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Design of Solar Home Charging for Individual Electric Vehicles: Case Study for Indonesian Household

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ABSTRACT

This study aims to examine the use of solar energy through Rooftop Photovoltaic (RPV) technology for solar-powered home charging of individual electric vehicles (EVs) in Indonesia. Simulations using HOMER Pro software are carried out to analyze both the energy and financial performance of the designed RPV system. According to the calculations, a 4 kW RPV system is required to meet the daily energy demand for EVs in the household sector. The off-grid RPV system design consists of 12 unit 325 wp PV panels, 36 units of 100AH battery as power storage, and a 4000-watt inverter to convert DC from RPV system into AC for battery charging. Simulation results from HOMER Pro software confirm that the designed RPV system can adequately supply the electricity needed for home charging, generating a total of 6449 Wh per year. With an annual energy consumption of approximately 4,190 kWh/year, the proposed system not only meets the daily energy needs of EVs but also provides excess power to be used by additional electrical equipment. Additionally, the proposed system can reduce 77.89 tons of CO2 emissions over the 25-year project lifespan.

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1. INTRODUCTION

Indonesia has committed to achieving Net Zero Emissions (NZE) by 2060 as part of the Paris Climate Agreement. One key strategy in this effort is the electrification of the transportation sector. The Indonesian government plans to stop selling conventional motorbikes by 2036 and conventional cars by 2041, to have all vehicles electric based by 2050. However, by the end of 2020, electric vehicles (EVs) represented only 0.15% of electric cars and 0.18% of electric motorbikes. There are three main challenges in the transition to EVs, such as the high price of EVs, the inadequate charging station infrastructure, and the need for more incentives from the government [1]. In response, the government introduced Regulation of the Minister of Finance Number 38 of 2023, which provides subsidies for purchasing EVs, effective from April 1, 2023. On the infrastructure side, the government is making significant efforts to expand the availability of Electric Vehicle Charging Stations through 3 schemes, including Public Electric Vehicle Charging Stations, Home Charging Systems, and Public Electric Vehicle Battery Exchange Stations. The target is to reach 24,720 units by 2030. These initiatives aim to remove the barriers to EVs adoption and encourage a broader shift to EVs.

The Ministry of Energy and Mineral Resources aims to have 7.46 million EVs on the road by 2030 as part of the Grand National Energy Strategy and NZE Plan. This shift is expected to drive a rise in electricity demand. According to the Ministry's projections, the transition to EVs will lead to an annual increase in electricity consumption of approximately 15.2 GWh. The primary goal of transitioning to EVs is to achieve NZE target, as EVs produce no exhaust emissions during operation. However, when EVs rely on electricity from the grid, they are still indirectly responsible for emissions. This is because Indonesian energy grid is predominantly powered by coal (63.92%) and gas (18.08%), with renewable energy accounting for only 14.95% of the energy mix [2]. Therefore, while EVs contribute to reducing emissions locally, the overall environmental benefits depend on decarbonizing the energy grid. A review of 44 studies on Life Cycle Assessment (LCA) of EVs highlights variations in their environmental impact. These differences are primarily shaped by the electricity mix used during Life Cycle Inventory (LCI) phase. Statistical regression analysis showed that 70% of the variation in electric vehicle LCA results was due to the electricity mix [3]. This underscores the energy source's significant influence on EVs environmental impact.

Considering the rapid depletion of fossil energy sources and growing environmental issues, efforts to achieve NZE through transportation electrification policies must be supported by providing clean energy sources. Changing the national electricity mix to 0% fossil will take a long time. Therefore, providing a means of charging EVs independently from renewable energy is a possible solution to optimize the achievement of NZE. A variety of studies have examined the benefits of photovoltaic (PV) charging systems for EVs. Existing references highlight the benefits of solar EVs charging and how it can increase the adoption of both PV and EVs [4]. Studies on solar home charging at the household level were carried out in areas where society has widely adopted PV systems due to the high cost of grid electricity, such as in Hawaii [5] and London [6]. A case study in Ohio showed that solar EVs charging is more economical and has a lower pollution impact than conventional grid-dependent charging methods [7]. The study found that grid-connected PV systems were more cost-effective compared to the other two methods (grid-only and PV with battery storage), highlighting the economic benefits of solar-powered EVs charging over grid-based alternatives. Numerous studies have explored alternative charging algorithms and their potential to advance financial, technological, and social objectives in solar EVs charging optimisation problems are often solved by convex models, such as linear or quadratic, which are relatively computationally inexpensive and can provide optimal solutions [8]. Rule-based or heuristic algorithms can provide adequate solutions for situations requiring a fast response, such as power changes or EVs connections [9].

