DESAIN DAN ANALISIS SISTEM ENERGI TERBARUKAN *HYBRID FLOATING SOLAR PHOTOVOLTAIC* DAN *WIND ENERGY* DI WILAYAH PANTAI

SKRIPSI

Diajukan untuk memenuhi salah satu syarat untuk memperoleh gelar Sarjana Teknik,
Pada Program Studi Teknik Elektro

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ABSTRAK

Peningkatan kebutuhan energi dan urgensi mitigasi perubahan iklim mendorong pengembangan *Hybrid Renewable Energy System* (HRES), khususnya kombinasi *Floating Solar Photovoltaic* (FSPV) dan *Wind Turbine* (WT) untuk wilayah pesisir yang memiliki energi surya dan angin signifikan serta mengatasi keterbatasan lahan. Penelitian ini bertujuan untuk merancang dan menganalisis sistem *Hybrid Floating Solar Panel dan Wind Energy* (*H-Flosow*) yang optimal untuk wilayah Pesisir Pantai Cirebon. Simulasi digunakan menggunakan perangkat lunak HOMER Pro dengan analisis tekno-ekonomi dan analisis sensitivitas untuk mengevaluasi kelayakan dan ketahanan sistem. Hasil menunjukkan bahwa desain *H-Flosow* yang dirancang layak secara teknis dan ekonomis. Studi ini juga membandingkan kinerja sistem ketika beroperasi secara terisolir dan secara *hybrid*. Sistem *hybrid* menunjukkan solusi terbaik secara ekonomi dengan *Net Present Cost* (NPC) sebesar $41,926.49 dan *Cost of Energy* (COE) sebesar $0.04768/kWh, dengan produksi listrik mencapai 138,264 kWh/tahun. Analisis sensitivitas membuktikan bahwa perubahan variabel lingkungan dapat memengaruhi keandalan sistem *H-Flosow*, seperti intensitas radiasi matahari dan kecepatan angin yang fluktuatif di wilayah Pantai. Hasil penelitian diharapkan dapat memberikan rekomendasi konfigurasi *H-flosow* yang paling optimal dan layak secara teknis maupun ekonomis, serta menjadi referensi bagi pengembangan energi terbarukan di wilayah Pantai Indonesia.

Kata kunci: HRES, *Floating Solar Photovoltaic*, *Wind Turbine*, HOMER, Analisis Tekno-Ekonomi, Analisis sensitivitas.

ABSTRACT

Increased energy demand and the urgency of climate change mitigation encourages the development of Hybrid Renewable Energy System (HRES), especially the combination of Floating Solar Photovoltaic (FSPV) and Wind Turbine (WT) for coastal areas that have significant solar and wind energy and overcome land limitations. This research aims to design and analyze the optimal Hybrid Floating Solar Panel and Wind Energy (H-Flosow) system for the Cirebon Coastal Area. Simulation was used using HOMER Pro software with techno-economic analysis and sensitivity analysis to evaluate the feasibility and robustness of the system. The results show that the designed H-Flosow design is technically and economically feasible. The study also compared the performance of the system when operating in isolation and in hybrid. The hybrid system showed the best solution economically with a Net Present Cost (NPC) of $41,926.49 and Cost of Energy (COE) of $0.04768/kWh, with electricity production reaching 138,264 kWh/year. Sensitivity analysis proves that changes in environmental variables can affect the reliability of the H-Flosow system, such as solar radiation intensity and fluctuating wind speed in the Coastal region. The results of the study are expected to provide recommendations for the most optimal and technically and economically feasible H-flosow configuration, as well as a reference for the development of renewable energy in the Indonesian Coast region.

Keywords**:** *HRES, Floating Solar Photovoltaic, Wind Turbine, HOMER, Techno-economic analysis, Sensitivity analysis*.

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DAFTAR SINGKATAN

COE	: *Cost of Energy*
$C_{ann,tot}$	: Total biaya tahunan
CRF	: *Capital Recovery Factor*
E_S	: Permintaan beban tahunan (kWh/tahun)
f	: Tingkat inflasi yang diantisipasi
FSPV	: *Floating Solar Photovoltaic*
GHI	: *Global Horizontal Irradiation*
H-Flosow	: *Hybrid Floating Solar Photovoltaic* dan *Wind Energy*
HRES	: *Hybrid Renewable Energy System*
HOMER	: *Hybrid Optimization of Multiple Energy Resources*
i	: *Discount rate*
i'	: *Discount rate* nominal
N	: Umur proyek
NPC	: *Net Present Cost*
NREL	: *National Renewable Energy Laboratory*
O&M	: *Operation* & *Maintenance*
POWER	: *Prediction of Worldwide Energy Resource*
PV	: *Photovoltaic*
WE	: *Wind Energy*
WT	: *Wind Turbine*

