

DOI:10.5937/jaes0-34086

Paper number: 20(2022)3, 995, 889-899

www.engineeringsscience.rs * ISSN 1451-4117 * Vol.20, No 3, 2022

ON-GRID AND HYBRID SOLAR POWER PLANTS COMPARABILITY IN SEMARANG CITY, INDONESIA

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The electricity produced by an on-grid system can be sold to the state electricity company in Indonesian (PLN), when electricity produced by a hybrid system can be stored in batteries for self-consumption. This research will compare the savings between on-grid and hybrid system with the most profitable between both systems. The research method will utilize a simulation on PVSyst software for assessing technical feasibility and RetScreen software to calculate economic feasibility. The research results are obtained based on the comparison of both systems which are the Hybrid system used with a 1,200 Wp panel, 2 series 24V 100 Ah batteries, and a 1,500 W inverter, while On-grid system uses a 1,200 Wp panel and 1,500 W inverter. The On-grid design will produce electrical energy of 4,57 kWh/kWp/day with an initial investment value of USD 1,733.70 while the Hybrid design will produce 4,04 kWh/kWp/day with an initial investment value of USD 1,871.63 for a 24 years project period and with approximately four times batteries replacement. The NPV value in the Hybrid system calculated is USD 1.43 and in the On-grid system is USD 1,700. Therefore, the Hybrid system is considered not economically feasible and does not gain more profit than On-grid System.

Keywords: PV, hybrid, on-grid, PVSyst 7.0, retscreen

1 INTRODUCTION

Electrical energy is considered fundamental energy for world development. With an estimated economic growth of around 7% - 10% per year, Indonesia's electricity consumption is projected to increase rapidly until 2025. The electricity supply in Indonesia is estimated to reach over 120 GW by 2025[1]. The utilization of modern and renewable energy also has great potentials if developed. In Indonesia, solar power is the most potential energy that can be utilized as an alternative renewable and environmentally-friendly energy and can be used as an alternative solution to reduce fossil energy. Indonesia has a higher amount of solar radiation due to its location which is located in the equator. Therefore, it has relatively high solar radiation throughout the year, which is 4.80 kWp/m²/day[2].

To meet the target of using electricity with the National Energy Policy, several alternative energies that must be developed such as renewable energy, including geothermal, micro-hydro, solar, wind, ocean, biomass, and nuclear which are targeted to reach more than 17% share of national primary energy. Geothermal, hydro, and micro-hydro energies are considered potential to be developed because they have achieved maximum potential, which have value of geothermal of 28.18 GW, hydro of 75 GW, and micro-hydro of 450 MW [3]. Thus, it can be considered as a big advantage for Indonesia to design and utilize solar power plants.

There are mainly three types of photovoltaic systems which are On-grid, Off-Grid, and Hybrid systems that can be used as solutions. On-grid systems practically send electricity directly to the grid. Whereas, in an Off-grid system, there is no synergy with the utility grid because the generated power is directly connected to the load. Meanwhile, the hybrid system can directly connect with the grid by adding some battery storage to store the energy from the photovoltaic source and it does not directly supply the load. The battery will store energy when the power supplied by the PV modules exceeds load demand and releases it back when the PV supply is insufficient[4].

The advantage of the on-grid system is that when the solar panels produce electrical energy that is greater than the load used, the energy can be sold to state companies in Indonesian (PLN). While the disadvantage is that it cannot supply electrical energy to the load when there is a blackout from the grid (PLN) because the inverter will turn off automatically when there is no reference voltage from the grid. Therefore, the electrical power generated from the PLTS during a power outage will be lost if there is no storage battery in the PLTS. This causes a considerable loss of energy and will result in an increase in the payback period for solar power plants[5], [6].

The advantage of a hybrid system is that when the solar panels produce electrical energy that is greater than the load used, the electrical energy will be stored in the battery to be used again when the solar panels no longer produce electrical energy. In addition, the hybrid system will not be affected when there is a blackout from the grid (PLN) because the inverter is not synchronized with the grid so that the load can absorb electrical energy from the battery[7], [8]. While the disadvantage of the hybrid system is that when the electrical energy stored by the battery

is fulfilled (the battery is not able to store more electrical energy) and the solar panel produces electrical energy that is greater than the load, the energy will be lost. In addition, the investment cost of a hybrid system is greater than that of an on-grid system because of the additional battery components (and replacement every 2 years)[9].

