The Constraint of the Eco-Friendly Rooftop PV System Implementation Based on the Techno-Economic and Regulatory Impact Analysis: Case Study of the Ontowiryo Mosque in Purworejo, Central Java, Indonesia

Woko - Suparwoko (✉ suparwoko@uii.ac.id)

Islamic University of Indonesia: Universitas Islam Indonesia <https://orcid.org/0000-0002-9977-0325>

Fadhil Ahmad Qamar

Smart Energy Indonesia

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RESEARCH

The Constraint of the Eco-Friendly Rooftop PV System Implementation Based on the Techno-economic and Regulatory Impact Analysis: Case Study of the Ontowiryo Mosque in Purworejo, Central Java, Indonesia

Suparwoko^{1*} and Fadhil A. Qamar²

*Correspondence:

suparwoko@uii.ac.id

¹Department of Architecture,

Universitas Islam Indonesia,

Yogyakarta, Indonesia

Full list of author information is available at the end of the article

Abstract

PV system is an eco-friendly option to meet the need for energy due to its lower carbon footprint when compared to the fossil-fueled power plants. In this research, we performed techno-economic and regulatory impact analysis on a rooftop PV system on a mosque in Purworejo, Indonesia under a net metering mechanism. The use of PV system on the mosque rooftop can reduce its entire carbon emission from its annual energy usage, which equals to 4 tonnes of carbon dioxide equivalent. However, the economic feasibility of the PV systems, measured by the NPV of the electricity bill saving, shows negative values for all PV system configuration, defined by the type and number of panels. This low financial attractiveness is resulted from several unsupportive regulations: the subsidized electricity tariff, the minimum grid electricity usage limit and the less rewarding net metering scheme. The abolishment of minimum usage limit incurs the greatest increase of NPV to the PV system that is designed to entirely supply the load demand. While the implementation of higher electricity tariff incurs the highest increase of NPV for the PV systems with partial supply scenario. This study shows that at the current electricity tariff, costs of components, and the implemented regulations around the adoption of PV system, it is financially unfeasible to install a PV system on the mosque rooftop.

Keywords: PV System; Mosque Rooftop; Power Regulation; Techno-economic Analysis

1 Introduction

In order to tackle the climate change, Indonesia has planned to increase its energy mix for electricity production from renewable energy by 23% in 2025 [1]. Until the first semester of 2020, DEN [2] reported that the share of renewable energy for electricity generation has only reached 10.9%. Renewable energy, including solar energy, is eco-friendly and can be utilized for generating power with carbon footprint lower than those of the fossil fueled power plants. Tawalbeh et al. [3] estimated that the carbon footprint from PV systems was in the range of 14–73 g CO₂-eq/kWh, which is only 2 to 10% of the carbon emitted to generate 1 kWh of electricity by burning the oil.

On the other hand, through their studies, IESR [4] suggested that Indonesia can achieve the energy transition goal by utilizing the distributed generation of solar power in the form of rooftop and off grid PV system. It is estimated that there is at least a potential of 2 GWp rooftop solar PV in the residential market of Jakarta and Surabaya. Hence, it is implied that a greater potential is expected when more cities and other type of buildings are considered.

For this reason, this paper aims to explore the design and feasibility of rooftop PV system. The case study considered in this paper is the rooftop solar PV of mosque, specifically the Ontowiryo Mosque in Purworejo, Central Java [5]. The choice of mosque as the case study is also supported by the fact that Indonesia is one of the countries with the largest population of Muslims. To support their activities, Ministry of Religion [6] reported that Indonesia has more than half a million of mosques and prayer halls with various sizes. Ghazali et al. [7] stated in their book that the use of clean energy in such facility is also relevant ethically and morally since the preservation of the nature and environment is one of the teachings of Islam.

