Techno-Economics Utilization Case Study of Renewable Energy PV Source for Swapping Battery Charging Stations

Handoko R. Iskandar, Nana Heryana, Agus Purwadi and Jihad Furqani

November 14, 2024

Techno-economics Utilization Case Study of Renewable Energy PV Source for Battery Swapping Charging Stations

Handoko Rusiana Iskandar
Electrical Engineering Department Faculty of Engineering
Universitas Jenderal Achmad Yani
Cimahi, Indonesia
handoko.rusiana@lecture.unjani.ac.id

Nana Heryana
School of Electrical Engineering and Informatics
Bandung Institut of Technology
Bandung, Indonesia
nana@itb.ac.id

Agus Purwadi
School of Electrical Engineering and Informatics
Bandung Institut of Technology
Bandung, Indonesia
agusp@konversi.ee.itb.ac.id

Jihad Furqani
School of Electrical Engineering and Informatics
Bandung Institut of Technology
Bandung, Indonesia
jfurqani@itb.ac.id

***Abstract*—This paper discusses the techno-economic assessment of the exploitation of new renewable energy (RE) that may be used as a source of energy from the Public Electric Battery Swapping Charging Station (PEBSCS). This paper analyzes RE systems and technologies, including identifying the potential use of various types of RE that can be applied in PEVBCS, analyzing their benefits and drawbacks, measuring the load profile of Gas Stations that already have BSCS, and calculating the RE contributions that can be made from electricity use at Hayam Wuruk Gas Station in Bali, Indonesia. When simulating techno-economy studies, cost inputs include capital costs, replacement costs, operational and maintenance costs that have been changed and selected based on current conditions, and inflation values updated in recent years in accordance with the Minister of Finance's regulation letter. The findings of the use of PV-based RE may be extended to all existing PEVBCS, since according to the studies conducted, the use of PV at the Hayam Wuruk Gas Station - Bali site results in a substantially cheaper Levelized Cost of Energy (LCOE) value than the use of PLN electrical energy tariff special services. The comparison of the findings and the resultant value is a description of the hybrid scheme (PV, battery, and grid) based on many models and simulations performed on the PEBSCS object utilizing both external and existing batteries.**

Keywords—Levelized Cost of Energy, Photovoltaic, Public Battery Swapping Charging Station, Renewable Energy, Techno-economy

I. Introduction

Indonesia has significant renewable energy potential. Solar, wind, and geothermal are some of Indonesia's potential renewable energy sources. According to the Indonesia Energy Transition outlook and IRENA assessment[1][2], the potential for renewable energy from the sun is 300 GW, with an emphasis on East Java, Sumatra, Nusa Tenggara, and Sulawesi. Average daily irradiation ranges from 4 to 5.8 kWh/m^2. Wind-derived renewable energy potential is estimated at 61 GW, with an emphasis on Nusa Tenggara, South Sulawesi, and some portions of Java[3][4]. The geothermal renewable energy potential is predicted to be 28.5 GW, with an operational geothermal generating capacity of 2 GW[5]. On the other hand, in order to accelerate battery-based electric motorized vehicles as operational service vehicles and/or individual service vehicles of central government agencies and support the government's target for electric vehicles to reach 600,000 two-wheelers by 2030[6], it is possible that the potential for the use of PV technology in battery charging stations can be realized. Some of the swapping station manufacturers operating in Indonesia include type X. Meanwhile, to support this background, it is necessary to analyze the benefits and drawbacks of renewable energy sources that may be used as a Public Battery Swapping Charging Station (PBSCS) energy source, such as solar, wind, and geothermal energy, allowing you to select the most appropriate one. Solar and wind are renewable energy sources that can be used to power PBSCS systems[7], [8]. Geothermal energy is less suited for use as an energy source in PBSCS due to the limited capacity of geothermal facilities that can be developed and the high investment cost. Wind energy, in particular, requires further evaluation in terms of wind speed, and the investment value of wind power plants remains higher than that of solar power plants[9], [10].