The electricity produced by a Solar Power Plant with an On-grid System can be sold to PLN at a price of USD 0.1015 per kWh[10], [11]. While the electricity produced by Hybrid System can be stored in batteries, it will not be distributed to the public but only for self-consumption [10], [12].

Until now, there has never been a study to compare on grid system and hybrid system due to differences in installation and electrical circuit so it will be difficult to make comparison. This comparison needs to be done to find out which system is more effective in reducing energy consumption from PLN (grid) and providing more savings based on economic analysis[13]. In this study, the authors will compare the target savings from the on grid system and hybrid system. This study aims to determine which system is more effective in reduce energy consumption from PLN (grid) and provide more saving based on economic analysis.

2 METHODS

The method used in this research including determine the research location, then collect data consisting of load data and solar radiation data. The next step is to determine the component specifications and design a series of solar power plants.

As a technical analysis, a solar power plant simulation carried out using PVSyst 7.0 software to determine the amount of energy produced, energy that can be stored or sold, and others.

In addition, this study also conducts an economic analysis based on the capital required for the installation of a solar power plant and the profits generated from the solar power plant.

2.1 Research Location

In this research, a household-scale rooftop solar power plant design is located in Pleburan, Semarang City. The location is astronomically located at coordinates -6.993, 110.423.



Figure 1 : Location of the Household

2.2 Daily Load Profile

The estimated daily load data in the research area is generated manually and periodically to obtain the exact daily load profile data. The household scale has an installed electrical capacity of 1,300VA. Table 1 displays the daily load profile in the research area.

Table 1 : Daily Load Profile

Variation	Quantity	Power (Watt)	Hour	Total (Watt hour)
Sharp Washing Machine	1	245	2	490
LG TV	2	28	2	112
Mini PC HP Elitedesk	1	130	8	1040
AQUA Refrigerator	1	80	24	1920
Cosmos Stand Fan	1	46	5	230
Cosmos Rice Cooker	1	300	2	600
LUMMENT Fluorescent Lamp	10	5	7	350
HANNOCH LED Lamp	3	10	7	210
ATMOS LED Lamp	13	5	4	260
Socket	4	25	6	600

From Table 1, the daily load profile in the research area is modified into an hourly load profile as described in the Figure 2.

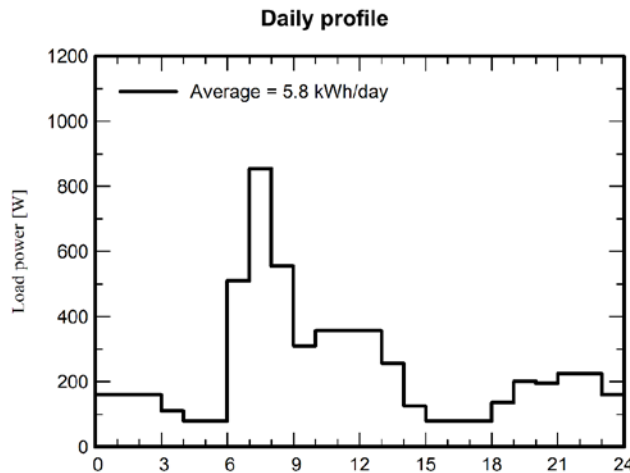


Figure 2 : Daily hourly profile distribution in the household

2.3 Sunshine Radiation Profile

According to NASA Prediction of Worldwide Energy Resources data, the solar insolation in 2019 in this area is 5,8 kWh/m²/day [6]. Moreover, data generated from NASA Prediction of Worldwide Energy Resources shows the diffuse radiation and wind velocity. Semarang city temperature data is also generated from Semarang-based Station Meteorology, Climatology, and Geophysical Agency. The data mentioned above can be used to generate the result of potential solar energy usage in a rooftop solar power plant in the research area.

Table 2 : Sunshine Radiation Data

Month	Insolation (kWh/m ² /day)	Temp. (°C)	Diffuse Radiation (kWh/m ² /day)	Wind Velocity (m/s)
January	4.6	27.6	2.33	2.59
February	5.29	27.9	2.39	1.42
March	4.55	27.6	2.32	2.06
April	5.08	28.7	2.06	1.76
May	5.41	29	1.76	2.65
June	5.14	28.3	1.62	2.82
July	5.37	27.7	1.63	3.04
August	5.94	28	1.8	3.11
September	6.49	28.8	2.06	2.99
October	6.54	29.8	2.31	2.75
November	6.02	30.1	2.34	2.37
December	5.3	28.7	2.32	1.42

2.4 Design of Solar Power Plant

The design of household scale and solar photovoltaic position is shown in the Figure 3.