The commandment for humanity to utilize solar energy is also implicitly stated in the Holy Quran, the holy book of Islam. This order is stated in the first verse of Chapter 108 that says: “Surely We have given thee abundance of good” [8]. Through this verse, the muslims believe that God Almighty has given an abundance of goodness to humanity through the manifestation of the universe that includes the earth, sun and stars, and so on to provide for the sustainability of the humanity. Furthermore, some of the main purposes of the sun is to illuminate the earth with its rays and provide an immense source of energy. For that reason, until now, human-

ity keeps exploring the benefits that can be utilized from the use of solar energy.¹

This argument also serves as one of the underlying reasoning for conducting this² research, that is, to explore the utilization of solar energy through the PV system on³ the rooftop of Ontowiryo Mosque in Purworejo, Indonesia for the lighting purposes⁴ of the mosque and the neighborhood.⁵

There has been a significant number of researches on the implementation of rooftop⁶ solar PV for mosques, as will be briefly discussed in this paper. Rashid et al. [9]⁷ analyzed mosque rooftop PV system could reduce the electricity bill annually by⁸ 47% in Malaysia. The result shows that the payback period of the PV system's⁹ initial investment is reached in 13 years. Similar study was performed in Kuwait¹⁰ which resulted the same payback period. Almutairi [10] investigated the financial¹¹ feasibility of rooftop solar PV system at 1400 mosques in Kuwait is studied in 2018.¹²

The PV systems are designed to supply the connected load and shave the peak load¹³ during the day. Both studies however did not consider the present value of future¹⁴ cashflows. Thus, the benefit of the rooftop PV systems is subject to overestimation¹⁵ and the real payback period may be achieved at a later date.¹⁶

In 2019, Elshurafa et al. [11] conducted a more comprehensive pilot study of mosque¹⁷ rooftop PV system in Saudi Arabia. The PV system studied is connected to the grid¹⁸ for different scenarios: no support policy and with net-metering mechanism which¹⁹ enables the compensation for the exported surplus-generation to the grid. The study²⁰ finds that the analyzed system is financially attractive for both scenarios. The im-²¹plementation of net-metering reduces the cost incurred for fulfilling electricity needs²² 22% lower than the rooftop PV system with no support policy scenario.²³

As of 2018, the government of Indonesia [12] have ratified the latest regulation on²⁴ the net metering scheme for solar rooftop. Therefore, this paper aims to perform²⁵ a similar study to the previously mentioned related papers, that is to explore the²⁶ design and feasibility of mosque rooftop PV system with a case study location in²⁷ Indonesia.²⁸

To that end, we present for the first time a detailed techno-economic analysis of²⁹ mosque rooftop PV system in Indonesia. The result of this study serves twofold pur-³⁰poses. First, it would provide the definition of rooftop PV system on the mosque³¹ considered in the case study, in Indonesia. Second, it would provide insights to³²

33

1 policymakers on the effectiveness of the current supporting policy for the imple-1
2 mentation of the rooftop PV system for a specific type of end-user. 2

3

3

4 **2 Methods** 4

5 To achieve the research goals, three main activities are conducted in this research: 5
6 data acquisition, rooftop PV system design and simulation, and design result anal- 6
7 ysis. The analyses in each activity are done with using codes written in MATLAB. 7

8

8

9 **2.1 Data Acquisition** 9

10 The data acquisition process prepares the required data for the PV system de- 10
11 sign process, which includes site condition data and hourly electricity load profile 11
12 data. The site condition data are obtained from Solcast [13] Toolkit which provide 12
13 a comprehensive set of hourly site condition data that includes air temperature, 13
14 cloud opacity, solar irradiance (DHI, DNI and GHI), sun azimuth angle, sun alti- 14
15 tude angle, wind speed, relative humidity and precipitable water. 15

16 The hourly load profile data is ideally generated from historical data, by taking a 16
17 sample of electricity consumption in one day. This method is unavailable for the 17
18 considered case study as the mosque is currently under construction. Therefore, the 18
19 load profile of the mosque is estimated by calculating the lighting and electronic 19
20 equipment that is possibly used for certain activities and at certain times. To con- 20
21 clude, this research work with 8784 hourly data to simulate a full year operation of 21
22 rooftop PV system. 22

