Technical and economic feasibility analysis of solar power plant design with off grid system for remote area MSME in Semarang City

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Abstract. The distribution of electricity from State Electricity Enterprise does not necessarily reach remote areas, so these areas require alternative sources of electricity, such as solar power plants. This study aims to design and analyze the potential of small-scale off-grid PV in terms of engineering and economics. The research method has used a simulation on PVSyst software with four components, namely solar panels and batteries. The research results were obtained based on four variations made: a 700Wp panel, a 24V 150Ah battery, and an 800W inverter. The design will produce electrical energy of 2 kWh/kWp/day with a total investment value of IDR 54,268,068 for a project period of 24 years. Compared to using a one kVA generator, the investment value was approximately IDR 208,575,063 for a 24-year project. Compared to batteries with the same specifications using a State Electricity Enterprise electricity charging source, the investment value for a 24-year project was IDR 81,036,162. NPV values in all variations obtained < 0, and PBP > the system project period. Thus, this system was considered not economically feasible and did not provide profit. Still, the off-grid solar power plant option was the most profitable than generators or battery power sources with State Electricity Enterprise charging.

1. Introduction

The electricity demand growth is projected to increase nine times from the original 254.6 TWh in 2018 to 1,918 TWh in 2050. During the 2018-2050 period, the demand for electrical energy recorded an increase of 6.5% per year and has a relatively similar pattern. The most significant electricity demand is in the household sector, followed by the industrial and commercial sectors, transportation, and other sectors. The demand for energy needs in the retail industry is still dominated by electricity with 60-70. By 2050, electricity demand in the commercial sector is expected to increase seven times to 305 TWh [1]. Energy production that still relies on fossil fuels makes the supply of petroleum dwindle. The commitment of world countries to reduce greenhouse gas emissions continues to boost. This reason encourages the Indonesian government to always maintain national energy security and independence. Increasing the role of new and renewable energy is continuously pursued.

Regarding National Energy Policy, PP No. 79 of 2014 targets the new and renewable energy mix in 2025 to be at least 23%, then move up to 31% in 2050. Indonesia's significant renewable energy potential is targeted to fulfill the primary energy mix plan [1]. The utilization of new and renewable energy in 2018 was only 8.8 GW, which is 0.019% of Indonesia's total renewable energy potential. Renewable energy that can use for power generation had a tangible potential equivalent to 442 GW. Solar energy had the most significant potential among other renewable energy sources, which is 207.8 GWp. With the average radiation level/day in Indonesia reaching 4.80 KWp/m^2/day, a relatively high category, solar energy was the best potential choice to utilize on a (small) household scale. This solar power plant was also a functional and flexible power plant to apply to places with sufficient sun exposure easily. It can easily be used solar power plant on the roof of houses, caravans, buses, or even cars without disturbing production activities and the surrounding environment. On this basis, the solar power plant was a strategic step for alternative use of electricity for MSMEs located in remote areas without electricity coverage. By utilizing the existing space, the use of solar power plant solar panels was one of the options for the benefit of renewable energy that is environmentally friendly on a small scale (MSMEs). The use of renewable energy will reduce global warming, although it was not too significant.

Bagaskoro et al. [2] conducted a similar study analyzing the application of PLTS off-grid in the commercial tourism sector. This study found that the cost of energy produced is IDR10,000 - IDR14,000/kWh, which is still relatively expensive and is about ten times that of State Electricity Enterprise electricity. The off-grid solar system is also mentioned in this study as a suitable system for use as a source of electricity in remote areas or areas that do not yet have a State Electricity Enterprise electricity source. Krismadinata et al. (2017) conducted a similar study in 2017 on designing a Solar Power Plant (PLTS) installed on MSME carts. This study demonstrates that the PLTS system is suitable for meeting the electricity needs of mobile or nomadic carts. However, this study did not detail the detailed loading and economic analysis that MSMEs will need to design this off-grid solar system.

2. Methodology

2.1. Solar power plant

Solar Power Plant is a power plant that uses sunlight as a source of energy. Solar Power Plants use solar cells to convert solar photon radiation into electrical energy solar cells made of a layer of pure silicon and semiconductor materials. Solar Power Plants are environmentally friendly power plants that do not produce pollution or hazardous waste for the environment. Solar cell output power efficiency is influenced by several factors, including solar radiation, solar cell temperature, solar panel orientation, and shadow leverage [3].

