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Floating Solar Photovoltaic System Design and Yield Estimation for Aulo Dam in Palayan City, Nueva Ecija

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ABSTRACT: This study presents the design and energy yield estimation of a Floating Solar Photovoltaic (FPV) system for Aulo Dam in Palayan City, Nueva Ecija, as a sustainable solution for agricultural irrigation. It addresses rising energy demand wh ile promoting renewable systems that do not compete with agricultural land, aligning with SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land). The system was designed and evaluated using simulation tools considering solar irradiance, wind load, and hydrological conditions, while a scaled prototype was developed to validate system performance and structural stability. Results show that the proposed 600 Wp system can generate 762.94 kWh annually with a 93.1% solar fraction. Paired with a 0.5 hp pump, the system can deliver approximately 10,800 liters of water within a 4.5-hour solar window and irrigate about 0.41 hectares of rice field. The findings demonstrate that FPV deployment at Aulo Dam is feasible and can provide a reliable, cost-effective, and land-efficient energy source for sustainable agricultural irrigation.

KEYWORDS: Floating Solar Photovoltaic System, Energy Yield Estimation, Renewable Energy, Irrigation, Aulo Dam, Sustainable Infrastructure

1.0 INTRODUCTION

One of the major challenges in Philippine agricultural communities is the high cost and unreliable supply of energy for irrigation systems, which are essential for sustaining crop productivity and rural livelihoods. In provinces such as Nueva Ecija, many farmers rely on diesel-powered pumps and unstable electricity, making irrigation highly vulnerable to fuel price fluctuations and energy interruptions (NIA, 2023; DOE, 2022). During dry seasons such as El Niño, water scarcity and increased irrigation demand force farmers to allocate a significant portion of their income to fuel and electricity, further reducing agricultural productivity (FAO, 2021; DOE, 2026). These conditions highlight the urgent need for sustainable and cost-effective energy solutions aligned with SDG 7, 12, 13, and 15 to support resilient agricultural systems.

The Philippines has strong solar energy potential supported by the Renewable Energy Act of 2008, and solar-powered irrigation systems have been introduced to reduce dependence on fossil fuels. However, most are land-based and compete with agricultural land use. Floating solar photovoltaic (FPV) systems offer an alternative by utilizing water bodies such as dams and reservoirs, improving efficiency through natural cooling and reducing evaporation while addressing land constraints (Mohd Azmi et al., 2014; Ravichandran et al., 2022). These advantages highlight the need to explore integrated energy-water solutions for sustainable agriculture.

Aulo Dam in Nueva Ecija is a suitable site for FPV due to its large reservoir supporting irrigation activities. An FPV system can provide clean and reliable energy for irrigation pumps, reduce operational costs, and lessen dependence on diesel. However, proper design is required to withstand environmental loads such as wind, waves, water-level fluctuations, and material degradation (Rahman & Karim, 2021; Lin et al., 2022). Although FPV systems show strong technical and economic potential, their application in Philippine irrigation reservoirs remains limited, emphasizing the need for further localized assessment for sustainable agricultural implementation.

1.2 OBJECTIVES

This study aims to design and estimate the energy yield of a floating solar photovoltaic (FPV) system for Aulo Dam in Palayan City, Nueva Ecija to support renewable energy planning and assess its potential contribution to local agricultural and irrigation energy needs. The specific objectives are:

1. To utilize simulation and design software to model, validate, and analyze the FPV system’s performance and structural response under different environmental conditions.
2. To analyze the effects of key solar and hydrological factors such as Global Horizontal Irradiance (GHI),

panel efficiency, wind pressure, hydrostatic forces, and debris impact on the system's design and energy performance.

3. To develop and test a small-scale prototype of a Floating Photovoltaic Energy System in a controlled water environment.
4. To estimate the projected energy output of the proposed FPV system under varying environmental conditions at Aulo Dam.

