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Achieving renewable energy targets: The impact of residential solar PV prosumers in Indonesia

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ABSTRACT

Indonesia, like many countries, has committed to reducing its greenhouse gas (GHG) emissions. To do this, the country needs to move from its current high reliance on non-renewable energy sources to renewable sources of energy. The issue is significant for Indonesia as the country is the 4th largest contributor to global CO_2 emissions. The country has abundant sources for energy and one of these sources is the potential for solar energy. Therefore, the country has set ambitious renewable energy targets based on the potential supply of solar energy. With domestic residential consuming up to 43% of total electricity consumption, the Government has targeted homeowners to install solar rooftop and become residential solar PV prosumers. However, a recent energy evaluation report indicates that the country's progress is very slow and it is highly likely that renewable energy goals will not be achieved. This study conducted an online survey of a small sample of regular electricity subscribers and residents who have installed solar rooftop in the hope of gaining a better understanding of various issues and factors which could be impeding the growth of residential solar. Some of areas the study explored included the level of knowledge and awareness of solar energy, initiatives for homeowners, policy on net-metering and feed-in tariff, and areas of concern related to economic, environmental, and technological factors. While many countries are struggling to shift to greener energy generation and consumption, in Indonesia's case, the country has its own unique set of challenges being the energy generation and distribution is centralised, state-owned, with an inflexible energy pricing system. Hence, energy management in Indonesia could benefit from becoming more market focused and transparent, while increasing technology adoption with hybrid community partnerships, including a mix of private and government ownership. A discussion on policy implications and suggestions for improvements can be found at the end of this paper.

Keywords

Renewable energy targets;
Residential solar PV;
Prosumer;
Indonesia;
Community participation;

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1. Introduction

Indonesia is a country that has abundant sources for energy, both renewable and non-renewable sources [1–4]. The country is the largest energy consumer in the ASEAN region and it's energy consumption rate has grown rapidly in the past decade [5,6]. In 2014, Indonesia launched the country's national energy policy, as reflected in Regulation Number 79/2014, which states a commitment to decrease non-renewable sources, and increase energy generation sources from the current 14% renewable energy, to 23% in 2025 and further to 31% by 2050 [2,4]. To meet these targets, solar energy provides Indonesia the highest potential source of renewable energy, as indicated in the national energy

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Table 1: Indonesians renewable energy source potentials [2]

Source of renewable energy	Potential supply (GW)
Solar energy	207.8 GW (47%)
Hydro	94.3 GW (21%)
Wind	60.6 GW (14%)
Biomass	32.6 GW (7%)
Geothermal	28.5 GW (7%)
Wave	17.9 GW (4%)
Total	**441.7 GW (100%)**

policy and presented in Table 1 above. Table 1 indicates that solar energy has the potential to provide 47% of Indonesia's renewable energy target by 2025, and this potential is expected to increase to 68% by 2050 [2,4].

Amongst Southeast Asian countries, the focus towards renewable energy started about the same time (e.g. Indonesia introduced a Feed-in tariff (FIT) policy in 2011, followed by the Philippines in 2012). However, Indonesia's renewable energy progress has not advanced as expected [7], and is lagging behind other countries in the region [8], resulting in Indonesia being the 4th largest contributor to world CO_2 emissions [9]. The Government of Indonesia (GoI) has introduced several policy initiatives to tackle the renewables issue, including sector-based (e.g. solar, hydro, wind, biomass, biogas and geothermal) and demand-based policies (e.g for industry, transport, and residential) [10]. These policies attempt to link how the different renewable energy generation, transmission, and distribution can be integrated and implemented in Indonesia. The GoI also propose incentives for industry, transport, and residents to invest in renewable energy initiatives [11]. However, the achievements have been far lower than what was targeted. Up until 2019, only 9.5 GW of the 441.7 GW potentially available has been exploited or only 2.15% of the potentially identified renewable energy [12]. It is worth noting, that from the potential sources of renewable energy identified, more than 70% is owned/controlled by Perusahaan Listrik Negara (PLN) [7], an Indonesian government-owned corporation which has a monopoly on electricity distribution in Indonesia and generates the majority of the country's electrical power. It was ranked 477 and 480 in in the Fortune Global 500 lists of 2014 and 2015 respectively [13,14].