2.2. Technical analysis

Technical analysis based on the designed solar power plant's capacity, utilization, and determination of the specifications of the components used the orientation of the solar panels and power generated by the plant. Several factors influence the power generated by a solar power plant, including solar radiation at the research site, the slope and direction of the solar panel, sunlight, temperature, and the technical performance of each component used [4].

The power generated will also decrease over time due to the degradation of solar panels and other features. The quality of solar power plants is seen from their performance ratio. The performance ratio is generally expressed as a percentage value that shows the system's total power and the losses compared to when the system is operating in STC conditions. The losses in the solar power generation system depend on the efficiency of the solar panels, temperature, and inverter efficiency [5].

2.3. Technical economic analysis

The technical-economic analysis can generally define as a financial analysis of an engineering investment. This analysis aims to assess the feasibility of a technical investment proposal by conducting an alternative study considered the most profitable. Generally, technological investments have a long economic life, namely years. On the other hand, currency values over time are not the same. Therefore, a currency value equivalence process is needed [2]. For technical economic analysis, the following equation is used to assist in the calculations.

$$\mathrm{P}WB = \sum_{t=0}^{n} Cb_t(FBP)_t \quad (1)$$
$$PWC = \sum_{t=0}^{n} Cc_t(FBP)_t \quad (2)$$
$$NPV = PWB - PWC \quad (3)$$

Where PWB is Present Worth Benefit, PWC is Present Worth Cost, and NPV is Net Present Value

2.4. Simulation design

In this study, PVSyst software is used to determine the performance of a solar power plant and as a tool for technical analysis. While the RetScreen software is used to analyze the feasibility of investing in solar power plants. The research flow chart entitled "Technical and economic feasibility analysis of solar power plant design with off grid system for remote area MSME in Semarang City" can be seen in Figure 1 below.

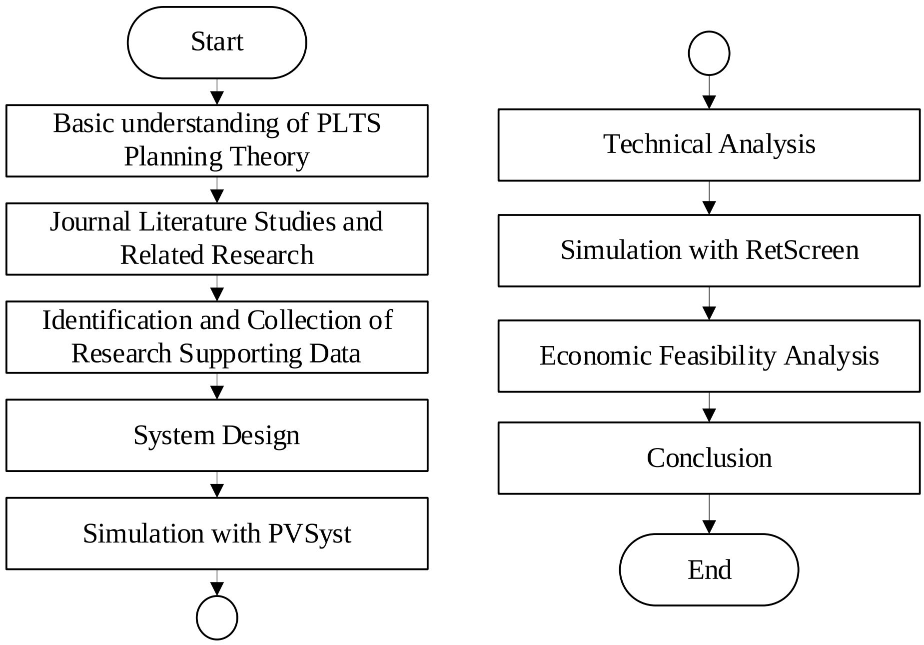

Figure 1. Research flowchart.

2.5. Research location

The research location was the Coffee Number, Tembalang, as astronomically located at coordinates -7.068564888359462, 110.44029635468642. To project the required PV mini-grid system estimates needed daily load data.

Figure 2. Research sites angka coffe, Kramas, Tembalang, Semarang.

2.6. Data collection

Based on meteorological data obtained from Photovoltaic Geographical Information System (PVGIS), the average solar energy isolation level from 2018-2019 in the Kramas, Tembalang area is 5 kWh/m^2 per day. Data obtained from PVGIS includes data on irradiation, regional temperature, wind speed, and moisture [6].

Table 1. Global irradiance, diffuse radiation, temperature, and wind velocity in Tembalang, Semarang.