2.0. METHODOLOGY.

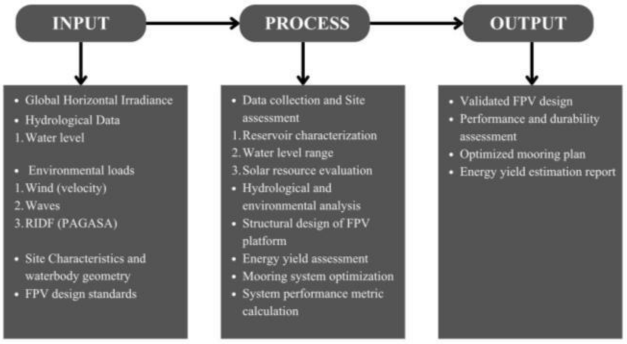

Figure 1: Conceptual Framework of the Structural Design and Energy Yield Assessment of the Floating Solar Photovoltaic System (FPV) Integration

2.1 Experimental and Simulation-Based Evaluation of the Floating Photovoltaic System at Aulo Dam

This study employs an experimental and simulation-based design focused on evaluating the feasibility of a floating photovoltaic (FPV) system in Aulo Dam, Palayan City, Nueva Ecija. The study is limited to technical and engineering analysis of system performance under local environmental conditions, considering hydrological, meteorological, and solar factors affecting structural stability and energy generation. Site-specific data such as Global Horizontal Irradiance (GHI), wind conditions, rainfall, wave action, water-level variation, and dam geometry are obtained from NIA-UPRIS III, PAGASA, and the LGU of Palayan City, Brgy. Mapait, while spatial and energy-related inputs are processed using Google Earth, QGIS, SketchUp, PVsyst, and HEC-HMS. The research is conducted in two phases: Phase 1 involves simulation-based analysis where engineering models are used to evaluate buoyancy, structural behaviour, and system response under environmental loads, while Phase 2 involves prototype testing of a small-scale FPV system in a controlled water setup to measure actual performance in terms of stability, displacement, panel temperature, voltage, current, and power output. Simulation and prototype results are then compared to validate system performance and assess consistency between predicted and actual behavior. The study concludes with an evaluation of structural feasibility, energy efficiency, and operational reliability of the FPV system, serving as basis for determining its suitability as a sustainable irrigation energy solution for Aulo Dam.

3.0 RESULTS AND DISCUSSION

3.1 Location Mapping for Floating Solar Photovoltaic System at Aulo Dam

Figure 2: QGIS Vector polygon for spatial mapping of the Aulo Dam

The proposed site for the floating solar photovoltaic system is located at coordinates 297953.9, 1716040.6. The surrounding terrain lacks tree cover, eliminating potential shading to maximize daily solar irradiance and system efficiency. Additionally, the adjacent stable, accessible ground provides an ideal platform for essential onshore infrastructure, including electrical control units, pumps, and maintenance access points.

3.2 Rainfall–Runoff Modelling using HEC-HMS

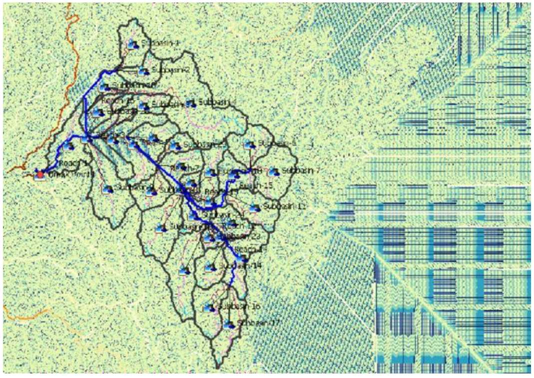

Figure 3: HEC-HMS Basin Model and Stream Network Delineation of the Aulo Dam Watershed

The rainfall-runoff behavior of the 98.2 km² Aulo Dam watershed was simulated using HEC-HMS for June 6–7, 2025, capturing near-saturated soil conditions during the dry-to-wet season transition. Following DPWH (2015) guidelines, the watershed was discretized into 33 subbasins to differentiate between the steep Sierra Madre headwaters and low-lying Palayan City agricultural plains, with routing modeled via the SCS Lag Method.

Based on NASA POWER data, total rainfall reached 138 mm. Due to the low infiltration capacity of the dominant Annam and Umingan Clay Loams (Hydrologic Soil Group C/D), 67% of the total precipitation was converted into surface runoff. Peak subbasin discharge reached approximately 10 m³/s, while the watershed outlet (sink) registered a peak discharge of 263.0 m³/s and a total inflow volume of 6,703 × 10³ m³.