Some studies argue that the failure of renewable energy to gain impact is critically associated with the social non-acceptance of the renewable energy program at the introduction phase, but on the same hand, social acceptance is an essential factor in the successful promotion of renewable energy [15,16], along with political support [17] and technological advancements [18]. Over the last decade, research in renewable energy has significantly increased. Studies are investigating the various dimensions of renewable energy development, e.g. policy [7,19,20], economic [21], political-economy [22], socio-legal [19], technology and policy [23] and socio-technical dimensions [24]. Recent studies confirm the necessity to include multi-dimensional aspects in promoting renewable energy, as countries differ in terms of policy and social context [25]. Mimicking other countries renewable energy policy without considering the socio-political-technology readiness of the country can lead to failure, as was the case by Hamdi et al. [26] in their review of Indonesia's solar energy development.

Focusing on solar energy, studies have attempted to understand the solar energy market via the integration of consumers and producers, referred to as prosumers [22,27], along with regulatory frameworks, motives, and the investigation of potential investment packages [22,28]. Some studies cover multi-aspects, such as policy incentives, investment drivers, product preferences, including comparisons of countries, using a range of quantitaitve and qualitatitve methods [22], while some studies narrow the focus to factors impacting residential solar PV adoption by homeowners [29]. These studies argue that solar energy development and acceptance may vary from country to country due to different policy development or incentive packages. To further advance the development, adoption and implementation of residential solar PV prosumers and domestic rooftop solar, more studies are needed, especially in the context of developing countries [29].

This study aims to extend our understanding from a developing country perspective with Indonesia being the country understudy. With respect to renewable energy, the study of this issue in Indonesia is timely because the country is struggling to meet its own renewable energy targets, along with being the world's 4th biggest CO_2 polluter [6]. With residential electricity accounting for 43% of PLN's total electicity sales in 2019 [30] and predictions that by 2050, about 30% of the country's energy will be needed for households, the potential of increasing residential solar PV prosumers in Indonesia is likely to significantly impact

the country's energy targets and climate change mitigation [31].

The paper is organised in the following order. Section 2 reviews the literature on renewable energy acceptance, including a discussion on the development of residential solar energy in Indonesia. Section 3 presents the methodology used to answer the four hypotheses. Section 4 presents the findings including sub-sections with discussion and policy implications. Lastly, Section 5 provides a conclusion to the study.

2. Renewable energy and Indonesia

Section 2 discusses renewable energy in the context of Indonesia. The literature on the Indonesian energy market and related policy is highlighted, along with renewable energy acceptance and community involvement. From the various discussion points, four hypotheses are developed for testing in this study.

2.1. Indonesia's energy market and policy uncertainty

In 2017, Indonesia signed a commitment to implement the Paris agreement to reduce greenhouse gasses by 29% (or 398 million tons of CO_2), as this target was within the country's own target of reaching a national renewable energy supply of 23% by 2025 [2,4]. Since then, numerous renewable energy projects have been introduced, including geothermal, biodiesel, wind power, hydropower and solar power. Although solar energy has been identified as offering the highest potential for renewable energy (see Table 1), progress up to 2019 has been dissapointing, with less than 0.15% of the target being exploited [32].

The Indonesian energy policy is complex and fluxing. The electrification of the country is a major challenge for the national government due to geographical issues. Indonesia is the largest archipelago in the world with 270 million people spread over more than 6,000 inhabitable islands, covering a geographical distance from London to New York [11]. As previously noted, PLN is the state-owned monopoly that generates, transmit and supplies energy to customers, but under the energy policy of 2014, private enterprises are invited to become contract suppliers of the generation of energy, but the transmission and distribution is still solely managed by PLN. The policy was an attempt by the government to stimulate private interest and investment in areas and regions which are outside of the national supply grid. To help promote the policy, the Ministry of Energy and Mineral Resources (MEMR) would provide community funding through government grants for solar energy projects. The policy has been successful in respect to improving electrification and promoting solar energy awareness, with more than 350,000 grants for rooftop solar being provided to those who can't access the national grid [12], along with 600 mini solar power plant installed [26].

While the Indonesian solar energy policy has recorded some successes, the policy has fell well short of significantly impacting on the country's 23% renewable energy target by 2025, and its Paris agreement obligations. The major contributing factor for a lack of significant progress is the fluxing policy changes which have occurred since 2014 by the two major policy developers, MEMR and PLN. Regulation changers have occurred regularly with regards to energy pricing, feed-in tariff, price capping for PLN, local content, project location, local electricity supply costs, net-metering, minimum charge hours for grid connection, installation standards and differences between business and individual producers.

Due to this situation, the Institute of Energy Economics and Financial Analysis [26] has criticised the fluxing nature of Indonesia's solar energy policy and the fact the policy has had little impact on promoting the growth of renewable energy. They argue that it removes the trust of investors with regards to government intentions, and is not fair for renewable producer, as the price is determined by PLN, based on their large-scale cheap coal powered operations. In 2018, PLN's power plants were mainly generating electricity by coal (56%), gas (20%) and diesel fuel (6%) [2]. The above criticism mirrors that by Yuliani [20], who argued that the adoption of a feed-in tariff model used in developed countries, would likely be detrimental in the Indonesian context, due to the fact that operational policy and infrastructure is unsettled, along with related communities and bureaucrats not being well informed on how to introduce and implement the new technology.