Month	Global Irradiance kWh/m²	DiffH kWh/m²	Temp °C	Wind Vel m/s
January	124.1	82.3	25.3	2.21
February	137.4	70	26	2.13
March	134.1	82.1	25.9	1.86
April	155.4	70.4	25.9	1.49
May	141.1	64.7	26.4	1.45
June	157.8	54.2	27.2	1.84
July	173.1	56.7	27.5	2.01
August	180.7	60.3	27.9	2.7
September	190.5	68.4	28.8	2.54
October	199.9	76.2	27.9	2.01
November	145	80.3	27	1.29
December	126.7	77.2	25.6	1.64
Year	**1865.8**	**842.8**	**26.8**	**1.93**

2.7. Daily load profile

Estimated daily load data in the research area is generated manually and periodically to obtain exact daily load profile data.

Table 2. Daily load profile data at the research site.

Load	Amount	Power (W)	Total Power (W)	Time Length (h)	Energy (Wh)
Latina Grinder T60	1	150	150	2	300
Idealife Water Heater	1	350	350	2	700

Load	Amount	Power (W)	Total Power (W)	Time Length (h)	Energy (Wh)
LED 4w	10	4	40	6	240
White LED Light 18w	1	18	18	3	54
Logo Light 5w	1	5	5	10	50
Router 10w	1	10	10	10	100
Electric Socket	10	15	150	2	300
Total		**552**	**723**		**1744**

Based on Table 2, the daily load profile data contained in the research location can be represented in the form of a diagram with hourly parameters as follows:

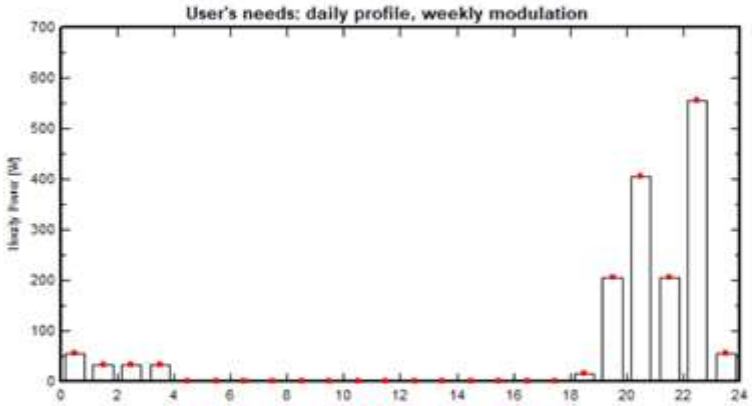

Figure 3. Diagram of daily load usage of research sites.

2.8. Solar power plant component

The main components of a solar power plant are solar panels, SCC, batteries, and inverters. In this study, two alternatives were chosen for the components of solar panels and batteries. The alternative component options used for the solar power generation have been defined into the PVSyst software and have been simulated as described below.

Table 3. Solar panel specification.

Specification	Maysun solar brand	Canadian solar brand
Pmax (Maximum power)	120 Wp	350 Wp
Voc (Open circuit voltage)	21.51 V	46.6 V
Vmpp (Maximum voltage)	18.2 V	39.2 V
Isc (Short circuit current)	7.19 A	9.51 A
Impp (Maximum current)	6.67 A	8.94 A
Module efficiency	16.3 %	19.9 %
Price	IDR 600,000	IDR 1,900,000

Table 4. Battery VRLA specification.

Specification	Inpowers brand	Kijo brand
Nominal Voltage	12 V	12 V
Nominal Capacity	150 Ah	80 Ah
Internal resistance	3.4 mΩ	8 mΩ
Max discharge current	840A (5s)	840A (5s)
Price	IDR 3,500,000	IDR 2,000,000

3. Results and discussion

3.1. Simulation

The design simulation of the solar power plant Angka Coffee Case Study using PVSyst software needed technical software data to affect the simulation results. Several factors that will affect the output/results of the solar power plant simulation include solar potential, irradiation value, location temperature, wind speed, position and orientation of solar panels, component specifications, and daily load data on the installation object. The simulation process was carried out to see how much will generate potential electrical energy if a solar power plant was installed at the research site. The simulation will also show the amount of electrical power produced, the amount of electric power supplied to the load at the location, and the minimum amount of battery needed. The object of this research was Angka Coffee which is located in Tembalang, Semarang.

The design will be carried out using a fixed type of support on the caravan's roof, as shown in the following figure.

Figure 4. Visualization of the research object.

