PV System Design, Economic Feasibility, and Environmental Impact as an Alternative Power Source for Hospital Application

by Andri Riyana

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***Abstract*—Renewable energy is currently promoted to substitute the ever-diminishing fossil fuel. Indonesia has a high potential for solar energy, which can be implemented in every sector of everyday life, including building-integrated PV systems such as hospital applications. This paper presents the design, economic feasibility, and environmental impact of a PV system applied as the alternative power source for a hospital in Palembang, Indonesia. The economic feasibility and environmental impact are given by simulation using System Advisory Model (SAM) and SimaPro for LCA analysis. The power produced by the PV system in the study shows that the implementation of the PV system as the alternative source to supply ventilators and monitors in ICU rooms is profitable considering how expensive and short life-time of the UPS used previously as the source.**

Keywords— Building Integrated PV System, On-Grid PV System, LCA, Solar Energy

I. Introduction

Renewable energy use has been promoted on a large scale worldwide, including in Indonesia. Given the diminishing supply of fossil fuel reserves, renewable energy is vital, and solar energy is the most promising alternative or substitutes for conventional energy in areas with tropical climates such as Palembang [1]-[3].

In Indonesia, the dependence on fossil energy sources to meet domestic energy needs remains high at 96%, with oil consumption at 48%, gas consumption at 18%, and coal consumption at 30%. However, this fossil energy source is rapidly depleting. To meet national energy demand, Indonesia will eventually have to abandon fossil fuels in favor of new energy sources. In response to the government-issued Government Regulation No. 79 of 2014 concerning the National Energy Policy. According to this regulation, the government intends renewable energy sources to meet 23% national energy needs by 2025 [4][5].

According to Presidential Regulation No 22 of 2017, concerning the General National Energy Plan, solar power development for electricity is projected at 6.5 GW in 2025 and 45 GW in 2050, or 22% of the solar potential of 207.9 GW [2]. Furthermore, there is a Regulation of the Minister of Energy and Mineral Resources No 49 of 2018 concerning Roof-top mounted PV systems, which encourages the application of roof-mounted PV systems. Solar Power Plants projections are optimistic, given the investment trend, and the price of electricity from global PV systems is becoming cheaper over time, thanks to technological advances.

Palembang has a high potential for solar energy, and this potential has been investigated by scientists such as Dewi et al. in 2018, Harahap et al. in 2019, and Sasmanto et al. in 2020 [7]-[16]. The educational institution and state-own enterprises have been developing the application of solar energy for substituting conventional energy such as Hanafiah et al. in 2018, Hamdi et al. in 2019, and Nurjanah et al. in 2021. [17]-[22] Hence, participation from all levels of society is required to ensure the government's objective is met. Educational and medical institutions can play an active role in developing and implementing PV systems as alternative energy sources and pilot projects to develop the technology and improve the output yields and efficiency [23]-[28].

PV system implementation gives room for many applications, such as for solar charging robots investigated by Tito et al. and Septiarini et al. in 2021 [29]-[31]. Other implementation includes solar panels for irrigation and wearing systems [32][33]. The building-integrated PV system is another alternative to increase the implementation of solar energy without sacrificing the arid land, such as a power source for a hospital [34]-[36]. Given the high cost of backup batteries during Palembang's frequent blackouts, using a PV system as a source of electricity in a hospital would be beneficial; thus, this is a topic worth researching.

This paper presents the design, economic feasibility, and environmental impact of a PV system as the alternative power source for a hospital in Palembang, Indonesia. The economic feasibility and environmental impact are given by simulation using System Advisory Model (SAM) and SimaPro for LCA analysis.

II. Methods

This paper presents the possibility of implementing an on-grid photovoltaic system in a hospital environment. The system is installed as the backup power for the ICU unit in RSI Siti Khadijah Palembang, Indonesia.

Material

A. Simulation Software

The assessment for this research is conducted by using the simulation program SAM (System Advisor Model) by

NREL to show the design, materials choice, system design, and economic analysis of the system. The System Advisor Model (SAM) is a free techno-economic software model that assists people in the renewable energy industry in making decisions for Managers of projects and engineers, Policy experts, Creators of cutting-edge technology, and Researchers. The interface of SAM is presented in Fig. 1, where the first step is setting up the Palembang location by its latitude and altitude.