However, few studies have examined the integration of EVs charging data with PV generation models [10]. Consequently, the level of electricity demand for individual mobility is not yet known with certainty, nor is how efficiently a PV system can meet this demand. The efficiency of EVs charging with a PV system is influenced by the availability of BEVs at home and ready to be charged as well as the availability of PV generation during that time [11]. Martin [11] conducted an empirical analysis using daily mobility data and BEVs charging behavior in Switzerland, combined with geographic data, to calculate solar energy needs that can be met by a BEVs owners' rooftop PV system. The investigation showed that PV system can satisfy 90% of energy requirements with an optimized charging strategy that incorporates home battery storage [11]. This strategy involves diverting solar power generated to EVs when the vehicles are at home and the battery is not fully charged, otherwise, solar energy will be stored in the battery.

Martin assumes that the entire rooftop of EVs owners' home is covered with PV panels [11]. This study does not accurately represent PV capacity needed to meet the daily energy demands of EVs. To address this gap, the result explores the design of PV system to meet the daily driving demands of EVs owners in Indonesia, considering EVs driving and charging behaviors in the country. This investigation has several key contributions:

- Empirical data from 24 EVs users, including information on vehicle location, battery charge status, and mobility of EVs owners was used to calculate the daily energy needs of each EV.
- Estimation of the rooftop PV generation needs was carried out based on the driving behavior and home location of EVs owners to design PV system that can meet the electricity needs of EVs.
- Solar energy generation potential was matched with EVs usage data to analyze the extent to which PV system can meet the energy needs of EVs.

This study expands on the previous investigation by Martin, regarding the energy needs of EVs and the design of PV systems that align with the driving behaviors of EVs owners.

2. METHOD

This study will design a rooftop PV system as a Solar Home Charging energy source for individual EVs. A solar home charging station is a system that utilizes solar energy to charge EVs at residential locations. It is specifically designed to charge a single private vehicle when EVs are at home. This study examines technical, economic and environmental aspects of solar home charging systems.

From a technical aspect, the off-grid Rooftop Photovoltaic (RPV) system will be designed to charge electric vehicle batteries to meet the demand for individual EVs. As a basis for design, data is required on the energy requirements of EVs charging stations, the availability of solar power resources, and the technical, financial, and environmental characteristics of PV system components. The survey was carried out to examine the driving habits of the Indonesian population and assess the daily energy requirements for EVs. This study uses an optimization tool named HOMER Pro software for simulation and analysis. The flexibility of HOMER is well suited for design assessment, planning, and decision-making to ensure project feasibility [12]. HOMER provides the optimal design of RPV systems and identifies Cost of Energy (COE), initial cost, and Net Present Cost (NPC) which indicate the economic performance of the designed RPV system. This study does not address the mathematical model used in HOMER, however, a comprehensive explanation can be found in the investigation by Bahramara [13]. In the environmental aspect, the reduction of greenhouse gas emissions resulting from using grid electricity to RPV-based electricity as an energy source for EVs will be studied.

3. DATA

3.1. Vehicle Usage Data

The energy consumption of EVs usage by considering the behavior of users in Indonesia who participated in the study from February 1 to 14, 2024 was analyzed. The survey participants were owners of Hyundai Ioniq vehicles who had consented to provide information regarding their daily EVs usage habits. Each participant was asked to report the times they departed from and returned home each day, along with their vehicle battery state of charge (SoC). Data were collected daily to monitor daily energy needs and the availability of EVs at home for charging. Participants recorded EVs location and battery status (SoC) data. New entries were entered when EVs left the home and returned home. The following information was recorded for each entry including time, geographic location, and SoC. For example, Figure 1 shows weekly data from an EVs user. The light blue areas indicate the segments when EVs were at home, while the dark blue regions indicate the segments when EVs were away from home. The black line represents EVs battery status (SoC) during that period. This figure allows for analyzing the study participants' usage behavior by showing different usage patterns between night and day and between weekdays and weekends.

