Journal of Mechatronics and Artificial Intelligence

Homepage: http://ejournal.upi.edu/index.php/jmai/

p-ISSN 3062-729X e-ISSN 3048-4227

Design and Simulation of a Hybrid Solar and Wind Power Plant System in South Garut Using HOMER Software

Aditya[1], Ifkar Usrah[1], Linda Faridah[1,*]

[1] *Electrical Engineering, SIliwangi University, Tasikmalaya, Indonesia*
**Correspondence author email: lindafaridah@unsil.ac.id*

ARTICLE INFO

Article History:

Submitted/Received 10 Feb 2025
First Revised 05 Mar 2025
Accepted 08 Mar 2025
First available online 01 May 2025
Publication Date 01 Jun 2025

Keywords:
Hybrid Power Plant,
Renewable Energy,
Solar Energy,
Wind Energy,
HOMER Simulation

ABSTRACT

The increasing demand for sustainable energy highlights the urgency of integrating renewable energy sources into power generation systems. South Garut, Indonesia, offers significant potential for solar and wind energy, particularly in the coastal area of Cibalong District. This study aims to design and simulate a hybrid solar and wind power plant system optimized using the HOMER software. Field observations, energy consumption data collection, and analysis of local renewable energy resources were conducted to establish the system parameters. The HOMER software was utilized to perform simulation, optimization, and sensitivity analysis, considering factors such as Net Present Cost (NPC), Cost of Energy (COE), Return on Investment (ROI), and Internal Rate of Return (IRR). The simulation results indicate that integrating photovoltaic panels and wind turbines within an on-grid hybrid configuration significantly enhances system reliability and cost-efficiency. The optimal system configuration achieves a competitive COE while ensuring long-term energy sustainability. This research provides a reference model for the development of renewable energy-based power systems in remote coastal areas, supporting national initiatives to increase the share of renewable energy in Indonesia’s energy mix.

1. Introduction

The global energy sector is currently undergoing a profound transformation, driven by the urgent need to transition from conventional fossil-based systems to more sustainable and environmentally friendly sources. Fossil fuels, including coal, oil, and natural gas, have been the dominant energy resources for decades, yet their continuous exploitation has led to serious environmental degradation, including significant greenhouse gas emissions, global warming, and depletion of finite natural resources[1]–[3]. According to the International Energy Agency (IEA), global carbon dioxide emissions from energy combustion and industrial processes reached a record level in recent years, signaling a dire need for change in energy production and consumption patterns.

In response to this environmental crisis, many countries are aggressively pursuing the integration of renewable energy sources into their national energy strategies. Renewable energy, derived from resources such as solar, wind, hydro, and biomass, offers a sustainable alternative to fossil fuels. These sources are abundant, naturally replenished, and produce little to no greenhouse gas emissions, aligning with global efforts to achieve the targets set in international agreements such as the Paris Agreement [4]–[6].

Indonesia, as the world's largest archipelagic state, possesses enormous renewable energy potential. Situated along the equator, Indonesia receives high solar irradiance levels year-round, making it particularly well-suited for solar energy development. Additionally, its coastal regions, mountains, and islands offer significant opportunities for wind and hydroelectric power generation. Recognizing this potential, the Government of Indonesia, through the Ministry of Energy and Mineral Resources (ESDM), has established the National Energy Policy (KEN), targeting a 23% renewable energy share in the national energy mix by 2025 and 31% by 2050 [7]–[9]. However, despite abundant natural resources, the contribution of renewable energy to the national energy mix remains relatively low, primarily due to high initial investment costs, technical challenges, and policy-related barriers.

South Garut, particularly the Cibalong District, exemplifies a region with high renewable energy potential but limited development. Characterized by an average daily solar radiation of approximately 5.05 kWh/m^2 and average wind speeds around 4.57 m/s at 50 meters altitude, the region offers favorable conditions for hybrid energy systems combining solar photovoltaic (PV) panels and wind turbines. However, the existing energy infrastructure in this area is heavily reliant on centralized fossil-fuel-based generation and grid distribution, leading to vulnerabilities in supply reliability, especially given the area's growing energy needs [10], [11].