PV is being used at Gas Stations and has been PT. Pertamina (Persero) primary emphasis in attempting to assist a more environmentally friendly energy transition[11], with installations in numerous areas and provinces across Indonesia. The installation of PV at Gas Stations is part of the Green Energy Station (GES) initiative, which seeks to provide integrated services to help consumers live a more environmentally conscious lifestyle. However, the RE application is now limited to Gas Stations; what about PBSCS, which is often used for two-wheeled transportation and also supports the green energy program, will be addressed more in the proposal in this paper. The first chapter of this paper discusses the background and references related to PBSCS; the second chapter describes the power characteristics of existing PBSCS at Gas Stations with proposed scenarios based on hybrid sources; and the third chapter presents a discussion of the results of calculations, simulations based on scenarios made, and the conclusions drawn after testing.

II. Battery Swapping Charging Station System

A. *Location and Energy Potential*

Hayam Wuruk Gas Station is situated in Hayam Wuruk, Denpasar City, Bali Island. The electrical load at Hayam Wuruk Gas Station is divided into two busbars: the Gas Station busbar and swapping charging station. The PLN Grid membership price for BSCS at the Hayam Wuruk Gas Station is 5.5 kVA. The potential solar energy that may be generated is computed using Peak Sun Hour. Assuming a PSH is >5 h/day and bright weather, the PV contribution at Hayam Wuruk Gas Station can provide maximum power supply.

TABLE I. ENERGY POTENTIAL BASED ON NASA SURFACE METEOROLOGY

Moth	Clearness Index	Daily Radiation ($kWh/m^2/day$)	Temp. (°C)	Wind Speed (m^2/sec)
Jan	0.454	4.930	26.760	3.780
Feb	0.464	5.040	26.690	3.750
Mar	0.518	5.430	26.800	3.270
Apr	0.558	5.390	26.920	3.770
May	0.593	5.190	26.450	4.660
Jun	0.585	4.840	25.710	5.120
Jul	0.564	4.790	24.910	5.470
Aug	0.574	5.330	24.740	5.420
Sep	0.586	5.950	25.380	4.910
Oct	0.580	6.190	26.380	4.340
Nov	0.524	5.670	27.020	3.720
Dec	0.488	5.280	26.930	3.600

TABLE II. SWAPPING BATTERY SPECIFICATIONS[12]

Rating Voltage (Volt)	Min. Rated Capacity (Ah)	Size (mm)		
		N1	N2	N3
48	12	77	179	425
	20	290	103	218
	20	155	178	296
60	20	200	155	248
	20	230	90	350
	20	195	165	350
	20	200	170	270
	20	225	165	350
72	20	118	127	410
	20	190	160	305

TABLE III. TYPE X BATTERY SPECIFICATIONS

No	Parameter	Information
1	Op. Voltage (Volt)	72
2	Op. Current (Ah)	20
3	Op. Power (kWh)	1,44
4	No. of Battery Slots (pcs)	10
5	Charging Time (hours)	3 – 4

According to secondary data, the average solar energy potential in a year, Global Horizontal Irradiance (GHI) that may be created at the Hayam Wuruk Gas Station in Bali is 5.34 $kWh/m^2/day$, with an average annual wind speed of 4.37 m/sec. The clearness index is a dimensionless quantity, which means it does not have a defined unit. It is defined as the ratio of surface radiation to extraterrestrial radiation and runs from 0 to 1; higher values suggest less polluted sky and lower values indicate cloudier skies. See Table 1.

In terms of potential, Solar PV is chosen based on the availability of solar energy in areas with a worldwide horizontal irradiance of 5.34 kWh/m^2. Solar PV can be used as rooftop PV to save space (no need for ground-mounted) or to reduce the amount of land required for other plants. In terms of civic development, electricity and other PV are less expensive than the installation of other renewable energy facilities. The operating and maintenance issues will be discussed in the next chapter, together with the techno-economic design.