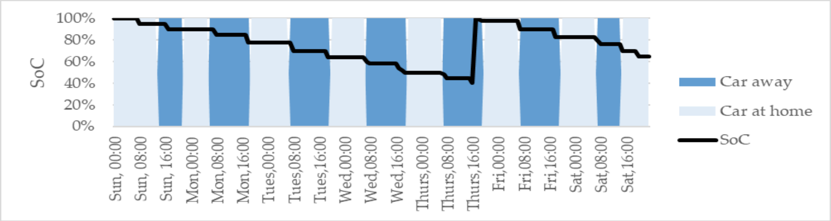


Figure 1. A data record of a single user shows the usage and SoC of EVs.

3.2. Solar Irradiation and Temperature Estimation

Important factors for designing a solar PV system for any residential location include solar irradiance, temperature, humidity, rooftop space, and installed electrical load. The astronomical location of the study is 6°58.9'S, and 110°24.7'E, showing the average annual solar radiation of 5.27 kWh/m²/day. The highest radiation was 6.48 kWh/m²/day, and the lowest was 4.22 kWh/m²/day, as shown in Figure 2.

This solar irradiance data was obtained using HOMER Pro software, which uses NASA Prediction of Worldwide Energy Resource (POWER) database. POWER also gives the average annual temperature at the site at 26.80°C, with the highest and lowest values at 27.72°C and 26.11 °C. All these parameters at this site are favorable for PV energy system.

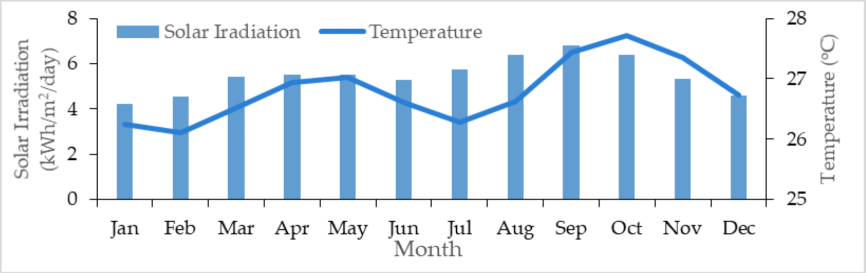


Figure 2. Data on Irradiation Levels and Temperature at the site [14]

4. DESIGN OF SOLAR HOME CHARGING BASED ON RPV

4.1. Daily Energy demand

Optimal utilization of RPV systems for home charging is achieved when EVs are charged daily while at home, provided SoC is not full {Martin}. Charging is carried out until SoC reaches 100%, thereby the energy required for charging is to return SoC position to 100% after it is used for driving while the vehicle is not at home [11]. EVs supply information on SoC at the start and end of the trip. However, the amount of energy needed to restore EVs to its initial SoC is unclear. The energy required to recharge EVs back to its original SoC is estimated using a least squares problem approximation, leveraging the extensive data available [11].

$$\text{Energy needed} = 0.293\text{kWh x } \Delta_{\text{SoC}} + 0.232\text{kWh}.\sqrt{\Delta_{\text{SoC}}} \qquad (1)$$

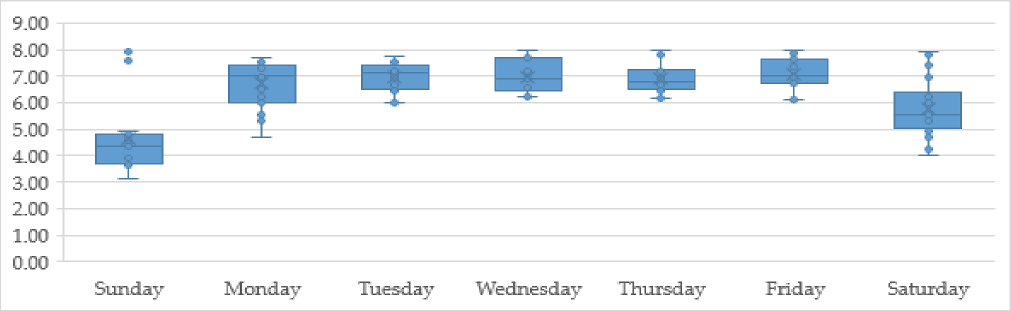


Figure 3. Box plots of participants' daily energy demand.

This study assumes that EVs battery capacity of all users is constant in the study period, ignoring the effects of aging and temperature. Figure 3 shows the daily demand (Ed) of all participants, having a median value between 6.96 kWh and 7.09 kWh, except for Saturdays and Sundays, where the demand is much lower with a median value of 5.75 kWh and 4.59kWh. Based on the data presented in Figure 3, the peak daily energy demand (E_d)is 8 kWh.