REFERENSI

Abdelrahim, M., Alkawsi, G., Alkahtani, A. A., Alhasan, A. M. W., Khudari, M., Abdul Kadir, M. R., Ekanayake, J., & Tiong, S. K. (2022). Techno-Economic Analysis of a Wind-Energy-Based Charging Station for Electric Vehicles in High-Rise Buildings in Malaysia. *Energies*, *15*(15). https://doi.org/10.3390/en15155412

Abnavi, M. D., Mohammadshafie, N., Rosen, M. A., Dabbaghian, A., & Fazelpour, F. (2019). Techno-economic feasibility analysis of stand-alone hybrid wind/photovoltaic/diesel/battery system for the electrification of remote rural areas: Case study Persian Gulf Coast-Iran. *Environmental Progress and Sustainable Energy*, *38*(5), 1–15. https://doi.org/10.1002/ep.13172

Al Saadi, K., & Ghosh, A. (2024). Investigating the integration of floating photovoltaics (FPV) technology with hydrogen (H2) energy for electricity production for domestic application in Oman. *International Journal of Hydrogen Energy*, *80*(May), 1151–1163. https://doi.org/10.1016/j.ijhydene.2024.07.260

Apribowo, C. H. B., Ibrahim, M. H., & Purnomo, M. R. B. (2020). Design and economic analysis of floating PV-wind turbine plant for renewable energy supply in Indonesia. *AIP Conference Proceedings*, *2217*(April). https://doi.org/10.1063/5.0000829

Aprilia, A., Abdurrahman, A. F., Ananda, A., Lampung, B., & Lampung, B. (2024). *ANALYSIS OF DAILY AND ANNUAL VARIATIONS OF SOLAR RADIATION , AIR TEMPERATURE , PRECIPITATION , WIND SPEED , HUMIDITY , AND AIR PRESSURE IN LAMPUNG AS INDICATORS OF*. 78–92.

Ashraful Islam, M., Naushad Ali, M. M., Al Mamun, A., Shahadat Hossain, M., Hasan Maruf, M., & Shihavuddin, A. S. M. (2024). Optimizing energy solutions: A techno-economic analysis of solar-wind hybrid power generation in the coastal

regions of Bangladesh. *Energy Conversion and Management: X*, *22*(February), 100605. https://doi.org/10.1016/j.ecmx.2024.100605

Astjario, P., & Harkins, F. X. (2011). Penelitian Lingkungan Pantai Wilayah Pesisir. *Teknika*, *XXII*(1), 19–26.

Babu, T. S., Vasudevan, K. R., Ramachandaramurthy, V. K., Sani, S. B., Chemud, S., & Lajim, R. M. (2020). A Comprehensive Review of Hybrid Energy Storage Systems: Converter Topologies, Control Strategies and Future Prospects. *IEEE Access*, *8*, 148702–148721. https://doi.org/10.1109/ACCESS.2020.3015919

Bhattacharya, S., Goswami, A., & Sadhu, P. K. (2023). Design, development and performance analysis of FSPV system for powering sustainable energy based mini micro-grid. *Microsystem Technologies*, *29*(10), 1465–1478. https://doi.org/10.1007/s00542-023-05457-2

BI. (2025). *Bank Indonesia*. https://www.bi.go.id/id/default.aspx

Cáceres González, R., Sarmiento-Laurel, C., Alcayaga, H., Díaz, A. J., Pizarro, A., Crespo Fuentes, J., Moya Caro, A., Vásquez Páez, C., Bustos Olavarría, F., Boscolo, R., & Bastani, H. (2025). Exploring climate-driven performance of floating photovoltaic systems: Energy production enhancement and evaporation reduction. *Applied Energy*, *386*(January), 125556. https://doi.org/10.1016/j.apenergy.2025.125556

Chirwa, D., Goyal, R., & Mulenga, E. (2023). *Floating solar photovoltaic (FSPV) potential in Zambia: Case studies on six hydropower power plant reservoirs*.

Das, M., & Mandal, R. (2021). Optimization, Sensitivity and Energy Management of a PV/Wind/Battery and PV/Wind/Supercapacitor Hybrid Renewable Energy System for the Climatic Conditions of Haldia using HOMER: A Case Study.