B. Battery Profile and Load BSCS Characteristic

The existing PV is only linked to the Gas Station busbar, which only delivers Gas Station power and does not include swapping battery charging system. The swapping charging system supply is solely derived from the grid. Measurements were taken at the grid supply for swapping charging station and the output to the swapping charging electric vehicle type X. In modeling this system, the load is determined by the battery requirements, which match Indonesian battery standards based on SNI 8928: 2020 (See Table 2). Each standard battery pack size must fulfill either the dimensions specifications in table 2 or the dimensional standards specified by the manufacturer. The capacity of detachable and exchangeable batteries must be represented as rated capacity in line with table 2. The capacity of such batteries must be able to meet 95% of their stated capacity. Whereas N1-N3 indicates the size required in the standard. The Brand X battery is a Lithium-ion battery with a voltage of 72 Volts, a current of 20 Ah, and a charging period of 3-4 hours base nameplate. The mileage for the Brand X battery using one battery is 50 km, while using two batteries covers a distance of 100 km. The Public Electric Vehicle Battery Swapping Station has ten battery slots available. Because of the sliding cabinet form of this BSCS, customers may change batteries quickly and efficiently. The hybrid source (PV-Grid) that will be offered as an electrical energy generating source for BSCS Type X in this study may be computed using Equation 1. The purpose is to determine the load on the BSCS.

$$E_{station} = E_{Batt}(KWh)\ X\ N_{Batt.\ per\_Station} \qquad (1)$$

Equation (1) indicates that $E_{station}$ is the result of multiplying the battery's energy capacity or E_{Batt}in (kWh) by the number (N) of slots available in a single battery charging station. To calculate the total amount of power required by the load, multiply the battery energy by the number of battery slots in a single station rack. A single-phase system required 10 station racks for type X batteries. This indicates that to calculate the total energy needed, the following equation may be used:

$$E_{SBCS} = E_{type-X\ Battery} \qquad (2)$$

Equation (2) indicates that the energy (E_{SBCS}) of the battery rack station is equal to the total energy ($E_{type-X\ Battery}$) required for the battery swapping operation.

C. Modeling and PV System Design

To calculate the capacity required by solar panels in this hybrid system can be determined through the following Equation (3).

$$PV_{Size}(Wp) = \frac{E_{Daily}\ (kWh)}{Ins.(kWh/m^2\ /d)} \times Adj._{factor} \qquad (3)$$

The equation (3) is used to calculate the capacity of solar panels in (Wp); it requires knowledge of the total power needed by the load and divides it by the best time of day in (kWh) for solar panel harvesting. Insolation is a term that refers to the amount of solar radiation received on a surface over a given time period in a day, which is supposed to equal 1,000 kWh/m^2. A 15% energy loss is factored in when estimating the capacity of solar panels. Diffuse or shading induced by cloud obstruction is the usual cause of potential power loss and adjusting factor in 1.1, preventing the power absorption from being maximized. According to Table 3, a single battery rack type X in a charging station can hold 14 kWh in a single day. So, after accounting for the 15% loss and the daily insulation at the location, the total photovoltaic panel demand is 3 kWp. To compare the techno-economic possibilities of the role and contribution as an energy source utilization in the Battery Swapping Charging Station system, two situations are created: the battery supply is added from outside and the battery is utilized from the swapping system.

Figure 1 (optional A) depicts a simulated hybrid setup that uses (PV + Batt) external batteries and is selected or assumed to be lead acid[13]. The choice of lead acid is determined by market availability. PV power systems may require battery backup, both for service dependability and to allow time for intervention in the event of unexpected events, such as severe weather or system component failure; thus, this system analyzes the amount of batteries during autonomous time. The number of days of autonomy is typically stated as a system design requirement and is determined by a variety of factors, the most important of which is the application of critical loads. Second, in terms of system availability, or the least percentage of time that the PV system can satisfy the stated system design load. Third, consider how solar radiation fluctuation (daily/seasonal) affects load forecasting. Furthermore, to determine the battery, the number of external batteries of BSCS in Hayam Wuruk about 7 pieces. Furthermore, another option is the scheme in Figure 1 (optional B), which is proposed on-grid (using existing batteries) with the consideration that it will save the proposed cost, for which it is necessary to calculate how the potential RE in the system and the components that can support the system in the BSCS. The design area required for a 3 kWp PV system, referring to the specifications of the si-mono type solar PV, has a PV efficiency used in the software of 17.30%. Use equation (4) to find out the output power assuming Irradiance at Peak Sun Hour (PSH) 1000W/m^2, then the power in unit area is around 138.4 W/m^2. Consider Eq. (5) to find out the required area in (m^2), and the result from this calculation of effective area for PV is 21.68m^2.

$$P_{out} = Irr_{W/m^2} \times \eta_{PV(\%)} \times Losses_{Factor} \tag{4}$$

$$Area_{(m^2)} = \frac{kWp}{P_{out}} \tag{5}$$

For the record, the equation employed is a planning calculation from the rooftop PV Installation guidebook/standard. The area in square meters (m^2) is determined by the efficiency of the solar panel being used. In general, the η_{PV} is17–24% for manufacturers and types of specific brands of si-mono types. The efficiency of the PV panels employed is determined by the software during simulation.