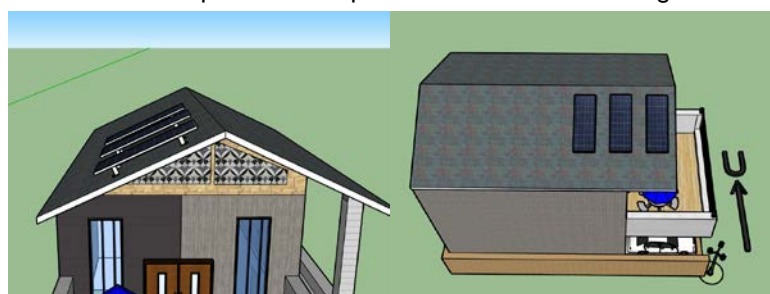


Figure 3 : Visualization of the research object

To determine the amounts of solar panels, the equation used are as follows:

$$\text{Amount of Solar Panel} = \frac{\text{Total Watt Peak (Wp)}}{\text{Watt Peak PV Module (Wp)}} \quad (1)$$

$$\text{Amount of Solar Panel} = \frac{1,200 \text{ Wp}}{400 \text{ Wp}} = 3 \text{ Solar Panel} \quad (2)$$

The size of inverter must bigger 25% – 30% than daily loads total. The total of daily loads is 1,102 Wh. Therefore, this equation is used to calculate the total daily load in inverter.

$$\text{Inverter Capacity} = 130\% \times \text{Daily Loads Total} \quad (3)$$

$$\text{Inverter Capacity} = 130\% \times 1,102 = 1,432.6 \text{ W} \quad (4)$$

$$\text{Inverter Capacity} \approx 1,500 \text{ W} \quad (5)$$

To calculate the PV in series configuration, the equation used is:

$$V_{\text{max Total}} = 3 \text{ Solar Panel} \times 40.36 \text{ V} \quad (6)$$

$$V_{\text{max Total}} = 121.08 \text{ V} \quad (7)$$

$$I_{\text{max}} = 9.92 \text{ A} \quad (8)$$

Vmax and Imax are needed to determine the specifications according to the inverter datasheet

$$\text{DOD (Depth of Discharge)} = 0.3 \quad (9)$$

$$\text{Autonomous Days} = 12 \text{ hours} \quad (10)$$

Autonomous days (number of days it takes the system to operate when no power is generated by the PV panels) = 0.5 days = 12 hours

The nominal battery block voltage selected is 24 V, which is considered safe to install the battery block in a residential house. The battery block storage capacity will be selected to cover the energy load demands for 12 hours without the sun and electrical grid. The total ampere-hour (CBAh) is obtained as follows [14]:

$$\text{CBAh} = \frac{\text{Edb} \times \text{AD}}{\text{DOD} \times \eta_{\text{BAh}} \times \text{VB}} \quad (11)$$

Edb is the daily energy required from the battery (E_d/η_{inv}), DOD is the permitted depth of discharge, AD is autonomy days, η_{BAh} is the ampere hour efficiency of the battery cell, and VB is the selected nominal DC voltage of the battery block.

$$\text{Battery Capacity (Ah)} = \frac{(\text{Total daily loads (Wh)} \times \text{Autonomous Days})}{(\text{DoD} \times \text{Nominal Voltage Battery (V)})} \quad (12)$$

$$\text{Battery Capacity (Ah)} = \frac{(5,812 \times 0.5)}{(0.3 \times 24)} = 151.35 \text{ Ah} \quad (13)$$

$$\text{Battery Capacity (Ah)} = 200 \text{ Ah} \quad (14)$$

To conduct this research, two 100 Ah batteries are required. From the results of the above calculations, a single line diagram technical design can be made for Hybrid and On-grid systems.

