believe that PLN should also provide installation and maintenance services to make it more convenient for solar PV system adapters.

Fourth, the Government should establish solar PV waste treatment facilities. The existence of a solar PV waste treatment facility was found to be affecting the perception of the public toward solar PV systems. The sooner the Government establishes solar waste treatment facilities, the better. However, establishing this facility also required a lot of investment cost, which makes this aspect connected to the solar PV systems campaign. In addition, establishing a solar PV waste treatment facility could increase public perception of solar PV manufacturing impact. The facility will also employ a recycling and recovery process to extract valuable material from solar PV waste. The public could be more confident in the environmental benefits of adopting solar PV systems.

Fifth, The TAM suggests that individuals are more likely to adopt a technology if they perceive it to be useful (Yang, 2021). Therefore, policymakers should create a solar PV campaign to increase public awareness of the benefits of solar PV systems adoption. Policymakers should go beyond campaigning on online media only, extending to visiting places of work or educational institutions to promote the adoption and increase public awareness of the given technology. This approach could also increase public perception of technical obstacle indicators resulting from the public's lack of understanding of solar PV or the RPVSS policy content. Based on the findings, around 80% of the respondents still need to gain awareness of solar PV systems under the RPVSS policy. While most respondents were 18-35 years old, policymakers could see this as an opportunity to target this age range in solar PV systems promotion.

7. Conclusions

After analyzing the current situation of solar PV systems under the RPVSS policy in Indonesia and the public perception toward the usefulness, ease of use, affordability, and environmental awareness of solar technology, the following conclusions can be drawn:

First, the main barriers to the widespread adoption of solar PV systems in Indonesia under the RPVSS policy are high upfront costs due to the TKDN policy and limited energy storage technology. Solutions include collaborating with real estate developers and foreign investment for subsidies, addressing grid instability caused by intermittency through affordable energy storage, ensuring consistent policies to boost investor confidence, and establishing solar waste treatment facilities to promote environmental awareness and sustainability.

Second, public perception of solar PV systems under the RPVSS policy is predominantly positive. Respondents view these systems as beneficial for reducing monthly electricity expenses and fulfilling daily energy needs. The perceived ease of use is generally favorable, although improvements are needed in the initial adoption process and overcoming associated obstacles. However, environmental awareness regarding solar PV systems could be higher, with concerns arising over inadequate waste treatment and the environmental impact of raw material extraction. Affordability perception is the lowest, with concerns about high upfront and maintenance costs and low return on investment (ROI).

Third, there were some recommendations for Indonesian policymakers, such as streamlining the adoption process and lowering barriers to entry for solar PV systems, launching a thorough campaign for solar PV systems that extends beyond online media to increase public understanding of the advantages of solar PV adoption, and offering various financing options like PLN loan schemes, leasing, and subsidies to make solar PV systems more affordable. In addition, collaborate with property developers to incorporate pre-installed solar PV systems in new residential areas and establish solar PV waste treatment facilities to address concerns about environmental sustainability.

To conclude this research, the TAM could accelerate solar PV systems adoption under RPVSS policy in several ways. By examining perceived usefulness, ease of use, affordability, and environmental awareness, TAM can help policymakers and researchers better understand how potential adopters view solar PV systems under RPVSS policy. By analyzing these indicators, TAM can provide insights into the key drivers and barriers to adoption. This understanding enables policymakers to develop targeted strategies to address concerns and increase the acceptance of solar PV systems. For instance, the survey results show that seven indicators need improvement: solar panel waste treatment, upfront cost, maintenance cost, ROI, the initial process to adopt solar PV, technical obstacles, and the impact of solar PV manufacture.

The present research offers comprehensive insights into the current solar PV systems adoption under the RPVSS policy in Indonesia. It highlights challenges, opportunities, public perceptions, and practical recommendations to enhance the adoption of solar technology. This research showcases the practical way to analyze public perceptions by combining quantitative and qualitative TAM approaches.

Finally, six recommendations for future study were identified based on the insights obtained from this thesis. First, different methods and tools to collect survey data must consider collecting a more even distribution of respondents' profiles. This research used social media to distribute the survey data, which was found to be uneven respondents' age and more inclined to people aged 18-35 as older people tend not to use social media. Second, this research could identify the challenges and opportunities from different social statuses of potential adopters that can be used to find the best strategies to promote solar PV adoption for different consumer segments.

Third, comparative studies between Indonesia and other nations with successful solar PV adoption policies should be conducted to identify best practices, lessons learned, and policy recommendations that can be customized to the Indonesian context. Fourth, determine whether the RPVSS policy has successfully achieved its stated objectives. This research could examine the policy's effects on the adoption of solar PV, the cost and security of energy, and the sustainability of the environment. Fifth, research could concentrate on innovations in solar PV efficiency, solar panel manufacturing process, and energy storage technologies to improve affordability, reliability, and environmental sustainability. Sixth, while focusing on Jakarta is a practical decision due to time and resource constraints, there are ways to approach the generalization of findings beyond Jakarta despite this limitation. Conducting a thorough review of existing literature on housing in other Indonesian cities or developing countries can help identify common challenges and trends. Collaborating with researchers in other cities or countries can provide a more comprehensive understanding. Shared methodologies and data collection approaches can enhance comparability.