While Indonesia may be a developing country, it is interesting to compare with another country in a similar situation. The Philippines have made much greatly progress on its renewable energy commitment due to the development of a comprehensive policy including policy consistency, long-term focus, economically viable for investors through financial incentives to complement the tariff, and absorbtion of costs by end-users rather

than generators [7]. In Indonesia, the short-term policy development with complex governance, including price setting scheme based on the ratio of local content, and the local average production price of energy, makes the process of investing and transacting in renewables complicated, uncertain and risky [10].

In October 2020, the Indonesia legislative introduced the omnibus law, a law that is designed to streamline Indonesian regulations. While the goverment claims that the omnibus law will help to accelerate economic growth [33], envrionmental specialist argue that the new law may slow green growth promotion [34,35]. The argument is that Indonesia needs sound, stable, long-term policies with community engagement to promote acceptance of renewable energy [5,20,36].

2.2. Renewable energy acceptance

Renewable energy acceptance is a complex issue and multi-dimensional in nature [37]. Wustenhagen et al. [16] state that social acceptance is a critical factor in the success of renewable energy being accepted by societies, and the acceptance process consists of three inter-related dimensions: socio-political acceptance, community acceptance and market acceptance. As renewable energy will involve the introduction of technology, the socio-political acceptance dimension relates to how a society gains knowledge of the concept, the technology used, how it works and how it can benefit individuals and the society. The impact of the socio-political dimension is enhanced when countries have developed institutional frameworks and supporting government policies [27]. Community acceptance refers not only to the need to build broad support from the general population but this support must also be obtained from the local communities and local areas. Market acceptance relates to the openness and willingness of the community, either as investors to support and provide the new technology, or as customers to accept and adopt the new technology. The social acceptance model is a mix of community, market and socio-political dimensions combining to support the concept of renewable energy [15,38].

Another key point in the acceptance of the introduction of renewable energy technology is the need for a dramatic shift in the mindset of energy providers from the traditional centralised focus to a more decentralised structure regarding decision making and the control of energy generation, distribution and supply. With the advent of new technology such as residential solar PV, homeowners and real estate investors become part of the generation, distribution and supply of energy, therefore interacting in the governance of renewable energy. Under such conditions, Gohari and Larssaether [39] propose that where there are developed institutions, the renewable energy sector should consider the implementation of multi-actor governance, to balance the power amongst stakeholders, as it mostly involves conflict of interest. For example, utility providers are looking to maximise profits, while the customers are seeking cost savings [21]. A multi-actor governance system for renewable energy may include both formal and informal arrangements, for profit and not-for-profit, and public-private organisations to maintain the focus for sustainable development in the sector.

For a large centralised state-owned organisation such as PLN, which has enjoyed a monopoly on the generation, distribution and supply of electricity in Indonesia, the reaction and impact of decentralisation and the interaction of control and governance is still very much unknown. Adding to the uncertainty is the constant changing of renewable energy policy and this inevitably raises questions about the country's commitment to renewable energy targets [26]. Furthermore, from a benefits/risk perspective of the technology acceptance model, technology adoption is positively associated with its perceived usefulness, and negatively associated with the risk of adoption [40]. Therefore, the decision to install rooftop solar is backed by the residents' knowledge, and hypothesis H1 is proposed.

H1: Solar rooftop residents have adequate knowledge about renewable energy to enhance acceptance.

2.3. Community involvement

Studies have found that the traditional centralised energy distribution model has failed to deliver a fair system of energy production and consumption [41]. On the other hand, a distributed energy resources approach, where consumers have the right to choose whether they will consume or sell their produced energy to the grid, is being promoted as a fairer system [42,43]. Therefore, the decentralisation of energy will change the rules of the energy market, offer a more democratic process and the actions of stakeholders' can directly be linked to carbon reduction [44]. Consumers are no longer viewed as only a consumer but also as active energy producers, which is called a 'prosumer' [27]. A prosumer is an effective model for integrating consumers and producers, which can contribute to better energy policy as both

sides of the equation are involved in the energy transaction [45].