4.2 Daily Load Profile

This charging station is designed to charge EVs at home and to finish charging in the morning when the vehicles are away. Figure 4 shows the status of vehicles at home or away over time. According to the data of 24 participants, all vehicles are at home every day between 21.00 pm and 06.00 am. Therefore, charging can be performed at 21:00 pm and end at 6:00 am or 10 hours. Based on the study, it is known that the daily energy load that the home charging station must meet is 8 kWH. To get the energy needed, EVs must get an intake of 0.8 kW per hour.

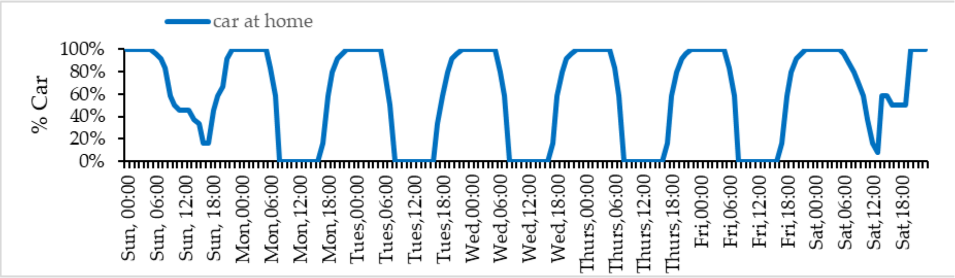


Figure 4. Share of BEVs at home or not at home.

4.3 Rooftop Photovoltaic System Configuration

RPV, a solar home charging energy source, is designed as an off-grid PV system that operates independently from the grid. The output of RPV system is stored in the battery and converted to AC. The system's output is only used for charging EVs battery, not other household electricity needs. RPV design is shown in Figure 5. During the day, solar irradiation hitting solar panel is transformed into direct current (DC) electrical energy and stored in the battery through MPPT control system, which optimizes power collection while protecting the battery. Then, DC is converted into alternating current (AC) power through an inverter [15], [16]. Connecting the electric vehicle to the inverter output will allow charging the electric car battery.

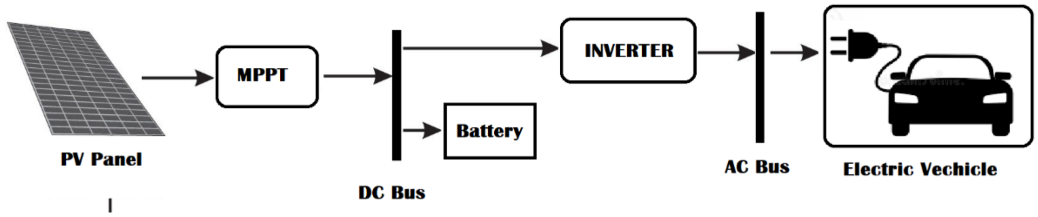


Figure 5. RPV system schematic diagram

The output energy of RPV system (EPV) is influenced by the efficiencies of the inverter (η_{inv}), the battery (η_{bat}), and MPPT (η_{MPPT}). Therefore, to meet the daily energy demand (Ed), the system output energy is calculated using the formula proposed by [12], [17]:

$$E_{pv} = \frac{E_d}{\eta_{inv}\,\eta_{bat}\eta_{mppt}} \tag{2}$$

Solar panel power capacity (P_{PV}) is calculated by considering peak sun hour (*PSH*) and derating factor (*d*) using the formulation proposed by [12], [17]:

$$P_{PV} = \frac{E_{PV}}{PSH\,.d} \tag{3}$$

The number of PV modules required (N_{PV}) is determined based on PV Module Power used in the system (*Pmod*) [12], [17]

$$N_{PV} = \frac{P_{PV}}{PMod} \tag{4}$$

In this design, the inverter efficiency (η_{inv}), battery efficiency (η_{bat}), and MPPT efficiency (η_{MPPT}) are set at 0.9, 0.85, and 0.95, respectively. Therefore, to fulfill the daily energy demand (Ed) of 8 kWh, the output energy from PV system (EPV) needs to be 11 kWh, which amounts to approximately 4019 kWh annually. Based on Figure 1, the minimum *psh* value is 4.2 h, considering the derating factor value (*d*) of 70%, thereby the designed PV system must have a capacity (P_{PV}) of 3931 watts. The number of PV modules required (N_{PV}) is determined based on the capacity of PV modules used in the system.

