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Techno-Economic Modeling of Hybrid PV-Hydroelectric Generator Systems in Semarang

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ABSTRACT

Though the most plentiful renewable energy, solar energy is not yet being used to its full potential. A growing number of industries are developing photovoltaic technology, which uses solar energy to create electricity. Furthermore, the integration of photovoltaic systems into residential areas in the form of Hybrid PV-hydroelectric generator technology has attracted significant attention. This study is dedicated to a meticulous economic evaluation of this hybrid system, utilizing a simulation methodology facilitated by the Hybrid Optimization Model for Electric Renewable (HOMER). The geographical scope of this simulation is Semarang, the provincial capital of Central Java. The outcomes of this investigation are auspicious, primarily attributed to the meticulous optimization of monthly energy production coupled with minimal maintenance costs and lucrative investment prospects. Through comprehensive simulations, the PV-Hydro generator system has emerged as the most suitable option for Semarang. This determination is founded upon an in-depth comparative analysis of energy output and economic viability. As a result of the feasibility research, the suggested system has an extremely short payback period of 2.41 years, a huge 76% Internal Rate of Return (IRR), and an astounding 55% Return on Investment (ROI).

1. INTRODUCTION

The need for electrical energy is an essential matter for today's modern society. The recent swift economic expansion and population surge are hastening the rise in electricity consumption [1]. According to the International Energy Agency (IEA)'s 2017 World Energy Outlook, the world's main energy consumption is expected to expand at a compound annual growth rate (CAGR) of 1.0% between 2016 and 2040. [2]. This is due to population growth and the increasing need for electrical energy, so the availability of this energy is essential for everyone [3]. However, using fossil fuels as a source of electrical energy is in the spotlight because it produces greenhouse gases, especially carbon dioxide, which plays a vital role in global warming. The impact is extreme climate change in various countries [4]. Thus, one of the most important ways to reduce the consequences of global warming is to generate power using renewable energy sources instead of fossil fuels [5].

Security problems related to technology, economy, and environment must be the main emphasis of policies pertaining to the use of innovative and renewable energy sources as a source of electrical energy [6]. Therefore, renewable energy can be used as an alternative energy solution to overcome the electricity crisis in the Indonesian archipelago [7]. When used to its full potential, solar energy is a cheap, plentiful, and clean renewable energy source [8]. Indonesia is a tropical area with a relatively sizeable light intensity and potential for renewable energy development of up to 112,000 GWp [9, 10].

Around 4.5 kWh/m^2/day of solar radiation is found in Indonesia's western area, whereas 5.1 kWh/m^2/day is found in its eastern part. As a result, Indonesia has a potential for solar radiation of about 4.8 kWh/m^2/day on average [7]. With an average speed of between two and seven meters per second, Indonesia offers a promising future for wind energy development. By using small- and medium-sized wind power facilities that are appropriate for Indonesia [8]. Indonesia began operating a 75 MW commercial wind power project in 2018. In the meanwhile, growth of 1800 MW is predicted by 2025 [9] to develop micro-hydro systems that have yet to be utilized by 8%. Hydro energy reaches 75 GW [11].

Solar energy has the most development potential and should be fully used, based on Indonesia's capability for producing power. Combining solar photovoltaic (PV) electricity with another controlled power source—like hydroelectric power—is a frequent strategy to make PV power more manageable and less disruptive to the grid [12], thermal power plant [13], hydroelectric generator with pump [14], and battery [15], being a system of hybridity. The energy source hydropower is economical, sustainable, and clean. Since it is highly adaptive, combining solar PV with large-capacity hydropower is seen to be an effective strategy for responding swiftly to variations in solar PV. In order to accept large-scale solar PV electricity [16].

According to the Central Java Province's 2018 electrification ratio, which was 85.29%, efforts are still required to fulfil the population's need for energy, mainly through the construction of micro-hydro and solar power facilities [17]. In order to characterize the possible use of a grid-connected PV-wind hydropower hybrid system, this research takes into account the load needs, potential for renewable energy, as well as the capacity and make-up of the power generating system in residential areas of Semarang, Central Java (Figure 1).

Figure 1. Residential area in Semarang

This research can solve the aforementioned issues by taking into account crucial elements including load needs, renewable energy potential, and the capacity and make-up of the power producing system. To calculate the time required to recoup investment, user fees and payback periods are also included in the techno-economic study [18]. The research aims to analyze and predict the profits from investing in a solar power generation system in Semarang over a specific period. Through this research, it is hoped to discover a hybrid system with the most profitable configuration and wide-ranging applications.

2. METHODOLOGY

HOMER is commonly used to conduct analyses related to investment opportunities in renewable energy development using feasibility analysis with adjustable project timelines [19, 20]. Investment opportunities in renewable energy, such as solar power, may foresee the possible profits or losses from the modeled system using projections supplied by HOMER. The investment estimates may offer a workable way to produce power in isolated locations without incurring undue expenses [21, 22]. The HOMER database is utilized to assess various geographic circumstances such as air temperature, wind speed, sun radiation, and urban loads [23-25]. PV system modeling is designed considering relevant components. Technical-economic analysis is valuable for evaluating several proposed schemes' most profitable system configurations and settings.

2.1 PV system design

Semarang is the capital of Central Java province with a large industrial area. Its location is highly strategic and accessible by land, sea, and air transportation. This easy accessibility has resulted in a high level of pollution, which needs to be reduced by implementing renewable energy [26]. The chosen research location is in the southern part of Semarang City. The implementation plan for the Hybrid PV-Hydroelectric Generator system is clearly illustrated in Figure 2, indicating that renewable energy can be a promising option to tackle pollution challenges and enhance environmental sustainability in this area.