In this solar power plant design, designing an off-grid PV mini-grid system will consider four main components: Solar Panels, Batteries, Inverters, and Solar Charge Controllers. The combination that will vary was solar panels with batteries. The alternative components that will be used were two brands of Solar Panels and two brands of batteries. The panel variation will use a monocrystalline type with a total power of +-700 Wp, while the battery will use a 12V VRLA type with 150Ah and 80Ah, respectively. The planned variation will be simulated using PVSyst software to compare production per year, System Performance. The specifications of the components that will be used as variations can be seen in the following table:

Table 5. Alternatives configuration of solar power plant component.

Variation	Solar Panel	Battery	Array Configuration	Battery Configuration
1	Maysun MS120M-36 Monocrystalline 120Wp	Inpowers 12V 150Ah	6 series-parallel module Vocs (21.51 V) Isc (7.19 A)	2 series batteries V (24 V) Ah (160 Ah)
2	Maysun MS120M-36 Monocrystalline 120Wp	Kijo 12V 80 Ah	6 series-parallel module Vocs (21.51 V) Isc (7.19 A)	4 series-parallel batteries V (24 V) Ah (150 Ah)

Variation	Solar Panel	Battery	Array Configuration	Battery Configuration
3	Canadian CS3U-350P Monocrystalline 350 Wp	Inpowers 12V 150Ah	2 parallel modules Vocs (39.2 V) Isc (8.94 A)	2 series batteries V (24 V) Ah (150 Ah)
4	Canadian CS3U-350P Monocrystalline 350 Wp	Kijo 12V 80 Ah	2 parallel module Vocs (39.2 V) Isc (8.94 A)	4 series-parallel batteries V (24 V) Ah (160 Ah)

3.2. Result

After inputting all the data needed in this PV mini-grid design simulation, we can obtain the PVSyst simulation.

Figure 5. Variation 1 results.

Figure 7. Variation 3 results.

Figure 6. Variation 2 results.

Figure 8. Variation 4 results.

3.3. Discussion

3.3.1. Technical analysis. After used PVSyst 7.0 software in the simulation, the results of the solar power plant simulation on MSME Coffeeshop Figures get the following results:

Table 6. Comparison of solar power plant simulation results 1,2,3 and 4 variations.

Variation	*Solar Panel Insolation (kWh/m²)*	*Electrical Energy Array STC (kWh)*	*Array Output Electrical Energy (kWh)*	**Energy Stored Battery (kWH)**	**Supply Energy (kWh)**
Variation 1	1754	1266	638	617	567
Variation 2	1754	1266	649	629	568
Variation 3	1747	1228	640	620	567
Variation 4	1747	1228	650	629	570

Based on the data obtained in Table 6, the amount of electrical energy produced in Variations 1 and 2 was 1266kWh/year. In contrast, in the simulation with Variations 3 and 4, the electrical energy produced was 1228kWh/year. This difference was caused by differences in the efficiency and surface area of each solar panel used. Variations 1 and 2 used a solar panel brand Maysun Solar MS120M-36 120Wp with an efficiency of 17.5% with an area of 4.2 m^2, producing electrical energy output. The array of 1266 kWh under STC conditions, while variations 3 and 4 used a solar panel brand Canadian Solar CS3U350P 350Wp with an efficiency of 17.64% with a 3.7 m^2 energy output area the array when the STC condition was 1228 kWh. The greater the efficiency of the solar panel and the greater the surface area of the panel, the better. The type of solar panel used had an impact on efficiency. Monocrystalline solar panels are generally more efficient than polycrystalline panels. That was due to using the primary material for making panels. Silicon was more significant in monocrystalline panels, so it was more efficient than polycrystalline panels. Still, Monocrystalline solar panels generally had a smaller surface area than polycrystalline at the same nominal power [7].

The electrical energy output of the array for one year in variations 1 and 2 experiences losses from the STC condition of 255 kWh or 20.1% and unused energy of 380 kWh or 30% of the STC condition that energy can be stored and supplied to the load was 567-568 kWh. Then, the electrical energy output of the array in variations 3 and 4 for one year experienced losses of 186 kWh or 17.7% and unused energy of 403 kWh or 32.8% of the STC conditions, so that the power that can be stored and supplied to the load was 567-570 kWh. Both panels have similar losses in the range of 18-20%, with the difference in losses for both panels of 2.3%.

