JURNAL PENELITIAN Saintek
Volume 31, Nomor 1, 2026 (1-8) p-ISSN:1412-3991 | e-ISSN: 2528-7036

Optimization of Singkarak hydropower outflow for renewable micro hydropower development

Rosnita Rauf*, Harry Setya Hadi, Hazlif Najif
Ekasakti University, Indonesia
Corresponding Email: ekasakti5974@gmail.com

Abstract: The government's initiative to enhance energy resilience and independence include the augmented use of green energy. PLTA Singkarak is a renewable energy facility that harnesses water from Lake Singkarak to operate its turbines, featuring an average tailrace discharge of 30 m^3/s. The Singkarak Hydroelectric Power Plant receives its energy from PLN's Singkarak Substation, utilizing a 5 MVA transformer for distribution to meet its own consumption needs. Consequently, each month, the Singkarak Hydroelectric Power Plant must diminish its total kWH output by its own use, averaging 4,127.8 kW each day. A small-scale Micro Hydro power plant will be developed to utilize the potential water source at the outflow of the Singakrak Hydroelectric Power Plant, serving as the primary supply for the facility and so decreasing the company's performance target for its own consumption. A sufficiently big outflow tailrace discharge is likely to be repurposed for a micro-hydropower plant. The initial elevation of the Singkarak Hydroelectric Power Plant tailrace exit is 71 meters above sea level, whereas the end elevation is 67 meters above sea level, according to hand measurements. A micro-hydropower plant (PLTMH) can be engineered with a net head of 3.8 m and a flow rate of 10,618 m^3/s, yielding a maximum power output of 327.8 kW. The turbine employed is a Kaplan turbine, while the generator utilized is a 3-phase synchronous generator, with both components functioning at 1000 rpm .This PLTMH design can supplant the self-consumption of the Singkarak hydropower plant (PLTA), hence enhancing the system's energy efficiency.

Keywords: *hydroelectric, tailrace, hydropower, turbine, generator*

How to Cite (APA 7th Style): Rauf, R., Hadi, H. S., & Najif, H. (2026). Optimization of Singkarak hydropower outflow for renewable micro hydropower development. Jurnal Penelitian Saintek, 31(1), 1–8. https://doi.org/10.21831/jps.v30i1.95116

INTRODUCTION

The increased utilization of green energy is the government's effort to maintain energy resilience and independence (Upadhyay et al., 2024). This study will discuss the potential of green energy in Indonesia, specifically in the West Sumatra region, particularly in Asam Pulau, Kecamatan 2 x 11 Enam Lingkuang, Padang Pariaman Regency. In that area, there is potential energy from the residual water usage or Outflow from the electricity consumption of the Singkarak Hydroelectric Power Plant, as well as the disposal location adjacent to the flow from Batang Anai. The Singkarak Hydroelectric Power Plant is one of the hydroelectric power plants under the auspices of PT PLN (Persero) UPK Bukittinggi with a maximum capacity of 4 x 43.5 MW. The Singkarak Hydroelectric Power Plant utilizes water from Lake Singkarak as the main material to rotate the turbines with an average inflow of 50 m3/s and an average outflow of 30 m3/s.

In order to support the optimal operation of Common equipment at the Singkarak Hydroelectric Power Plant, the Singkarak Hydroelectric Power Plant utilizes Power Supply directly from PLN electricity, namely GI Singkarak, as the main supply for the Control Building. The recording of KWh transactions is carried out on the 1st of each month between the GI Singkarak staff and the PLTA Singkarak operation staff as an attachment to the monthly report.

Based on the potential water resources found in the outflow of the Singkarak Hydroelectric Power Plant, a small-scale power generation (Micro Hydro) has been designed to become the main supply for the Singkarak Hydroelectric Power Plant, thereby reducing the company's performance target for Self-Consumption (Gallego-Castillo et al., 2021).

This research, introduces an analytical methodology for assessing the capacity of run-of-river power plants to optimize energy production and economic profitability (Alonso-Travesset et al., 2022). He employs a miniature hydroelectric power facility in Italy to illustrate its potential as a design instrument (Shahzad et al., 2022). This model offers insights into the hydrological and economic regulation of optimal plant capacity, aiding in the identification of policy initiatives to bridge the disparity between economic and energy optimization of run-of-river plants (Yuvaraj et al., 2025). The run-of-river system for medium size can manage disturbances such garbage, however mini-hydro employs a penstock because to the longer channel compared to medium-scale hydro (Basso & Botter, 2012).