Reach 2 functioned as the primary hydraulic corridor, carrying 93% of the peak flow (244.7 m³/s). A 110-minute lag between subbasin and outlet peaks demonstrated significant stream network attenuation, reducing instantaneous discharge risks. Ultimately, these peak discharge, routing, and volumetric data established the technical baseline for the floating solar photovoltaic (FPV) system's mooring, anchoring, and structural footprint design to ensure stability under peak hydrodynamic loading.

3.3 Spatial Distribution and Peak Flow Hierarchy across Watershed Elements

The global hydraulic summary indicates that watershed discharge is highly localized, with Reach 2 (88.2 km² drainage area) routing 244.7 m³/s—approximately 93% of the total peak inflow. The stream network demonstrated significant routing efficiency, evidenced by a 110-minute lag between the subbasin peak flows (21:00) and the integrated outlet peak at Sink 1 (22:50). This staggered arrival attenuates instantaneous peak discharge, satisfying DPWH (2015) safety requirements for spillway design.

Detailed watershed discretization validated the cumulative contribution of minor agricultural zones alongside high-volume mountainous flows, yielding a total inflow volume of 6,703.0 × 10³ m³ and a maximum peak discharge of 263.0 m³/s at Sink 1. These hydrologic parameters establish the technical baseline for the FPV system's mooring and anchoring mechanisms, ensuring structural stability against rapid water-level and velocity fluctuations while accurately defining the usable reservoir footprint for optimized energy yield.

3.4 Irrigation Service Areas Supplied by Aulo Dam

The NIA-UPRIIS Aulo Division Thematic Map (Figure 4) outlines the Aulo Irrigation System, which services approximately 350 agricultural parcels spanning 674.5208 ha in Palayan City. This gravity-fed network distributes reservoir water through main and lateral canals to support regional rice and vegetable cultivation. Spatial analysis indicates that the flat, densely clustered north-central basin forms the highly efficient core irrigation zone. Conversely, the elongated southern parcels and steeper eastern boundaries represent hydraulic extremities vulnerable to delivery delays, canal seepage losses, upland sedimentation, and dry season supply inequities.

Figure 4: Division Thematic Map of Aulo Dam (Source: NIA-UPRIIS)

3.5 Interpretation and Analysis of the SketchUp-Based Floating Solar Photovoltaic Platform Design

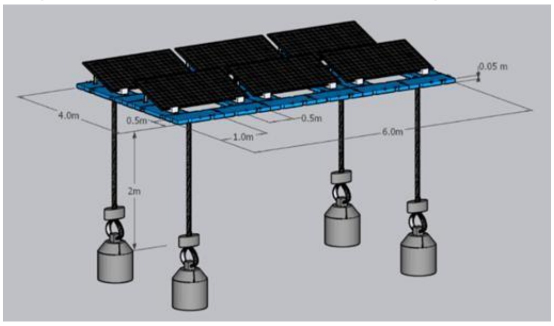

Figure 5: SketchUp Design of the FPV System

Using SketchUp, a modular floating solar photovoltaic (FPV) platform was designed to support six 1.32 m × 0.67 m solar panels (0.884 m² each) configured in a 2×3 array, totalling a 5.31 m² collection area. The 6.0 m × 4.0 m HDPE pontoon platform yields a total area of 24 m², meaning the solar panels occupy 22% of the surface. The remaining area accommodates structural framing, 0.5 m inter-panel gaps, and a 1.0 m central aisle to optimize airflow cooling, mitigate shading, and ensure maintenance access.

The structural load is transferred from the solar panels to a rectangular frame, which is secured by a four-point mooring system. Four vertical 2-m mooring lines connect the platform corners to concrete deadweight blocks on the reservoir bed, a configuration optimized to minimize lateral displacement in calm waters like the Aulo Dam.

To validate the concept, a small-scale 4.0 m × 4.0 m prototype weighing 36 kg was constructed. It features a 6-inch diameter PVC pipe floatation system, a plastic matting deck, a single 160W solar panel (1.32 m × 0.67 m) powering a pump, and four 10-kg concrete mooring blocks.