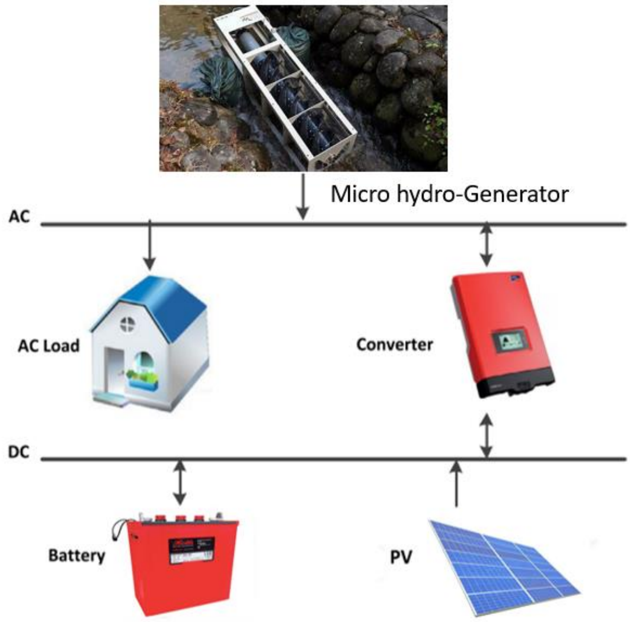

Figure 2. Configured hybrid photovoltaic system design

For the created system, the configured system period is projected to be 25 years. Based on the PV panels' anticipated lifetime and the assumption that they are maintained under ideal circumstances, this time estimate was created. Using HOMER's data for the Generic Flat PV model, a predicted return on investment study was carried out. Central Java's inflation rate was 5.22% in March 2023, according to the Central Statistics Agency (BPS) [27]. Moreover, in March 2023, BI's discount rate was 5.75% [28]. Figure 3 below displays the estimated value that was provided.

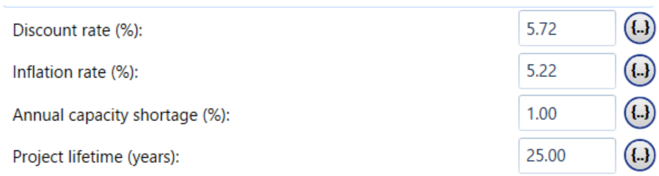

Figure 3. Yearly inflation

The PV size should, in general, be able to provide the peak power that the load requires. The unmet demand and the percentage of renewable energy in the system, among other system limits, determine the PV module's size. An inverter in a grid-connected photovoltaic system changes the direct current (DC) that the photovoltaic system produces into alternating current (AC), which may be sent to the load side [19]. Table 1 displays the technical and financial specifications of the different hybrid system components.

Table 1. Hybrid system components

Parameter	Capital (IDR)	Replacements (IDR)	O&M (IDR)	Lifetime
Generic Generators	248,000,000.00	135,000,000.00	6,754,000.00	20,000 hours
Converters	11,533,000.00	11,533,000.00	225,990.00	20 years
Battery	9,259,900.00	9,259,900.00	800,132.00	15 years
PV Arrays	35,198,000.00	35,198,000.00	119,652.00	25 years
Generic Hydro	159,845,000.00	118,423,000.00	6,795,000.00	30 years

2.2 Data collections

The HOMER has certified the projected load of power consumption for residential areas in Semarang. Assuming an average daily consumption of 11.26 kWh in Indonesia and a maximum peak load of 2.09 kW, the average consumption load is calculated for the Semarang region [29]. According to Figure 4, the utilization burden is computed on a monthly basis.