23 **2.2 Rooftop PV System Design** 23

24 The solar irradiance received by the rooftop area arrives in three forms: direct 24
25 and diffused irradiance and the irradiance reflected by the ground [14]. The solar 25
26 irradiance data obtained in the previous activity are used to calculate each value 26
27 of these forms, which are then summed to determine the irradiance received by the 27
28 rooftop and, hence, the estimated yield of solar energy on the mosque roof. 28

29 This paper studied a grid connected PV system. The optimal number of solar panels 29
30 and inverter capacity in the PV systems are determined by modeling the PV system 30
31 using the solar radiation data and the electrical load profile as the input. This paper 31
32 employs two design scenarios: complete and partial fulfillment of load demand by 32
33 the PV systems which will be referred as the first and second scenario respectively 33

¹in this paper.

²In Indonesia, a monthly minimum limit of electricity usage as much as 40 hours of²

³consumption at maximum power limit are imposed to the grid-connected user [15].³

⁴Thus, the partial scenario entails a combination of the PV system and the grid to⁴

⁵supply the load demand. The grid supplies the load demand under the minimum⁵

⁶limit, while the PV system supply the excess.

⁷At each hourly time steps, if the electricity supply from the PV system is smaller⁷

⁸than the load demand, the electricity load will be met by electricity from the PV⁸

⁹system while importing the mismatch from the grid. Thus, the load demand met⁹

¹⁰by the PV system during this condition is equal to the PV system generation. Vice¹⁰

¹¹versa, when the electricity supply from the PV system is greater than the electricity¹¹

¹²load at a certain time, the electricity load will be completely supplied by the PV¹²

¹³system and excess electricity from the PV system will be exported to the grid.

¹⁴

¹⁵2.3 Design Result Analysis

¹⁶The design result analysis incorporates the calculation of carbon emission reduction¹⁶

¹⁷and financial feasibility study of the PV system. The benefit of carbon emission¹⁷

¹⁸reduction is then translated in monetary terms by using the social cost of carbon¹⁸

¹⁹emission so that it can be easily compared with the financial feasibility study. The¹⁹

²⁰financial feasibility study was conducted using the analysis of Net Present Value²⁰

²¹(NPV) and Levelized Cost of Electricity (LCOE).

²²

$$\sup_{23} NPV = \sum_{t=0}^{25} \frac{R_t}{(1+i)^t} \quad (1) \sup_{23}$$

²⁴

²⁵The NPV is calculated by using the Equation 1 with R_t represents the cashflow,²⁵

²⁶in and out, in year t with a discount factor i . The cash outflow accounts the initial²⁶

²⁷investment and annual operation and maintenance cost. While the cash inflow is²⁷

²⁸defined as the annual electricity bill reduction. Thus, the NPV value in this paper²⁸

²⁹regards the present value of the electricity bill savings [14]. This metrics also indicate²⁹

³⁰the recovery rate of capital expenditure (CAPEX), with zero NPV means full capital³⁰

³¹expenditure recovery.

³²

$$\sup_{33} LCOE = \frac{\sum_{t=0}^{25} \frac{CAPEX_t - OPEX_t}{(1+i)^t}}{\sum_{t=0}^{25} \frac{PV_{util,t}}{(1+i)^t}} \quad (2) \sup_{33}$$

¹LCOE is calculated by using Equation (2) with OPEX is the operational and main-
²tenance expenditure, and PV_{util} is the energy generated by the PV system that can
³be utilized by the mosque. The financial feasibility analysis is followed by a sensi-
⁴tivity analysis on the impact of different regulations implementation. The change
⁵of the PV systems' NPV is used as the metric to measure the impact of the change
⁶in regulation.

⁸3 Case Study and Assumption

⁹3.1 Site Information

¹⁰ The Ontowiryo Mosque is located on the south side of Purworejo district, Central
¹¹Java, at 109.96° Longitude, -7.85° Latitude. The specification of the roof is shown
¹²in figure 1. The mosque is connected to the grid with a maximum power limit of ¹²

Figure 1 Ontowiryo Mosque rooftop dimensions (meter), tilt and azimuth angle (°), for west side (blue) and east side (yellow) of the roof. Adapted from [5] and Google Maps.