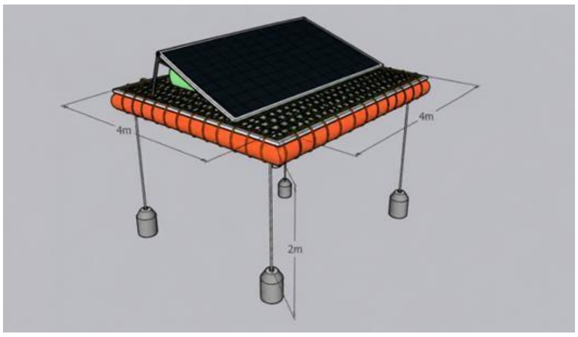

Figure 6: SketchUp Design of the FPV System Prototype (Scale: 1:3.75)

Figure 7: Actual Prototype of the Device

3.6 Geospatial Characterization and Surface Area Analysis for Floating Solar Photovoltaic System

QGIS vectorization of satellite imagery indicates the Aulo Dam reservoir encompasses a surface area of approximately 765,799.74 m² (76.58 ha). The site is characterized by an irregular, "fingered" shoreline that conforms to the surrounding undulating terrain, with a prominent straight-edged embankment on the northwestern boundary governing water impoundment.

This complex geometry results in a non-linear stage-storage relationship, meaning the available surface area and water depth fluctuate unpredictably with changing water levels. This variability serves as a critical constraint for engineering the FPV mooring and anchoring systems, which must accommodate significant lateral movement within the narrow branches of the reservoir. However, the 76.58-ha baseline offers substantial renewable energy potential; utilizing a conservative 10% of the reservoir surface would accommodate a multi-megawatt FPV installation while leveraging the water’s natural cooling effect to enhance solar cell efficiency relative to land-based alternatives.

3.7 Structural Response and Buoyancy Analysis

STAAD.Pro v8i structural simulation of the 4.0 m × 6.0 m FPV platform, which utilizes a 50-mm-thick HDPE pontoon, demonstrates stable floating equilibrium. By shifting the mooring attachment points inward from the extreme corners, the design leverages the hull's global buoyancy and mitigates edge submergence. Under operational loading, the mooring nodes exhibited a minimal average vertical displacement of –23.75 mm.

Furthermore, the platform exhibits high tilt stability, registering a maximum rotational displacement of only 0.002 radians. This negligible rotation confirms that the moment forces generated by the inward mooring placement do not cause significant pitch or roll, ensuring a level orientation for optimal solar exposure. This configuration optimizes material efficiency by maintaining structural integrity and level flotation without requiring heavy structural framing.

Table I Vertical Displacement Analysis using STAAD pro v8i

LC	*Hor.*	*Ver.*	*Hor.*	*Res.*	*Rotational*		
	Xmm	*Ymm*	*Zmm*	*mm*	*rX rad*	*rY rad*	*rZ rad*
Ave.	0	-23.8	0	23.75	0.0002	0	0.0000285

3.8 Comparative Analysis: PVSyst Modeling and Field Testing at Aulo Dam

The results of this study are divided into two primary components: the theoretical performance of a 600Wp FPV system simulated via PVSyst, and the empirical validation provided by a 160Wp scaled prototype. This dual method approach ensures that the proposed design for the Aulo Dam is both technically and practically feasible.

a. Theoretical System Performance (PVSyst results):

Table II Technical Specifications of the Proposed 600 Wp Floating PV System

Component	*Specification*
Location	Aulo Dam, Palayan City, Nueva Ecija
Total PV Power	600 Wp (6 modules)
Module Type	Monocrystalline (Hantech 100Wp)
Storage Capacity	180 Ah at 26V (Lithium-ion LFP)
Controller	MPPT (Optimized for 24V System)
Tilt/Azimuth	31.5/0° (True South)
Albedo	0.07 (Water Surface Calibration)

The system design consists of a 600Wp array specifically optimized for the environmental conditions of the Aulo Dam. A key adjustment in the simulation was the reduction of the Albedo coefficient to 0.07, reflecting the lower solar reflectance of deep-water surface compared to terrestrial sites. This ensures that the simulated energy yield is a realistic representation of a floating installation.