In this article, the discussion is about Planning Complexity, covering technical, environmental, social, and economic factors that must be considered (Lu et al., 2022). Stages of the Hydroelectric Power Plant Project, such as feasibility studies, preliminary design, risk assessment, and implementation (Johri et al., 2025). Similarly, there are planning constraints, namely uncertainties related to location, water availability, construction costs, and government regulations (Bradley et al., 2016).

The article titled evaluates the impact of cost overruns on hydropower projects within Canada’s electricity generation strategy (Babaei et al., 2022). It uses the GCAM (Global Change Assessment Model), which includes an endogenous representation of hydropower to analyze its role relative to other renewable energy sources (Vilotijević et al., 2021). Hydropower's Current Role: Hydropower contributes around 60% of Canada’s and is projected to grow as part of renewable energy goals (Zhironkin et al., 2023). However, the economic viability of these projects is challenged by frequent cost overruns(Shi et al., 2024) .

This research stands at the intersection of technical, ecological, and climate issues (Daramola et al., 2023). Scientific literacy on this topic indicates that the future success of RoR plants in the alpine region heavily depends on technological adaptation to climate change, a deep understanding of ecological flow requirements, and the implementation of energy policies that support sustainability (Hanna & Gross, 2021).

METHOD

For the data collection technique, we conducted field observations to understand the characteristics of the Singkarak Hydroelectric Power Plant's outflow and the environmental conditions around the Tailrace flow.

The data processing technique used systematic calculations and trial-and-error methods based on Layman’s Hydropower Handbook.

1. To determine water discharge, based on Chezy and Manning:

   $$Q = A \, x \, V \qquad (1)$$

   Where Q is the water discharge (m3/s), A is the river cross-section (m2), and V is the water velocity (m/s).
2. Potential Water Power

   For potential water power, we use the formula:

   $$P = \eta_{turbin} \, x \, \eta_{generator} \, x \, \rho \, x \, g \, x \, H \, x \, Q \qquad (2)$$

Where P is the power generation capacity (Watts), ρ is the water density (1000 kg/m3), g is the gravitational acceleration (9.81 m/s), H is the height difference from the forebay to the turbine center (m), and Q is the water discharge (m3/s). As seen in Figure 1, we conducted measurements of water discharge and head at the PLTA Singkarak discharge location.

Figure 1. The process of measuring the depth of the Outflow at Singkarak Hydroelectric Power Plant

To calculate how much capacity is needed for self-consumption, we need to calculate how much energy is produced per hour each month over a period of 5 months (Lombardi et al., 2024). For the specifications of the turbine and generator to be used in the planning of this SHP, we use an approach method based on the guidelines from Layman's (Refdinal et al., 2016).

How to develop a small hydro power plant, europe 1990 , and the efficiency graph for selecting the type of turbine can be seen in Figure 2.