Solar power plant in this research will be designed for two systems. The first design is aimed to estimate the On – Grid System with two main components which are a 1,200 Wp Solar Panel and a 1,500 W On – Grid Inverter. The second design is aimed for Hybrid System which includes three main components, a 1,200 Wp Solar panel, a 1,500 W Hybrid Inverter, and a 24 V 200 Ah Batteries. The planned variation system will be simulated using PVSyst software to compare the annual production result, System Performance, and other necessary calculations. The specifications of the components that will be used as variations can be seen in the Table 3.

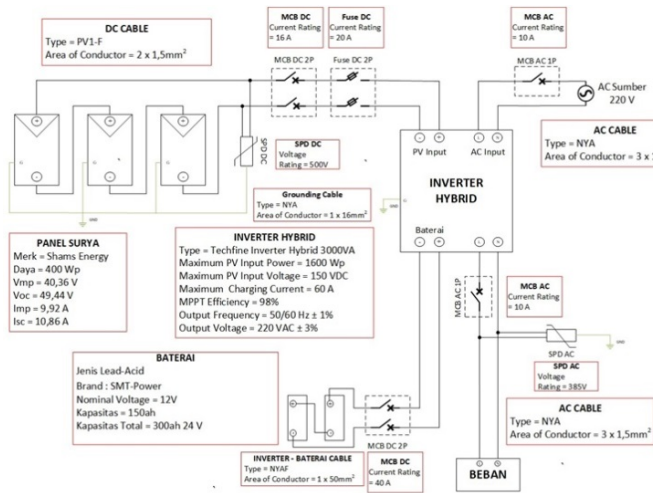


Figure 4 : Hybrid System Wiring Diagram

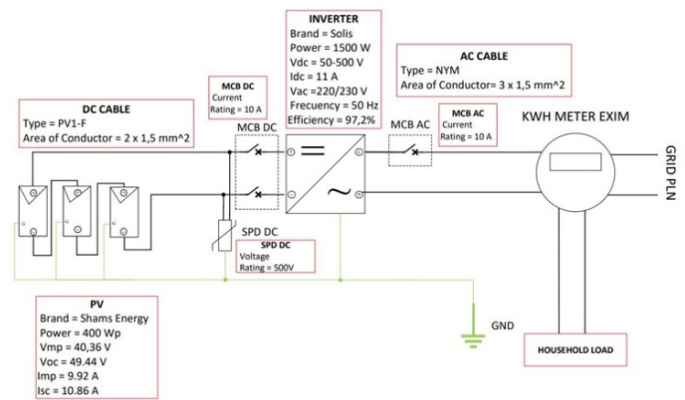


Figure 5 : On – Grid System Wiring Diagram

Table 3 : Configuration system between an On – grid and a Hybrid solar power plant components

System	Solar Panel	Battery	Array Configuration	Inverter
On–Grid	Shams Energy Monocrystallin Specification: 400 Wp Vocs (49,44 V) Isc (10,86 A)	n/a	3 series Modul PV	Solis Inverter On–Grid Mini 1,500 W
Hybrid	Shams Energy Monocrystalline Specification: 400 Wp Vocs (49,44 V) Isc (10,86 A)	Brand: Kayaba Battery VRLA Specification: 12 V 100 Ah (2 series)	3 series Modul PV	Techfine Inverter Hybrid 1,500 W

2.5 Technical Analysis

Solar Power Plants exists as a part of a pre-feasibility study which depends on primary energy asset and estimated result. The plant configuration is additionally improved during the study, which will consider site estimations, site geography, and ecological and social factors. Key plan highlights are including the PV module type utilized, shifting point, mounting and global positioning frameworks, inverters, and module action course. Plan configuration improvement are including contemplations such as concealing, execution debasement, compromises between expanded venture (e.g., for follow-up action), and energy result value. There are several factors that influence the solar cells output power efficiency, such as solar radiation, solar cells temperature, solar panel orientation, and shadow leverages. Typically, the achievability concentrate additionally creates plan determinations on which the gear to be secured [15], [16].

2.6 Economic Analysis

Technical economic analysis can generally be defined as an economic analysis of an engineering investment. This analysis aims to assess the feasibility of a technical investment proposal by conducting a study of alternatives that are considered the most profitable. In general, technical 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 [17], [18]. For technical economic analysis, the following equation is used to assist in the calculations.

$$PWB = \sum_{t=0}^n Cb_t (FBP)_t \quad (15)$$

$$PWC = \sum_{t=0}^n Cc_t (FBP)_t \tag{16}$$

$$NPV = PWB - PWC \tag{17}$$

$$BC - R = \frac{PWB}{PWC} \tag{18}$$

PWB is Present Worth Benefit, PWC is Present Worth Cost, and NPV is Net Present Value[18].