Journal of Nano- and Electronic Physics, *13*(3), 1–5. https://doi.org/10.21272/jnep.13(3).03011

Duman, A. C., & Güler, Ö. (2018). Techno-economic analysis of off-grid PV/wind/fuel cell hybrid system combinations with a comparison of regularly and seasonally occupied households. *Sustainable Cities and Society*, *42*, 107–126. https://doi.org/10.1016/j.scs.2018.06.029

Dykes, K., King, J., DiOrio, N., King, R., Gevorgian, V., Corbus, D., Blair, N., Anderson, K., Stark, G., Turchi, C., & Moriarty, P. (2020). Opportunities for Research and Development of Hybrid Power Plants. *Nrel*, *May*. https://www.osti.gov/servlets/purl/1659803/

Enersys Co., Ltd. (2025). *EnerSys PowerSafe SBS 900*. https://www.mlperformance.co/products/sbs-900-2-enersys-powersafe-eon-agm-battery-2v-900ah%09%0A

Fereshtehpour, M., Javidi, R., Farrokhi, A., Bahrami, E., & Ebrahimi, E. (2021). *Evaluation of factors governing the use of floating solar system: A study on Iran's important water infrastructures*. *171*, 1171–1187.

Fofang, T. F., & Tanyi, E. (2020). Design and Simulation of Off-Grid Solar/Mini-Hydro Renewable Energy System using Homer Pro Software: Case of Muyuka Rural Community. *International Journal of Engineering Research & Technology (IJERT)*, *9*(9), 597–604. https://www.researchgate.net/publication/344401458

Fulghum, N. (2025). *Electricity Review 2025 Global Electricity Review 2025*. *April*.

Huang, L., Elzaabalawy, H., Sarhaan, M., Sherif, A., Ding, H., Ou, B., Yang, D., & Cerik, B. C. (2025). Developing reliable floating solar systems on seas: A review. *Ocean Engineering*, *322*(November 2024). https://doi.org/10.1016/j.oceaneng.2025.120525

IEA. (2024). *Evaluation of Software Tools for Standalone Microgrid Design and Optimization 2024 Task 18 Off-Grid and Edge-of-Grid Photovoltaic Systems*. www.iea-pvps.org

Institute for Essential Services Reform (IESR). (2024). Indonesia Energy transition Outlook. *Essential Concepts of Global Environmental Governance*, 86–88.

IPCC. (2022). Climate Change 2022 - Mitigation of Climate Change - Full Report. In *Cambridge University Press* (Issue 1).

IRENA. (2023). World energy transitions outlook 2023: 1.5°C Pathway. In *International Renewable Energy Agency,Abu Dhabi*. https://www.irena.org/Publications/2023/Jun/World-Energy-Transitions-Outlook-2023

Jahangir, M. H., Fakouriyan, S., Vaziri Rad, M. A., & Dehghan, H. (2020). Feasibility study of on/off grid large-scale PV/WT/WEC hybrid energy system in coastal cities: A case-based research. *Renewable Energy*, *162*, 2075–2095. https://doi.org/10.1016/j.renene.2020.09.131

Kementrian ESDM, Wahyu Kencono, A., Dwinugroho, M., Satra Baruna, E., & Ajiwihanto, N. (2024). *Handbook Of Energy & Economic Statistics Of Indonesia 2023*. 73.

Khan, I., Guanghua, L., Sahito, A. A., Memon, A. A., Hao, C., Soomro, A. H., & Shah, S. H. H. (2023). Analysis of Jamrao canal for potential of hybrid photovoltaic/hydrokinetic turbine system. *Energy Reports*, *10*, 419–430. https://doi.org/10.1016/j.egyr.2023.06.052

Khare, V., Khare, C. J., & Bhuiyan, M. A. (2023). Design, optimization, and data analysis of solar-tidal hybrid renewable energy system for Hurawalhi, Maldives.