Fig. 1. SAM interface and Palembang altitude and longitude location

The environmental impact of the On-Grid PV system installed on the roof-top of RSI Siti Khadijah will be analyzed using life cycle assessment (LCA). The analysis is made possible using SimaPro, whose interface is shown in Fig. 2. SimaPro is a powerful solution for those seeking to effect long-term change. The sustainability software, which is based on solid science and life cycle thinking, is ideal for product designers, decision-makers, and sustainability experts. Its fact-based LCA approach provides the insights needed to make better decisions, empower better choices, and reduce the environmental footprints of products and services.

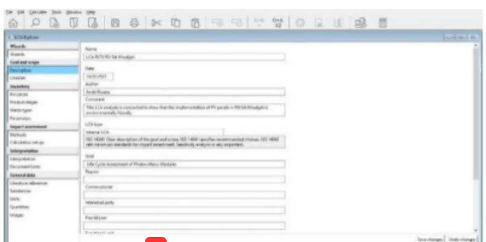

Fig. 2. LCA interface of PV system design installed on the roof-top of RSI Siti Khadijah

B. PV Panel Material

The PV panels implemented in this study are monocrystalline with the specification technics shown in Fig. 3.

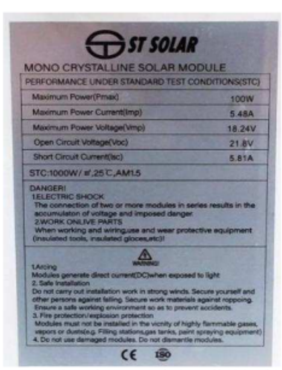

Fig. 3. Specification technics of PV panels installed in this study

Methods

A. Simulation Methods

The methods conducted in this study to show the PV System Design, Economic Feasibility, and Environmental Impact as an Alternative Power Source for Hospital Application in Palembang, Indonesia is by generating the simulation in SAM and environment impact of PV system using SimaPro.

The PV system design and the possibility of its development in SAM are conducted by setting with the PV panels specification and installation, inverter use, and PV panels materials, as shown in Fig.s 4-6. The first step in simulating the possibility of PV system application in hospitals is setting the location of RSI Siti Khadijah in Palembang, which is latitude −2.9908620143202236 and longitude 104.73128454003884, as shown in Fig. 1.

The PV panel configuration setting is based on specs in Fig. 3, and the resulted fill factor is given in Fig. 4. The following configuration is inverter selection, including specs and number of inverters, and panels' tilt angle determination based on Palembang's latitude and longitude. The environmental impact investigation is conducted in SimaPro by listing of materials implemented in this study, as shown in Fig. 5.

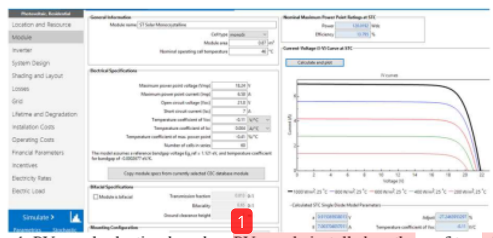

Fig. 4. PV panel selection based on PV panels installed on the roof-top of RSI Siti Khadijah

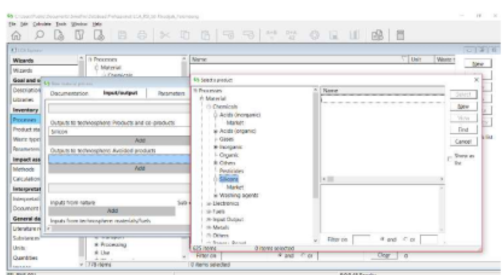

Fig. 5. SimaPro for environmental impact analysis.

B. PV Panels' Sizing

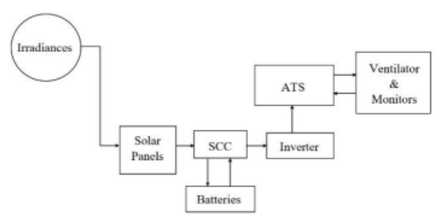

Fig. 6. PV system diagram blok

The PV panels' sizing is started by calculating the load that needs to be powered, shown as a diagram block in Fig 6.

The loads are ventilators and monitors for ICU rooms; details are given in Table I.