3 RESULTS AND DISCUSSIONS

3.1 Simulation Results

After inputting all the data needed in this PV mini-grid design simulation, the PVSyst simulation can be implemented. The following pictures are the result of the simulation using PVSyst software.

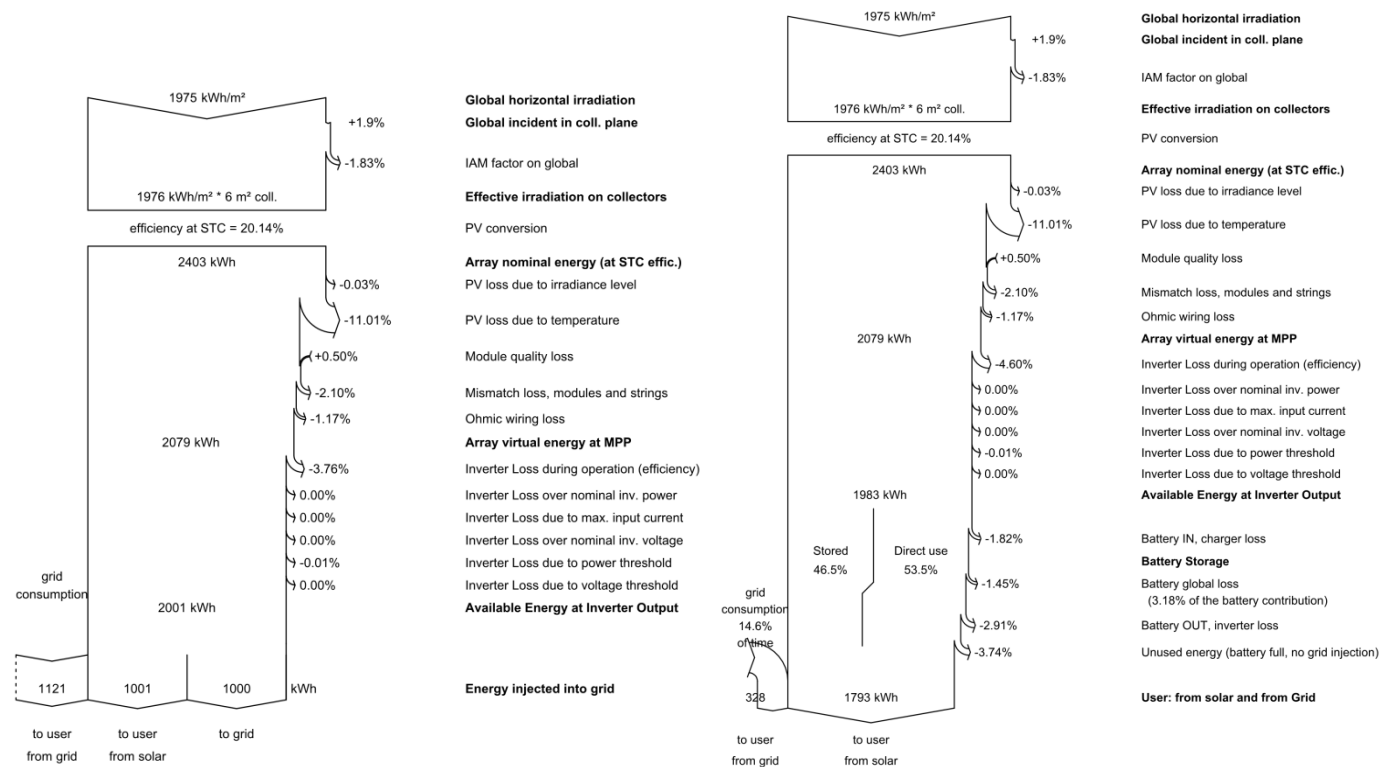


Figure 6 : On-Grid System Result

Figure 7 : Hybrid System Result

3.1.1 Technical Analysis

After used PVSyst 7.0 software in the simulation, the results of the solar power plant simulation on Household Scale 1300 VA Figures are described in the Table 4.