The simulation results demonstrate high system reliability, with a total annual production of 762.94kWh. The Solar Fraction of 93.15% confirms that the 600Wp array and

180Ah battery bank can successfully power the water pump for nearly the entire year. While there is a small amount of missing energy (56.12 kWh/year), this is concentrated in the peak rainy months of June to August. Crucially, this deficit does not impact farm operations as the increased rainfall during this period naturally supplies the necessary water needs, eliminating the demand for “patubig” (irrigation). Conversely, the 51.46 kWh of unused energy suggests the system has a surplus during the dry season, providing strategic advantage for extended pumping hours when irrigation demands is at its peak.

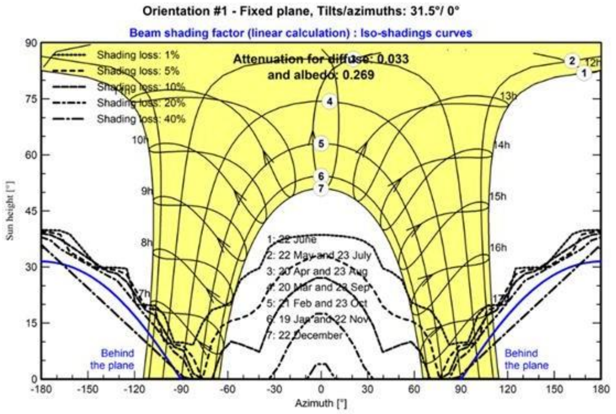

Figure 8: Iso-shading Diagram of the Location

Table III Simulated Annual Energy Production and Efficiency (kWh)

	EAvail	*EUnused*	*EMiss*	*EUse*	*ELoad*	*Sol Frac*
Res	833.64	51.46	56.116	762.9	819.06	93.1 %

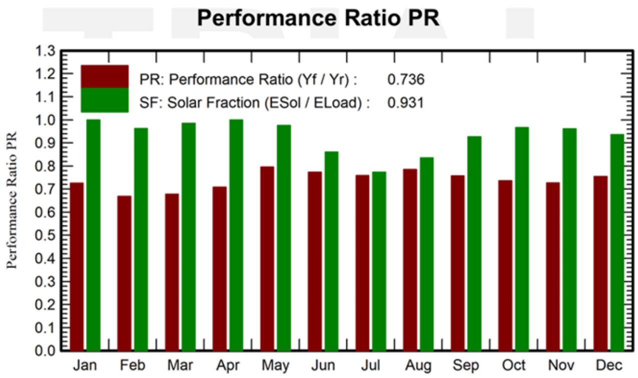

Figure 9: Performance Ratio based on the simulation

A detailed analysis of the system loss diagram indicates that the largest performance constraint is temperature, accounting for a 5.94% loss. However, this is relatively low for the climate of Nueva Ecija, supporting the hypothesis that the floating nature of the system provides a convective cooling effect from the water. Near shadings were minimized to 1.28% through optimized 3D placement, ensuring high incidence efficiency throughout the day.

Experimental Validation via 160Wp Scaled Prototype: To validate the theoretical findings, a physical prototype was constructed at a 1:3.75 scale, utilizing a 160Wp photovoltaic array. The prototype was deployed at the Aulo Dam for a 3-day field test to observe the buoyancy of the floating structure and the actual energy harvest under site- specific conditions. This experimental phase is critical to confirm that environmental variables, such as cooling effect of the water, align with the PVsyst model. While Albedo was not directly measured on-site, the correlation between the prototype’s energy yield and the scaled simulation results suggests that the selected Albedo coefficient of 0.07 is an appropriate representation of the Aulo Dam’s water surface reflectivity.

From the PVSyst report, the researchers know that the daily energy need is 2.24 kWh/day **(819.06 kWh/year ÷ 365 days)**. This formula can be used to see if the 160W prototype matches this daily need:

Average of Total Wh x Scale Factor

Since the test was 15 mins, this formula can be used to find the projected daily yield (PDY) using this formula:

Measured Avg. x 4 (four 15mins per day) x 4.5 (peak sun hour in Nueva Ecija)