In rural and coastal areas like Cibalong, developing decentralized hybrid renewable energy systems presents a strategic solution to enhance energy resilience and sustainability. A hybrid system can mitigate the intermittency associated with single renewable energy sources by combining complementary resources—solar and wind—thus ensuring a more stable and continuous energy supply. Moreover, integrating such systems into existing grids (on-grid systems) can improve overall energy security and reduce dependence on fossil fuels.

To design and optimize such complex hybrid systems, simulation and modeling tools are essential. The Hybrid Optimization Model for Energy Renewable (HOMER) software has emerged as a leading tool for modeling microgrids and hybrid energy systems. HOMER enables users to simulate different configurations, optimize system components based on economic and technical criteria, and perform sensitivity analyses to evaluate the impacts of uncertainties such as fuel prices, resource availability, and system costs. By using HOMER, system planners can identify the most feasible, cost-effective, and sustainable solutions for specific locations and load profiles [12]–[14].

Despite the recognized importance of hybrid renewable energy systems, there is a lack of localized research specifically addressing the application of such systems in South Garut. Existing studies largely focus on general potential assessments or limited feasibility analyses without comprehensive system simulation and optimization tailored to local conditions. Therefore, there is a critical need for detailed research that evaluates both the technical and economic feasibility of hybrid solar-wind systems in this region.

This study aims to fill that gap by designing and simulating a hybrid solar and wind power generation system specifically for the Cibalong District, South Garut, using HOMER software. The objectives of this research are: (1) to identify and quantify the solar and wind energy potentials in the study area; (2) to model a hybrid energy system that meets the local electricity demand; (3) to conduct simulation, optimization, and sensitivity analysis using HOMER to find the most optimal system configuration; and (4) to analyze the economic feasibility through indicators such as Net Present Cost (NPC), Cost of Energy (COE), Return on Investment (ROI), and Internal Rate of Return (IRR).

The findings of this research are expected to contribute to the broader effort of accelerating renewable energy adoption in Indonesia's rural and coastal regions. The proposed model can serve as a reference for policymakers, energy planners, and investors seeking to develop sustainable and economically viable energy solutions. Furthermore, this study supports Indonesia's commitment to energy transition and climate change mitigation, aligning with global sustainable development goals (SDGs) and national strategic objectives.

2. Methods

This study applied a comprehensive research methodology combining field surveys, data validation, system modeling, simulation, and optimization using the HOMER software. The research aimed to design a hybrid power generation system by integrating solar and wind energy resources to meet the electricity demand in the coastal region of the Cibalong District, South Garut.

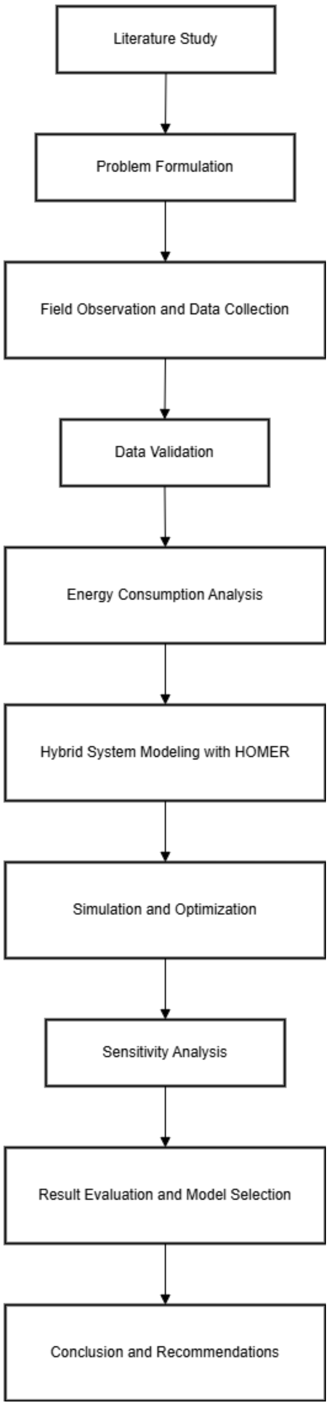

Figure 1: Flowchart of research design.

