The Potential of Solar Panel Implementation Towards Sustainable Affordable Housing Development

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Abstract. Affordable housing is often associated with low-cost housing that pays lack of attention to the principle of sustainable housing. It is due to having limited price which meet the decree of Minister of Public Works and Public Housing No.552/KPTS/M/2016. However, the application of solar panels in the affordable housing has potential of cost efficiency by replacing the cost of monthly electricity payment with the initial investment and maintenance cost of a solar panel network in the housing. The potential of electricity power in Parung Panjang housing is calculated by applying spatial analysis using GIS. Parung Panjang housing has the total area of 214.1 hectares. The results of spatial analysis showed that the potential of roofs that can be used for solar panel installation is 44.6 hectares. By managing that area and electricity payments, the potential for solar cost of energy is 929.14 IDR/kWh. It is lower than the cost of energy from State Electricity Company of 1,352 IDR/kWh. Besides, the implementation of solar energy in large residential area is more efficient than in a single house and small area.

1. Introduction
Indonesia is a tropical country which located around the equator line. Hence, Indonesia has a huge potential of renewable resources, yet it is still undeveloped, especially for solar renewable resource [4]. In fact, Indonesia is still less in utilizing renewable energy, where 96% of energy is from fossil fuel (18% gas, 30% coal, and 48% fuel) and only about 4% of energy is from renewable energy [2]. In this day, Indonesia has installed solar energy with capacity of 14.0 MWp. In the 2006 president decree, it is stated that Indonesia is planning to have 80 MWp by 2025 [1]. Therefore, this country needs to do a lot of researches about solar energy and implement the result soon. There were some researchers who have done researches that gave information about potential or implementation of solar renewable energy in various locations in Indonesia, for example; photovoltaic for hotels in Nusa Lembongan [3], solar panel in Haluoleo University [5], photovoltaic panel in Medan [6], and solar panel for households in Surabaya [8]. The previous research showed that the implementation of solar panel will provide long-term benefit in single building or small area [10]. This research will focus on the implementation of solar panel in a large residential area.
Perumnas Parung Panjang is a subsidized housing, where the middle-low resident class settled in this area must have a good level of resilience in their electricity needs and implement solar panel for renewable energy that will be profitable in the long term [3]. This research showed the potential of solar panel implementation in large affordable housing area to support green concept in housing. In addition, if this research hypothesis is proven, that energy cost from sunlight is lower than energy cost from State Electricity Company, then the application of solar energy as a source of electricity will for sure help the middle-low resident to increase their economic level in the future.

2. Method

2.1 Study Area
The study area, especially Perumnas Parung Panjang Housing is located in Tangerang, West Java, Indonesia. It is located at 6.345879 °S, 106.569354 °E coordinates. The area is about 214 hectares, and it has around 6,000 households.

2.2. Data Collection
The data consists of roof area and Global Horizontal Irradiation. The roof area data is obtained by digitalized used of Geographic Information System (GIS) from ArcMap 10.1, while Google earth image is used as the base-map of the digitalization. (Figure 1). The Global Horizontal Irradiation data [7] (Figure 2) and Photovoltaic Power Potential data are obtained from Solargis data.

![Figure 1. Roof Area of Parung Panjang Housing](image1.png)

![Figure 2. Global Horizontal Irradiation (GHI) of Indonesia](image2.png)
2.3. Assesment of Solar Panel Potential in Housing

The research methodology for assessment of solar panel potential in housing is presented in Figure 3.

![Flow Chart of Research Methodology](image)

3. Result and Discussion

3.1. Potential of Energy and Estimation of Cost

3.1.1 Power Capacity of Solar System

The power capacity of solar electricity system (Wp) is calculated by using the equation below. The area of PV panel array in Perumnas Parung Panjang housing is 446,224 m$^2$. $\eta_{pv}$ is the PV panel array efficiency = 12%, Peak Sun Insulation (PSI) = 1,000 W/m$^2$ from Figure 3 [7].

$$W_p = \text{Panel area} \times \text{PSI} \times \eta_{pv} = 446,224 \times 1000 \times 0.12 = 53,546,880 \text{ Wp}$$

The solar panel that will be used is BP3150M. This panel can produces 150 Wp.