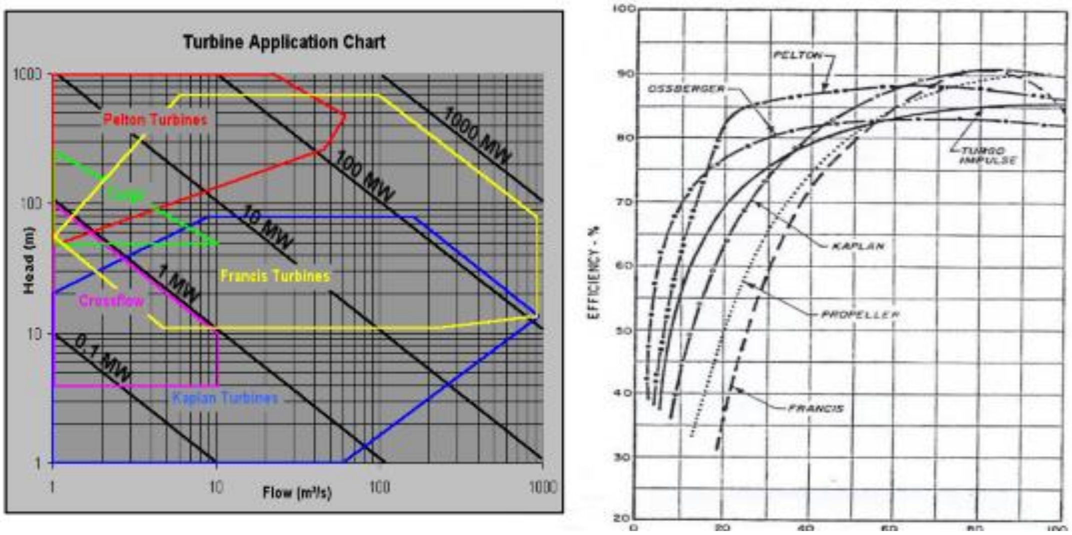


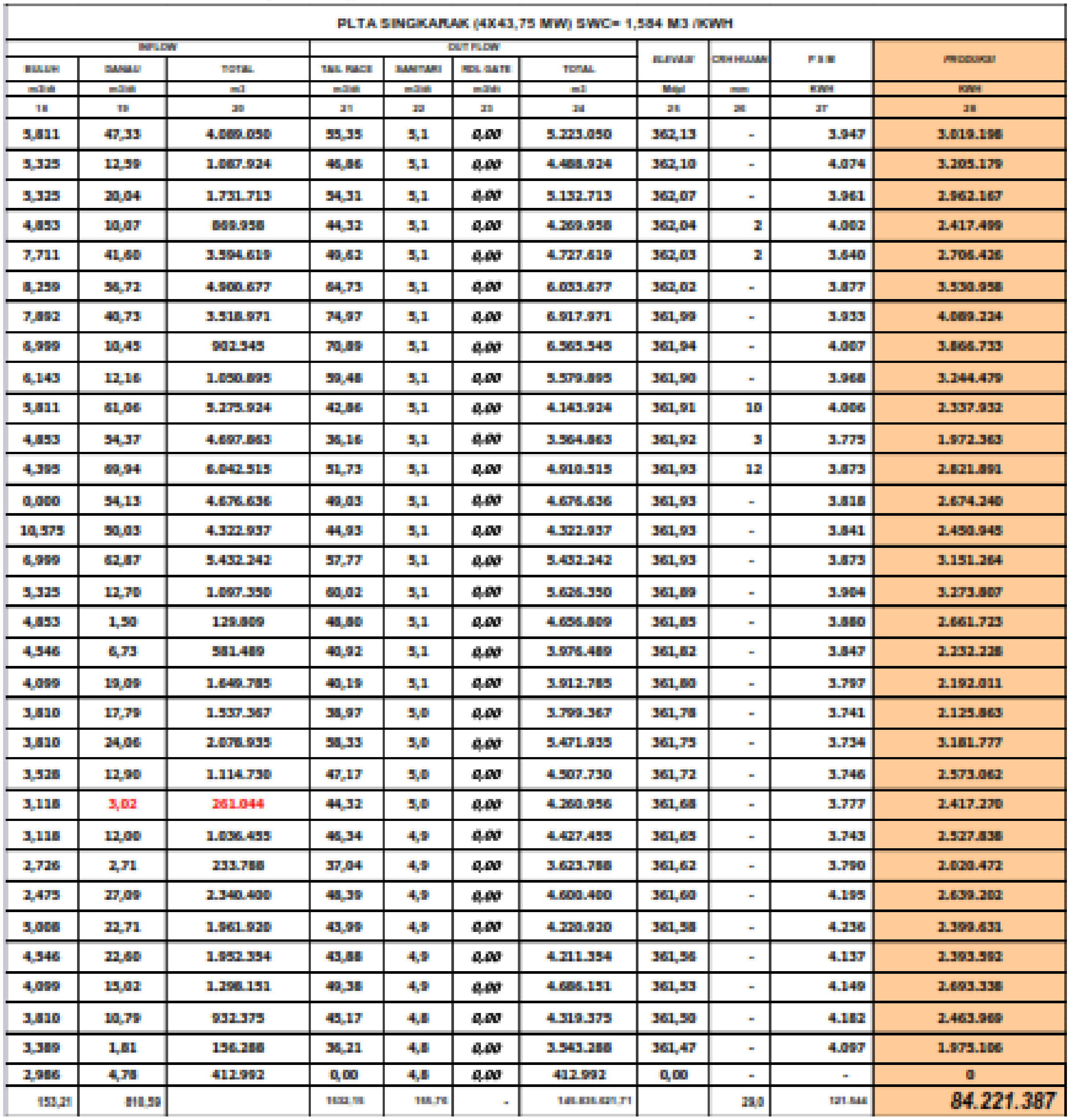
Figure 2. How to develop a small hydro power plant, Europe 1990 , and the efficiency graph for selecting the type of turbine