D. Economic Aspects of Renewable Energy Utilization

The utilization of clean energy or RE from fossil fuels is not typically mentioned when discussing the extent of Indonesia's green energy potential, but several factors can impact this. In terms of funding, where RE projects have a substantial Capital Expenditure (CapEx) and Operating Expenditure (OpEx) that are considered[14]. This paper examines how CapEx and OpEx links interact with technical and economic aspects of the proposed PV additions to the BSCS system. Capital costs, CapEx for PV include the cost of solar panels, batteries, inverters, wiring, protection, and other components. These costs are large and represent a significant initial investment in a solar installation. The overall cost can be assessed using methods such as Net Present Cost (NPC) and Discounted Payback Period (DPP) to determine the investment's feasibility. OpEx for PV comprises maintenance costs, battery replacement costs, inverter costs, and other expenses. These costs are smaller than CapEx but nonetheless important in the long run. Methods for estimating the total cost include the annual cost of running the PV system and the cost of replacing system components[15], [16]. The connection with Techno-Economics clarifies the feasibility of PV investment. Using NPC, replacement cost, and operation and maintenance (O&M) cost, we can establish whether a solar PV plant is capital and operating cost viable. The Cost of Energy (CoE) is the estimated production cost necessary to generate one kWh of energy. The greater the CoE value, the higher the cost of producing electricity. Thus, CoE analysis is vital in

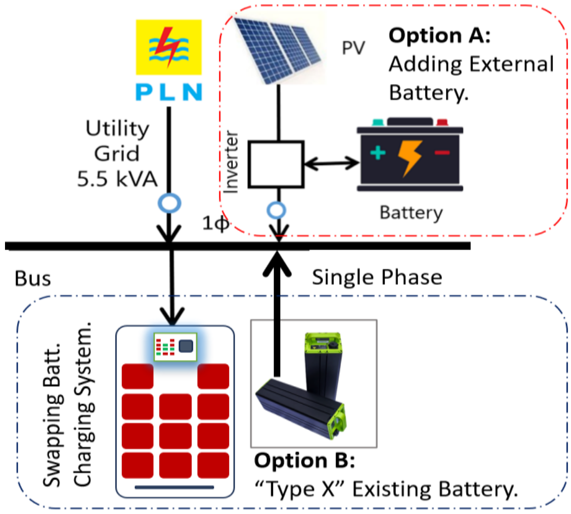

Fig. 1. Optional schematic diagram model design

TABLE IV. PV ECONOMIC ANALYSIS SIMULATION PARAMETERS

No	Design Cost Equipment	Cost (Million IDR)	
		Option A	Option B
1	PV Panel	11.75/kWp	11.75/kWp
2	Battery	3.25	0
3	Inverter	1.9	1.9
4	Battery Replacement	3.25	0
5	Inverter Replacement	1.9/kW	1.9/kW
6	O&M for SBSC System	0.5/year	0.5/year
7	Grid Power Price	0.1650/kWh	0.1650/kWh

TABLE V. HOMER INPUT PARAMETER SIMULATION

No	Component	Capacity	
		Option A	Option B
1	Photovoltaic	3 kWp	3 kWp
2	Battery	17.9 kWh	14 kWh
3	Inverter	3 kW	3 kW

TABLE VI. ELECTRICITY OUTPUT SIMULATION RESULT

No	Total Electricity Production	Electricity Output (kWh/year)	
		Option A	Option B
1	PV Production	4,556	4,556
2	Battery Energy Out	1,933	-
3	Inverter Energy Out	4,278	4,328
4	Inverter Losses	225	228,0
5	Grid Energy Purchased	539	2,376
6	Energy Sold/Grid Sales	708	2,595