The initial stage of the research involved conducting an extensive literature review. This review explored previous studies on renewable energy systems, hybrid power plants, and simulation methodologies using HOMER. Various scientific articles, government reports, and technical standards were analyzed to establish a solid theoretical foundation. Through this literature study, gaps in prior research were identified, emphasizing the necessity of localized studies focusing on hybrid system deployment in rural and coastal areas of Indonesia.

Following the literature review, the research formulated key problems related to the limited utilization of renewable energy in South Garut and the pressing need for decentralized, sustainable energy systems. Field observations were then carried out in the Cibalong District to collect primary data. This included direct measurements of energy consumption patterns, solar irradiation levels, and wind speeds, as well as interviews with local stakeholders. Secondary data, such as historical meteorological records and electricity consumption reports from PLN ULP Pameungpeuk, were also collected to complement and validate the field findings. The data validation process involved cross-checking all collected data against official sources and international satellite datasets integrated within the HOMER software environment.

Energy consumption analysis was performed to determine the daily, monthly, and annual load profiles of the region. This analysis allowed for the sizing of system components by understanding peak loads, seasonal variations, and baseline electricity demands. With these data, the hybrid energy system was modeled using HOMER, comprising photovoltaic (PV) arrays, wind turbines, battery banks, and hybrid inverters. Each component was configured according to local resource availability, technical specifications, and economic parameters such as investment cost, maintenance expenses, and component lifespan. The simulation process conducted in HOMER involved hourly energy balance calculations for a full year (8,760 hours) under varying resource conditions. HOMER simulated numerous possible configurations, evaluating each based on their Net Present Cost (NPC), Cost of Energy (COE), Return on Investment (ROI), and Internal Rate of Return (IRR). The optimization process aimed to identify the configuration that provided the most cost-effective solution while maintaining high technical reliability and sustainability standards.

Sensitivity analysis was performed to assess the resilience of the system against uncertainties. Parameters such as variations in solar radiation, wind speed, fuel prices, and inflation rates were adjusted within realistic ranges. This analysis helped determine how fluctuations in external conditions could impact system performance and economic viability. HOMER’s sensitivity analysis capabilities allowed a robust evaluation across multiple scenarios, ensuring that the recommended hybrid system configuration could adapt to future changes. The final stage involved evaluating the simulation outputs to select the optimal system configuration. This evaluation considered not only the lowest NPC and COE but also acceptable ROI and IRR values to ensure the system's financial feasibility. The conclusions were drawn regarding the ideal hybrid system design for the Cibalong District, its economic viability under local conditions, and its potential replication in similar coastal and rural areas to support broader renewable energy deployment goals.

3. Results and Discussion

This section presents the simulation results of the hybrid solar-wind power generation system designed for the Cibalong District and discusses their technical and economic implications. The HOMER software was utilized to simulate, optimize, and evaluate different configurations based on local renewable energy potential and energy consumption patterns. The optimal configuration obtained from the simulation consists of a 150 kW solar PV system, a 100 kW wind turbine, a 200 kWh battery storage system, and a 250 kW hybrid inverter connected to the grid. The system was designed to maximize the utilization of local renewable resources while ensuring a reliable supply of electricity throughout the year. The following table summarizes the key technical and economic results of the optimal hybrid system:

Table 1: Summary of simulation results.