FINDINGS AND DISCUSSION

Monitoring Distributed Energy

This channeled energy is highly relevant in research because it affects the sustainability and efficiency of various energy technologies we use (Trahan & Hess, 2022). Understanding the workings, conversion, and efficiency of energy distribution can help us improve systems and develop more environmentally friendly and efficient energy sources (Martínez-Pérez et al., 2023). Energy consumption profiles need to monitor energy usage patterns, including peak and low loads, to assist in the management and planning of more efficient energy distribution (Zhang & Liu, 2025). This is done to determine how much energy used at a certain time can help optimize the system to reduce excess capacity or supply shortages (Markom et al., 2022). The monitoring of the transmitted energy can be seen and efficient energy sources (El-Madany et al., 2012). The monitoring of the transmitted energy can be seen in table 1.

Table 1. Hydrological data for the month of July



PLTA SINGKARAK (4X43,75 MW) SWC= 1,584 M3 /KWH

INFLOW			OUT FLOW				ELEVASI	CRH HUJAN	P S M	PRODUKSI
BULUH	DANAU	TOTAL	TAIL RACE	SANTARI	ROL GATE	TOTAL				
m3/dt	m3/dt	m3	m3/dt	m3/dt	m3/dt	m3	Mdpl	mm	KWH	KWH
18	19	20	21	22	23	24	25	26	27	28
5,811	47,33	4.089.050	55,35	5,1	*0,00*	5.223.050	362,13	-	3.947	3.019.198
5,325	12,59	1.087.924	46,86	5,1	*0,00*	4.488.924	362,10	-	4.074	3.205.179
5,325	20,04	1.731.713	54,31	5,1	*0,00*	5.132.713	362,07	-	3.961	2.962.167
4,853	10,07	869.958	44,32	5,1	*0,00*	4.269.958	362,04	2	4.002	2.417.499
7,711	41,60	3.594.619	49,62	5,1	*0,00*	4.727.619	362,03	2	3.640	2.706.426
8,259	56,72	4.900.677	64,73	5,1	*0,00*	6.033.677	362,02	-	3.877	3.530.958
7,892	40,73	3.518.971	74,97	5,1	*0,00*	6.917.971	361,99	-	3.933	4.089.224
6,999	10,45	902.545	70,89	5,1	*0,00*	6.565.545	361,94	-	4.007	3.866.733
6,143	12,16	1.050.895	59,48	5,1	*0,00*	5.579.895	361,90	-	3.968	3.244.479
5,811	61,06	5.275.924	42,86	5,1	*0,00*	4.143.924	361,91	10	4.006	2.337.932
4,853	54,37	4.697.863	36,16	5,1	*0,00*	3.564.863	361,92	3	3.775	1.972.363
4,395	69,94	6.042.515	51,73	5,1	*0,00*	4.910.515	361,93	12	3.873	2.821.891
0,000	54,13	4.676.636	49,03	5,1	*0,00*	4.676.636	361,93	-	3.818	2.674.240
10,575	50,03	4.322.937	44,93	5,1	*0,00*	4.322.937	361,93	-	3.841	2.450.945
6,999	62,87	5.432.242	57,77	5,1	*0,00*	5.432.242	361,93	-	3.873	3.151.264
5,325	12,70	1.097.350	60,02	5,1	*0,00*	5.626.350	361,89	-	3.904	3.273.807
4,853	1,50	129.809	48,80	5,1	*0,00*	4.656.809	361,85	-	3.880	2.661.723
4,546	6,73	581.489	40,92	5,1	*0,00*	3.976.489	361,82	-	3.847	2.232.228
4,099	19,09	1.649.785	40,19	5,1	*0,00*	3.912.785	361,80	-	3.797	2.192.011
3,810	17,79	1.537.367	38,97	5,0	*0,00*	3.799.367	361,78	-	3.741	2.125.863
3,810	24,06	2.078.935	58,33	5,0	*0,00*	5.471.935	361,75	-	3.734	3.181.777
3,526	12,90	1.114.730	47,17	5,0	*0,00*	4.507.730	361,72	-	3.746	2.573.062
3,118	3,02	261.044	44,32	5,0	*0,00*	4.260.956	361,68	-	3.777	2.417.270
3,118	12,00	1.036.455	46,34	4,9	*0,00*	4.427.455	361,65	-	3.743	2.527.838
2,726	2,71	233.788	37,04	4,9	*0,00*	3.623.788	361,62	-	3.790	2.020.472
2,475	27,09	2.340.400	48,39	4,9	*0,00*	4.600.400	361,60	-	4.195	2.639.202
5,008	22,71	1.961.920	43,99	4,9	*0,00*	4.220.920	361,58	-	4.236	2.399.631
4,546	22,60	1.952.354	43,88	4,9	*0,00*	4.211.354	361,56	-	4.137	2.393.592
4,099	15,02	1.298.151	49,38	4,9	*0,00*	4.686.151	361,53	-	4.149	2.693.338
3,810	10,79	932.375	45,17	4,8	*0,00*	4.319.375	361,50	-	4.182	2.463.969
3,389	1,81	156.288	36,21	4,8	*0,00*	3.543.288	361,47	-	4.097	1.975.106
2,986	4,78	412.992	0,00	4,8	*0,00*	412.992	0,00	-	-	0
153,21	818,59		1132,18	155,70	-	149.835.021,71		29,0	121.544	84.221.387