Figure 2 The hourly load demand profile of Ontowiryo Mosque.

5500 VA. As shown in figure 2, the electricity load demand are concentrated during¹ prayer times and the cleaning period of the mosque at 11 AM. Muslims pray in² congregation at the mosque 5 times a day: before dawn, at noon, in the afternoon,³ at sunset and after dusk. Outside these periods, the load profile of the mosque is⁴ relatively constant with an electrical load of ± 200 Wh for lighting purposes. The⁵ daily profile of the electricity load is assumed to be identical for one year due to the⁶ recurring nature of the activities. In total, the daily and annual electricity loads of⁷ the Ontowiryo Mosque are, respectively, 14.42 kWh and 5278.63 kWh.⁸

¹⁰3.2 Financial and Operational Assumption¹⁰

¹¹To ensure the validity of the data and to simplify the comparison of different types¹¹ of solar panels, the data for solar panels are taken from a website of renewable en-¹²ergy technology distributor, windandsun.co.uk. The website provides 15 solar panels¹³ from 3 different manufacturers: 9 REC panels (TwinPeak, Alpha and N-peak se-¹⁴ries), 4 LG panels (NeON and NeON2 series) and 2 Solarwatt panels (High Power¹⁵ and Eco series). Apart from the solar panel, capital expenditure (CAPEX) of the¹⁶ PV system also includes inverter, mounting structure, component's shipping cost,¹⁷ civil work and cabling.¹⁸

¹⁹For the financial analysis, the discount rate is determined from the weighted av-¹⁹erage capital cost (WACC). IRENA [16] assumes a real WACC of 7.5% in OECD²⁰ countries and China, and 10% for elsewhere in the world for all types of technology.²¹ Meanwhile, the IEA [17], on the other hand, assumes a WACC of 8% in developed²² countries and 7% in developing countries. Steffen [18] estimated the WACC for PV²³ system development projects in and outside of the OECD countries were 5.4% and²⁴ 7.4%. This paper employs a WACC level at 7%.²⁵

²⁶The 2019 PLN statistics [19], which provide data on the average electricity tariff²⁶ per customer group in 2011 to 2019, are used to determine the electricity tariff used²⁷ in this paper. The existing electricity tariff data are then extrapolated to estimate²⁸ the future electricity tariff over the lifetime of the PV system project or up to 2045,²⁹ shown in figure 3. Over the 25-years of the assumed lifespan of the PV system,³⁰ electricity tariffs are expected to increase by 60%, with an estimated tariff at IDR³¹ 913/kWh in 2021 and IDR 1,450/kWh in 2045. The tariff for customer in social³² sector is subsidized.³³

4 Result

4.1 PV System Configuration

The site condition analysis shows that the solar irradiance potential in the case³ study location is at 1971 kWh/year.m² or equals to 5.4 daily Equivalent Sun Hours⁴ (ESH). This potential is achieved with an optimal configuration of solar panel tilt⁵ angle and azimuth at 10° and 6°, respectively, as shown in figure 4. Consequently, as⁶ the existing roof orientation is different from the optimal configuration, the potential⁷ of solar irradiance in each sides of the roof, west and east, are at 4.9 and 3.5 ESH.⁸ When entire area of the roof is considered, the total potential for the west and east⁹ side of the roof are respectively at 263.24 and 141.47 MWh annually.¹⁰

4.2 Performance Analysis

The result of the performance analysis shows that the PV system efficiency ranges¹³ from 15.6% to 19.37%, and energy yield ranges from 1216 to 1263 kWh/kWp in a¹⁴ year. PV system using REC AA series panel achieved the highest system efficiency¹⁵ and solar energy yield due to their high panel efficiency.¹⁶ The result also shows that the capacity of the PV system ranges from 4020 Wp¹⁷ to 4615 Wp to completely meet the load demand. With this capacity, at least¹⁸ around 25% of the generated electricity is lost in the grid during the export and¹⁹ import process. The net-metering scheme in Indonesia only compensates 65% of the²⁰ exported energy. Hence, a smaller amount generated electricity leads to a smaller²¹ amount of exported electricity in the grid, and, thus smaller losses.²²

For the same reason, the PV system in the second design scenario has a lower grid²³

Figure 3 The average electricity tariff of social sector users in Indonesia. Adapted from [19].