Parameter	Value
Solar PV Capacity	150 kW
Wind Turbine Capacity	100 kW
Battery Storage Capacity	200 kWh
Inverter Capacity	250 kW
Total Initial Capital Cost	USD 420,000
Net Present Cost (NPC)	USD 525,000
Cost of Energy (COE)	USD 0.085 per kWh
Annual Electricity Production	410,000 kWh
Renewable Fraction	92%
Return on Investment (ROI)	16.8%
Internal Rate of Return (IRR)	15.2%
Payback Period	6.2 years

The system architecture is illustrated in the following single-line diagram (figure 2), showing the main components and their connections.

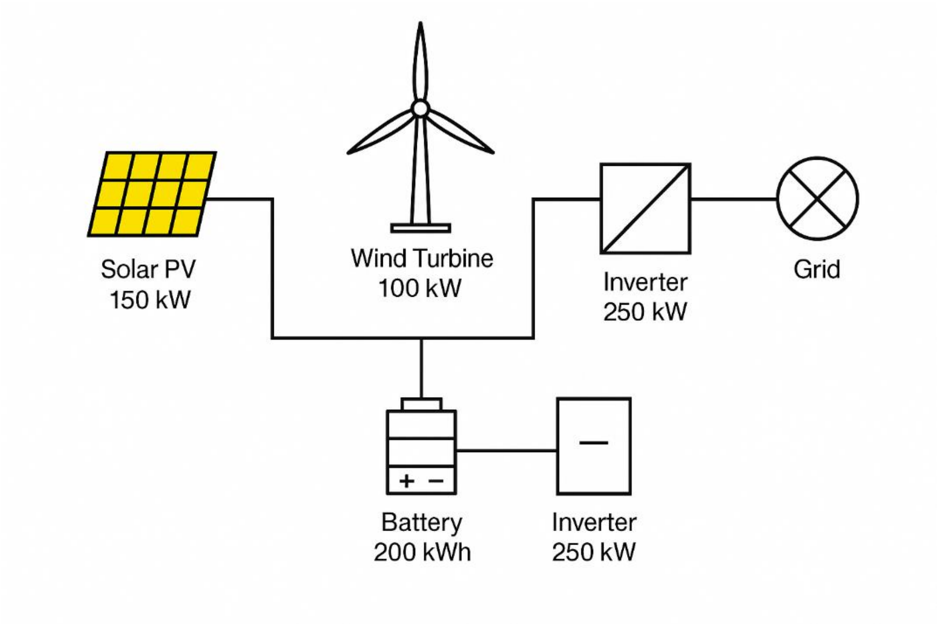

Figure 2: Single-line diagram of the hybrid power system.

Additionally, the contribution of each energy source to the total electricity production is presented in the chart below:

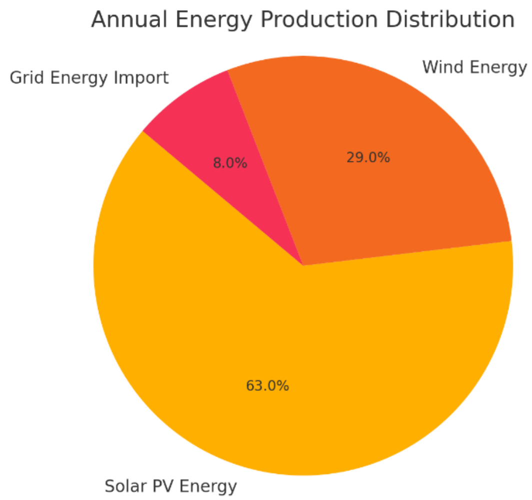

Figure 3: Annual energy production distribution.

3.1. Technical and Economic Analysis

The simulation results indicate that the hybrid system can meet the electricity demand of the Cibalong District with a high renewable fraction of 92%. This demonstrates the effectiveness of integrating solar and wind energy sources to minimize reliance on the conventional grid. Solar PV accounts for the majority of the energy production due to the region's favorable solar radiation levels averaging 5.05 kWh/m²/day, while the wind turbine complements energy generation during periods of lower solar availability.