To facilitate the move to decentralise the energy market, a platform such as smart grids is needed, which will allow prosumer to actively engage with the production, storage, selling and retrieving of energy from the grid. The smart grid technology boost innovation in metering, energy display, smart appliances, and allows prosumers to actively monitor and manage their energy production and consumption [27]. In Indonesia the energy market and its management is still centralised and controlled by PLN and MEMR, with policy transparancy still problematic and implementation being impacted by policy uncertainty. For example, the introduciton of the net-metering policy, is not being driven by the need for better transparency for consumer, but an attempt to reduce public pressure on the centralised management of energy. Adding to the issues is the tenuous relationship between PLN and MEMR which impacts at both the national and local levels, the varying quality of infrastructure and grid throughout the country, and the fact that in many locations, the grid may not be design/capable of importing energy. Up to the end of 2018, there were only 1435 solar rooftop residentials registered with PLN [46], which is a very small number considering Indonesia has more than 270 million people [47]. The empirical indications are that community involvement is limited due to a lack of awareness of the solar rooftop program, and therefore the following hypothesis is proposed.

H2a: There is a lack of awareness about the net-metering policy from PLN to both regular subscribers and solar rooftop resident subscribers.

While policy uncertainty and knowledge about renewable energy is problematic, for residents who have already installed solar rooftop, they face their own unique decisions, with respect to Indonesia's energy trilemma, security, affordability, and sustainability [12]. Energy security refers to the ability of PLN to supply the country's energy demands on a reliable basis. Affordability reflects consumer's buying power in all parts of the country, where the geographical challenges creates various levels of poverty, uneven population density and underdeveloped infrastructure. Furthermore, independent power producers may fine a mismatch between selling and buying prices defined by the government. Lastly, sustainability refers to PLN ability to management a balance between non-renewable and renewable sources. We argue that energy security is a key energy factor, as it directly impacts subscribers day-to-day lives, including business operations and quality of life. It is likely that solar rooftop residents undertake the additional investment to better control the reliability of their power supply. Therefore, we argue that solar rooftop residents, concerned about the security of their energy supply, may choose not to be linked to the national energy grid. To measure concerns surrounding Indonesia's energy trilemma, three areas will be evaluated: economic, environmental, and technological, and therefore the following hypothesis is proposed.

H2b: Concerns, such as economic, environmental and technological, will impact solar rooftop residents decisions to sell energy to PLN through the net-metering program.

With respect to energy affordability, residential energy subscribers can choose from a number of supply allocation levels, ranging from 1,300 VA to 6,600 VA, as stated in the Ministry of Energy and Mineral Policy number 28, 2016 [48]. These supply levels are grouped into three different tariff rates, with the lowest VA also having the lowest tariff rate, as PLN subsidizes tariffs to assist efforts in poverty alleviation. It is therefore logical to assume that residents who can afford to invest in solar rooftop are more likely to subscribe to higher supply allocation levels than residents subscribing to the lower supply allocation levels.

H2c: Installed rooftop solar will predominately be on houses with higher supply allocation than on houses with lower supply allocation subscription.

3. Methodology

This study aims to understand the socio-economic-political impact and technology acceptance of Indonesia's solar rooftop program. While exploratory in nature, the study adopts a selection of measures and questions from two similar studies conducted in the European Union in 2017 [22] and the USA in 2020 [29]. With respect to questions on the topic of prosumers, the study by Espe et. al. [27] was used as a guide. The online survey was undertaken in June-July 2020, during the Covid-19 pandemic, with the target sample being PLN subscribers. The sample included both PLN subscriber groups, regular subscriber (who have not install rooftop solar) and solar rooftop residents, to allow examination of subsribers awareness of Indonesia's solar rooftop policy.

A purposive sampling method is adopted, as this method suits the requirements for comparative research and mixed methods [49]. In order to reach the desired target groups, the questionnaire was distributed through several community and association groups, which included the Solar Energy Producers Associaton (Asosiasi Energi Surya Indonesia or AESI), Community of One Million Solar Rooftop (Gerakan Nasional Sejuta Surya Atap or GNSSA), Community of Solar Rooftop Residents (Perkumpulan Pengguna Listrik Surya Atap or PPLSA), and the Renewable Energy Community (Masyarakat Energi Terbarukan Indonesia or METI). For regular PLN subscribers the questionnaire was publicly available. The study received 125 useable questionnaires, which was split between 75 regular PLN subscribers and 50 rooftop residents PLN subscribers. In Section 2.1 it is highlighted that Indonesia has a very large population, therefore bringing into question issues related to sample size and representation. Clearly, the number of responses do not meet the required sample standards to test the categorical data collected, and therefore, this limitation should be considered when analysing the findings of this study.