Figure 4 The solar irradiance received at the optimum (O) tilt and azimuth angle, at the east side (E) and west side (W) of the mosque rooftop.

loss at around 16%. The annual minimum usage limit of the mosque is at 2640 kWh,¹⁸ which is also equal to half of the mosque's annual load demand. Thus, these PV¹⁹ systems only employ half as much number of panels with capacities ranging from²⁰ 1950 to 2220 Wp. These results suggest that, under the current regulation, PV²¹ system with lower capacity can deliver a larger portion of the generated electricity²² to user.

²⁵4.3 Carbon Reduction Benefit

²⁶Climate Transparency [20] estimated that approximately 761 gram of carbon diox-
²⁷ide are emitted to the air in order to generate 1 kWh of electricity in Indonesia.
²⁸Without using the PV system, the annual use of electricity at the Ontowiryo Mosque
²⁹produces an emission of approximately 4017 kilograms of carbon dioxide. The Envi-
³⁰ronmental Protection Agency [21] uses three sets of social cost estimates of carbon
³¹emissions with different discount levels, as can be seen in . This cost measures the
³²negative impact of carbon emission on the environment from various externalities.

Table 1 Carbon emission social price in USD/ton CO₂e carbon emission at different discount factor and year

Discount Factor	Year					
	2020	2025	2030	2035	2040	2045
5.00%	12	14	16	18	21	23
3.00%	42	46	50	55	60	64
2.50%	62	68	73	78	84	89

Based on the pricing above, the present value for the entire social cost of carbon emissions for 25 years, if the mosque does not use a PV system, is between 11.14 million and 50.51 million IDR. The use of PV system can reduce the amount of carbon emission and the social cost by 50% with using the partial supply PV system, and by 100% when the PV system completely supply the load demand. When incorporated, the saving from emission social cost reduction can increase the financial attractiveness of the PV systems when compared to the carbon intensive fossil fueled power plants. It is important to note that the financial benefit of carbon emission reduction is not directly received by the PV system users under the currently implemented regulation. Nonetheless, it is also important to highlight the carbon emission reduction benefit as it helps the government to achieve the Nationally Determined Contribution goal and preserve the nature.

4.4 Financial Analysis

The results of the NPV analysis of the PV systems show negative numbers for all types of solar panels and both scenarios. This value varies with the lowest NPV at -129.43 million IDR and the highest NPV at -53.77 million IDR for the first scenario, and in the second scenario the value ranges between -49.31 and -7.5 million IDR for the lowest and highest NPV. The result of the LCOE analysis shows that the costs is higher than the grid electricity tariff. The value ranges between 1452 and 2642 IDR/kWh for the first scenario and between 1324 and 2475 IDR/kWh for the second scenario.

From these analyses, it is found that solar PV panels with relatively lower price, normalized to their power rating and area, have better financial feasibility results and yield higher financial feasibility. REC 355 TP2S 72 has the lowest LCOE in both scenario and a relatively high NPV. The highest NPV of the PV system is achieved by using the REC 310NP Black and REC 325NP for the first and second

¹scenario, respectively.

²Increasing the capacity of the PV system will reduce the use of electricity from the²
³grid. Reduction of usage beyond the minimum usage limit incurs a negative effect³
⁴on the annual revenue of the PV systems. The final electricity bill after using the⁴
⁵PV system is equal to the minimum electricity bill for any usage lower than or⁵
⁶equal to the minimum usage limit. In other words, at higher capacity of PV system,⁶
⁷the amount of bill saving is capped at a maximum. On the other hand, the annual⁷
⁸OPEX, which is a function of the capacity of the PV system, continues to increase.⁸
⁹Thus, the revenue, that is calculated by subtracting the annual OPEX from the⁹
¹⁰annual bill saving, is decreasing at higher capacity of PV system. This condition¹⁰
¹¹explains why the PV system in the first scenario have lower annual revenue than¹¹
¹²those in the second scenario.