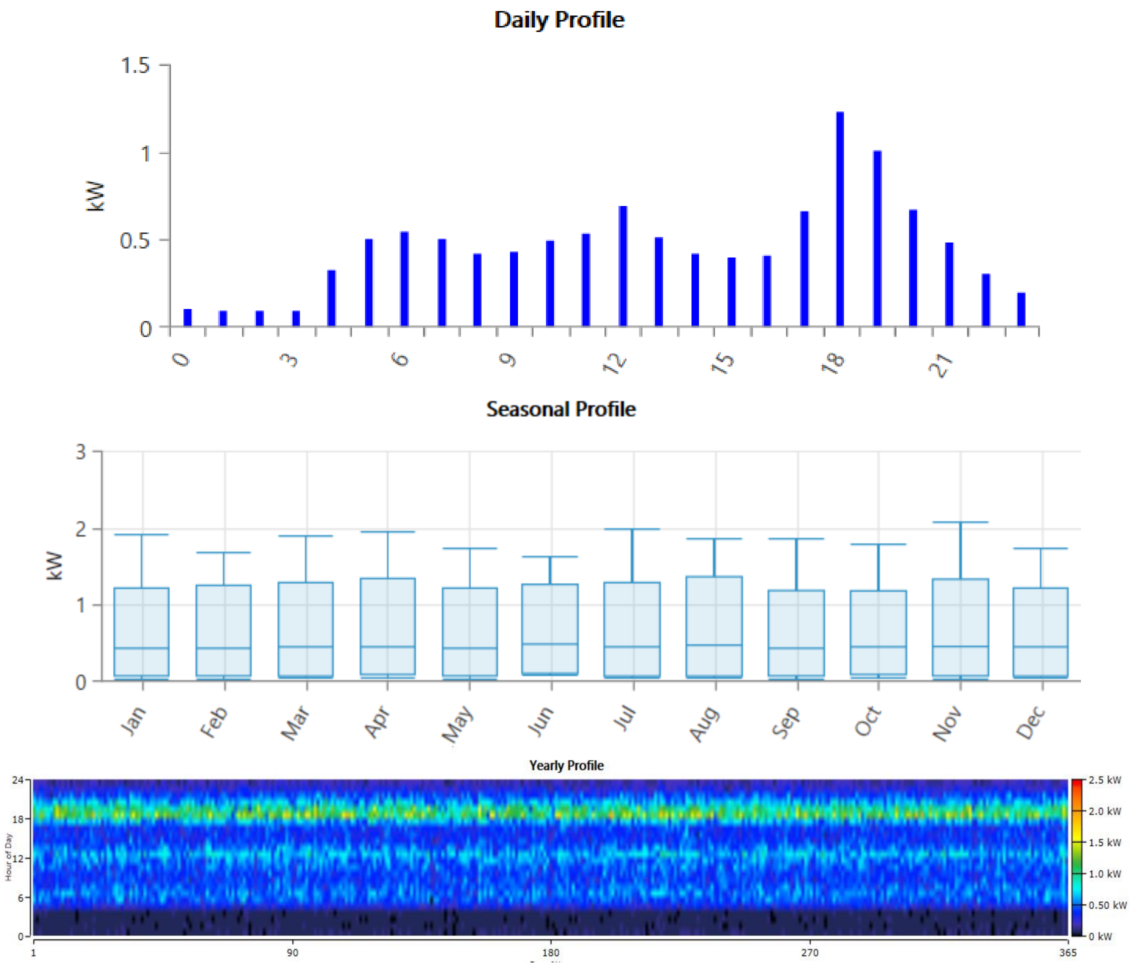

Figure 4. Semarang's electrical load

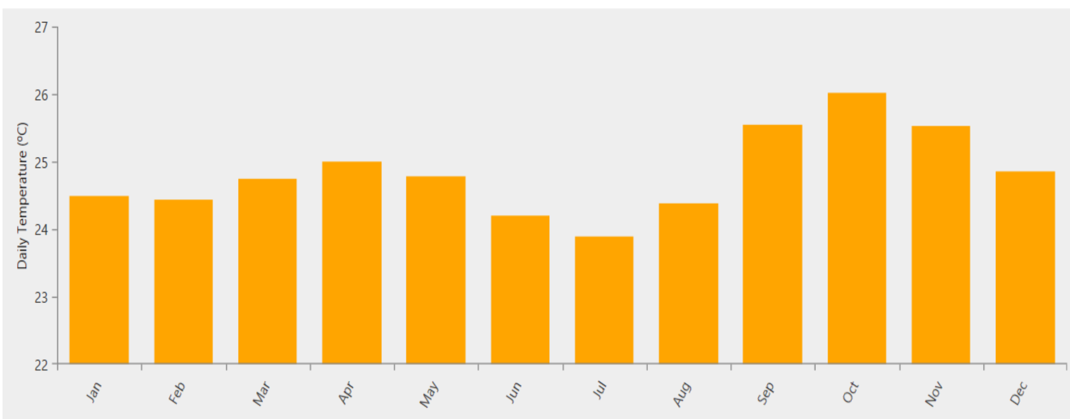

Figure 5. Average monthly temperature

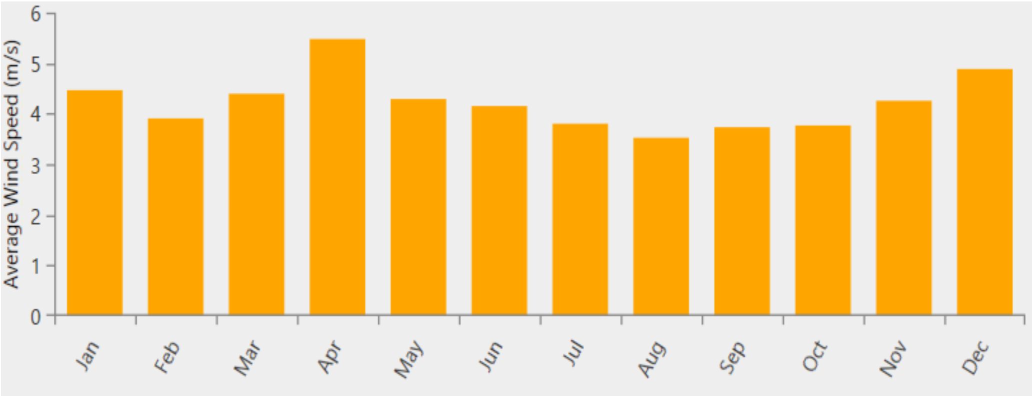

Figure 6. Average monthly wind speed

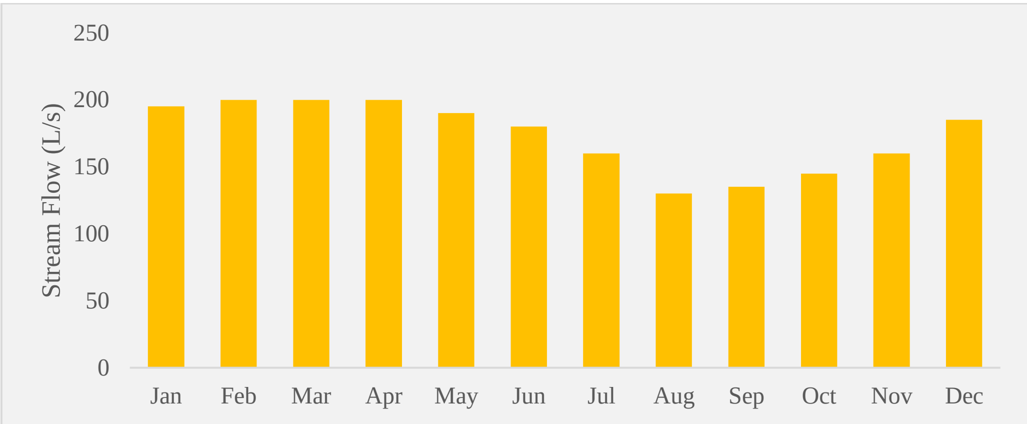

Figure 7. Average stream flow per month (L/s)