When compared between variations 1 and 3, the energy stored in the battery was less than variations 2 and 4. Variation 1 was compared with Variation 2 with the same array conditions, the electrical energy generated and stored in the battery Variation 1 was more significant than variation 2 with a difference of ±3 kWh. The battery's specifications had a total capacity difference of 20Ah, so that the total stored energy in variations 1 and 3 was 3.0 kWh. In contrast, variations 2 and 4 have a total stored energy of 3.2 kWh. The batteries used in Variations 1 and 3 were the Empowers brand type GED150-12V150Ah, then the battery used in variations 2 and 4 is the Kijo brand type JDG12-80-12V80Ah.

The same thing is also found in variations 3 and 4. When compared to both of them, variation 3 had a smaller stored energy value than variation 4. Variation 4 had a slightly larger battery specification than variation 3, namely a 20Ah difference from the total capacity. If variation 3 compared with Variation 4 with the same array conditions, the electrical energy produced and stored in the battery of variation 1 was more significant than variation 2 with a difference of ±2 kWh. The battery used in variations 1 and 3 was the Empowers brand type GED150-12V150Ah, the battery used in variations 2 and 4 was the Kijo brand type JDG12-80-12V80Ah.

Variation 4 is a component variation that produces the highest value of energy supplied to the user, 570kWh, followed by variation 2 with the value of supplied energy produced at 568kWh. In the end, variation 1 and variation 3 with the resulting supplied energy value of 567 kWh. The value of supplied energy produced in each variation ranges from 567 to 570 kWh, with a difference of +-3 kWh. So, in terms of technical analysis, Variation 4 is the most appropriate variation of the PV mini-grid component among all existing variations, referring to the highest energy value that can be supplied.

3.3.2. Economics analysis. The determined feasibility of solar power plant mini-grid investment is designed at the research site based on the Present Net Value (NPV). The total investment costs, operational costs, electrical energy savings, discount rates, and inflation values all impacted the simulation results. We obtained the total investment cost of each variation and online stores in various e-commerce sites in Indonesia through surveys and offline stores in the Semarang City area. In contrast, the discount rate and inflation value were obtained from the Bank Indonesia's official website [8].

This research location was a remote area. Alternative sources of electricity possible as supply were solar power plants, generators, and batteries with charging from State Electricity Enterprise electricity. This study will compare these three alternatives from an economic analysis point of view.

A. Solar power plant

The investment costs for each component in the PV mini-grid system design with variations 1,2,3 and 4 at the research location can be seen in table 7, table 8, table 9, and table 10 below:

Table 7. The initial investment cost of variation 1 solar power plant system.

Component	Amount	Unit	Price	Total Price
Maysun Solar Panels 120Wp	6	Module	IDR 600,000	IDR 3,600,000
Inpowers Battery 12V 150Ah	2	pcs	IDR 3,500,000	IDR 7,000,000
Inverter 1000W	1	pcs	IDR 2,000,000	IDR 2,000,000
Solar Charge Controller Epever	1	pcs	IDR 1,500,000	IDR 1,500,000
Solar Panel Stand	1	package	IDR 1,000,000	IDR 1,000,000
Grounding packages	1	package	IDR 250,000	IDR 250,000
Power Cable	1	package	IDR 500,000	IDR 500,000
Electrical Protection	1	package	IDR 200,000	IDR 200,000
Services and others	1	package	IDR 1,500,000	IDR 1,500,000
	Total			**IDR 17,550,000**

Table 8. The initial investment cost of variation 2 solar power plant system.

Component	Amount	Unit	Price	Total Price
Maysun Solar Panels 120Wp	6	Module	IDR 600,000	IDR 3,600,000
Baterai Kijo 12V 80Ah	4	pcs	IDR 2,000,000	IDR 8,000,000
Inverter 1000W	1	pcs	IDR 2,000,000	IDR 2,000,000
Solar Charge Controller Epever	1	pcs	IDR 1,500,000	IDR 1,500,000
Solar Panel Stand	1	package	IDR 1,000,000	IDR 1,000,000
Grounding packages	1	package	IDR 250,000	IDR 250,000
Power Cable	1	package	IDR 500,000	IDR 500,000
Electrical Protection	1	package	IDR 200,000	IDR 200,000
Services and others	1	package	IDR 1,500,000	IDR 1,500,000
	Total			**IDR 18,550,000**

Table 9. The initial investment cost of variation 3 solar power plant system.