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ANNEX

ANNEX 1. INTERVIEW INVITATION AND QUESTIONS

FACULTY OF BEHAVIOURAL, MANAGEMENT AND SOCIAL SCIENCES (BMS)

The Section of Governance and Technology for Sustainability (CSTM)

OUR REF	MEEM 2022-2023	PHONE	+31(0)53 4892396
DATE	28 August 2023	EMAIL	r.j.koster@utwente.nl

Dear

SUBJECT: Master Thesis Research

sir/madam,

With this letter we confirm that Vincent Setiawan is a registered student at the University of Twente, The Netherlands, and studies in our one-year Master programme ‘Environmental and Energy Management’ (MEEM).

Name	: Vincent Setiawan
Student no.	: 3062643
Programme	: Master of Environmental and Energy Management (MSc)

Vincent Setiawan is in the final phase of his studies and is conducting research for his master thesis titled "***Accelerating Solar PV Systems Development in Jakarta, Indonesia: The Role of Technological Acceptance Model***". This research aims to better understand how key stakeholders perceive and experience the key factors that influence solar PV systems adoption under RPVSS policy in Indonesia.

To get needed information, **Vincent Setiawan would like to invite you for an interview**, which will be a part of his thesis. Your answers to the below questions will be treated confidentially and for study purposes only. Accordingly, this invitation also works as consent permission (by doing the interview, it means that the interviewee permits to use the data for study purposes). In addition, you have the right to stop in the middle of the interview process if you wish, due to personal reasons. The interview session will take approximately 45 minutes. The interview questions are:

1. What is your affinity related to solar PV systems in Indonesia, and how long have you been working in this area?
2. In your opinion, do you think the speed of solar PV systems adoption in Indonesia has been fast enough to meet Indonesia's National Energy Plan? Please indicate your reason.
3. In your opinion, what are the key factors that influence solar PV systems adoption in Indonesia?
4. In your opinion, what is the importance of public perception toward solar PV systems and RPVSS policy?
5. In your opinion, what are the barriers and opportunities of RPVSS policy?
6. What suggestions would you like to give to policymakers to accelerate the adoption of solar PV systems in Indonesia?
7. Is there anything else that you would like to add to this topic?

Please let Vincent know when would be the most convenient date and time for you.

If you have any questions, please feel free to contact him at vincentsetiawan@student.utwente.nl

Your cooperation will be highly appreciated. Thank you in advance for your time and consideration in this matter.

UNIVERSITY OF TWENTE.

MB-CSTM

Sincerely,

Ms. Rinske Koster

Programme Coordinator Master of Environmental and Energy Management (MEEM)

ANNEX 2. SURVEY FORM

UNIVERSITY OF TWENTE.

English

This questionnaire is by no means mandatory. You may stop filling it out anytime by closing the browser. If you have any questions or remarks about the questionnaire beforehand, feel free to email me via: vincentsetiawan@student.utwente.nl

Your privacy will stay protected because this questionnaire is anonymous. In this questionnaire, no personally identifiable information will be collected. There are no questions that will ask for things such as your name, e-mail address, or phone number. In addition, only summaries and analyses of the data and no individual data will be shared with peers or professors. Only summaries and analyses can be published. The collected data from individual responses will be deleted after the completion of this research.

Hereby, I say that I have read the above consent form and agree with it.

- ○ Yes
- ○ No

Important: This survey is meant for the residents of Jakarta and Individuals older than 18 years old

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Indonesia's National Energy Plan

Climate change issue has become a pivotal challenge that faces the world in the last decades. This concern leads to the need for energy transition as fossil fuel consumption accounts for around 89% of global CO2 emissions (Client Earth, 2023). Regarding the global energy transition challenge, Indonesia plays a key role as the highest energy consumption country in ASEAN in total and is forecasted to keep growing along with economic and population growth in the future (IRENA, 2022). Consequently, the Indonesian Government has stipulated to increase the Renewable Energy mix by 23% and 31% in 2025 and 2050 respectively through Government Regulation No.79 of 2014 in National Energy Plan and 2015 Paris Agreement (MEMR, 2019).

RPVSS Policy

To promote the adoption of solar PV systems, the Government of Indonesia introduce Rooftop Photovoltaic Solar Systems (RPVSS) policy in 2018 to encourage the public to adopt solar PV systems and reduce reliance on fossil fuels which are the major contributor to climate change. The RPVSS policy enables "on-grid PV systems" to PLN customers which allow the customers to install photovoltaic panels and connect them to the national grid on residential, governmental, commercial, and industrial buildings.

Are you living in Jakarta?

- ○ No
- ○ Yes

How old are you?

- ○ Below 17 years old
- ○ 18-25 years old
- ○ 26-35 years old
- ○ 36-45 years old
- ○ Older than 46 years old

Before reading the survey's introduction, are you aware of the RPVSS policy in Indonesia?