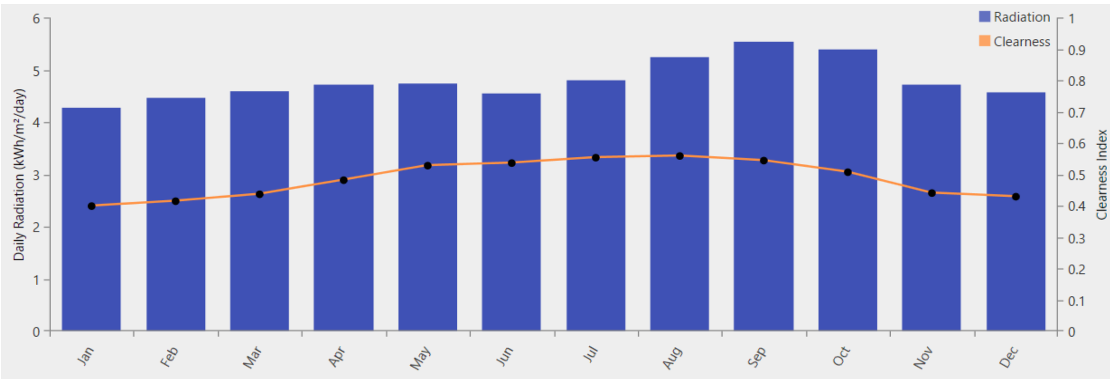

Figure 8. Monthly average radiation intensity

Through Design Homer Pro's Resources tool, you may get information on solar radiation, wind speed, water flow velocity, and ambient temperature in the South Semarang location that was derived from NASA Predictions of Worldwide Energy Resources. Monthly averages for global radiation during a 22-year period, average air temperature over a 30-year period, and average wind speeds at 50 meters above Earth's surface are provided by this feature [30]. The average temperature in the southern Semarang residential area is depicted in Figure 5. The average yearly temperature in this area is 24.82°C. October saw the greatest temperature of 26.01°C, while July saw the lowest temperature of 23.89°C. The wind speed in this residential area is shown in Figure 6. Wind speed on average is 4.22 m/s per year. The windiest month was August with 3.72 m/s, while the highest, 4.88 m/s, was recorded in December. The water flow velocity in this location, with an annual average of 173.33 (L/s), is depicted in Figure 7. Meanwhile, Semarang's average solar radiation is seen in Figure 8. The sun radiation average per year is 4.80 kWh/m^2/day. On September 5, the radiation level was at its peak.

2.3 Techno-economic analysis

The HOMER application's simulation results yield economic analysis. The cost of capital owned (IDR), the cost of replacing components (IDR), and the cost of operation and maintenance (IDR/year) all go into the price of a PV series. In the HOMER simulation process, economic value is crucial since it determines the system configuration with the lowest Net Present Cost (NPC) through operational procedure. The following formula is used by HOMER to determine this [31]:

$$\text{CNPC}=\frac{C_{ann,tot}}{CRF.i.Rproj} \quad (1)$$

where, C_{ann}, *tot*: Total annual fees (IDR/year); *CRF*: Capital recovery factor; *i*: Interest rates; *IDRproj*: age/service life (years).

The remaining amount in the HES component is known as the salvage value. This had a big impact when the project was finished. NPC and was computed in this way [32]:

$$SC=Cr\frac{L_{rem}}{L_{com}} \quad (2)$$

where, *cr*: Replacement Cost (IDR); L_{rem}: Remaining life of the component (years); L_{com}: Component lifetime (year).

The average cost per kWh of useable electrical energy generated by the system is known as the Cost of Energy, or COE. The formula for COE is as follows [33]:

$$COE=\frac{C_{ann,tot}}{L_{prim,AC}+L_{prim,DC}} \quad (3)$$

The AC and DC loads on the system are denoted by Lprim, AC and Lprim, DC. HOMER is capable of doing a techno-economic analysis of the system assessment by taking into account several factors related to Eqs. (1) and (3). Over a 25-year period, energy optimization and return analysis are also conducted. With up-to-date data, HOMER can perform all computations and power collecting procedures.

3. RESULT

The findings of the techno-economic study and the optimization of solar PV combined with generators are covered in this part. First, the optimization findings are described; next, the techno-economic analysis results are briefly provided.

3.1 Electrical generation

The suggested plan is put together before running a HOMER simulation. The precise specs and pricing of the suggested hybrid PV-hydroelectric generator systems are available for every pre-specified location. As seen in Figure 9, the system linked to the main grid is made up of PV panels, micro hydrogenerators, converters, and batteries. The system optimization and techno-economic analysis results in the southern half of the Semarang residential area show that this system can work appropriately based on the environmental circumstances that have been carried out.

The power output produced by the solar panels utilized is displayed in Figure 10. With excellent results from 07.00 to 17.00 in that time zone, the average nominal power output per day in this system is 1.31 kW, with a daily production potential of up to 31.3 kWh/d. Has a 11,438 kWh yearly output. The output power simulation results for this system using the Homer program are displayed in Table 2.

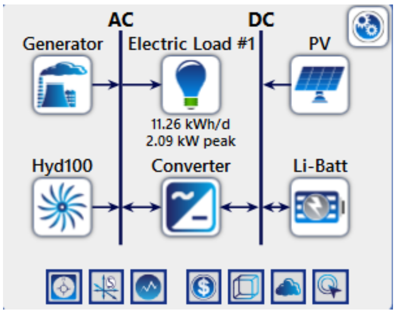

Figure 9. Designed hybrid system configuration

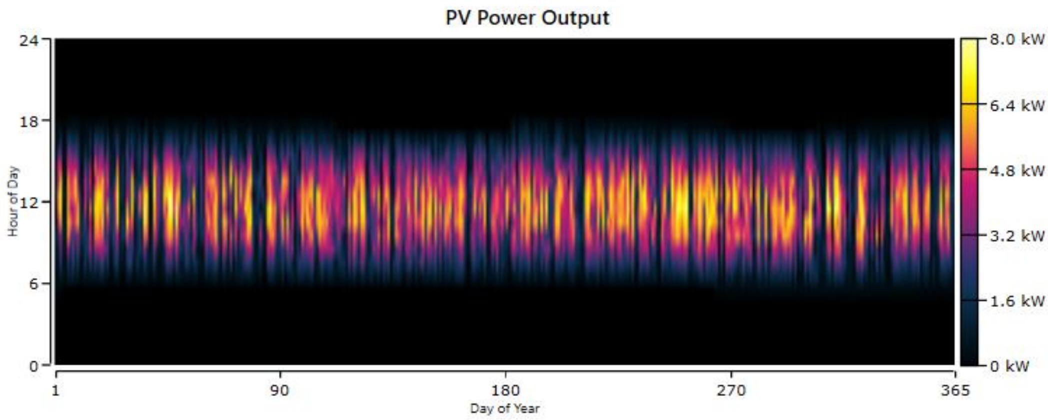

Figure 10. Solar PV outputs

Table 2. PV output values

Quantity	Value
Rated Capacity	8.11 kW
Mean Output	1.31 kW
Mean Output(daily)	31.3 kWh/d
Capacity Factor	16.1%
Total Production	11,438 kWh/yr