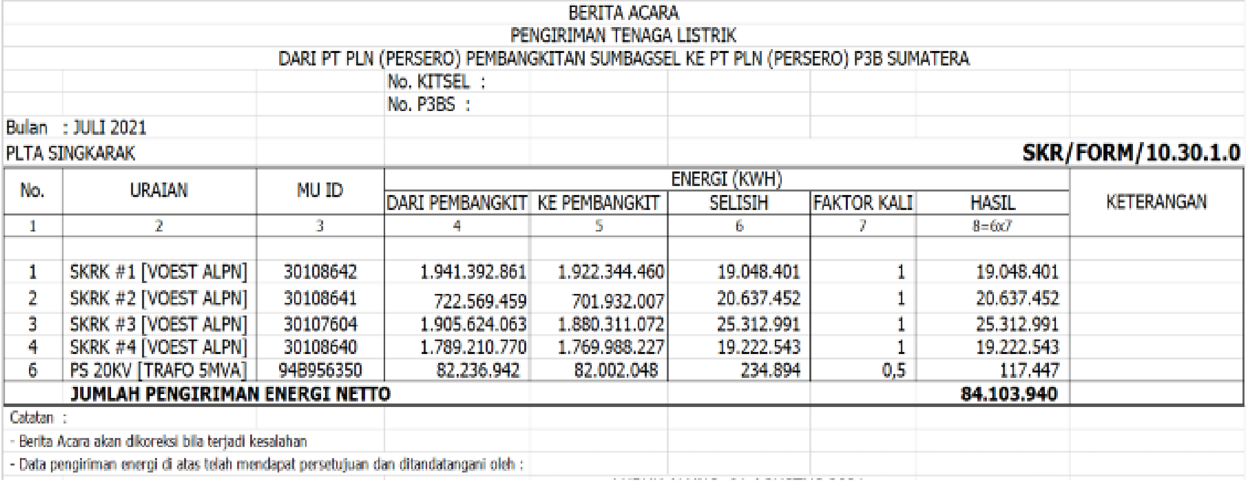
This hydrological data was collected over a period of 3 months, namely July, August, and September. In the data above, the flow rate at the tailrace is 54.35 m^3/s with an energy output of 84,221,387 KWh. If the average is calculated from these three months, the flow rate is 44.5 m3/s. Therefore, the design flow rate taken is 20 m^3/s.