Table 4 : Comparison of On-Grid and Hybrid solar power plant system

System	Array Output Electrical Energy (kWh)	Energy Stored Battery (kWh)	Energy Supply to Load (kWh)	Supply Energy to Grid/ PLN (kWh)	Energy Used from Grid/ PLN (kWh)
On-Grid	2,001	–	1,001	1,000	1,121
Hybrid	1,793	834	959	–	329

Based on the data obtained in Table 4, the array output electrical energy amount result in the On-grid system is 2,001 kWh/year. On the other hand, in the Hybrid system is 1,793 kWh/year due to the battery storage has losses of 3.27% and the unused energy (battery in a full energy condition with no grid injection) is 6.65%. The Hybrid System stores energy in the battery at 834 kWh/year with the battery specification of 24 V 200 Ah. Meanwhile, the

On-grid system does not include any battery, so that energy fails to be stored. For energy supply to the load, the Hybrid system is capable to provide direct energy to the load of 959 kWh/year and the On-grid system can provide up to 1,001 kWh/year. There is a slight difference in the energy supply produced by the Hybrid and On-grid systems due to unused energy when there is overproduction in the Hybrid system, which results in the excessive energy being unable to be distributed to PLN and considered a loss. The On-grid system can sell electricity production up to 1,000 kWh/year. The Hybrid system is not able to conduct the same production goal because the hybrid system does not have Export-Import kWh activities that makes it sell-able to PLN.

The two systems also have different energy consumption from PLN. The On-grid system produces 1,121 kWh/year while the Hybrid system produces only 329 kWh/year. The difference in the electrical energy usage from PLN from the two systems is 792 kWh/year and this can happen due to the failure in Hybrid system to store the production of electrical energy into the battery. Therefore, when insufficient energy occurs, the battery will support to fulfill the energy demand from the load. Moreover, this causes electrical energy used from PLN in Hybrid system are less than in the On-grid system. Based on the data in table 4, it can be seen that the on grid system can save electricity usage from the grid by 47.17% while the hybrid system can save 84.50%. Based on previous research on on-grid systems conducted by Apriboyo et al, 2021, it can be seen that on-grid solar power plants installed in areas with coordinates (-7.56133; 110.8543) and global irradiation of 5.09 kWh/m²/day can save energy use from the grid is 36.04% [19]. Based on previous research on hybrid systems conducted by Wahyuni et al, 2020, it can be seen that hybrid solar power plants installed in areas with coordinates (-7.68863; 110.4253) and global irradiation 4.89 kWh/m²/day can save energy use. from the grid by 78.15% [20]. The difference in savings obtained is due to differences in the installation location and the components used so that it can be seen that an in-depth study is needed before installing a solar power plant in an area[2]. Batteries can also be utilized when solar panels are not available for the production of electrical energy, especially at night time when there is no sun radiation which is the main source of energy. Meanwhile, the On-grid system uses electrical energy from PLN at night. This simulation runs depending on the STC conditions, especially at a 25°C room temperature and a 1,000 W/m² irradiation that are used in measuring the panel performance. By doing this simulation, the writers are able to calculate the targeted savings between the two systems and compare them. Moreover, the writers can conclude that the Hybrid system is better to be implemented from the technical aspect because it can save excessive production on solar panels and can be used as the back-up for the household when the PLN blackouts occurs. In the On-grid system, the household load will be reduced if there is PLN blackout occurs. This research needs to be reviewed from an economic analysis where the batteries installment cost and batteries replacement will cost expensively so that the total investment cost of a Hybrid system will be much more expensive than the On-grid system.

3.2 Economic Analysis

To conduct economic analysis of the two systems, the Retscreen software is utilized to calculate the initial investment, Operational & Maintenance Cost (O&M Cost), and annual savings. The inflation rate also affects the money value in the future so it needs to be included in the simulation. The annual inflation rate in Indonesia is 1.75% according to the official website of Bank Indonesia [17]. Therefore, the estimation will conclude the NPV (Net Present Value), BCR (Benefit Cost Ratio), and DPP (Discounted Payback Period) calculation. When a project has a BCR value of more than 1, then the project is still considered feasible. When the BCR value is higher than 1, the project is considered better from the economic aspect. The writers surveyed the components price in offline stores in the Semarang City area and online store in various e-commerce sites to estimate the total investment cost. This study will compare these two different systems from economic aspect. The writers has surveyed the components price in offline stores in the Semarang City area and online store in various e-commerce sites to estimate the total investment cost. This study will compare these two different systems from economic aspect. The investment costs for each component in the On-grid and Hybrid system can be seen in Table 5 and Table 6.