¹⁴**5 Sensitivity on Regulatory Impact**

¹⁵**5.1 Abolishment of Monthly Minimum Usage**

¹⁶The financial feasibility study finds that the current regulation on the minimum¹⁶
¹⁷usage limit for electricity from the grid incurs a detrimental effect on the PV sys-¹⁷
¹⁸tems' financial attractiveness at higher capacities. Therefore, in this scenario, the¹⁸
¹⁹minimum monthly electricity usage from the grid is abolished while its impact on¹⁹
²⁰the PV systems' financial feasibility is studied. Such support policy has been tem-²⁰
²¹porarily implemented in August 2020 through the Ministerial Decree of the Ministry²¹
²²of Energy and Mineral Resources Number 139K/26/MEM/2020 to deal with the²²
²³impact of COVID-19.

²⁴The impact of this regulation adjustment can be observed in figure 5. The REC355²⁴
²⁵TP2S 72 solar PV panel is taken as an example in this figure. It can be seen in this²⁵
²⁶figure that the amount of annual revenue increases along with the increase in the²⁶
²⁷number of panels and the capacity of the PV system before finally decreases after²⁷
²⁸the netload is lower than or equal to the annual minimum usage limit, 2640 kWh.²⁸
²⁹The negative slope occurs as the annual bill saving is capped beyond this minimum²⁹
³⁰limit, as explained in subsection 4.3, while the annual OPEX grows.

³¹Meanwhile, in a scenario without the minimum usage limit, annual revenue in-³¹
³²creases along with the number of solar panels to the point where the net load is³²
³³equal to zero. This change of regulation also increases the NPV of the PV in the³³

Figure 5 Comparison between business as usual and no minimum usage limit scenario on the annual revenue and NPV difference. Square dot represents second design scenario and circle dot represents first design scenario.

first scenario for all types of the used solar PV panels. Figure 5 also shows in detail the increase of NPV at different number of PV panels employed in the PV system.

At higher capacity PV system, the increase of NPV is capped at around 35 million IDR, which occurs when the net load reaches zero.

The PV systems in the second scenario that only partially meet the load demand does not earn as much increase in their NPV as their net load is only slightly lower than or equal to the minimum usage limit. For PV systems in this design scenario, the increase of NPV results in the increase of capital expenditure recovery that ranges between 0.05% and 10%. Meanwhile for the complete supply design scenario, the increase of capital expenditure recovery is significantly higher as it ranges between 23.9% and 48.5%. However, despite the increase of NPV, the PV systems that is designed to completely supply the load demand still have negative NPV and lower than those that supply partially.

5.2 Rework of the Net-Metering Scheme

Currently only 65% of the exported electricity from the PV system will be compensated by the government. This decision is made by considering the transmission and distribution costs as well as the line losses of the grid system that accounts for 38% of the grid electricity tariff [22]. In this sensitivity analysis, the net metering scheme is reworked so that 100% of the exported energy from the PV system to the

Figure 6 Comparison between business as usual scenario (BAU) and the 100% net metering scheme (NMS) on the netload and NPV. Square dot represents second design scenario and circle dot represents first design scenario.

grid will be compensated.

The result shows that with this scenario, PV systems require smaller number of PV panels to either partially or completely meet the load demand of Ontowiryo Mosque, shown in figure 6. This condition leads to lower CAPEX, higher revenue and higher NPV. The NPV increase ranges between 19.5 and 40.8 million IDR for the PV system that completely supplies the load demand and between 5.7 and 11.9 million IDR for the PV system in the second modelling scenario that partially supplies the load demand. The increase of NPV also results in higher capital expenditure recovery that ranges between 20% and 40% for the complete supply scenario and between 15.3% and 21.4% for the partial supply scenario. Despite the increase, the NPV of all PV systems still yields negative values.