Battery is essential for storing solar energy produced during the day, allowing EVs to be powered at home at night. The number of batteries required (N batteries) is calculated based on the number of days to be backed up (n_d), the voltage ($V_{battery}$), the ampere-hours (AH), and the depth of discharge (*DOD*) of battery [12].

$$\mathrm{N_{Batteries}} = \frac{\mathrm{E_d \, x \, n_d}}{\mathrm{V_{battery} \, xAH \, x \, DOD}} \tag{5}$$

RPV is designed to back up energy needs for two days. This study used a 12V battery with a capacity of 100 Ah, assuming a five-year lifespan. Based on the specified formula (6), 32 batteries are required. The costs per unit for installation and replacement are IDR 1,750,000 each, with annual maintenance costs of IDR 87,500.

A charge controller safeguards the system against overvoltage, excessive current, short circuits, reverse polarity, and lightning. When properly used, it can extend the system's lifespan, contributing to lower overall system costs. In this study, a charge controller is included, costing IDR 1,000,000. The inverter transforms DC power produced by the PV panels into AC electricity, as EVs charging system operates on AC power. The inverter's capacity matches that of PV system. A 4000-watt inverter with a 24-volt DC input and a 220-volt AC output, operating on a single phase, has been selected for PV system. The installation and replacement costs for this 4 kW inverter are both estimated at IDR 7,200,000.

4.4. PV Tilt

The tilt angle of solar module is important for achieving optimal energy generation from PV system. This system uses a fixed installation, meaning the module cannot be adjusted to follow the sun's movement. One advantage of installing PV systems near the equator is the consistent availability of sunlight throughout the year. Solar panels should generally be oriented north in the southern hemisphere and south in the northern hemisphere. A simple rule states that the tilt is determined for latitudes below 25° by multiplying the latitude by 0.87 [18]. A simple rule states that the tilt is determined for latitudes below 25° by multiplying the latitude by 0.87 [18]. Since the PV is located at latitude 6°58'.9" or 6,969 (decimal), the optimal tilt is calculated as 6,969 × 0.87 = 6.063°. Figure 6 illustrates this tilt.

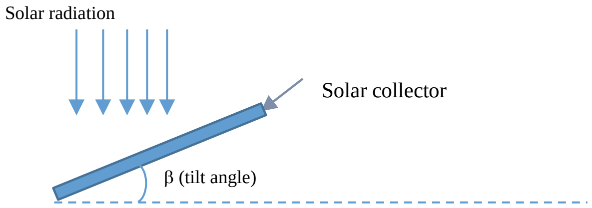


Figure. 6. PV Tilt

5. SIMULATION WITH HOMER PRO

In this section, a simulation of RPV system designed in the previous stage is carried out using HOMER Pro software to determine its performance. The design aims to satisfy the maximum daily demand. Daily energy consumption of 8 kWh is considered sufficient for the proposed case, as mentioned in Section 3.1. Based on the design, it is known that the daily energy load that the home charging station must meet is 8kWH. The charging station is designed to charge the vehicle battery at night when the vehicle is at home. Subsequently, charging starts at 8.00 pm and ends at 06.00 am, thereby to the energy needed every hour, there must be an intake of 0.8WH. Figure 7 shows the electricity load every hour of the day as set in HOMER Pro software.

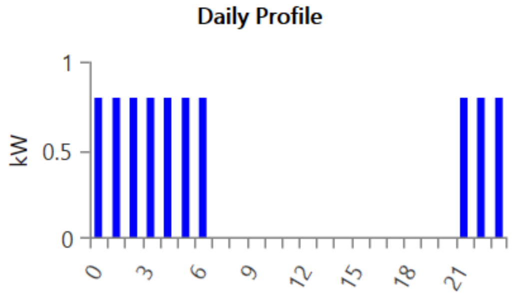
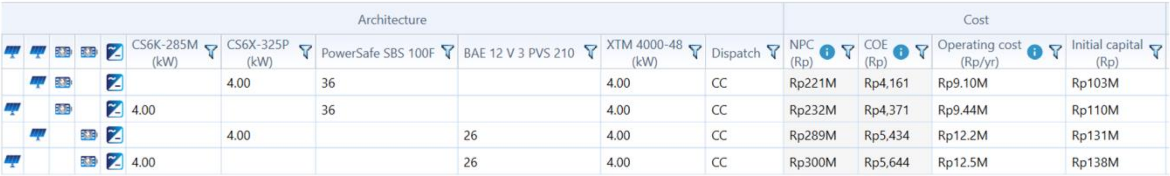