TABLE VII. TECHNO-ECONOMIC HYBRID SIMULATION RESULT

No	Techno-economy	Cost (IDR)	
		Option A	Option B
1	Tot. Net Present Cost	107 M	90,9 M
2	CapEx	40,0 M	40,0 M
3	OpEx	5,59 M	4,39 M
4	Lev. Cost of Energy	1,753/kWh	1,169/kWh

establishing PV's economic viability. Energy savings in the planned on-grid PV system can lower grid power prices while also helping to save the environment by lowering greenhouse gas emissions[17]. According to market data from 2017, solar panel costs account for 47% of the planned rooftop PV installation cost, 13% for inverter expenses, and 40% for other supplementary components and installation services (see Table 4). As a result, the typical cost of rooftop PV installation is around IDR 25.000.000/kWp[18].

This assumptions of the "option A" (Fig.1) may focus on renewable energy schemes in the BSCS system with external batteries. For the simulation parameters, the capital cost to O&M price is calculated or assumed based on the cost assessment source. It should be noted that the capital cost information provided by Raiford (2020a) corresponds to $/kWh of energy available at 50% DOD for a lead-acid Battery Energy Storage System (BESS) made up of single cells, which is more expensive but has a longer cycle life[19]. To be consistent with other BESS, the capital cost of the SB is represented in this study as $/kWh of metered energy and $236/kWh for a single cell BESS, with rack expenses estimated at $70/kWh (30% of the SB cost). The 12 V battery module is anticipated to cost $100/kWh (Raiford, 2020c).

III. RESULT AND DISCUSSION

The overview in the economic study aims to simulate and optimize the grid-connected power generation system for system operation by providing energy balance calculations for in a year and estimating the system's installation and operation costs during its operating life.

A. *Grid Simulation Result*

In this study, what needs to be considered in the simulation architecture and optimization analysis is the type of energy source, energy potential data, and scenarios of the energy system. Then for the economic analysis, the scenarios include the cash discount rate for the real discount rate, the discount factor as the discount factor and the capital recovery factor for the capital recovery factor. Some factors that need to be considered as input in the software simulation are that the type of grid subscription is considered and selected as a cost consideration that forms the total cost in the system. The tariff class scheme entered is medium subscription (B-2/TR), regular and prepaid usage cost IDR 1,444.70/kWh for Gas Stations while regular and prepaid usage cost is assumed IDR 1,650.00/kWh for SBSC. The first factor is the capital recovery factor. This factor is a ratio used to compute the present value of an annuity (a series of annual cash flows). The interest rate used in HOMER is the real annual interest rate. This is the discount rate utilized during conversion. Second, consider Net Present Cost (NPC). NPC is the sum of all expenses incurred over a lifetime, minus the present value of all profits gained during that period. Capital costs, replacement costs, operation and maintenance costs, fuel costs, emission fines, and grid power purchase costs are all included. Cost The residual value generates money, as does the expense of selling power to grid. The PV, grid modeling scheme's findings with external and existing batteries in BSCS. This system is presented as a hybrid system with PV energy sources connected to batteries and the PLN grid, so that the battery and grid can function even when the PV is not performing well.

Table 5 shows the parameters for the simulation, which have been calculated beforehand. The selected PV panels refer to the existing libraries in the software. Grid sales are the sale of electrical energy to the grid. The simulation definitively calculates the total electrical energy generated by PV and sold to the grid. Grid sales are calculated using data on electrical energy generated by PV, the percentage of sales to the grid, and an economic analysis that includes costs and revenues from those sales. Table 6 shows that PV total production is 4,556 kWh/year, contributing 89.4% to the system in both system configurations. This is because the proposed design is the same 3 kWp. Following a year of simulation, the results can provide an annual summary of the electrical energy consumption of 4,109 kWh/year (AC primary load). This includes the total energy produced, the total energy consumed, and the ratio between production and consumption. The battery and inverter output determines the quantity of energy produced after deducting the PV system's losses and the efficiency of each component.