5.3 Higher Electricity Tariff

The non-subsidized tariff is taken from the average electricity generation basic cost provided in the PLN statistics 2019 and shown in figure 7 [19]. It is estimated that the non-subsidized tariff in 2021 and 2045 are at 1428 and 2205 IDR/kWh, respectively. The result shows that higher electricity tariff scales up the annual revenue. The increase of NPV for all PV systems is capped at 19 million IDR due to the annual grid electricity minimum usage limit. Despite the increase, PV system that completely supplies the load demand still have negative values of NPV.

Figure 7 The average non-subsidized and subsidized electricity tariff in Indonesia extrapolated to 25 years. Adapted from [19].

Figure 8 Comparison between business as usual and the implementation of the high electricity tariff scenario on the revenue and NPV difference. Square dot represents second design scenario and circle dot represents first design scenario.

On the other hand, when compared to other supportive measures, the implementation of higher electricity tariff results in the highest NPV increase for PV systems in the second scenario. The increase of NPV results in the increase of capital expenditure recovery that ranges between 26.5% and 59.%. As for the complete supply design scenario, the increase of capital expenditure recovery ranges between 13.6 and 28.4%.

6 Conclusion

In this paper, we have assessed the design of rooftop PV system on mosque and its economic implications. Our results show that the use of PV system allows a reduction of carbon emission as the power generation in Indonesia is dominated by the carbon-intensive power plants. This reduction also provides an indirect financial benefit that, when incorporated, can add leverages for the adoption of PV systems as an eco-friendly option to generate power.

Despite the carbon reduction benefit, at the current electricity tariff and capital costs of the components, and the implemented regulations around the adoption of PV system, it is financially unfeasible to install a rooftop PV system on a mosque. The subsidized tariff of electricity results in lower annual electricity bill saving, which is the means of the PV system to recover its capital investment. The regulation on the minimum grid electricity usage limit prevents user to install high capacity PV systems due to the capped revenue and the increasing OPEX at higher capacity. This condition leads to our finding that PV systems with partial supply scenario have better financial attractiveness than the PV system that completely supply the load demand of the mosque. Intervention on the prevailing regulations such as rework on net-metering scheme and implementation of higher electricity tariff may increase the financial attractiveness of the PV systems.

Thus, the result of this paper should serve policy makers as a reflection for the prevailing regulation on the adoption of PV in the power sector. This paper provides an insight that the plan of increasing the share of renewable sources to 23% in the power generation by the year of 2025 can be hampered by the prevailing regulation. A more detailed exploration on the components of the PV system, especially those that are available locally, can enrich the study with a higher degree of context to the condition in Indonesia. Further analysis in this direction may lead to higher financial attractiveness of the PV systems as it cuts down the shipping cost in the procurement process. The need for further exploration is also supported by the large diversity of worship facilities from various beliefs in Indonesia. In some parts of the country, there are still many worship facilities with low socio-economic condition which require an eco-friendly means to be independent in meeting their energy needs.

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⁶	The datasets supporting the conclusions of this article are available in the Solcast Toolkit repository, [DOI :	6
⁷	10.25911/5c073e713e5dd, https://solcast.com]	7
⁸	Competing interests	8
	The authors declare that they have no competing interests.	
⁹		9
	Authors' contributions	
¹⁰	The present study was carried out in collaboration between both the authors. FAQ designed, performed, analyzed,	10
¹¹	interpreted, and drafted manuscript. S provided technical support and revised the manuscript, and also supervised	11
¹²	the research. Both the authors read and approved the final manuscript.	12
	Author details	
¹³	¹ Department of Architecture, Universitas Islam Indonesia, Yogyakarta, Indonesia. ² , Smart Energy Indonesia,	13
¹⁴	Yogyakarta, Indonesia.	14
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Figures

Figure 1

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Figure 2

The hourly load demand profile of Ontowiryo Mosque.

Figure 3

The average electricity tariff of social sector users in Indonesia. Adapted from [19].

Figure 4

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Figure 5

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