The diesel system combined with PV, on the other hand, has a maximum output power of 2.09 kW and an average output power of 0.469 kW. A typical diesel generator with a capacity factor of 21.8%, as indicated in Table 3, has an annual production of Figure 11.

Table 3. Generator output value

Quantity	Value
Capacity	2,299 kW
Mean Output	3.06 kW
Maximum Output	4.07 kW
Capacity Factor	2.62%
Hours of Operation	8,757 hrs/yr
Energy Production	11,576 kWh/yr

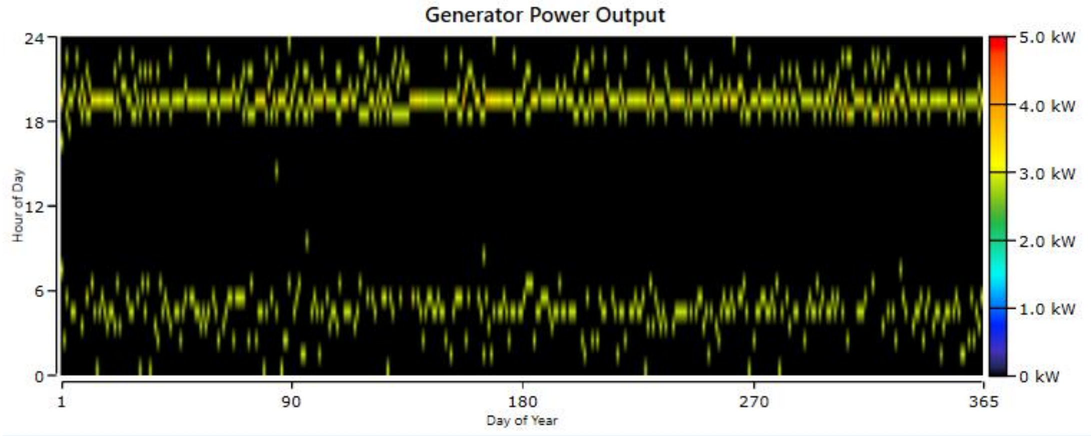

Figure 11. Micro hybrid-generator output

3.2 Economic feasibility

A critical feasibility assessment is conducted as an economic analysis to test the project's financial feasibility within the proposed timeframe. In addition, this economic feasibility test is also helpful as a comparison between the costs that must be incurred and the benefits that will be obtained. Three important factors need to be taken into account while doing a feasibility analysis: initial investment, return on investment (ROI), and internal rate of return (IRR).

Comparison between the main components of economic feasibility projected by the system for 25 years obtained a ratio of 55% ROI and 76% IRR. Besides that, for 2.4 years, simple payback can be obtained periodically. In addition, it is essential to compare several other economic matrices as an index for the feasibility test of the proposed system. NPC, CAPEX, and OPEX can be used as considerations in this electricity generation system, while the effects of emissions also need to be considered, as shown in Table 4.

The suggested system has strong test feasibility and a lot of promise, as seen by Table 4's reduced total NPC when compared to the standard system [21]. As demonstrated in Figure 12 by a drop in investment expenses over the duration of the system's operation. Additionally, Table 5 provides information on the overall cost of NPC in residential areas of Semarang, the southern metropolis, during the course of the system's 25-year deployment.

Table 4. Economic comparison of systems

Name	Base System	Proposed System
Net Present Cost	IDR 1.52B	IDR 659M
CAPEX	IDR 284B	IDR 332B
OPEX	IDR 52.7M	IDR 13.9B
LCOE (per kWh)	IDR 15,763	IDR 6,822
CO_2 Emitted (kg/yr)	35,755	3,098
Fuel Consumption (L/yr)	13,578	1.176