Monitoring KWh Transactions

Electricity payment tariffs are the costs charged to customers for the use of electrical energy (Zhu et al., 2024). These tariffs are determined based on several factors, such as the amount of electricity consumption, customer categories, electricity production costs, and the policies of the government and electricity providers in each country or region (Sari et al., 2022).

In Figure 3, the energy data generated in August is shown, where the energy used from the own power plant is seen in the data as 117,447 KWh. This energy data was taken over 5 months, June, July, August, September, October, and the total energy generated is 639,820 KWh.

Table 2. Monitoring KWh transactions for the month of August



BERITA ACARA
PENGIRIMAN TENAGA LISTRIK
DARI PT PLN (PERSERO) PEMBANGKITAN SUMBAGSEL KE PT PLN (PERSERO) P3B SUMATERA
No. KITSEL :
No. P3BS :

Bulan : JULI 2021
PLTA SINGKARAK
SKR/FORM/10.30.1.0

No.	URAIAN	MU ID	ENERGI (KWH)					KETERANGAN
			DARI PEMBANGKIT	KE PEMBANGKIT	SELISIH	FAKTOR KALI	HASIL	
1	2	3	4	5	6	7	8=6x7	
1	SKRK #1 [VOEST ALPN]	30108642	1.941.392.861	1.922.344.460	19.048.401	1	19.048.401	
2	SKRK #2 [VOEST ALPN]	30108641	722.569.459	701.932.007	20.637.452	1	20.637.452	
3	SKRK #3 [VOEST ALPN]	30107604	1.905.624.063	1.880.311.072	25.312.991	1	25.312.991	
4	SKRK #4 [VOEST ALPN]	30108640	1.789.210.770	1.769.988.227	19.222.543	1	19.222.543	
6	PS 20KV [TRAFO 5MVA]	94B956350	82.236.942	82.002.048	234.894	0,5	117.447	
	JUMLAH PENGIRIMAN ENERGI NETTO						**84.103.940**	

Catatan :
- Berita Acara akan dikoreksi bila terjadi kesalahan
- Data pengiriman energi di atas telah mendapat persetujuan dan ditandatangani oleh :

From the total energy of 639.820 KWh, the daily energy value can be calculated as 4127.8 KWh. From the daily KWh usage of PLTA Singkarak of 4127.8 KWh, the self-consumption of PLTA Singkarak per hour is 222 KW. Therefore, the planned self-generation capacity is 250 KW to replace the self-consumption supply of PLTA Singkarak taken from the Singkarak Substation.

Planned Discharge Calculation

Based on the measured and calculated data, the planned discharge can be calculated using formula 2.

$$\mathbf{P = \eta\_turbin \;\; x \; \eta\_generator \;\; x \; \rho \; x \; g \; x \; H \; x \; Q}$$

$$Q = \frac{P}{\eta_{turbin} \, x \, \eta_{generator} \, x \, \rho \, x \, g \, x \, H}$$

$$= \frac{250 \, kW}{0.6 \, x \, 1000 \, x \, 9.81 \, x \, 4} = 10.681 \; {}^{m^3}\!/_{dtk}$$

Therefore, based on the calculations that have been carried out, a discharge of 10.618 m3/s, a height (head) of 4 meters, and a planned power of 250 KW were obtained. Thus, according to figure 2, the most suitable turbine for the planning of this micro-hydropower plant is the Kaplan turbine .

Limitations and Future Work

Upon reevaluation, numerous deficiencies persist in this research, particularly on the investigation of environmental hazards stemming from the discharge of the Singkarak Hydroelectric Power Plant. Consequently, research must be undertaken to guarantee that the use of the outflow preserves a balance between ecological and human requirements. Establish training programs for the community to comprehend micro-hydro technology and enhance their involvement in operations and maintenance (Nguyen et al., 2024). Investigating the integration of micro-hydro with additional renewable energy sources, such as solar or wind, to establish a more stable and sustainable hybrid energy system, with the deployment of smart grid technology to regulate energy supply and demand in the vicinity. It is essential to examine the legal considerations pertaining to the utilization of river water or the byproducts of hydroelectric power plants as an energy source.