B. *Techno-economy Simulation Result*

The simulation's Annualized Capital Cost calculates the company's annualized capital cost by factoring in the initial capital of each component during the project's life. Levelized Cost of Energy (LCOE). The Levelized Cost of Energy is defined as the average cost per kWh of Electrical Energy Production used by the system, whereas operational and maintenance costs are the costs connected with the day-to-day operation and administration of a company, see Table 7. Hybrid systems in BSCS that use existing batteries have a lower LCOE of IDR 1,169/kWh, followed by hybrid systems with additional batteries at IDR 1,753/kWh. These findings demonstrate that the capital cost of purchasing new batteries will significantly contribute to the LCOE. Maintenance involves the importance of PV panel cleanliness, since dirt causes a 0.05% drop in production per day. As a result, it is preferable to adapt the cleaning schedule based on the rain, pollen, and bird seasons, and to clean the PV Panel with approved chemical agents. The O&M cost ranges from IDR 500,000.00 to IDR 1,000,000.00 per visit/system. and the design of PV Installation for up to 25 years is 50 visits (2 times per year) with notes based on the company's SOP (once every 6 months).

The Homer.pro-based techno-economic analysis study uses economic parameters based on the average BI Rate for the last 10 years, maximum inflation adjustment, lowest inflation value, and 3% with a 1.0% deviation from the finance minister's 2021 report. Sensitivity variables can be defined as a range of values. All variables with multiple values have a sensitivity feature next to them. The sensitivity button will be used to assess service life, inflation, and so on. Identification of economic studies for the potential utilization of various types of renewable energy as an energy source from BSCS requires the help of software simulations to support economic studies. Some of the things needed in the analysis are assisting in the design of micro power systems, facilitating the comparison of power generation technologies and modeling the physical behaviour of the power system and its life cycle costs (total cost of installing and operating the system during its lifetime) supported using tools from Homer.pro software. If adjusted into IDR, each $1 is equal to IDR 15,555.00 so we can multiply this value for parameter input in Homer software as a battery-specific analysis while for other PV system components (Photovoltaic Panels and Inverters) using uniform prices like some previous modeling. For the price of this type of battery in the market approximately ranges from IDR. 1,500,000.00 to IDR. 3,500,000.00 then the percentage is shown in capital cost, and replacement in Table 4. Replacement is also used for the battery because the maximum estimated useful life is only up to 15 years and inverter in 10 years. Economic data from a hybrid system designed to improve battery storage has been collected and modeled. Each scenario that has been conducted demonstrates that the existing battery system (Type X) on BSCS has the highest NPC, operational, and COE costs when compared to the design of the battery component. The simulation result displays the results of the energy system planning that has been made in the two scenarios above.

The comparison between energy sold and energy purchased in kWh units may be interpreted as follows, which is further displayed in Figure 2 and Figure 3. Sold energy is the entire amount of electrical energy generated by the generation system and sold back to the grid (e.g., PLN). In the HOMER simulation, this energy is computed using the production capacity of various renewable energy sources (in this example, PV systems) as well as total load consumption estimates. In this article, the hybrid system's total energy production for the desired scenario A is 539 kWh/year (see table 6), with a portion of this energy sold back to PLN for 708 kWh/year. Meanwhile, for scenario B, the average is 198 kWh/year. Paid energy is the quantity of electricity purchased from the grid to meet load requirements that the generating system cannot meet on its own. It comprises the cost of purchasing energy from the electricity provider based on the appropriate rate. In the same example, the total load consumption plus electricity sales in figure 2 demonstrate how