In order to control the large geographical spread of Indonesia, which presents large gaps in economic development between Java and other regions, respondents were asked a number of demographics questions, which included identifying of type of energy supply, location, education and occupation. While this study utilised the survey design and questions from other similar studies, due to the Indonesian context, country specific questions were still required. As an example, respondents were asked about their knowledge of the governments solar rooftop policy via MEMR Policy Number 49, 2018, including the government's promotion and advertising of this policy and its solar rooftop program. Other areas of difference included the need to measure respondent's knowledge about solar energy from the perspective of two different energy subscribers. For solar rooftop residents, specific solar energy knowledge was sort regarding the efficiency of solar panels, 'day-time only' generation, effectiveness of solar generation in cloudy/rainy conditions, panels require significant roof space, and issues about roof positioning and cleaning.

In terms of economic acceptability, existing solar rooftop residents were asked if solar rooftop would improve the value of their homes, if homes would be easier to sell with solar rooftop, was solar rooftop reducing electricity expenses, and whether homeowners were interested to sell extra energy created to the PLN grid. With respect to the environment, participants were asked their views on the environmental impact of solar energy technology and whether renewable energy would help climate change, including Indonesia's commitment to reduce reliance on non-renewable energy.

For regular energy subscribers (non-solar rooftop residents) their solar energy knowledge was also sort but more in general terms. Regular PLN subscribers were asked their opinion about installing solar rooftop but were also provided a table presenting investment costs and energy savings across a range of rooftop sizes and capacity. Finally, respondents were asked whether they would be interested to be more involved in the demand and supply of energy by becoming prosumer, or happy to maintain a consumer status.

4. Findings

The findings section firstly presents the results of the four hypotheses developed from section 2. Following the results of the study, a discussion of the findings is undertaken, and the section is concluded by assessing the policy implications of the study.

4.1. Results of study

The study received 125 useable survey's from PLN power customers, of which 50 were solar rooftop residents and 75 regular power subscribers. From these subscribers, 69% were male, 31% female, with 92% living in urban areas/cities and 87% owning their house. With respect to occupation, 34% had their business, 25% worked for private firms, and 13% worked in government organisations, with 31% being in senior management and/or business owners, 32% being middle managers, and 13% being regular employees. Although the study was available to all PLN customers throughout Indonesia, 91% of the respondents come from the most populous island of Java (with 32% from DKI Jakarta province, 28% from East Java province, 20% from West Java province and 11% from Banten province). Of the 50 solar rooftop subscribers, the vast majority (94%) have had their solar panels installed of at least 4 years.

To test the first hypothesis, *H1: Solar rooftop residents have adequate knowledge about renewable energy to enhance acceptance,* an independent T-test was conducted to compare the knowledge of regular PLN subscriber versus solar rooftop resident customers (see Table 2).

Table 2: Comparing solar energy knowledge of PLN's two customer groups

	PLN customer groups	N (Mean)
Knowledge about solar energy	Regular PLN subscriber	75 (1.60)
	Solar Rooftop residents	50 (3.92)
Independent sample T-test	Equal variance assumed	F = 34.758 Sig = 0.000***

The study found that regular PLN subscriber have much lower knowledge about solar energy, with the mean being 1.6 out of a maximum value of 5, while for the solar rooftop residents, the mean for knowledge about solar energy is 3.92 out of 5. The independent sample T-test found that this difference between the two PLN customer groups was highly significant.

Therefore, hypothesis H1, that solar rooftop residents have adequate knowledge about renewable (solar) energy to enhance acceptance, is accepted.

While hypothesis H1 tested the level of renewable energy knowledge of those who had installed solar rooftop energy systems on their homes, the second hypothesis, *H2a: There is a lack of awareness about the net-metering policy from PLN to both regular subscribers and solar rooftop resident subscribers,* is designed to narrow the focus to determine the level of awareness of PLN's current policy on solar rooftop for both customer groups. The key issue regarding PLN's current policy is it provides customers the ability to become prosumers in the energy market, therefore not only consuming electricity but also generating/supplying electricity to the grid via the net-metering process.

Table 3 provides a crosstab analysis of the two types of PLN customers, those who are regular PLN subsribers and those who are already solar rooftop residents, comparing each groups awareness of PLN's policy regarding solar rooftop energy and net-metering.

The results show that around half of the participants from both PLN subscriber groups are not aware of PLNs solar rooftop policy regarding net-metering, and therefore the opportunity to become prosumers in the energy market. With the number of PLN subscribers who are not aware of the policy (50.4%) being marginally higher than the number of subscribers who are aware (49.6%), Chi-square testing of the two groups was undertaken and there was no significant difference found between the groups. Therefore, hypothesis H2a, that there is a lack of awareness about the net-metering policy from PLN to both groups of customers, regular subscribers and solar rooftop residents, is accepted.