CONCLUSION

Conclusions should answer the objectives of research. Tells how your work advances the field from the present state of knowledge. Without clear conclusions, reviewers and readers will find it difficult to judge the work, and whether or not it merits publication in the proceedings. This research shows that the outflow from the Singkarak Hydroelectric Power Plant has the potential to be utilized as a micro-hydro energy source, which is an innovative solution to improve water use efficiency. It can provide an efficient alternative for generating electricity from renewable energy sources. The sustainable development of renewable energy, by utilizing existing water flows without requiring large additional infrastructure. By utilizing the outflow as an energy source, this research emphasizes the importance of sustainability in water resource management, as well as its contribution to reducing carbon emissions and promoting the use of renewable energy. It is crucial to ensure that the development of renewable energy does not harm the environment. The use of water from this stream can be directly utilized by the local community, both for providing stable electricity and for creating new economic opportunities, such as supporting infrastructure or developing small industries.

REFERENCES

Alonso-Travesset, À., Martín, H., Coronas, S., & De La Hoz, J. (2022). Optimization models under uncertainty in distributed generation systems: A review. *Energies, 15*(5), Article 1932. https://doi.org/10.3390/en15051932

Babaei, R., Ting, D. S.-K., & Carriveau, R. (2022). Feasibility and optimal sizing analysis of stand-alone hybrid energy systems coupled with various battery technologies: A case study of Pelee Island. *Energy Reports, 8*, 4747–4762. https://doi.org/10.1016/j.egyr.2022.03.133

Basso, S. M. M., & Botter, G. (2012). Streamflow variability and optimal capacity of run-of-river hydropower plants. *Water Resources Research, 48*(10). https://doi.org/10.1029/2012WR012017

Bradley, P., Coke, A., & Leach, M. (2016). Financial incentive approaches for reducing peak electricity demand: Experience from pilot trials with a UK energy provider. *Energy Policy, 98*, 108–120. https://doi.org/10.1016/j.enpol.2016.07.022

Daramola, A. S., Ahmadi, S. E., Marzband, M., & Ikpehai, A. (2023). A cost-effective and ecological stochastic optimization for integration of distributed energy resources in energy networks considering vehicle-to-grid and combined heat and power technologies. *Journal of Energy Storage, 57*, Article 106203. https://doi.org/10.1016/j.est.2022.106203

El-Madany, H. T., Fahmy, F. H., El-Rahman, N. M. A., & Dorrah, H. T. (2012). Optimization and feasibility analysis of satellite earth station power system using HOMER. *TELKOMNIKA (Telecommunication Computing Electronics and Control), 10*(2), 359–370.

Gallego-Castillo, C., Heleno, M., & Victoria, M. (2021). Self-consumption for energy communities in Spain: A regional analysis under the new legal framework. *Energy Policy, 150*, Article 112144. https://doi.org/10.1016/j.enpol.2021.112144

Hanna, R., & Gross, R. (2021). How do energy systems model and scenario studies explicitly represent socio-economic, political and technological disruption and discontinuity? Implications for policy and practitioners. *Energy Policy, 149*, Article 111984. https://doi.org/10.1016/j.enpol.2020.111984

Johri, A., Verma, V., & Basu, M. (2025). Optimization and intelligent control in hybrid renewable energy systems incorporating solar and biomass. *Energy Engineering, 122*(5), 1887–1918. https://doi.org/10.32604/ee.2025.062355

Lombardi, G., Cioccolanti, L., Del Zotto, L., Tomassetti, S., & Campana, P. E. (2024). The role of electric vehicles in hybrid solar-based small energy communities. *Energy Conversion and Management, 321*, Article 119074. https://doi.org/10.1016/j.enconman.2024.119074

Lu, Y., Dai, J., Wang, L., Liu, Y., & Wu, C. (2022). The impact of the energy transition on China's economy under the carbon peaking and carbon neutrality goals: A simulation analysis based on the CGE model. *Thermal Science, 26*(5 Part A), 4043–4056. https://doi.org/10.2298/TSCI2205043L