$$\frac{53,546,880}{150} = 356,979.2 \approx 356.980 \text{ panels}$$

Cost of solar panel (C) in housing is 1.11 USD every 5 – 10 Wp [9], but for this equation, 10Wp is used, which include sun panel, inverter, and balance of system.

$$C = W_p \times \text{Cost/Wp} = 53,546,880 \times 1.11 / 10 = 5,943,703.68 \text{ USD} \approx 80,239,999,680 \text{ IDR}$$

3.1.2 Life Cycle Cost

The Life Cycle Cost (LCC) is influenced by the long term cost of maintenance ($M_{PW}$) and cost of total initial investment (C). The investment is 8,023,999,968 IDR and the cost of maintenance per year is assumed at 1%. The discount rate (DR) is 11% and the expected development is 25 years.

$$M_{PW} = \text{Inv} \times \frac{(1+DR)^{T-1}}{DR(1+DR)^{T}}$$

$$M_{PW} = 802,399,997 \times \frac{(1+0.11)^{25-1}}{0.11(1+0.11)^{25}} = 6,557,607,892 \text{ IDR}$$

$$LCC = C + M_{PW} = 80,239,999,680 + 6,557,607,892 = 86,997,607,572 \text{ IDR}$$

3.1.3 Cost of Energy

Cost of Energy (COE) of solar electricity system is based on the Cost Recovery Factor (CRF), LCC and the annual energy production.

$$\text{CRF} = \frac{DR(1+DR)^{T}}{(1+DR)^{T-1}} = 0.1187$$
Cost of Energy (COE) is calculated by using the equation below, where the production of solar panel is 5 kWp.

\[
\text{COE} = \frac{\text{LCC} \times \text{CRF}}{\text{annual kWh}} = 929.14 \text{ IDR/kWh}
\]

3.2. Economical Comparison

Cost of Energy (COE) estimation from State Electricity Company (Perusahaan Listrik Negara, PLN) is 1,352 IDR/kWh per March 2019. The projection of the equation showed that the COE of solar panel in Parung Panjang will be equal with COE of PLN if the project is developed in 9.275 years or 9 years 4 months based on Table 1.

| Year | Investment | LCC          | CRF   | COE  |
|------|------------|--------------|-------|------|
| 25   | 80,239,999,680 | 86,997,607,572 | 0.1187 | 929.14 |
| 20   | 80,239,999,680 | 86,629,774,136 | 0.1256 | 978.48 |
| 10   | 80,239,999,680 | 84,965,519,427 | 0.1698 | 1,297.66 |
| 9    | 80,239,999,680 | 84,682,926,602 | 0.1806 | 1,352.36 |
| 9.275| 80,239,999,680 | 84,763,602,024 | 0.1774 | 1,352.36 |
| 8    | 80,239,999,680 | 84,369,248,567 | 0.1943 | 1,474.62 |

The results of this research provide information that the implementation of solar panels on a large residential area will give benefits, and it is in line with previous research on single building or small area [3], [4], [5]. However, the benefits of implementation of solar panels in large area are greater than on single building or cluster. In single building or small area, the COE of solar panel is higher than COE in the large area of residential. Thus, it will be more efficient to implement the solar panels in large area based on Table 2.

| Location / Scale | COE | Duration |
|------------------|-----|----------|
| Haluoleo University, Southeast Sulawesi Campus area | 0.3 USD/kWh \times 14.495 = 4,348.5 IDR/kWh | 25 years |
| Medan, North Sumatera Single house | € 0.09/kWh \times 16,292.76 = 1,466.34 IDR/kWh | 20 years |
| Nusa Lembongan, Bali Single hotel | 8,500 IDR/kWh | 25 years |
| Surabaya, East Java Single house | 0.34 - 0.62 USD/kWh \times 14,495 = 4,928.3 IDR/kWh | 20 years |
| Perumnas Parung Panjang Large residential Area | 978.48 IDR/kWh | 20 years |
| PLN (Perusahaan Listrik Negara/ State Electricity Company) All Scale | 1,352 IDR/kWh in March 2019 | - |

4. Conclusion

The COE of solar system in large residential area is lower than the cost of energy in single building or small area. Finally, the results showed that the solar energy can be an alternative source of electricity for housing, especially for large residential area.
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