Table I shows data on daily electrical power usage, and it shows that the total daily use of electricity is 3,330 Watt. It should be noted, however, that the electrical energy generated by PLTS is not entirely usable because up to 20% of the electrical energy is lost during the transmission from the solar panels to the load (electronic devices). As a result, 20% of the total power used must be added. So, mathematically, it is as follows [38]:

TABLE I. LOADS CONSIDERED IN THIS STUDY

No	Load	Qty	Power	Hour	Total Power
1	Ventilator	2	450	2	1.800
2	Monitor	10	30	5	1.500
Total Watt		1.200			3.300

The total daily energy Watt-hours (E), the average sun hour per day Tmin, and the DC-voltage of the system (V_{DC}) are determined before sizing the array, and the losses should be included to avoid undersizing. Losses are determined by dividing the total power demand in Wh.day^{-1} by the product of efficiencies of all components in the system to get the required energy Er as below:

$$E_r = \frac{\text{Daily Average Energy Consumption}}{\text{Efficiency}} \quad (1)$$

The peak power obtained by the system is given by

$$P_p = \frac{\text{Daily Energy Consumption}}{\text{Minimum Peak Sun} - \text{Hours per Day}} \quad (2)$$

The number of modules needed based on Eq. (1) is

$$N_p = \frac{\text{Total DC Current}}{\text{Rated Current of One Module}} \quad (3)$$

$$N_s = \frac{\text{Total DC Voltage}}{\text{Rated Current of One Module}} \quad (4)$$

$$N_m = N_s \times N_P \quad (5)$$

III. RESULT AND DISCUSSION

This study discusses the feasibility and advantage of installing a PV system on the roof-top of RSI Siti Khadijah Palembang, South Sumatra, as shown in Fig 7, the google map position.

Fig. 7. RSI Siti Khadijah position in Palembang

Sizing PV System

A. PV Panel Sizing

Knowing the Watt peak (Wp) is necessary to determine the number of solar panels required. Watt Peak is the amount or maximum power generated by the PV panel (P_H). The optimal power generated from the PV panels during the day in Indonesia is about 4 to 5 hours, from 09.00 AM to 01.00 PM. The total Watt Peak is calculated by

$$P_H = \frac{P_T}{T_{opt}} = \frac{4125}{4} = 1.031 \text{ Wp} \quad (6)$$

Hence, the total panels required is

$$N_M = \frac{P_H}{\text{Panel Capacity}} = \frac{1.031}{100} = 10.31 \text{ pcs} \quad (7)$$

However, to accommodate the possibility of load addition in the ICU room, the installed panels are increased to 15 panels.

B. Battery Sizing

During the day, the battery is used directly and is also charged by solar panels, allowing it to use electrical energy without relying on the utility's electricity network at night. However, the battery's electrical energy is not entirely usable due to the potential for energy loss at the time of the inverter can be as high as 5%; therefore, a 5% reserve must be added, and the required battery capacity (B_C) can be calculated as below.

$$B_C = \frac{P_H}{100\% - 5\%} = \frac{4.125}{95\%} = 4.342 \text{ W} \quad (8)$$

The battery's electric power reference is 4,342 Watt, and the battery specification (B_S) used in this study is 12 V 100 Ah; therefore, the number of batteries (N_B) required is

$$N_B = \frac{B_C}{B_S} = \frac{4342}{12 \times 100} = 3.6\text{W} \quad (9)$$

C. Inverter Sizing

The inverter is a device that converts direct current (DC) to alternating current (AC). According to Table I, the total power is 1200 W; therefore, the inverter used in this study should be more than 1,200 watts. The inverter installed in this study is 1,500 watts.

D. Solar Charge Controller Sizing

The specifications on the back of the solar panel can be used to determine the SCC (Solar Charge Controller). Hence, based on I_{SC} listed in Fig. 3, the SCC required in this study is

$$SCC = I_{SC} \times N_m = 6 \times 15 \text{ panels} = 90 \text{ A} \quad (10)$$

where the panels installed in this study are 15 panels.

E. PV System Output in SAM

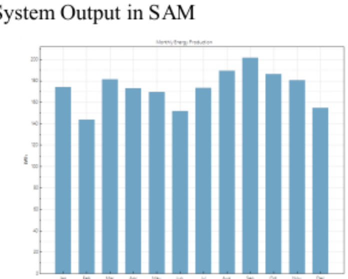

Fig. 8. The projection of monthly production of the On-Grip PV system installed in RSI Siti Khadijah

Fig 8 shows the monthly projection of the On-Grid PV system installed on the roof-top of RSI Siti Khadijah. It shows electricity produced by 15 PV panels of 100 Wp each year.

F. PV System Results

Fig 9 shows the PV system installed on the RSI Siti Khadijah Palembang roof-top, where Table II shows the total cost of the installation.