Figure 7. The daily electricity load that RPV system will bear

This study was carried out in Semarang, Central Java, Indonesia. After entering the location coordinates, HOMER Pro software obtains solar radiation and temperature values for the resource at that location. RPV design is an off-grid system, thereby the components only consist of PV modules, batteries, and inverters/converters. Two types of PV modules were considered, namely CanadianSolar Quintech 285 W monocrystalline, with an efficiency of 17.41%, and Canadian Solar Mas Power Polycrystalline 325 W, with an efficiency of 16.94%. Based on the local market, the price of the panels is IDR 10,000/wp and IDR 8,525/wp. Operation/maintenance costs are 5%, and the lifetime is 25 years. This simulation considers two types of 12 V lead acid batteries such as EnerSys PowerSafe SBS 100F and BAE Secura Solar 12 V 3 PVS 210. The battery lifetime is 10 years, thereby there will be a battery replacement every 10 years. The Struder Xtender XTM 4000-48 inverter is used in modeling with HOMER to match PV system that has been designed above. Four combinations are simulated in HOMER for system analysis based on the component selection. After the simulation, the following optimal results were obtained, as shown in Figure 8.



Architecture						Cost			
CS6K-285M (kW)	CS6X-325P (kW)	PowerSafe SBS 100F	BAE 12 V 3 PVS 210	XTM 4000-48 (kW)	Dispatch	NPC (Rp)	COE (Rp)	Operating cost (Rp/yr)	Initial capital (Rp)
	4.00	36		4.00	CC	Rp221M	Rp4,161	Rp9.10M	Rp103M
4.00		36		4.00	CC	Rp232M	Rp4,371	Rp9.44M	Rp110M
	4.00		26	4.00	CC	Rp289M	Rp5,434	Rp12.2M	Rp131M
4.00			26	4.00	CC	Rp300M	Rp5,644	Rp12.5M	Rp138M

Figure 8. Optimized result from HOMER

The optimal design, determined by the lowest Levelized Cost of Energy (LCOE), consists of installing 4 kW polycrystalline PV panels, 36 batteries rated at 12V and 100 AH, and a 4 kW inverter. Regarding formula (4), the selected design requires 12 325 Wp PV panel units. This design uses a 48 V inverter, so the panel configuration must be adjusted to produce the voltage [19]. The configuration of 4 series panels will produce a voltage of 48 V, so 12 325 W panels are arranged in 3 strings, each with four series panels providing 3900 W of power according to the characteristics of the inverter used.

6. RESULTS AND DISCUSSION

6.1. Energy Performance

Energy performance is assessed by examining the electricity produced by the designed system and the energy used. Figure 9 shows the electricity production and consumption of the optimal PV system designed in HOMER Pro software. The developed system generates 6,554 kWh of electricity annually, while the total consumption is 4,109 kWh per year, showing no shortfall in electricity supply. The system generates a total surplus power of 2,163 kWh per year, which can be utilized to fulfill other household electricity requirements. It can be concluded the proposed system is capable of satisfying the daily energy requirements of EVs while also providing sufficient power for additional electrical equipment.

System Architecture: Studer Xtender XTM 4000-48 (4.00 kW)
CanadianSolar MaxPower CS6X-325P (4.00 kW) HOMER Cycle Charging
EnerSys PowerSafe SBS 100F (18.0 strings)

Total NPC: Rp221,050,700.00
Levelized COE: Rp4,161.29
Operating Cost: Rp9,098,417.00

Production	kWh/yr	%
CanadianSolar MaxPower CS6X-325P	6,554	100
Total	6,554	100

Consumption	kWh/yr	%
AC Primary Load	4,109	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	4,109	100

Quantity	kWh/yr	%
Excess Electricity	2,163	33.0
Unmet Electric Load	0	0
Capacity Shortage	0.224	0.00550

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	160	%

Figure 9. Simulation Results

Figure 9 shows that solar power generation fluctuates with the seasons but consistently meets the required demand. The monthly electricity production data indicates that output is highest from March to September. Figure 10 shows more details about the daily profile of excess electricity, with the highest value in August reaching 6.25 kW. In most months, excess electricity occurs between 09.00 am and 5.00 pm.