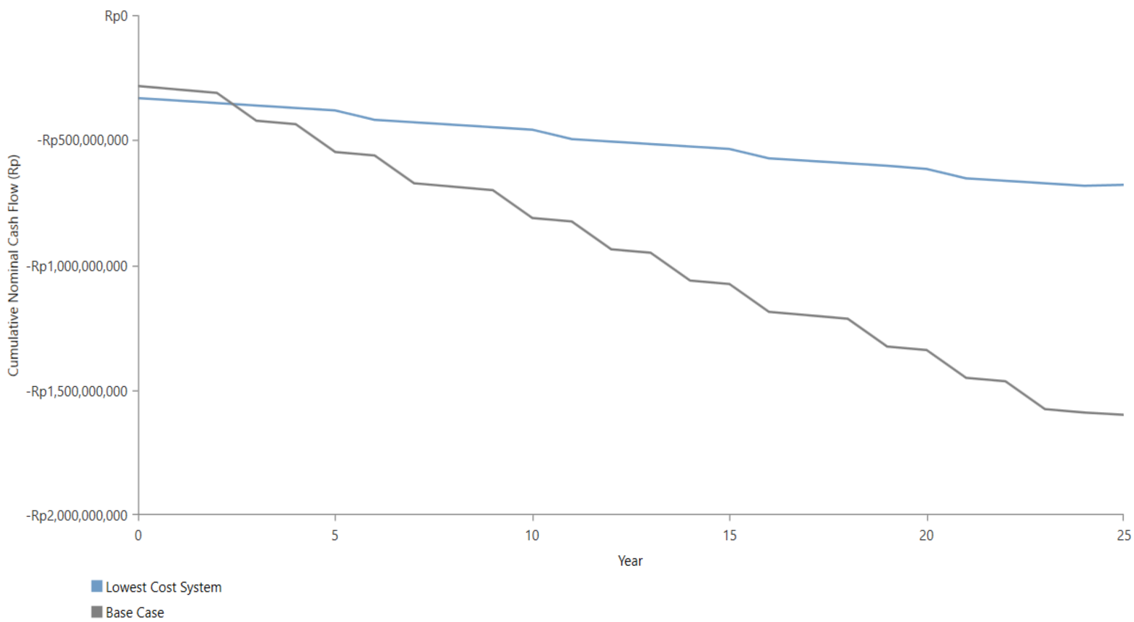

Figure 12. Comparison of hybrid PV-hydroelectric generator systems

Based on the NPC cost figures in Table 5, an IDR 659 million total system cost and an IDR 232 million yearly running cost are determined. Furthermore, a value per kWh of IDR 6,822 is attained for the energy expenses optimized using the technology. This power is produced for 56% less money than the base system's electricity. Table 6 illustrates how

HOMER may compute the precise yearly expenses of utilizing the PV-hydroelectric generator hybrid system components in addition to the NPC's overall cost.

Table 6 provides a breakdown of all NPC expenses incurred during the course of the 25-year HRES system. The average annual cost of using components is displayed in Table 5. Annual Operating and Maintenance Costs: IDR 2,400,396.00 for batteries; IDR 4,606.00 for generator; IDR 6,795,000.00 for generic hydro; and IDR 864,497.50 for converter. It is well known that, as compared to other components, Generic Hydro has the highest O&M expenditures. Based on the projected project timeframe, PV panels and generators have a 25-year lifespan, thus component replacement is not necessary. With a 15-year lifespan, a new battery would set you back IDR 4,438,288.

Table 5. Details of the total cost of the NPC

Name	Capital	Operating	Replacement	Salvage	Resources	Total
Converters	IDR 2.88B	IDR 1.33B	IDR 2.62B	-IDR 1.92B	IDR0.00	IDR 4.91B
Generator	IDR 124B	IDR. 14.1 B	IDR0.00	-IDR 5.20M	IDR 11,068	IDR 133B
Generic Hydro	IDR 160 B	IDR 160 B	IDR0.00	IDR0.00	IDR0.00	IDR 320M
Battery	IDR 27.8B	IDR 56.5M	IDR 105B	-IDR 4.84M	IDR0.00	IDR 184B
PV	IDR 17.8B	IDR0.00	IDR0.00	IDR0.00	IDR0.00	IDR 17.8B
System	IDR 332B	IDR 232B	IDR 107B	-IDR 12.0M	IDR 11,068	IDR 659M

Table 6. Details of the cost of using components every year

Name	Capital	Operating	Replacement	Salvage	Resources	Total
Converters	IDR 1.12B	IDR864,498	IDR 111,500	-IDR 81,666	IDR0.00	IDR 208,921
Generator	IDR 5.27B	IDR 4.61B	IDR0.00	-IDR 220,931	IDR470.58	IDR 5.65B
Generic Hydro	IDR 6.80M	IDR 6.79B	IDR0.00	IDR0.00	IDR0.00	IDR 13.6M
Battery	IDR 1.18B	IDR 2.40B	IDR 4.44B	-IDR 205,815	IDR0.00	IDR 7.82B
PV	IDR 758,342	IDR0.00	IDR0.00	IDR0.00	IDR0.00	IDR 758,342
System	IDR. 15.1 B	IDR 10.45M	IDR 4.56B	-IDR 508,412	IDR470.58	IDR 28.0M

There is an output power analysis in addition to the cost analysis. Figure 13 displays the monthly power generation from the PV-Hydroelectric Generator panel. This picture illustrates how monthly geographical circumstances affect the amount of power generated by the PV panels, as Figures 5-8 indicate 13,737 kWh of power are produced annually in total. The amount of clean energy produced annually by PV panels and hydro-generators amounts to 11,438 kWh, or 16.7% of total energy produced.

Based on the outcomes of the HOMER software simulation, it is possible to install a hybrid power generating system in this residential section of the city that combines solar energy, generators, and micro-hydro energy. Because the other major components have a longer lifespan and more operating hours than the project, only a small amount of maintenance will be needed during the course of the project's 25-year duration.

Sensitivity analysis is conducted to anticipate potential future value changes. Major sensitivity factors in the hybrid power system configuration involve daily load consumption and fuel prices. Fuel prices are assumed to experience annual inflation at predetermined rates, and daily load projections are made for the next 25 years based on HOMER data from previous decades. Simulation results indicate that in terms of project cost flow, hybrid power system components will add value in the project's final stage. In the future, investment costs for hybrid system components can be reduced by enhancing efficiency compared to conventional systems. This will further enhance the appeal of hybrid systems over time due to their reliability, continuous operation, and low pollution levels.