Table 5 :Initial Investment Cost of On-grid System Based on Offline Store and E-Commerce

Component Name	Amount	Unit	Price	Total Price
Shams Energy Solar Panels 400 Wp	3	Module	USD 217.93	USD 653.79
kWh Export-Import	1	Piece	USD 316.35	USD 316.35
Solis Inverter On-Grid Mini 1500 W	1	Piece	USD 386.65	USD 386.65
Solar Panel Stand	1	set	USD 106.93	USD 106.93
Cable	1	set	USD 110.86	USD 110.86
Protection	1	set	USD 69.32	USD 69.32
Services and others	1	set	USD 63.27	USD 63.27
Total				USD 1,707.15

Table 6 :Initial Investment Cost of Hybrid System Based on Offline Store and E-Commerce

Component Name	Amount	Unit	Price	Total Price
Shams Energy Solar Panels 400Wp	3	Module	USD 217.93	USD 653.79
KAYABA Battery 12V 100 Ah	4	Piece	USD 147.80	USD 295.60
Techfine Inverter Hybrid 2400W	1	Piece	USD 435.86	USD 435.86
Solar Panel Stand	1	set	USD 106.93	USD 106.93
Cable	1	set	USD 140.11	USD 140.11
Protection	1	set	USD 82.67	USD 82.67
Services and others	1	set	USD 63.27	USD 63.27
Total				USD 1,778.21

The annual operational and maintenance costs for two system solar power plants are generally calculated at 1% – 2% of the total initial investment costs [21], for two system solar power plants components plus battery replacement costs in the Hybrid system during the project period. Therefore, the annual operational costs for On-grid and Hybrid system are obtained as in Table 7 and Table 8.

Table 7 : Solar Power Plant System Operational Costs On-Grid System

Component Name	Amount	Unit	Price	Total Price
O&M Solar Panel	1	Year	USD 13.08	USD 13.08
O&M Inverter	1	Year	USD 7.73	USD 7.73
O&M Solar Panel Stand	1	Year	USD 2.14	USD 2.14
O&M Cable	1	Year	USD 2.22	USD 2.22
O&M Protection	1	Year	USD 1.39	USD 1.39
Total				USD 26.55

Table 8 : Solar Power Plant System Operational Costs Hybrid System

Component Name	Amount	Unit	Price	Total Price
O&M Solar Panel	1	Year	USD 13,08	USD 13,08
O&M Battery	1	Year	USD 5,91	USD 5,91
O&M Inverter	1	Year	USD 8,72	USD 8,72
O&M Solar Panel Stand	1	Year	USD 2,14	USD 2,14
O&M cable	1	Year	USD 2,80	USD 2,80
O&M Protection	1	Year	USD 1,65	USD 1,65
Battery Replacement	1	Year	USD 59,12	USD 59,12
Total				USD 93,42

Based on Table 5 and Table 7 above, it showed an initial investment cost in On-grid system is USD 1,707.15 with an annual O&M cost of USD 26.55 while (based on Table 6 and Table 8) Hybrid system shows an initial investment cost of USD 1,778.21 with an annual O&M cost of USD 93.42. Savings for both systems are calculated from the beginning of the project. The value of electrical energy savings in the On-grid system is obtained from electricity sales to PLN where electrical energy is distributed directly to the load. Meanwhile, the value of electrical energy savings for the Hybrid system is obtained from the total energy stored in the battery where the energy is distributed directly to the load. To find the difference in the electrical energy usage between On-grid and Hybrid system from PLN, the PVsyst 7.0 software is needed. It can be concluded that the electrical energy value to PLN will be estimated at a price of USD 0.1015 and the electrical energy savings of USD 0.1015. The total savings from On-grid and Hybrid systems can be seen in Table 9.