Markom, A. M., Hadri, M. H. A., Yazid, T. Z. M., Yusof, Z. M., Markom, M. A., & Muhammad, A. R. (2022). Electricity generation from renewable energy based on abandoned wind fan. *Indonesian Journal of Electrical Engineering and Computer Science, 26*(1), 1–8. https://doi.org/10.11591/ijeecs.v26.i1.pp1-8

Martínez-Pérez, R., Ríos-Fernández, J. C., Laine-Cuervo, G., Soto-Pérez, F., Rubio-Serrano, F. J., & Gutiérrez-Trashorras, A. J. (2023). Comparative study of energy performance and water savings between hygroscopic and Rankine cycle in a nuclear power plant: Case study of the HTR-10 reactor. *Results in Engineering, 20*, Article 101600. https://doi.org/10.1016/j.rineng.2023.101600

Nguyen, T. H., Paramasivam, P., Dong, V. H., Le, H. C., & Nguyen, D. C. (2024). Harnessing a better future: Exploring AI and ML applications in renewable energy. *JOIV: International Journal on Informatics Visualization, 8*(1), 55–78. https://doi.org/10.62527/joiv.8.1.2637

Refdinal, N., Nurdin, M., & Fitrianto, E. (2016). Voltage profile improvement of the 20 kV Painan distribution system with multiple distributed renewable energy generation. *International Journal of Technology, 7*(1), 26–37.

Sari, A., Majdi, A., Opulencia, M. J. C., Timoshin, A., Huy, D. T. N., Trung, N. D., Alsaikhan, F., Hammid, A. T., & Akhmedov, A. (2022). New optimized configuration for a hybrid PV/diesel/battery system based on coyote optimization algorithm: A case study for Hotan county. *Energy Reports, 8*, 15480–15492. https://doi.org/10.1016/j.egyr.2022.11.059

Shahzad, M., Qadir, A., Ullah, N., Mahmood, Z., Saad, N. M., & Ali, S. S. A. (2022). Optimization of on-grid hybrid renewable energy system: A case study on Azad Jammu and Kashmir. *Sustainability, 14*(10), Article 5757. https://doi.org/10.3390/su14105757

Shi, S., Zhang, Q., Wei, X., Liu, J., Wang, Y., & Xu, Y. (2024). Anti-fragile planning of urban distribution network for survivability improvement. *Electric Power Construction, 45*(1), 56–67. https://doi.org/10.12204/j.issn.1000-7229.2024.01.006

Trahan, R. T., & Hess, D. J. (2022). Will power be local? The role of local power organizations in energy transition acceleration. *Technological Forecasting and Social Change, 183*, Article 121884. https://doi.org/10.1016/j.techfore.2022.121884

Upadhyay, S., Ahmed, I., & Mihet-Popa, L. (2024). Energy management system for an industrial microgrid using optimization algorithms-based reinforcement learning technique. *Energies, 17*(16), Article 3898. https://doi.org/10.3390/en17163898

Vilotijević, V., Karadžić, U., Vujadinović, R., Kovijanić, V., & Božić, I. (2021). An improved techno-economic approach to determination of more precise installed parameter for small hydropower plants. *Water, 13*(17), Article 2419. https://doi.org/10.3390/w13172419

Yuvaraj, T., Thirumalai, M., Dharmalingam, M., Thanikanti, S. B., & Padmanaban, S. (2025). Smart energy management for revenue optimization and grid independence in an Indian RDS. *Energy Conversion and Management: X, 26*, Article 100955. https://doi.org/10.1016/j.ecmx.2025.100955

Zhang, X., & Liu, J. (2025). Distributed power, energy storage planning, and power tracking studies for distribution networks. *Electronics, 14*(14), Article 2833. https://doi.org/10.3390/electronics14142833

Zhironkin, S., Abu-Abed, F., & Dotsenko, E. (2023). The development of renewable energy in mineral resource clusters—The case of the Siberian Federal District. *Energies, 16*(9), Article 3843. https://doi.org/10.3390/en16093843

Zhu, C., Zhang, Y., Wang, M., Deng, J., Cai, Y., Wei, W., & Guo, M. (2024). Optimization, validation and analyses of a hybrid PV-battery-diesel power system using enhanced electromagnetic field optimization algorithm and ε-constraint. *Energy Reports, 11*, 5335–5349. https://doi.org/10.1016/j.egyr.2024.04.043