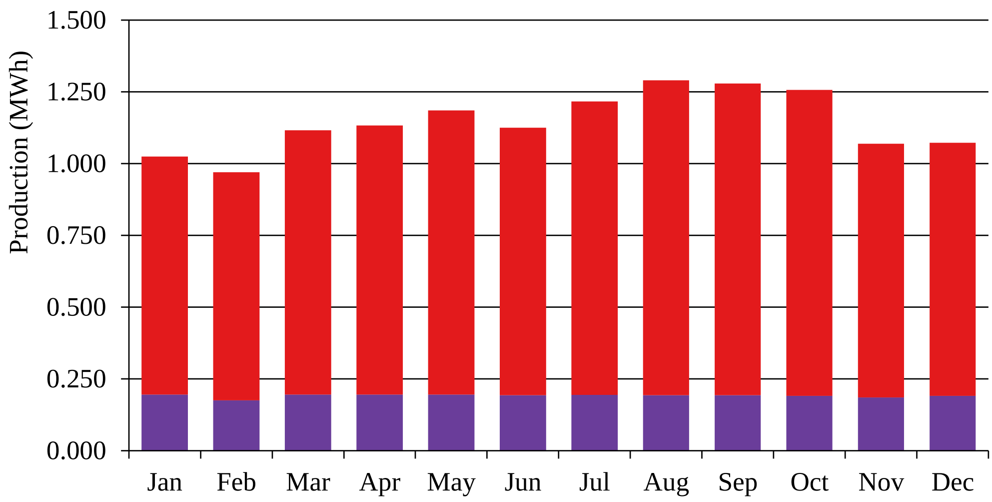

Figure 13. Monthly electricity production

4. CONCLUSIONS

This study compares the costs and benefits of installing solar panels with a hybrid PV-hydro generator system. The outcomes demonstrate that the hybrid system has lower investment costs and is more lucrative. While the conventional system can reach 1.52 billion IDR with an annual inflation rate not surpassing 5.22%, the hybrid system has a total cost of 659 million IDR. According to tests of economic viability, the hybrid system may make up to 56% in profit. The feasibility analysis yielded compelling results, showing a noteworthy 76% Internal Rate of Return (IRR), an excellent 55% Return on Investment (ROI), and an exceptionally quick payback period of 2.41 years for the proposed system.

Based on some results simulated using HOMER, the PV-hydroelectric generator hybrid system can produce even more impressive profits, with the energy produced per year reaching 13,737 kWh. This research is expected to aid in exploring the use of solar energy alongside other renewable energy sources, modelling the most suitable hybrid system while considering supportive geographic potentials. Moreover, surplus electricity can also be sold to help reduce conventional electricity production capacity. Several configurations can be developed more variably, focusing on higher profits and broader applications. However, it is essential to note that different geographical conditions pose a challenge in developing this hybrid system.

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REFERENCES

[1] Kim, T.Y., Cho, S.B. (2019). Predicting residential energy consumption using CNN-LSTM neural networks. Energy, 182: 72-81. https://doi.org/10.1016/j.energy.2019.05.230

[2] Sieminsky, A. (2014). International energy outlook. Outlook, 70-99.

[3] Xu, A., Awalin, L.J., Al-Khaykan, A., Fard, H.F., Alhamrouni, I., Salem, M. (2023). Techno-economic and environmental study of optimum hybrid renewable systems, including PV/Wind/Gen/Battery, with various components to find the best renewable combination for ponorogo regency, East Java, Indonesia. Sustainability, 15(3): 1802. https://doi.org/10.3390/su15031802

[4] Riayatsyah, T.M.I., Geumpana, T.A., Fattah, I.R., Mahlia, T.I. (2022). Techno-economic analysis of hybrid diesel generators and renewable energy for a remote island in the Indian Ocean using HOMER Pro. Sustainability, 14(16): 9846. https://doi.org/10.3390/su14169846

[5] Riayatsyah, T.M.I., Geumpana, T.A., Fattah, I.R., Rizal, S., Mahlia, T.I. (2022). Techno-economic analysis and optimisation of campus grid-connected hybrid renewable energy system using HOMER grid. Sustainability, 14(13): 7735. https://doi.org/10.3390/su14137735

[6] Elkadeem, M.R., Wang, S., Sharshir, S.W., Atia, E.G. (2019). Feasibility analysis and techno-economic design of grid-isolated hybrid renewable energy system for electrification of agriculture and irrigation area: A case study in Dongola, Sudan. Energy Conversion and Management, 196: 1453-1478. https://doi.org/10.1016/j.enconman.2019.06.085

[7] Jaelani, A., Firdaus, S., Jumena, J. (2017). Renewable energy policy in Indonesia: The Qur'anic scientific signals in Islamic economics perspective. International Journal of Energy Economics and Policy, 7(4).

[8] AlJuhani, M., Gomaa, M.R., Mandourah, T.S., Oreijah, M.M. (2021). The environmental effects on the photovoltaic panel power: Jeddah case study. Journal of Mechanical Engineering Research and Developments, 44(6): 251-262.

[9] Yuliani, D. (2016). Is feed-in-tariff policy effective for increasing deployment of renewable energy in Indonesia? The Political Economy of Clean Energy Transitions, Oxford University Press, 144.

[10] Arifin, Z., Tribhuwana, B.A., Kristiawan, B., Tjahjana, D.D.D.P., Hadi, S., Rachmanto, R.A., Prasetyo, S.D., Hijriawan, M. (2022). The effect of soybean wax as a phase change material on the cooling performance of photovoltaic solar panel. International Journal of Heat and Technology, 40(1): 326-332. https://doi.org/10.18280/ijht.400139

[11] Gokhale, P., Date, A., Akbarzadeh, A., Bismantolo, P., Suryono, A.F., Mainil, A.K., Nuramal, A. (2017). A review on micro hydropower in Indonesia. Energy Procedia, 110: 316-321. https://doi.org/10.1016/j.egypro.2017.03.146

[12] Yuan, W., Liu, Z., Su, C., Wang, X. (2020). Photovoltaic capacity optimization of small and medium-sized hydro-photovoltaic hybrid energy systems considering multiple uncertainties. Journal of Cleaner Production, 276: 124170. https://doi.org/10.1016/j.jclepro.2020.124170

[13] Singh, P., Mudgal, V., Khanna, S., Mallick, T.K., Reddy, K.S. (2020). Experimental investigation of solar photovoltaic panel integrated with phase change material and multiple conductivity-enhancing-containers. Energy, 205: 118047. https://doi.org/10.1016/j.energy.2020.118047