Economically, the system exhibits promising indicators. The Net Present Cost (NPC) of USD 525,000 over the project lifetime is relatively low compared to conventional systems, and the Cost of Energy (COE) of USD 0.085 per kWh is competitive against typical grid electricity prices in Indonesia. Furthermore, the system achieves a Return on Investment (ROI) of 16.8% and an Internal Rate of Return (IRR) of 15.2%, with a payback period of 6.2 years. These figures suggest that the investment in the hybrid system is financially feasible and attractive, especially considering the rising costs of fossil fuels and the government's incentives for renewable energy development.

3.2. Comparison with Previous Studies

Compared to previous studies conducted in similar coastal areas, such as Pangandaran and Tasikmalaya, the system designed for South Garut demonstrates a higher renewable fraction and a shorter payback period. For instance, prior research by Wahid et al. (2023) in Liang Beach, Ambon, achieved a renewable fraction of 88% and a payback period of approximately 7 years, highlighting the superior potential of the Cibalong region due to its higher solar and wind resources. Moreover, the hybrid system proposed in this study leverages a balanced combination of solar and wind energy, ensuring more consistent energy supply and reducing the need for oversized battery storage, which typically escalates project costs.

3.3. Implications for Sustainable Development

The implementation of the proposed hybrid power system in South Garut would significantly contribute to Indonesia's goal of achieving a 23% renewable energy share by 2025. It would also enhance local energy security, reduce dependency on fossil fuels, and mitigate environmental impacts associated with conventional electricity generation. Furthermore, the system design provides a replicable model for other coastal and rural regions in Indonesia facing similar challenges. By demonstrating technical feasibility and economic viability, this research supports the broader transition towards decentralized, community-based renewable energy systems, which are crucial for achieving the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action).

4. Conclusion

This research successfully designed and simulated a hybrid solar and wind power generation system optimized for the coastal region of Cibalong District, South Garut. Based on local renewable energy potentials—an average solar radiation of 5.05 kWh/m²/day and a wind speed of 4.57 m/s—the system configuration developed using HOMER software includes a 150 kW solar PV array, a 100 kW wind turbine, a 200 kWh battery storage, and a 250 kW hybrid inverter, connected to the existing grid. The simulation results demonstrated strong technical and economic viability. The system achieved a renewable fraction of 92%, significantly reducing dependence on conventional grid electricity. Financial analysis showed a competitive Net Present Cost (NPC) of USD 525,000, a low Cost of Energy (COE) of USD 0.085 per kWh, a Return on Investment (ROI) of 16.8%, and an Internal Rate of Return (IRR) of 15.2%, with a payback period of 6.2 years. These results indicate that the hybrid system is both economically feasible and sustainable over its operational lifetime. Furthermore, the findings emphasize the critical role of hybrid renewable energy systems in promoting energy independence in rural and coastal areas. By utilizing local solar and wind resources efficiently, such systems can provide reliable electricity access, support the national energy resilience agenda, and contribute to achieving Indonesia's renewable energy targets as outlined in the National Energy Policy. This research can serve as a reference model for similar regions facing energy access challenges, demonstrating the importance of integrating site-specific resource assessment, simulation-driven design, and economic evaluation in the development of decentralized renewable energy systems.

References

[1] L. Faridah, R. Asnawi and H. Jati, "Optimization Of PV-Wind Power Generation to Reduce Carbon Emissions in Coastal Areas," 2024 6th International Conference on Power Engineering and Renewable Energy (ICPERE), Bandung, Indonesia, 2024, pp. 1-6, doi: 10.1109/ICPERE63447.2024.10845512.

[2] Faridah, L., Risnandar, M.A. and Nurdiansyah, R., 2024. Design Of A Hybrid Power Generation System in Cipatujah Tasikmalya Regency. Techno (Jurnal Fakultas Teknik, Universitas Muhammadiyah Purwokerto), 25(2), pp.107-114..