TABLE II. THE TOTAL COST OF INSTALLING PV SYSTEM

No	Items	Qty	Total Cost
1	Solar Panel 100Wp	15	Rp. 22.500.000
2	Battery 100 Ah	4	Rp. 10.000.000
3	Inverter 1500W	1	Rp. 4.000.000
4	SCC 100A	1	Rp. 750.000
5	Combiner Box	1	Rp. 3.500.000
6	Battery Box	1	Rp. 2.000.000
7	Cable	2	Rp. 700.000
8	Connector MC4	10	Rp. 400.000
9	BOS	1	Rp. 4.000.000
10	Protection Installation	5	Rp. 1.500.000
11	Installation Cost	1	Rp. 5.000.000
Total Cost			RP. 55.350.000

Fig. 9. The projection of monthly production of the On-Grip PV system installed in RSI Siti Khadijah

The total cost of installing a PV system for an alternative power supply of 2 ventilators and 5 monitors for the ICU room in RSI Siti Khadijah, as shown in Fig 10, is Rp. 55.350.000,-. This cost is much cheaper than the price of UPS which is Rp.18.430.000- for one UPS and the ICU room needs 2 UPS.

Fig. 10. Ventilator and monitors as the load for PV system considered in this study

Fig 11 shows the irradiance taken for 7 days as the sample of how much Palembang owns the potential in terms of Solar Energy. Fig 12 shows the power produced daily in 7 days relative to irradiance in Fig 11.

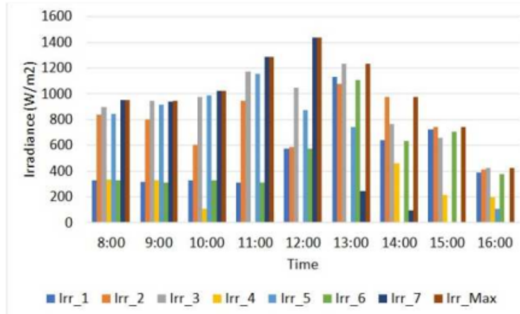

Fig. 11. Irradiance in 7 days.

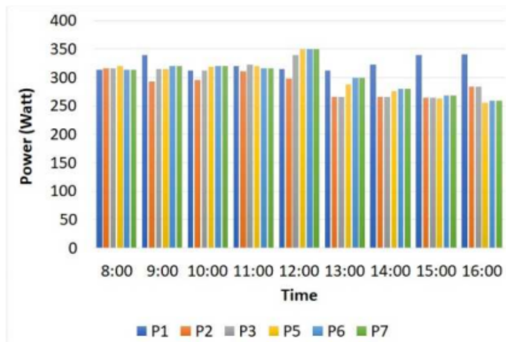

Fig. 12. The power produced in 7 days.

G. Environmental Impact of PV Panels Installation

The environmental impact of PV system installation on RSI Siti Khadijah Palembang's roof-top is investigated using SimaPro. Fig. 15 shows the significant impact of PV panels during the fabrication and installation, including transport. While, during the application, PV panels give minimum impact since no CO2 emission is released.

The environmental impact will be released after 20-25 years when the PV panels stop functioning and need to be dismantled. Aside from PV panels, batteries can be dangerous to the environment due to their chemical composition. However, solar energy is one of the safest renewable energies to be implemented since it creates no pollution in terms of CO2 emission and noise. Hence, the PV system is the perfect solution for Palembang, blessed with all year-long sunlight and high irradiance, as shown in Fig. 13.

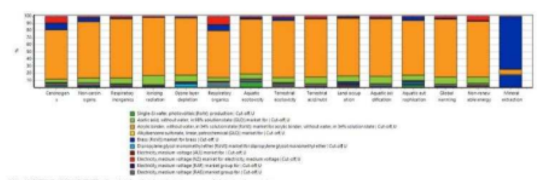

Fig. 13. SAM interface and Palembang altitude and longitude location

IV. Conclusion

This paper presents the design, economic feasibility, and environmental impact of a PV system applied as the alternative power source for a hospital in Palembang, Indonesia. The economic feasibility and environmental impact are given by simulation using System Advisory Model (SAM) and SimaPro for LCA analysis. The power produced by the PV system in this study shows that the implementation of the PV system as the alternative source to supply ventilators and monitors in ICU rooms is profitable considering how expensive and short lifetime the UPS used previously as the source.

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