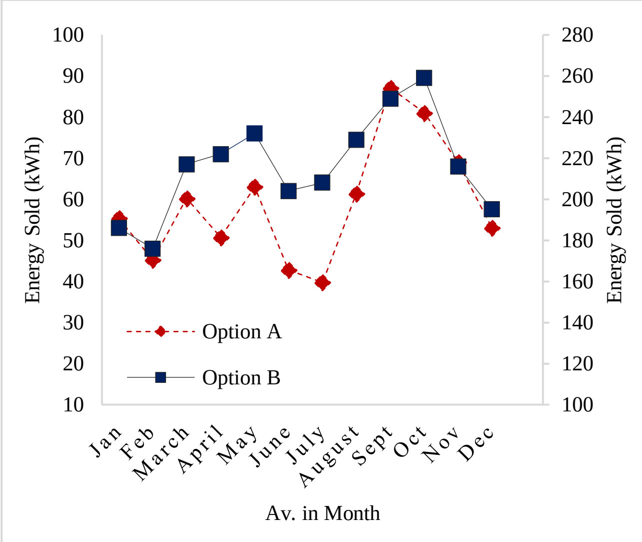

Fig. 2. Scenario energy sold comparison

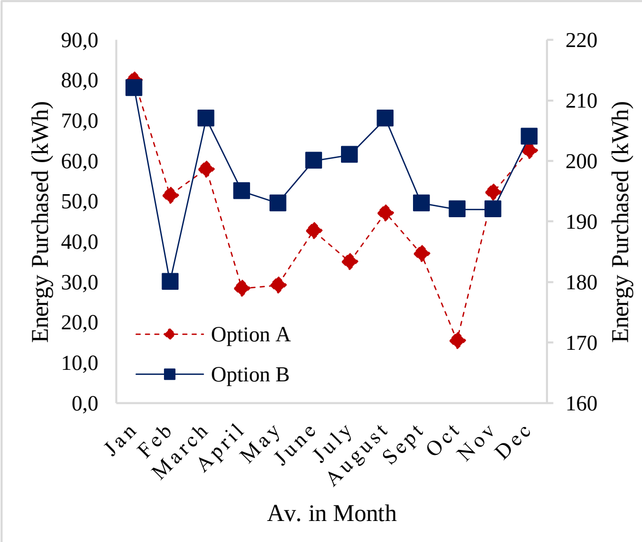

Fig. 3. Scenario energy purchased comparison

much energy the user must spend to meet the needs of the proposed system.

IV. Conclussion

According to the findings of the analysis of renewable energy systems and technologies that can be used as an energy source for the swapping battery charging system, the use of PV-based non-conventional sources is applicable at all gas stations where a swapping battery charging system is installed. The suggested PV energy hybrid-based system takes advantage of Indonesia's vast renewable energy potential from the sun, with lower investment costs than other RE sources. The use of PV-based can be implemented since, according to the studies that have been conducted, the use of PV can yield a substantially cheaper LCOE value than the use of grid electrical energy tariff L category. When simulating techno-economy studies, input costs include capital costs, replacement, O&M costs that have been changed and selected based on current conditions, and inflation values updated in recent years in accordance with the Minister of Finance's regulatory letters. The comparison of findings and values obtained is a description of the hybrid scheme (PV + battery + grid), based on multiple models and simulations performed on BSCS objects with both external and existing batteries.

The comparison of the results and the resulting values provides a more detailed description of the current on-grid-battery strategy (type X) that should be examined. As a result, a strategy is derived from many models and simulations performed on the aforementioned gas station object. The analytical link between energy produced and energy paid for provides insight into the efficiency of the generation system. If production (energy sold) exceeds consumption (energy purchased), the system can be deemed efficient and profitable.

REFERENCES

[1] International Renewable Energy Agency, *Indonesia Energy Transition Outlook 2022*, 2022nd ed. Abu Dhabi: International Renewable Energy Agency, 2022. doi: 10.7551/mitpress/9780262037419.003.0003.

[2] International Renewable Energy Agency, *Renewable Energy Statistics 2024*, 2024th ed. 2024. [Online]. Available: www.irena.org

[3] Traction Energy Asia, "Renewable Energy in Indonesia," 2019. Accessed: Dec. 14, 2023. [Online]. Available: https://tractionenergy.asia/wp-content/uploads/2020/12/Reports_-Renewable-Energy-in-Indonesia-Overview-Trends-Challenges-and-Opportunities-for-NZTE-Ourworks-Regional-Low-Carbon-Development-Low-Carbon-Development-Energy-Renewa.pdf

[4] Global wind energy council, "GWEC Global Wind Report 2022," Brussels, 2022. [Online]. Available: https://gwec.net/global-wind-report-2022/

[5] J. C. Adiatma, "A transition towards low carbon transportation in Indonesia: A Technological Perspective," Jakarta, 2020. [Online]. Available: https://iesr.or.id/en/pustaka/a-transition-towards-low-carbon-transport-in-indonesia-a-technological-perspective

[6] Climate Policy Implementation Check 2023, "Policy Instrument: General National Electricity Plan (RUKN) 2019 - 2023," 2023. Accessed: Dec. 15, 2023. [Online]. Available: https://www.climate-transparency.org/wp-content/uploads/2023/11/Implementation-Check-Indonesia-General-National-Electricity-Plan-Scorecard-2023.pdf

[7] S. Syafii, P. Anugrah, H. D. Laksono, and H. Yamashika, "Economic Feasibility Study on PV/Wind Hybrid Microgrids for Indonesia Remote Island Application," *TEM Journal*, vol. 10, no. 4, pp. 2001–2006, 2021, doi: 10.18421/TEM104-66.