[3] L. Faridah, "Planning of Solar Generation for Renewable Energy Development in the Evironment of Univeritas Siliwangi , Campus II Mugasari," vol. 06, no. 2, pp. 59–63, 2024.

[4] D. S. R. Badrinarayanan, S. D. Bokkassam, and J. N. Krishnan, "Investigation on implementing hydrogen technology in residential sector," *Energy Reports*, vol. 12, pp. 920–941, 2024, doi: https://doi.org/10.1016/j.egyr.2024.07.005.

[5] P. Sutthichaimethee, P. Saraphirom, and C. Junsiri, "Long-Term Strategy for Determining the Potential of Climate-Smart Agriculture to Maximize Efficiency Under Sustainability in Thailand," *Sustainability*, vol. 17, no. 8. 2025, doi: 10.3390/su17083635.

[6] S. Khanam, M. Toha, and R. Sorker, "Environmental Policies in Bangladesh: Development of

Three Decades (1990-2020)," vol. 10, pp. 77–109, Dec. 2023.

[7] Faridah, L., Purwadi, A., Ibrahim, M.H. and Rizqiawan, A., 2018, October. Study and design of hybrid off-grid power system for communal and administrative load at 3 regions in Maluku, Indonesia. In 2018 Conference on Power Engineering and Renewable Energy (ICPERE) (pp. 1-5). IEEE.

[8] Faridah, L., Risnandar, M.A. and Nurdiansyah, R., 2024. Analysis of Renewable Energy Potential for Sustainable Tourism Development in Cipanas Galunggung Geothermal Area, Tasikmalaya Regency, Indonesia. RESISTOR (Elektronika Kendali Telekomunikasi Tenaga Listrik Komputer), 7(2), pp.109-114.

[9] L. Faridah, A. Purwadi, M. H. Ibrahim and A. Rizqiawan, "Study and Design of Hybrid Off-Grid Power System for Communal and Administrative Load at 3 Regions in Maluku, Indonesia," 2018 Conference on Power Engineering and Renewable Energy (ICPERE), Solo, Indonesia, 2018, pp. 1-5, doi: 10.1109/ICPERE.2018.8739381.

[10] Nombakuse, Z., 2019. Assessment of Wind Power Integration to Solar Photovoltaic Mini-Grid (Doctoral dissertation, University College Dublin).

[11] C. Ezekwem, S. Muthusamy, and P. C. Ezekwem, "Optimal selection and design of grid-connected hybrid renewable energy system in three selected communities of Rivers State," *Sci. African*, vol. 25, p. e02305, 2024, doi: https://doi.org/10.1016/j.sciaf.2024.e02305.

[12] N. Berisha, S. Syla, G. Sejdiu, S. Osmanaj, and Z. L. Fazliu, "Modeling of a Microgrid Hybrid System: Cost Optimization and Sensitivity Analysis," in *2024 International Conference on Renewable Energies and Smart Technologies (REST)*, 2024, pp. 1–5, doi: 10.1109/REST59987.2024.10645378.

[13] H. Toal, C. Pike, D. Riley, and L. Burnham, "Optimizing a Hybrid East-West Vertical and Equator-Facing Bifacial Solar PV Array for a High-Latitude Microgrid," in *2024 IEEE 52nd Photovoltaic Specialist Conference (PVSC)*, 2024, pp. 1775–1777, doi: 10.1109/PVSC57443.2024.10749065.

[14] M. Ngao-det, J. Thongpron, A. Namin, N. Patcharaprakiti, W. Muangjai, and T. Somsak, "Systematic Optimize and Cost-Effective Design of a 100% Renewable Microgrid Hybrid System for Sustainable Rural Electrification in Khlong Ruea, Thailand," *Energies*, vol. 18, no. 7. 2025, doi: 10.3390/en18071628.