Table IV Daily Energy Performance Comparison

Para-meter	*Prototype Ave.*	*PDY*	*Scaled Prototype*	*Report Ave.*
Daily Energy Yield	33.56 Wh	604.08 Wh/day	2.3 kWh/day	2.24 kWh/day
Solar Fraction	100% (During Testing)	100% (During Testing)	100% (During Test)	93.15 (Annual)

Validation of the FPV system focused on Daily Energy Yield. The 160Wp prototype generated an average of 33.56 Wh per test interval. Extrapolating this to a standard 4.5 Peak Sun Hour (PSH) day and scaling by a factor of 3.75 projected a yield of 2,265.3 Wh/day for the proposed 600Wp system. This field-measured output strongly correlates with the 2.24 kWh/day predicted by the PVsyst simulation, confirming the model’s accuracy under Nueva Ecija’s environmental conditions.

While the simulation predicted an annual Solar Fraction of 93.15% due to seasonal monsoons and typhoons, the prototype achieved 100% operational reliability during its dry-season deployment (April). Proximity to the water body provided a natural heat sink, maintaining stable charging voltages during peak thermal hours and validating the –5.94% temperature loss coefficient used in the PVsyst model.

To assess agricultural utility, the energy harvest was quantified by the volume of water delivered for irrigation. Operating a 0.5-hp pump rated at 40 L/min across the 4.5-hour solar window, the system delivers 10,800 L/day. Adhering to PhilRice guidelines for shallow submergence (1–2 cm depth) to optimize rice crop quality, the 160Wp prototype sustains an area of approximately 1,100 m². Scaled to the proposed 600Wp design, the daily irrigation capacity increases to 0.41 hectares.

This decentralized, floating infrastructure bypasses traditional land-clearing requirements, preserves tillable acreage, and eliminates fuel costs for pumps. Consequently, the FPV system provides a technically sufficient, climate-resilient infrastructure model for off-grid or tail-end farms near reservoirs like the Aulo Dam.

4.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1 Summary of Findings

This study evaluated the design, structural stability, hydrological suitability, and energy yield of a floating photovoltaic (FPV) system at Aulo Dam in Palayan City, Nueva Ecija using integrated simulation and prototype testing. PVsyst, HEC-HMS, STAAD.Pro, and QGIS were used for solar simulation, watershed analysis, structural assessment, and spatial mapping, supported by 3D modeling for system design. Results showed that the proposed 600 Wp FPV system can generate about 762.94 kWh annually with a 93.15% solar fraction, while temperature losses remained low at –5.94%, indicating improved efficiency due to the water-based cooling effect. Prototype testing of a 160 Wp system produced an average of 33.56 Wh per interval, which when extrapolated under 4.5 peak sun hours closely matched the simulated output of 2.24 kWh/day, confirming strong agreement between simulation and actual performance. Hydrological analysis confirmed stable runoff conditions suitable for FPV deployment, while QGIS estimated the dam surface area at about 76.58 hectares, indicating high potential for large-scale installation. Structural analysis using STAAD.Pro showed that the HDPE pontoon and mooring system can withstand hydrostatic and environmental loads, ensuring stability under site conditions. Field testing further confirmed 100% operational reliability during dry conditions and showed benefits such as stable voltage output, reduced temperature losses, and elimination of land use requirements. In terms of application, a 0.5 hp pump (40 L/min) can supply about 10,800 liters of water within a 4.5-hour solar window, sufficient for roughly 1,100 m² of rice field based on PhilRice guidelines, and up to about 0.41 hectares when scaled to the full system. Overall, the findings confirm that the FPV system is technically feasible, structurally stable, hydrologically suitable, and energy efficient, with strong agreement between simulation and prototype results, supporting its potential as a sustainable irrigation energy solution aligned with SDGs 7, 12, 13, and 15.

Conclusions and Recommendations

Based on the findings of the study, the proposed Floating Solar Photovoltaic (FPV) system for Aulo Dam is concluded to be technically feasible and structurally stable under varying environmental conditions, as demonstrated through simulation results indicating reliable performance under solar irradiance, wind loads, and hydrological factors. The system is capable of generating sufficient renewable energy to support irrigation requirements, with results showing consistent and efficient energy production across varying environmental scenarios. The integration of simulation and prototype testing further validates system performance under actual conditions, where the floating configuration enhances efficiency through natural cooling effects while simultaneously minimizing land use requirements. Identified limitations include variability in solar irradiance, potential measurement uncertainties, and the need for continuous data acquisition, emphasizing that energy assessment is more accurately represented through cumulative energy values (Wh or kWh) over extended observation periods. Overall, the FPV system demonstrates strong potential as a renewable, cost-effective, and sustainable solution for agricultural energy demands in irrigation applications at Aulo Dam.