In an attempt to better understand the concerns current solar rooftop residents may have to becoming prosumers in the energy market, the study analysed three areas likely to impact joining the electricity grid: economic, environmental and technological. From the 50 residents who had installed a solar rooftop system, only 8 had become prosumers, linking their solar system to the electricity grid via PLN's net-metering program. With respect to economic impacts, participants via Likert scale, were asked to rate the following statements: installing solar energy adds value to your house; the house will be easier to sell with a solar system installed; a solar system reduces the monthly energy costs; having a solar system provides the opportunity to sell energy to PLN; and over the long run using solar energy is more economical. With respect to environmental impacts, participants were asked to response to the following statements: using solar energy I am making a positive contribution to the environment; and using solar energy

Table 3: Crosstab of PLN's customer groups and solar rooftop policy awareness

			PLN customer groups		Total
			Regular PLN customer	Solar rooftop resident	
Awareness of PLN's policy on solar rooftop and net-metering.	No	Count	39	24	63
		Expected Count	37.8	25.2	63.0
		% of total	31.2%	19.2%	50.4%
	Yes	Count	36	26	62
		Expected Count	37.2	24.8	62.0
		% of total	28.8%	20.8%	49.6%
Total		Count	75	50	125
		Expected Count	75.0	50.0	125.0
		% of total	60.0%	40.0%	100%

Table 4: Areas impacting existing solar rooftop residents from becoming prosumers

		Levene's Tests for Equality of variances		t-test for Equality of Means				
		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Economic concerns	Equal variance assumed	8.099	0.006	–0.197	48	0.844	–0.038	0.193
	Equal variance not assumed			–0.134	7.855	0.896	–0.038	0.283
Environmental concerns	Equal variance assumed	2.159	0.148	0.030	48	0.976	0.006	0.200
	Equal variance not assumed			0.022	8.093	0.983	0.006	0.272
Technological concerns	Equal variance assumed	3.282	0.076	–1.757	48	0.085	–0.331	0.188
	Equal variance not assumed			–1.290	8.100	0.233	–0.331	0.256

helps lower the demand for non-renewal energy. From the technological side, participants were asked to respond to the following statements: they have knowledge about how to maintain a solar rooftop system; the availability of technicians to conduct solar rooftop maintenance is not a concern; and the time to realise a return on the solar rooftop investment is not a concern.

To test the third hypothesis, *H2b: Concerns, such as economic, environmental and technological, will impact solar rooftop residents decisions to sell energy to PLN through the net-metering program,* an independent samples T-test was conducted (see Table 4). With respect to the consumers who had installed solar to their rooftops, the study found that only 8 (16%) had subscribed as prosumers. Of the reminding 42 (84%), it was found that 29 (69%) were not prosumer due to a lack of knowledge about net-metering, feed-in tariff, and the export-import energy policy in general. The reasons for the remaining 13 (31%) not to sell their energy to PLN is unknown.

When examining reasons why residents who install solar rooftop systems but don't become prosumer, the results show that economic and technological concerns both play a significant role (see Table 4). The results indicate that while those who install solar rooftop, the majority are not convinced of the economic benefit of connecting their solar system to the national electricity grid via PLN's net-metering program. While some residents may not be aware of the net-metering program, it would seem that residents are either happy to directly control their own solar generated energy or reluctant trust PLN's net-metering program. The other significant concern is linked to the technological understanding of solar rooftop and the net-metering program. The issue here relates to the fact that linking to the national grid and/or PLN's program, adds further technological concerns to a technology (solar rooftop) that is not well understood by consumers and the community in general.

When regular PLN subscribers were asked about their interest in becoming prosumers, 35% indicated that they would be interested in such a program, 48% indicating they would maintain their current consumer status, and the remaining 17% saying they were not interested in solar energy and were happy for PLN to deal with energy matters. With respect to costs, 70% of regular PLN subscribers indicated that the cost of investing in solar PV is too high. Finally, when regular PLN customers, those who have not install solar PV, were asked whether they had received information/offer from PLN to install solar energy, 67% answered 'never' while 33% indicated that they had received information.

For the fourth and final hypothesis, *H2c: Installed rooftop solar will predominately be on houses with higher supply allocation than on houses with lower supply allocation subscription,* was found to be true. As is shown in Table 5, those with solar rooftop tended to choose higher VA supply allocation. Eighty percent (80%) of solar rooftop residents chose supply levels of 3500 VA and above. When compared to regular PLN subscribers, the percentage drops to 36% for supply levels of 3500 VA and above. Therefore, hypothesis H2c

Table 5: Supply allocation choice of PLN's two customer groups

	Tariff R1 1300 VA	Tariff R2 2200 VA	Tariff R2 3500-5500 VA	Tariff R3 > 6600 VA	Total
Solar Rooftop Residents	3 (6%)	7 (14%)	19 (38%)	21 (42%)	50
Regular PLN subscribers	25 (33%)	23 (31%)	22 (29%)	5 (7%)	75
	28	30	41	26	125

is accepted, indicating that the installation of solar rooftop energy was strongly correlated with households which had higher supply allocation subscription, therefore implying that these properties were either using or needing higher levels of electricity consumption.