Component	Amount	Unit	Price	Total Price
Canadian Solar Panels 350Wp	2	Module	IDR 2,100,000	IDR 4,200,000
Battery Inpowers 12V 150Ah	2	pcs	IDR 3,500,000	IDR 7,000,000
Inverter 1000W	1	pcs	IDR 2,000,000	IDR 2,000,000
Solar Charge Controller Epever	1	pcs	IDR 1,500,000	IDR 1,500,000
Solar Panel Stand	1	package	IDR 1,000,000	IDR 1,000,000
Grounding packages	1	package	IDR 250,000	IDR 250,000
Power Cable	1	package	IDR 500,000	IDR 500,000
Electrical Protection	1	package	IDR 200,000	IDR 200,000
Services and others	1	package	IDR 1,500,000	IDR 1,500,000
Total				**IDR 18,150,000**

Table 10. The initial investment cost of variation 4 solar power plant system.

Component	Amount	Unit	Price	Total Price
Canadian Solar Panels 350Wp	2	Module	IDR 2,100,000	IDR 4,200,000
Baterai Kijo 12V 80Ah	4	pcs	IDR 2,000,000	IDR 8,000,000
Inverter 1000W	1	pcs	IDR 2,000,000	IDR 2,000,000
Solar Charge Controller Epever	1	pcs	IDR 1,500,000	IDR 1,500,000
Solar Panel Stand	1	package	IDR 1,000,000	IDR 1,000,000
Grounding packages	1	package	IDR 250,000	IDR 250,000
Power Cable	1	package	IDR 500,000	IDR 500,000
Electrical Protection	1	package	IDR 200,000	IDR 200,000
Services and others	1	package	IDR 1,500,000	IDR 1,500,000
Total				**IDR 19,150,000**

Annual operational and maintenance costs for PV mini-grid systems were generally calculated at 1-2% of the total initial investment costs for PV mini-grid system components plus battery replacement costs during the project period [9]. So that the annual operational costs for PV mini-grid systems variations 1,2,3 and 4 can be seen in table 11, table 12, table 13, and table 14 below:

Table 11. Annual operational costs of variation 1 solar power plant system.

Component	Total Price
O&M Solar Panel	IDR 36,000
O&M SCC	IDR 15,000
O&M Battery	IDR 70,000
O&M Inverter	IDR 20,000
O&M Solar Panel Stand	IDR 10,000
O&M Solar Panel Grounding	IDR 2,500
O&M cable	IDR 5,000
O&M Protection	IDR 2,000
Battery Replacement	IDR 875,000
Total	**IDR 1,035,500**

Table 12. Annual operational costs of variation 2 solar power plant system.

Component	Total Price
O&M Solar Panel	IDR 36,000
O&M SCC	IDR 15,000
O&M Battery	IDR 80,000
O&M Inventer	IDR 20,000
O&M Solar Panel Stand	IDR 10,000
O&M Solar Panel Grounding	IDR 2,500
O&M cable	IDR 5,000
O&M Protection	IDR 2,000
Battery Replacement	IDR 1,000,000
Total	**IDR 1,170,500**

Table 13. Annual operational costs of variation 3 solar power plant system.

Component	Total Price
O&M Solar Panel	IDR 42,000
O&M SCC	IDR 15,000
O&M Battery	IDR 70,000
O&M Inventer	IDR 20,000
O&M Solar Panel Stand	IDR 10,000
O&M Solar Panel Grounding	IDR 2,500
O&M cable	IDR 5,000
O&M Protection	IDR 2,000
Battery Replacement	IDR 875,000
Total	**IDR 1,041,500**

Table 14. Annual operational costs of variation 4 solar power plant system.

Component	Total Price
O&M Solar Panel	IDR 42,000
O&M SCC	IDR 15,000
O&M Battery	IDR 80,000
O&M Inventer	IDR 20,000
O&M Solar Panel Stand	IDR 10,000
O&M Solar Panel Grounding	IDR 2,500
O&M cable	IDR 5,000
O&M Protection	IDR 2,000
Battery Replacement	IDR 1,000,000
Total	**IDR 1,176,500**

Based on Table 11 above, it showed an initial investment cost in variation 1 of IDR 17,550,000 with an annual O&M cost of IDR 1,03500. Then in Variation 2 of IDR 18,550,000 with an annual O&M cost of IDR 1,170,500. Then in Variation 3, it was IDR 18,150,000 with an annual O&M cost of IDR 1,041,500, and finally, in Variation 4, it was IDR 19,150,000 with an O&M cost per year of IDR 1,176,500.

Electrical energy saving was a linear calculation of savings from the beginning of the solar power plant project. Electrical energy savings was the value obtained from the amount of energy supplied to the load to meet this MSME Coffee shop's daily electrical energy needs using PVSyst 7.0 software.