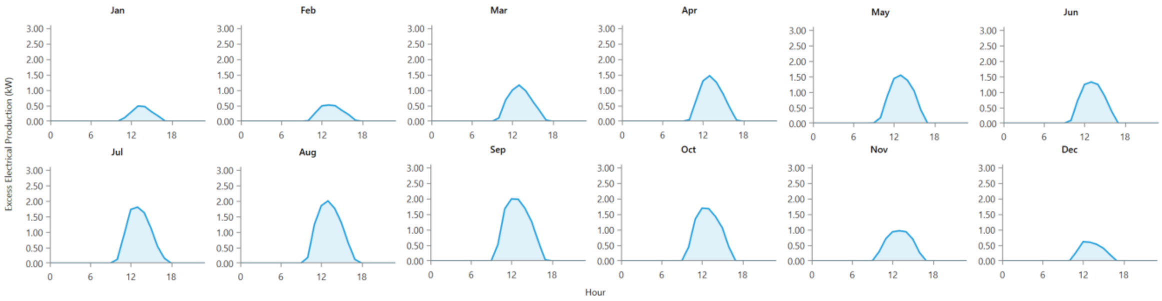


Figure 10. Excess Electrical production daily profile

6.2. Financial Performance

Financial performance of the designed system is assessed from NPC, annual cost, and levelized COE produced by the system being built. NPC represents the current net value of all costs incurred in the project's life, consisting of capital, operating, replacement, and salvage value components and fuel. Table 1 presents NPC of PV system as simulated in HOMER Pro software, categorized by cost type. Capital costs are the most significant NPC component, consisting of costs for procuring PV modules, batteries, and inverters. Furthermore, operating & maintenance costs are the second largest, coming from maintenance costs for PV modules and batteries, whose value is 2% of capital costs. Replacement costs result from the need to replace batteries every 5 years.

Table 1. Net Present Cost based on Cost Type

Component	Capital(IDR)	Replacement (IDR)	O&M(IDR)	Fuel(IDR)	Salvage(IDR)	Total(IDR
CanandianSolar MaxPower CS6X-325P	33,230,769.23	-	21,479,565.96	-	-	54,710,335.33
EnerSys Powersafe SBS 100F	63,000,000	55,656,570.53	40,721,677.13		(7,546,072.28)	151,832,175.38
Struder Xtender XTM 4000	7,200,000	6,360,750.92	1,809,852.32		(862,408.26)	14,508, 194.98
System	103,430,769.23	62,017,321.45	64,011,095.41		(8,408,480.54)	221,050,705.69

Figure 11 shows the cash flow for each component throughout its lifespan. This cash flow diagram clarifies the overall expenses associated with different RPV components. The most significant cost is the initial investment required to acquire all components, followed by more minor, periodic expenses in subsequent years. Subsequently, it is important to note that the battery must be replaced every 5 years due to its limited lifespan. Additionally, after 15 years, the costs for the inverter and charge controller are expected to rise, and by the end of the system's lifespan, either the residual value will be recouped or the entire system will need replacement. The annual costs also consist of routine maintenance for the inverter and cleaning of the panels.

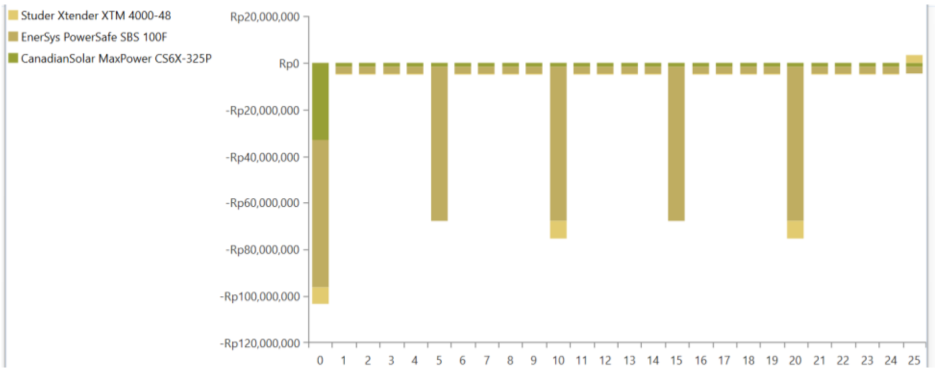


Figure 10. Cash flow

The annual cost of a component refers to the total NPC if distributed evenly over the project's lifetime. HOMER determines the yearly cost by multiplying NPC by the capital recovery factor. Table 2 shows the annual cost of components for a system designed by setting a project lifetime of 25 years, obtaining a total yearly cost of IDR 17,099,239.81.