Cleaner Energy Systems, *6*(September), 100088. https://doi.org/10.1016/j.cles.2023.100088

Koholé, Y. W., Wankouo Ngouleu, C. A., Fohagui, F. C. V., & Tchuen, G. (2025). Optimization and comparative analysis of hybrid renewable energy systems for sustainable and clean energy production in rural Cameroon considering the loss of power supply probability concept. *Energy Conversion and Management: X*, *25*(October 2024). https://doi.org/10.1016/j.ecmx.2024.100829

Kumar, N. M., Islam, S., Podder, A. K., Selim, A., Bajaj, M., & Kamel, S. (2023). Lifecycle-based feasibility indicators for floating solar photovoltaic plants along with implementable energy enhancement strategies and framework-driven assessment approaches leading to advancements in the simulation tool. *Frontiers in Energy Research*, *11*(February). https://doi.org/10.3389/fenrg.2023.1075384

López, M., Claus, R., Soto, F., Hernández-Garrastacho, Z. A., Cebada-Relea, A., & Simancas, O. (2024). Advancing offshore solar energy generation: The HelioSea concept. *Applied Energy*, *359*(December 2023). https://doi.org/10.1016/j.apenergy.2024.122710

López, M., Rodríguez, N., & Iglesias, G. (2020). Combined floating offshore wind and solar PV. *Journal of Marine Science and Engineering*, *8*(8). https://doi.org/10.3390/JMSE8080576

Lozano, L., Querikiol, E. M., Abundo, M. L. S., & Bellotindos, L. M. (2019). Techno-economic analysis of a cost-effective power generation system for off-grid island communities: A case study of Gilutongan Island, Cordova, Cebu, Philippines. *Renewable Energy*, *140*(9513), 905–911. https://doi.org/10.1016/j.renene.2019.03.124

Mahmud, R., Moni, S. M., High, K., & Carbajales-Dale, M. (2021). Integration of techno-economic analysis and life cycle assessment for sustainable process design – A review. *Journal of Cleaner Production*, *317*(December 2020), 128247. https://doi.org/10.1016/j.jclepro.2021.128247

Mojumder, M. F. H., Islam, T., Chowdhury, P., Hasan, M., Takia, N. A., Chowdhury, N. U. R., & Farrok, O. (2024a). Techno-economic and environmental analysis of hybrid energy systems for remote areas: A sustainable case study in Bangladesh. *Energy Conversion and Management: X*, *23*(April), 100664. https://doi.org/10.1016/j.ecmx.2024.100664

Mojumder, M. F. H., Islam, T., Chowdhury, P., Hasan, M., Takia, N. A., Chowdhury, N. U. R., & Farrok, O. (2024b). Techno-economic and environmental analysis of hybrid energy systems for remote areas: A sustainable case study in Bangladesh. *Energy Conversion and Management: X*, *23*(April), 100664. https://doi.org/10.1016/j.ecmx.2024.100664

Nallolla, C. A., & Vijayapriya, P. (2022). Optimal Design of a Hybrid Off-Grid Renewable Energy System Using Techno-Economic and Sensitivity Analysis for a Rural Remote Location. *Sustainability (Switzerland)*, *14*(22). https://doi.org/10.3390/su142215393

NASA POWER. (2024). *NASA Prediction of Worldwide Energy Resource (POWER)*. https://power.larc.nasa.gov/data-access-viewer/

Nuri, M., Putri, S., Hidayat, T., Puspadimiati, W., & Priyono, B. (2025). *Techno-Economic Analysis of the Integration of Floating Photovoltaic (FPV) Solar Power Plant and Pumped Hydro Storage (PHS) Hydroelectric Power Plant at Matenggeng*. *1*(1), 95–105.

Nurtiyanto, W. A., Irwansyah, N., & Nugroho, A. A. (2023). Optimasi Ketinggian Floating Pv Pada Instalasi Pv 340 Wp. *Transmisi: Jurnal Ilmiah Teknik Elektro*, *25*(1), 10–16. https://doi.org/10.14710/transmisi.25.1.10-16

Nurunnabi, M., Roy, N. K., Hossain, E., & Pota, H. R. (2019a). Size optimization and sensitivity analysis of hybrid wind/PV micro-grids- A case study for Bangladesh. *IEEE Access*, *7*, 150120–150140. https://doi.org/10.1109/ACCESS.2019.2945937

Nurunnabi, M., Roy, N. K., Hossain, E., & Pota, H. R. (2019b). Size optimization and sensitivity analysis of hybrid wind/PV micro-grids- A case study for Bangladesh. *IEEE Access*, *7*(November), 150120–150140. https://doi.org/10.1109/ACCESS.2019.2945937

Oladigbolu, J. O., Ramli, M. A. M., & Al-Turki, Y. A. (2020). Optimal design of a hybrid pv solar/micro-hydro/diesel/battery energy system for a remote rural village under tropical climate conditions. *Electronics (Switzerland)*, *9*(9), 1–22. https://doi.org/10.3390/electronics9091491