[14] Al-Masri, H.M., Magableh, S.K., Abuelrub, A., Saadeh, O., Ehsani, M. (2020). Impact of different photovoltaic models on the design of a combined solar array and pumped hydro storage system. Applied Sciences, 10(10): 3650. https://doi.org/10.3390/app10103650

[15] Beck, T., Kondziella, H., Huard, G., Bruckner, T. (2016). Assessing the influence of the temporal resolution of electrical load and PV generation profiles on self-consumption and sizing of PV-battery systems. Applied Energy, 173: 331-342. https://doi.org/10.1016/j.apenergy.2016.04.050

[16] Lian, J., Zhang, Y., Ma, C., Yang, Y., Chaima, E. (2019). A review on recent sizing methodologies of hybrid renewable energy systems. Energy Conversion and Management, 199: 112027. https://doi.org/10.1016/j.enconman.2019.112027

[17] Syahputra, R., Soesanti, I. (2020). Planning of hybrid micro-hydro and solar photovoltaic systems for rural areas of central Java, Indonesia. Journal of Electrical and Computer Engineering, 2020: 5972342. https://doi.org/10.1155/2020/5972342

[18] Xu, X., Wei, Z., Ji, Q., Wang, C., Gao, G. (2019). Global renewable energy development: Influencing factors, trend predictions and countermeasures. Resources Policy, 63: 101470. https://doi.org/10.1016/j.resouIDRol.2019.101470

[19] Al Garni, H., Awasthi, A. (2017). Techno-economic feasibility analysis of a solar PV grid-connected system with different tracking using HOMER software. In 2017 IEEE International Conference on Smart Energy Grid Engineering (SEGE), Oshawa, ON, Canada, pp. 217-222. https://doi.org/10.1109/SEGE.2017.8052801

[20] Rachmanto, R.A., Regannanta, F.J., Arifin, Z., Widhiyanuriyawan, D., Yohana, E., Prasetyo, S.D. (2023). Analysis development of public electric vehicle charging stations using on-grid solar power plants in Indonesia. International Journal of Transport Development and Integration, 7(3): 215-222. https://doi.org/10.18280/ijtdi.070305

[21] Aditya, I.A., Aisyah, S., Simaremare, A.A. (2021). Optimal sizing and sensitivity analysis of hybrid renewable energy systems: A case of Ur Island in Indonesia. IOP Conference Series: Materials Science and Engineering, 1098(4): 042049. https://doi.org/10.1088/1757-899x/1098/4/042049

[22] Rachmanto, R.A., Juwana, W.E., Akbar, A., Prasetyo, S.D., Bangun, W.B., Arifin, Z. (2023). Economic analysis of on-grid photovoltaic-generator hybrid energy systems for rural electrification in Indonesia. International Journal of Sustainable Development and Planning, 18(9): 2967-2973. https://doi.org/10.18280/ijsdp.180935

[23] Tjahjana, D.D.D.P., Suyitno, Rachmanto, R.A., Juwana, W.E., Prasojo, Y.J., Prasetyo, S.D., Arifin, Z. (2023). Economic feasibility of a PV-wind hybrid microgrid system for off-grid electrification in Papua, Indonesia. International Journal of Design & Nature and Ecodynamics, 18(4): 811-818. https://doi.org/10.18280/ijdne.180407

[24] Juwana, W.E., Rachmanto, R.A., Alfaiz, N.F., Prasetyo, S.D., Arifin, Z. (2023). Economic analysis of PV-generator hybrid off-grid systems in underdeveloped Indonesian Regions. Journal Européen des Systèmes Automatisés, 56(4): 519-527. https://doi.org/10.18280/jesa.560401

[25] Arifin, Z., Rosli, M.A.M., Prasojo, Y.J., Alfaiz, N.F., Prasetyo, S.D., Mulyani, W. (2023). Economic feasibility investigation of on-grid and off-grid solar photovoltaic system installation in central Java. International Journal of Energy Production and Management, 8(3): 169-175. https://doi.org/10.18280/ijepm.080305

[26] Subiyanto, S., Ramadhanis, Z., Baktiar, A.H. (2018). Integration of remote sensing technology using sentinel-2A satellite images for fertilization and water pollution analysis in estuaries inlet of Semarang eastern flood canal. E3S Web of Conferences, 31: 12008. https://doi.org/10.1051/e3sconf/20183112008

[27] Badan Pusat Statistik. (2023). Maret 2023 Perkembangan Indeks Harga Konsumen Gabungan Enam Kota di Jawa Tengah mengalami Inflasi sebesar 0,19 persen. dengan Inflasi tertinggi di Kota Kudus sebesar 0,25 persen.

[28] Badan Pusat Statistik. (2023). Bank Indonesia Rate 2023.

[29] Arifin, Z., Tjahjana, D.P., Danardono, D., Muqoffa, M., Prasetyo, S.D., Alfaiz, N.F., Sanusi, A. (2022). Grid-connected hybrid PV-wind system simulation in urban Java. Journal Européen des Systèmes Automatisés, 55(4): 477-483. https://doi.org/10.18280/jesa.550406

[30] Panhwar, I., Sahito, A.R., Dursun, S. (2017). Designing off-grid and on-grid renewable energy systems using HOMER Pro Software. Journal of International Environmental Application and Science, 12(4): 270-276.

[31] Türkay, B.E., Telli, A.Y. (2011). Economic analysis of standalone and grid connected hybrid energy systems. Renewable Energy, 36(7): 1931-1943. https://doi.org/10.1016/j.renene.2010.12.007

[32] Aziz, A.S., Tajuddin, M.F.N., Adzman, M.R., Mohammed, M.F., Ramli, M.A.M. (2020). Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq. Energy, 191: 116591. https://doi.org/10.1016/j.energy.2019.116591

[33] Rezzouk, H., Mellit, A. (2015). Feasibility study and sensitivity analysis of a stand-alone photovoltaic–diesel–battery hybrid energy system in the north of Algeria. Renewable and Sustainable Energy Reviews, 43: 1134-1150. https://doi.org/10.1016/j.rser.2014.11.103