Table 2. Cost Summary Annualized by Component

Component	Capital(IDR)	Replacement (IDR)	O&M(IDR)	Fuel(IDR)	Salvage(IDR)	Total(IDR)
CanandianSolar MaxPower CS6X-325P	2,570,545.48	-	1,661,538.46	-	-	4,232,083.94
EnerSys Powersafe SBS 100F	4,873,325.81	4,305,279.39	3,150,000.00		(583,721.73)	11,744,883.47
Struder Xtender XTM 4000	556,951.52	492,031.93	140,000.00		(66,711.05)	1,122,272.40
System	8,000,822.81	4,951,538.32	4,951,538.46		(650,432.78)	17,099,239.81

COE represents the expense needed to generate 1 kWh of electricity, calculated using formula (6). According to Table 2, the total yearly cost amounts to IDR 17,099,240, while Figure 6 shows a total production of 5242 kWh per year. However, only 4109 kWh is used to power the AC load as the energy source for solar home charging, indicating that some of the electricity remains unused, leading to higher costs. Therefore, COE is IDR 4,161 per kWh.

$$\text{COE} = \frac{Total\ Annual\ Cost}{\text{Annual energy output}} \tag{6}$$

6.3. Environmental Impact

The environmental impact is analyzed by examining the reduction in CO_2 emissions from switching from grid electricity to RPV-based electricity as the power source for EVs. LCA of Indonesian electricity grid reports emissions of 1.12 kg CO_2-eq/Wh [20]. On the other hand, PV systems in Indonesia emit 0.053 kg CO_2-eq/Wh [21]. Based on these data, the reduction in CO_2 annual emissions of RPV system is calculated using the formula proposed by [22]:

$$Total\ CO_2\ reduction_t = \sum_{t=1}^{T} Ed\ x\ 365\ x\ (1.12 - 0.053) kg\ CO_2eq \tag{7}$$

The proposed rooftop PV system can reduce 77.89 tons of CO_2 emissions over the 25-year project life. Besides lowering the energy demand from the grid, the standalone PV system can also contribute to reducing CO_2 emissions.

7. CONCLUSION

In conclusion, this study emphasized the advantages of utilizing RPV system as a practical alternative to fossil fuels. A comprehensive case analysis was conducted to assess how self-sustainable EVs owners can be through rooftop solar power generation. Detailed mobility data from 24 EVs were integrated with the residential locations of their owners to estimate the required rooftop PV system capacity for home-based EVs charging. This highlights the significant potential of rooftop solar energy to contribute to the decarbonization of transportation through EVs. The current phase of this study has resulted in the design of RPV system as an energy provider for charging individual EVs in households. Based on the calculations performed, a 4 kW PV system was required to meet the electrical energy demands for solar home charging of EVs in the household sector. This result is in line with Martin's investigation, which stated that the 7 kW RPV capacity can certainly meet the daily energy needs of EVs. The off-grid RPV system was designed to consist of 12 units of 325wp PV panels, equipped with 36 battery units worth a total of 100AH as power storage and a 4000-watt inverter to convert DC from RPV system into AC for battery charging. From the simulation results with HOMER Pro software, the designed RPV system has proven sufficient for solar home charging electricity needs, with a total electrical energy produced of 6554kWh per year. The motivation for integrating renewable energy to support EVs was driven by both financial and environmental considerations. The proposed system can alleviate the load on the fuel system, decreasing greenhouse gas emissions and promoting a more sustainable environment. From the analysis carried out, it was identified that the resulting system was able to reduce CO_2 emissions by 77.89 tons over 25 years. Based on the simulation results, the designed PV system can meet the daily energy needs of electric vehicles. Validation using experimental data is an opportunity for future research.Future studies should focus on developing intelligent charging algorithms to optimize the utilization of rooftop solar energy, as this approach is more economical and environmentally friendly for users. Achieving high self-consumption rates for EVs charging will depend on accurate predictions of EVs energy demand. However, reliable forecasting of individual mobility patterns, which drives this demand, remains an unresolved challenge that should be addressed in future studies.

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