Further exploring the reasons why solar rooftop residents have invested in renewable energy, the study found that the five main reasons to install solar energy were: 1) the information at the exhibition was very intriguing (44%), 2) our cost of energy is high (38%), 3) I love technology (30%), 4) my work is related to energy (10%), 5) influenced by a friend or neighbour (10%). With respect to the promotion of renewable energy, 90% of current solar rooftop residents suggested that PLN should offer customers solar rooftop installation packages, with 88% wanting the return-on-investment to be 5 years or less, and awareness about renewable energy, such as solar, should be introduced in schools (41%). Participants also indicated that MEMR and PLN should both play a significant role in promoting net-metering, simplfying the net-metering application process, provide incentives to investors (such as offering affordable investment packages to install solar energy), making the policy and process more transparent, and providing a feed-in tariff which is more attractive, e.g. 90% of the government's set price instead of the current 65%.

4.2. Discussion

It should be noted that the findings are bias towards, not only the most populous, but also the most economically advanced island in Indonesia, being Java. The study shows that PLN subscribers who have installed solar rooftop have greater knowledge about solar energy than regular PLN subscribers, which is an expected outcome. The interesting issue is that the majority of respondents tended to be working professionals who owned their own home, therefore the knowledge gap between the two subscriber groups may be due to a lack of available knowledge, especially from PLN. It would seem that those who have installed solar rooftop may have individually sought information about solar energy and programmes, rather than having received information from PLN, as the wider evidence of the study is confirming.

Pushing the issue of knowledge about PLN policies further, a majority of the combined subscriber groups, albeit a slight majority, indicated they had no awareness of PLN's policy on solar rooftop and net-metering. Interestingly, around half of those who had installed solar rooftop to their homes indicated they had no awareness of PLN's policy on solar rooftop and net-metering. The evidence of awareness of PLN's policies is further enhanced when only the solar rooftop resident subscribers are analysed. From this group, only 16% have taken the decision to connect to the net-metering programme and become prosumers. For the remaining 84% who have solar rooftop installed but have not connected to PLN's net-metering programme, the major majority (69%) highlighted that the main reasons behind not joining the programme was a lack of understanding of net-metering, the feed-in tariff and the export-import energy policy. Due to this lack of understanding, it would seem that many don't trust the economic benefits of being linked to PLN's net-metering, and secondly, many don't trust the net-metering technology and/or don't understand the technology well enough to build trust in the programme. For both these issues, it would seem that PLN, the state-owned monopoly electricity provider, has fallen short of integrating the government's policy on renewable energy.

Further to the points be discussed above, while 65% of regular PLN subscribers were happy with the status quo, 35% indicated that they would be interested to explore the opportunity to become prosumers. This point may be linked to the fact that 36% of regular subscribers had higher supply allocation (3500 VA and above), which was popular for solar rooftop subscribers. Finally, a key point highlighted by regular PLN subscribers was the fact that 70% indicated that the cost of installing solar rooftop was still too expensive.

4.3. Policy implications

If the ultimate outcome is for Indonesia to achieve the renewable energy targets it has set, then this study has highlighted a number of policy implications which need consideration.

The study highlights a conflict of interest between the state-owned PLN, which has a monopoly on electricity generation and distribution in the country, and the need to reduce the country's CO_2 emissions. While the Government may have legislation to support renewable energy targets, there seems to be little incentive for PLN to change its current business model of utilising its abundant coal reserves. Firstly, it would seem that the Indonesian National Energy Council and PLN operate independently of each other, preferring to recognise each other's role while not wanting to antagonise the other. Under the current monopoly, expecting PLN to take moral responsibly for the country's carbon emissions won't happen until there are major incentives to do so. Secondly, without incentives, why would PLN promote solar energy and feed-in tariffs if it is likely to harm the company's revenues and profit. Mittal et al. [50] argue that utility companies see PV rooftop installation as a threat to reducing company income. While the situation appears like a two-edged sword, the government must move the conversation away from revenues and profit to one that analyses the future cost and mix of electricity generation, either heavy investment in new power plants or incentives for renewables such as solar.