[8] M. Zikra, H. D. Armono, and F. Pratama, "Wave modeling for the establishment potential area of offshore aquaculture in Indonesia," *Fluids*, vol. 5, no. 4, pp. 1–13, 2020, doi: 10.3390/fluids5040229.

[9] G. Pambudi and N. Nananukul, "Wind turbine site selection in Indonesia, based on a hierarchical dual data envelopment analysis model," *Energy Procedia*, vol. 158, pp. 3290–3295, 2019, doi: 10.1016/j.egypro.2019.01.980.

[10] J. Donker and X. Van Tilburg, "Three Indonesian Solar-powered Futures: Solar PV and Ambitious Climate Policy," 2019. [Online]. Available: https://ambitiontoaction.net/wp-content/uploads/2020/01/A2A-2019-Three-Indonesian-solar-powered-futures.pdf

[11] N. Heryana, H. R. Iskandar, and J. Furqani, "Utilization of Renewable Energy for Charging Station in Indonesia New Appointed Capital City, Nusantara," in *Proceedings of 2023 4th International Conference on High Voltage Engineering and Power Systems, ICHVEPS 2023*, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 460–465. doi: 10.1109/ICHVEPS58902.2023.10257531.

[12] Badan Standarisasi Nasional, *SNI 8928:2020*. Indonesia: www.bsn.go.id, 2020, pp. 1–17. Accessed: Sep. 02, 2024. [Online]. Available: www.bsn.go.id

[13] IEEE Standards Association, *IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems*, vol. 1013. IEEE, 2019. Accessed: Sep. 04, 2024. [Online]. Available: https://ieeexplore.ieee.org/document/8845030

[14] Y. Astriani, G. M. Shafiullah, M. Anda, and H. Hilal, "Techno-economic evaluation of utilizing a small-scale microgrid," *Energy Procedia*, vol. 158, pp. 3131–3137, 2019, doi: 10.1016/j.egypro.2019.01.1013.

[15] L. N. Xing, H. L. Xu, A. K. Sani, M. A. Hossain, and S. M. Muyeen, "Techno-economic and environmental assessment of the hybrid energy system considering electric and thermal loads," *Electronics (Switzerland)*, vol. 10, no. 24, 2021, doi: 10.3390/electronics10243136.

[16] S. L. Gbadamosi, F. S. Ogunje, S. T. Wara, and N. I. Nwulu, "Techno-Economic Evaluation of a Hybrid Energy System for an Educational Institution: A Case Study," *Energies (Basel)*, vol. 15, no. 15, pp. 1–12, 2022, doi: 10.3390/en15155606.

[17] M. Raman, P. Meena, V. Champa, V. Prema, and P. R. Mishra, "Techno-economic Assessment of Microgrid in Rural India Considering Incremental load Growth Over Years," *AIMS Energy*, vol. 10, no. 4, pp. 900–921, 2022, doi: 10.3934/energy.2022041.

[18] H. R. Iskandar, A. Nurfatah, A. Daelami, E. Taryana, and A. Yani, "Techno-economic Analysis and Optimization of Renewable Energy Forecasting at Universitas Jenderal Achmad Yani," *Jurnal ELECTRON*, vol. 4, no. 2, pp. 78–88, 2023, doi: https://doi.org/10.33019/electron.v4i2.52.

[19] K. Mongird, V. Viswanathan, J. Alam, C. Vartanian, V. Sprenkle, and R. Baxter, "2020 Grid Energy Storage Technology Cost and Performance Assessment," Richland, Dec. 2020. Accessed: Sep. 04, 2024. [Online]. Available: https://www.pnnl.gov/sites/default/files/media/file/Final%20-%20ESGC%20Cost%20Performance%20Report%2012-11-2020.pdf