The electricity savings of variations 1, 2, 3 and 4 each year can be seen in Table 15 as follows:

Table 15. Savings of variations 1, 2, 3, and 4 Solar power plant system.

Component Name	*kWh / Tahun*	*Price*	**Total Price**
Variation 1	567	IDR 1,467	IDR 831,789
Variation 2	568	IDR 1,467	IDR 833,256
Variation 3	567	IDR 1,467	IDR 831,789
Variation 4	570	IDR 1,467	IDR 836,190

The following were the NPV values for each variation based on the calculation results:

Table 16. NPV Value of PV mini-grid variations 1, 2, 3 and 4.

Name of Variation	PWC	PWB	NPV
1	IDR 54,268,068	IDR 29,494,626	-IDR 24,773,442
2	IDR 60,055,069	IDR 29,546,645	-IDR 30,508,424
3	IDR 55,080,824	IDR 29,494,626	-IDR 25,586,198
4	IDR 60,867,824	IDR 29,650,682	-IDR 31,217,142

According to table 16, the NPV value in each variation was negative or less than zero, implying that the solar power plant investment for each variation was not feasible to implement.

Variation 1 has the lowest PWC and NPV values of the four, with PWC IDR54,268,068 and NPV IDR24,773,442. Then came variation 3 with a PWC of IDR 55,080,824 and an NPV of -IDR 25,586,198. The PWC value of Variation 2 is IDR 60,055,069, and the NPV is -IDR 30,508,424. Finally, Variation 4 has the highest PWC and NPV values, with PWC IDR 60,867,824 and NPV -IDR 31,217,142, respectively. Variation 1 has the lowest investment value over the 24-year project period in terms of technical and economic analysis.

B. Generator

The generator used according to the load data at the research site was a generator with 1KVA power. The following is the investment cost of using a generator.

Table 17. Initial capital for generator use.

Component Name	*Amount*	*Unit*	*Price*	**Total Price**
Generator Set Silent 1 KVA	1	set	IDR5,720,000	IDR 5,720,000
Cable	1	set	IDR 500,000	IDR 500,000
Protection	1	set	IDR 200,000	IDR 200,000
Services and others	1	set	IDR 500,000	IDR 500,000
	Total			IDR **6,920,000**

Based on the results of calculations with the equation S = K x P x T [10], it found that the use of fuel in a day was 2.1 liters. The current price of gasoline was IDR 7,650. Fuel consumption in a day was IDR 16,000, and in a year, it reaches IDR 4,820,000. So that the costs for operating the use of generators per year can be shown in the following table.

Table 18. Annual O&M generator usage.

Component Name	**Total Price**
O&M Generator	IDR 57,200
O&M Cable	IDR 5,000
O&M Protection	IDR 2,000
Fuel	IDR 5,622,750
Total	**IDR 5,686,950**

With the initial costs and operational costs in tables 17 and 18 to meet the load at the research site, the NPV value in the 24-year project period was -IDR 178,924,381.

The total investment cost that needs to be spent on the use of the generator was the sum of the initial capital costs and operational costs during the project period. The total investment cost for the use of the generator in this study was IDR 208,575,063.

C. Battery charging system from State Electricity Enterprise

Here were the investment costs for using batteries with charging from State Electricity Enterprise

Table 19. Initial capital for charging system.

Component Name	*Amount*	*Unit*	*Price*	**Total Price**
Suoer Battery Charger	1	Piece	IDR 250,000	IDR 250,000
Inpowers Battery 12V 150Ah	2	Piece	IDR 3,500,000	IDR 7,000,000
800W Inverter	1	Piece	IDR 2,000,000	IDR 2,000,000
Cable	1	set	IDR 500,000	IDR 500,000
Protection	1	set	IDR 200,000	IDR 200,000
Services and others	1	set	IDR 500,000	IDR 500,000
	Total			IDR **10,450,000**

The power used for charging the battery was equal to the load power plus system losses, which is about 2 kWh per day. So that the operational costs for using this system in one year can be shown in the following table:

Table 20. Annual O&M battery charging system.

Component Name	**Total Price**
O&M Charger	IDR 2,500
O&M Battery	IDR 70,000

Component Name	**Total Price**
O&M Inverter	IDR 20,000
O&M Cable	IDR 5,000
O&M Protection	IDR 2,000
Battery Replacement	IDR 875,000
Battery charging	IDR 1,026,900
Total	**IDR 2,001,400**

With the initial costs and operational costs in tables 19 and 20 to meet the load at the research site, the NPV value in the 24-year project period was -IDR 51,545.084.