Patil, A., Mamatha, G., Kulkarni, P. S., & Verma, A. (2022). Analysis of Hybrid Floating Photovoltaic and Hydro-Power plant with HOMER Pro Software. *10th IEEE International Conference on Power Electronics, Drives and Energy Systems, PEDES 2022*, *March*. https://doi.org/10.1109/PEDES56012.2022.10080502

Prasetyo, S. D., Regannanta, F. J., Birawa, A. R., & Alfaridzi, M. S. (2023). Techno-Economic Evaluation of Hybrid Photovoltaic-Wind Energy Systems for Indonesian Government Buildings. *Journal of Sustainability for Energy*, *2*(3), 132–144. https://doi.org/10.56578/jse020303

Ramanan, C. J., Lim, K. H., & Kurnia, J. C. (2025). Thermal behavior of floating photovoltaics: A comparison of performance at varying heights and benchmarking against land-based photovoltaics. *Applied Energy*, *388*(March), 125642. https://doi.org/10.1016/j.apenergy.2025.125642

Rauf, H., Gull, M. S., & Arshad, N. (2020). Complementing hydroelectric power with floating solar PV for daytime peak electricity demand. *Renewable Energy*, *162*, 1227–1242. https://doi.org/10.1016/j.renene.2020.08.017

Rezki Fajry, F., Garniwa, I., & Fajar Tofani, A. (2018). Techno Economic Analysis of Hybrid Sea Floating Photovoltaic and Wind Turbine for Fish Cold Storage at Remote Island in Indonesia (Case Study: Small Kei Island, Maluku, Indonesia). *MATEC Web of Conferences*, *218*, 0–5. https://doi.org/10.1051/matecconf/201821801001

Roy, D., Zhu, S., Wang, R., Mondal, P., Ling-Chin, J., & Roskilly, A. P. (2024). Techno-economic and environmental analyses of hybrid renewable energy systems for a remote location employing machine learning models. *Applied Energy*, *361*(February). https://doi.org/10.1016/j.apenergy.2024.122884

Sakti, B., Utomo, R. M., Burhandenny, A. E., Siregar, I. R. S., & Ridho, A. (2023). *Simulation of the Use of Solar and Wind Energy as a Hybrid Power Plant in Malahing Village Using Software Homer*. Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-180-7_37

Serat, Z., Danishmal, M., & Mohammad Mohammadi, F. (2024). Optimizing hybrid PV/Wind and grid systems for sustainable energy solutions at the university campus: Economic, environmental, and sensitivity analysis. *Energy Conversion and Management: X*, *24*(August), 100691. https://doi.org/10.1016/j.ecmx.2024.100691

Shenzhen KSTAR Science and Technology Co., Ltd. (2025). *KSTAR Blue -20KT-M1*. https://id.aliexpress.com/item/1005008187454082.html?gatewayAdapt=glo2idn

Sukarso, A. P., & Kim, K. N. (2020). Cooling effect on the floating solar PV: Performance and economic analysis on the case of west Java province in Indonesia. *Energies*, *13*(9). https://doi.org/10.3390/en13092126

Sunpal Energy Co., Ltd. (2025). *Tall Max DE - 460 W*. https://id.aliexpress.com/item/1005008187454082.html?gatewayAdapt=glo2idn#nav-store

T. Chingkheinganba, I. C. M. and B. A. S. (2022). "Optimization of Hybrid Renewable Energy System using Homer-Pro in both Standalone and Grid systems." *IEEE Access*. https://doi.org/10.1109/CALCON56258.2022.10060545

Thango, B. A., & Obokoh, L. (2024). Techno-Economic Analysis of Hybrid Renewable Energy Systems for Power Interruptions: A Systematic Review. In *Eng* (Vol. 5, Issue 3). https://doi.org/10.3390/eng5030112

Tracker, C. A. (2024). *worsens , the warming Climate Action Tracker*. *November*.

Wardhana, A. R., & Marifatullah, W. H. (2020). Transisi Indonesia Menuju Energi Terbarukan. *Jurnal Tashwirul Afkar*, *38*(2), 269–283.

Wuxi Rexco Technology Co., Ltd. (2025). *RexCo RC-5K-A*. https://rexcotech.en.made-in-china.com/product/OxSRWCuVfAcj/China-Rexco-Wind-Turbine-Products-Home-Use-48V-5000W-Wind-Turbine-System.html%09%0A