- ○ Yes I am aware of that
- ○ I only heard about this policy but I don't really know the content
- ○ No, This is the first time I heard that

About the function of solar PV systems under RPVSS policy in a residential context:

The RPVSS policy enables “on-grid PV systems” to PLN customers which allow the customers to install photovoltaic panels and connect them to the national grid on residential, governmental, commercial, and industrial buildings. Solar PV systems on the grid in residential contexts serve as a source of renewable energy that can supplement or replace electricity purchased from the grid. The primary function of a solar PV system is to generate electricity from sunlight, which can then be used to power household appliances and electronics.

Under the RPVSS policy, the maximum installed capacity of the solar panel is 100% of the existing electricity capacity contract, and the fed-in tariff of excessive exported electricity will be valued at 65% of the normal PLN tariff (around 5.5 cents USD/kWh - 7 cents USD/kWh, based on 2023 electricity prices in Indonesia and March 2023 exchange rate). If the export energy exceeds the import, the excess can be transferred to the following month to offset the monthly bill (maximum of three months).

Regarding the "on-grid" term, it refers to the connection between the solar PV systems to the national grid which also enables the adopters of the technology to use electricity that is generated from PLN when the solar PV systems are offline (e.g. when there is no sun available).

Solar electricity can serve my daily needs of electricity

On a scale of 1-5, how useful do you think it is? ☆☆☆☆☆

I can lower my electricity bill if I adopt solar PV systems under RPVSS policy

On a scale of 1-5, how useful do you think it is? ☆☆☆☆☆

Solar panel can enable me to complete my tasks without extensive efforts

On a scale of 1-5, how useful do you think it is? ☆☆☆☆☆

Solar PV systems are clean renewable energy with zero emission of GHG while using and consider a promising technology to increase energy supply and reduce fossil-fuel dependency. However, there are consequences of the manufacturing process for the environment, such as raw material extraction, manufacturing, disposal, and recycling which can be a potential barrier to development.

Overall, the production of solar PV systems requires various materials, including silicon, glass, and metals such as aluminum and copper. The extraction and processing of these materials can have significant environmental impacts, including habitat destruction and water and air pollution. The manufacture of solar PV systems can generate waste, including hazardous waste, such as solvents and chemicals used in the production process. The improper disposal of this waste can harm the environment and human health.

Based on the interview with experts, since the solar PV systems in Indonesia are still in the early stage, waste treatment facilities are still not available while the lifespan of solar panels is around 25 years. In addition, the majority of solar panels are imported from China.

I believe the negative impact of manufacturing solar panels is worth the positive effect from the use of solar panels

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

By adopting solar PV systems, I can contribute to reducing GHG emissions

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

The existence of solar panel waste treatment is affecting my willingness to adopt the technology

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

I believe that solar PV technology can help reduce dependence on fossil fuels and address climate change

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

The upfront cost of the kWh net meter device is Rp. 2,000,000, and the cost of installation is around Rp. 17,000,000/kWh (on average, one household may need to install 2kWh of solar panel capacity, approximately Rp. 34,000,000 or US 2210, March 2023 exchange rate). The maintenance cost is around Rp. 700,000 to Rp. 1,000,000 per session (solar panels need two maintenance per year). All in all, with the advantage of the feed-in tariff and other costs related to solar panels, the average return on investment (ROI) or payback period of rooftop solar PV adoption under the RPVSS policy would be around 9-10 years.

I find that the upfront cost to adopt solar PV systems under the RPVSS policy is not expensive and affordable

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

I find that the maintenance cost of solar PV systems under the RPVSS policy is not expensive and affordable

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

I feel that under RPVSS policy, a 9-10 years return on investment rate is beneficial for me

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

Regarding RPVSS, to install the technology, the customer requires prior approval and verification from PLN. This process consists of application submission along with administrative requirements such as PLN customer number, the specification of capacity and equipment to install, and the option to install the battery storage.

Under the RPVSS Policy, PLN is authorized to give a “certificate of operation” for PV systems that consumers buy from private entities. Regarding the installment process, all the installment activities only take one day and require professional technicians which are usually provided by private entities. Before the installation, the technician will analyze the building's compatibility. On average, a household with 2200 watt capacity, requires 10 m square on their rooftop for the solar panels. In addition, the building structure needs to be strong enough to support the solar panels which weighting for 15 kg/m square. To reiterate, the potential customer needs prior approval and verification from PLN before installing the solar panel.

Then, the private entities will send a professional technician to analyze the best position and compatibility to install the solar panel. After that, the users can monitor electricity production via mobile apps and do not have to interact with the technology itself. However, solar panels need to be maintained at least twice every year.

The initial process to adopt solar PV systems under RPVSS policy is easy and convenient for me

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

I believe with the current installment requirements, my house or future house is compatible with the installation, which I find easy to use

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

Under the RPVSS policy, I do not feel the frequency of maintenance is redundant for me

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

Under the RPVSS policy, I find the installment is not complex and easy

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

The frequency of interaction with the technology is not bothering which I find it easy to use

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

I believe, there will only be a little technical obstacle when adopting solar PV systems under RPVSS policy

On a scale of 1-5, how much do you agree with the statement? ☆☆☆☆☆

ANNEX 3. RESEARCH TIMELINE