The total investment cost that needs to be spent on the charging system was the sum of the initial capital costs and operational costs during the project period. The total investment cost in the charging system in this study was IDR 81,036,162.

D. Ratio

From the analysis results obtained for all existing alternatives, we can make a comparison table, as follows:

Table 21. Comparison values of NPV and PWC.

Variation Name	PWC	NPV
Solar power plant Variation 1	IDR 54,268,068	-IDR 24,773,442
Solar power plant Variation 2	IDR 60,055,069	-IDR 30,508,424
Solar power plant Variation 3	IDR 55,080,824	-IDR 25,586,198
Solar power plant Variation 4	IDR 60,867,824	-IDR 31,217,142
Generator	IDR 208,575,063	-IDR 178,924,381
Charging Sistem	IDR 81,036,162	-IDR 51,545,084

We can also see the comparison through the following chart

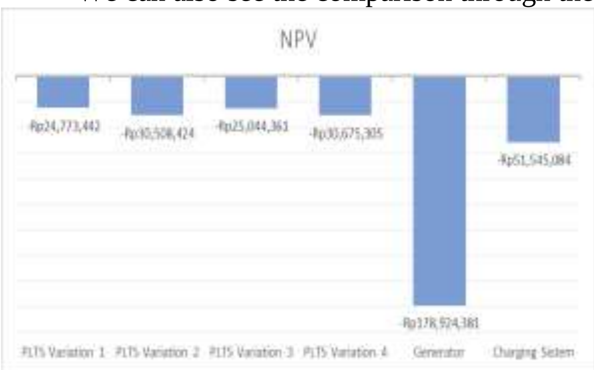

Figure 9. NPV comparison chart.

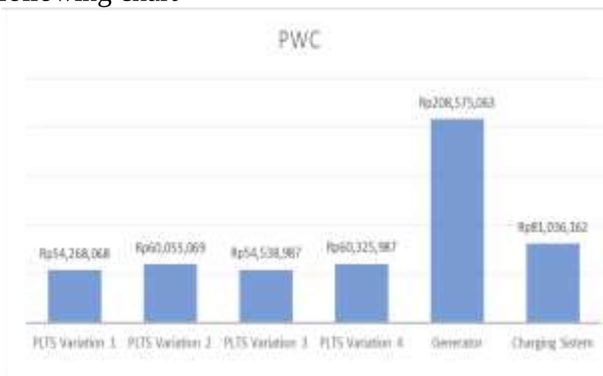

Figure 10. PWC comparison chart.

Based on Table 21 and Figure 10, we can determine alternative sources of electricity that were considered the most profitable. solar power plant variation 1 and variation 3 were alternative sources of electricity with the smallest investment costs, and generators were alternative sources of electricity with the most significant investment costs.

4. Conclusion

The solar power generation system designed in this study was an off-grid system. Solar power plant planning was divided into four variations, each of which has its configuration. The varied combination was solar panels with batteries. The alternative components that will be used were two brands of Solar Panels and two brands of batteries. In Variation 1, the electricity used was 567 kWh, and the NPV value was -IDR 24,773,442. While in variation 2, the electricity used was 568 kWh, the NPV value was -IDR 30,508,424. Variation 3 shows that the electricity used was 567 kWh, and the NPV value was -IDR 25,586,198. In variation 4, the electricity used was 570 kWh, the NPV value was -IDR 31,217,142. Then, on the use of a 1kVA generator, the NPV value was -IDR 178,924,381. Finally, on the use of the battery charging system, the NPV value was -IDR 51,545,084.

The electricity generated from the solar power plants ranges from 567-570 kWh per year, and each variation of this plan was considered inappropriate because it had an NPV value of less than 0. However, the investment value of solar power plants was still much more efficient and cheaper when compared to using a generator power source or charging system battery from State Electricity Enterprise. Based on the technical-economic analysis that has been done previously, the most viable investment was the first variation because it has the most outstanding NPV value, which was -IDR 24,773,442.

In terms of technical analysis, variation 4 produces the most supplied energy compared to variations 1, 2 and 3, but it also has the highest investment costs compared to variations 1, 2, and 3. Meanwhile, in terms of economic analysis, Technically, Variation 1 has the lowest investment value when compared to variations 2, 3 and 4, but the value of the supplied energy produced is the lowest when compared to variations 1, 2 and 3 with a 3 kWh energy difference. Variation 1 is the most technically and economically feasible system component variation because with a 3 kWh energy difference, the required investment value is IDR 6,057,919 less.

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