An area of consideration for PLN would be to invest in solar energy as corporate social responsibility (CSR) projects. By Indonesian Law, state-owned enterprises are required to invest 2% of their revenue on CSR projects. PLN could develop solar energy projects using CSR as an initiative for lower income communities. [51] proposed such an initiative under the banner of Community Solar. Funkhouser et al. argues that low income comminities are economically less attractive for business as the individual energy consumption is often low. With the collective power of a community, the utility company can invest in rooftop solar and manage the low distribution cost for less profitable area. Hence, energy providers such as PLN can impact both low income communities and the environment (renewable energy targets) creating a win-win situation.

The study highlights that higher use and/or small business owner residents are willing to undertake the investment of installing solar rooftop without incentives or taking advantage of the net-metering (feed-in tariff) provided by PLN. It would seem that many of these people undertake this investment to stabilise supply and/or guarantee the supply of electricity. With a growing middle class, the government could well tap into the increasing social sentiment towards renewables, and this outcome would be further boosted by incentives, as has been the case in a number of developed countries. One such scheme would be low-interest rate loans for investment in solar rooftop. It has been argued [6] that the slow progress towards solar in Indonesia is due to a lack of financing incentives to support renewable projects, either at the business or residential levels. Providing such loans can have a multiplier impact on the economy due to the flow-on effect to solar panel manufacturers, importers, sellers, distribution, installers, electricians etc. Having said that, it should be noted that PLN have expressed concerns that the current distribution system may not be capable to support the export and import of energy, and the system requires further investment to meet technological requirements.

Another consideration for the Government with regards to the promotion of renewable energy is the community participation model as proposed by [6,41]. Such a model requires the active involvement of the various social stakeholders from project planning to the implementation of renewable enrgy, including the opportunity to become solar PV installers. For PLN, the model opens the opportunity for partnership in the project planning, implementation, monitoring and control, but such initiatives need investment in education and skill development [52]. The benefit for the Government and PLN if implementation is successful is the impact of shared knowledge, renewable energy awareness, community ownership, and the environment.

Most developing countries face the challenge of shifting to greener energy generation and consumption. In Indonesia's case, the country has its own unique challenges such as the energy generation and distribution is centralised, state-owned, with inflexible pricing. Hence, energy management in Indonesia could benefit from becoming more democratic, transparent, increasing technology adoption with hybrid community partnerships and a mix of private and government ownership. Indonesia needs to adopt a more comprehensive policy and be open for social inclusion in the business of energy.

5. Conclusion

In an effort to reduce the impact of climate change by lowering greenhouse gas (GHG) emissions, Indonesia, like many countries around the world, has developed its own renewable energy targets, aligned with international treaties and agendas such as the Kyoto Protocol, Paris Agreement and Sustainable Development Goals (SDGs). While these targets are easy to legislate, achieving renewable energy targets is becoming notoriously difficult for many countries, with developing countries finding it especially difficult. Indonesia now finds itself in a situation which it has struggled to progress on its commitments and is highly unlikely to meet the targets it set for 2025. While Indonesia is the 4th most populated country and the 4th largest contributor to global CO_2 emissions, the country finds itself in both an unenviable situation and one of potential opportunity. The country has its population spread over 6,000 islands and 8,000 kms, creating a logistics and supply chain nightmare, but on the other hand, the country has access to an enormous array of potential renewable energy sources, with solar energy being the leading source, an ideal source for the world's largest archipelago. While this paper has identified many shortcomings in the country's efforts to introduce and promote solar energy, the paper also provides a number of policy implications, which need consideration if Indonesia is to reduce its CO_2 emissions footprint, and take advantage of a major potential renewable in the form of solar energy.

In summary this study found:

1. Both solar rooftop residents and regular PLN subscribers indicate that the promotion and awareness of solar energy is lacking, creating a low level of knowledge and understanding about solar energy in the society.
2. The policy of net-metering and feed-in tariff is not well publicised, even for existing solar rooftop residents.
3. Economic and technological concerns were hindering existing solar rooftop residents from becoming prosumers.

Suggestions for improvement:

1. Government and PLN must improve the awareness of renewable energy, especially solar energy, within the society via community engagement and education programs. Providing basic energy management information on energy bills, as suggested by [53], would start to create interest and understanding.
2. PLN should take advantage of the growing middle class to install solar rooftop to their homes via low-interest rate loans.
3. PLN should utilise its corporate social responsibility (CRS) obligations to develop community solar energy partnership, especially in lower income communities.
4. The Government and MEMR should facilitate independent research centers to conduct regular monitoring and evaluation of the renewable energy progress and targets. Such initiative have been undertaken independently by IESR [54] but the Government must show serious intent on the matter of renewable energy targets.

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