Table 9 : On-Grid and Hybrid System Solar Power Plant Saving per Year

System	Energy Stored Battery (A)		Energy Supply to Load (B)		Supply Energy to Grid/PLN (C)		Energy Used from Grid/PLN (D)		Total Saving (A+B+C-D)
	kWh	USD	kWh	USD	kWh	USD	kWh	USD	USD
On-Grid	–	–	1,001	101.66	1,000	101.56	1,121	113.85	89.37
Hybrid	771	78.30	959	97.42	–	–	329	33.41	142.31

Based on Table 9, results of the saving energy with hybrid system have more saving than on-grid system. This is because the hybrid system has backup energy from the battery so it does not use a large PLN electricity source compared to the on-grid system. The total saving in the On-grid system is USD 89.37 and in the Hybrid system is USD 142.31. Therefore, hybrid system has bigger value than the On-grid system. However, based on Table 5 – Table8, it is found that the total investment for hybrid system is higher than On-grid system. The hybrid system needs battery replacement every five years. To analyze project feasibility from economic evaluation use the Retscreen software simulation and economic parameter feasibility with value of NPV (Net Present value), BCR (Benefit-Cost Ratio), and DPP (Discounted Payback Period).Based on the simulation results, the NPV, BCR, and DPP values for each system are as in figures 8 and 9.

Financial viability			Financial viability		
Pre-tax IRR - equity	%	11%	Pre-tax IRR - equity	%	3,6%
Pre-tax MIRR - equity	%	4,8%	Pre-tax MIRR - equity	%	1,9%
Pre-tax IRR - assets	%	11%	Pre-tax IRR - assets	%	3,6%
Pre-tax MIRR - assets	%	4,8%	Pre-tax MIRR - assets	%	1,9%
Simple payback	yr	9,7	Simple payback	yr	12,6
Equity payback	yr	8,9	Equity payback	yr	17,1
Net Present Value (NPV)	\$	1.700	Net Present Value (NPV)	\$	1,43
Annual life cycle savings	\$/yr	107	Annual life cycle savings	\$/yr	0,09
Benefit-Cost (B-C) ratio		2	Benefit-Cost (B-C) ratio		1
Debt service coverage		No debt	Debt service coverage		No debt
GHG reduction cost	\$/tCO ₂	No reduction	GHG reduction cost	\$/tCO ₂	No reduction

Figure 8 :Retscreen Simulation Result On-Grid System

Figure 9 :Retscreen Simulation Result Hybrid System

Refers to the figures 8 and 9, comparisons can be made based on the NPV, BCR, and DPP parameters for On-grid and Hybrid systems listed in the table 10.

Table 10 : NPV, BCR, and DPP Value of On-Grid and Hybrid

System	NPV	BCR	DPP (Years)
On – Grid	USD 1,700	2	9.7
Hybrid	USD 1.43	1	12.6

Based on table 10, it can be seen that the NPV value in Hybrid system is less than NPV value in On-grid system. BCR value for On-Grid system is 2 and hybridof 1. In DPP value, Hybrid system can reach payback period at 12.6 years, while the On-gridsystem can reach payback period at 9.7 years. Therefore, itcan be concluded that the solar power plant investment for Hybrid system is not feasible from economicaspect.

Based on table 10, we can determine electricity savings that are considered the most feasible between On-grid and Hybrid system. Hybrid system acquires more savings than On-grid system, however, the On-grid system is considered more profitable than the Hybrid system.

4 CONCLUSION

The Hybrid system can store energy in the battery at 834 kWh/year and capable of providing direct energy to the load of 959 kWh/year while the On-grid system can provide direct energy to the load of up to 1,001 kWh/year.

The On-grid system can sell electricity production up to 1,000 kWh/year and this can't be done by the hybrid system. Energy consumption from PLN on the On-grid system is 1,121 kWh/year, while the Hybrid system is only 329 kWh/year. In Hybrid system, total savings is USD 142.31 and in On-grid system is USD 89.37.

From economic analysis, Hybrid system NPV value is USD 1.43, BCR value is 1, and Payback Period can reach 12.6 years, while in the On-grid system NPV value is USD 1,700, BCR value is 2, and Payback Period can reach 9.7 years.

Hybrid system has more savings value than the On-grid system. However, the Hybrid system needs battery replacement every 4 years project lifetime. Therefore, the On-grid system is more profitable than the Hybrid system. The Hybrid system solar power plant is still considered feasible from the technical analysis. Due to the Hybrid system can provide back-up energy when the blackout occurs. Therefore, this system can secure the electricity in a household scale.

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Paper submitted: 22.09.2021.

Paper accepted: 29.12.2021.

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