In view of these findings, it is recommended that detailed engineering design and phased pilot-scale implementation be undertaken prior to full-scale deployment, with particular attention to mooring system optimization to accommodate water level fluctuations and hydrodynamic forces. Regular monitoring of sediment accumulation within the reservoir is also advised, as it may influence structural stability and platform positioning over time. Implementation of protective measures such as dust-proofing, corrosion resistance, and scheduled maintenance of photovoltaic components is essential to sustain long-term operational efficiency. Furthermore, extended-duration performance monitoring, preferably under continuous 12-hour testing conditions, is recommended to ensure accurate and representative energy yield assessment under variable meteorological conditions. Additional studies focusing on system optimization, including panel orientation, spacing, and configuration, as well as long-term assessments of durability, water quality impacts, evaporation reduction, and hybrid integration with irrigation infrastructure, are also encouraged. Lastly, a cost-benefit and life-cycle analysis is recommended to evaluate economic viability and sustainability, alongside coordination with relevant agencies such as NIA UPRIIS Division III and LGU Palayan City to support possible scaling and implementation of the system.

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REFERENCES

1. Attar, H., Alahmer, A., Borowski, G., & Alsaqoor, S. (2025). Comprehensive review of advancements, challenges, design, and environmental impact in floating photovoltaic systems. Ecological Engineering & Environmental Technology, 26(2), 301– 322. https://doi.org/10.12912/27197050/199520
2. Asian Development Bank. (2018). Philippines energy sector assessment, strategy, and road map. https://www.adb.org/documents/philippines- energy-sectorassessment-strategy-and-road-map
3. Asian Development Bank. (2018). Philippines: Renewable energy development status report. https://www.adb.org/publications/philippines-renewableenergy-development-status-report
4. Baptista, J., Vargas, P., & Ferreira, J. R. (2021). A techno-economic analysis of floating photovoltaic systems, for southern European countries. Renewable Energy and Power Quality Journal, 19, 57–62. https://doi.org/10.24084/repqj19.214
5. Bhattacharya, S., & Jana, C. (2020). Solar powered irrigation system using floating photovoltaic technology. Renewable and Sustainable Energy Reviews, 135, 110201. https://doi.org/10.1016/j.rser.2020.110201
6. Centre for Study of Science, Technology and Policy. (n.d.). Canal top solar photovoltaic (CTPV) manual. https://staai.cstep.in/staai/assets/manual/CTPV.pd
7. Chen, Y., Xu, B., & Li, J. (2021). Environmental and performance assessment of 62 floating photovoltaic systems on reservoirs. Journal of Cleaner Production, 280, 124474. https://doi.org/10.1016/j.jclepro.2020.124474
8. Congress of the Philippines. (2008). Republic Act No. 9513: Renewable Energy Act of 2008. https://www.officialgazette.gov.ph/2008/12/16/republic-act-no9513/
9. Country Economy. (2024). Philippines energy consumption. https://countryeconomy.com/energy-andenvironment/energy-consumption/philippines
10. Da Silva, G. D. P., & Castelo Branco, D. A. (2018). Is floating photovoltaic better than conventional photovoltaic? Assessing environmental impacts. Impact Assessment and Project Appraisal, 36(5), 390–400. https://doi.org/10.1080/14615517.2018.1477498
11. Dellosa, R. M., Dimalanta, A. C., & Manalo, J. J. (2024). Simulation and economic modelling of a floating solar photovoltaic (FSPV) system. Journal of Energy Storage and Renewable Resources, 6(2), 45–58. https://journal.esrgroups.org/jes/article/view/2299
12. Dellosa, R. M., & Palconit, M. G. (2022). Resource assessment of a floating solar photovoltaic (FSPV) system with artificial intelligence applications in Lake Mainit, Philippines. Engineering, Technology & Applied Science Research, 12(5), 8971–8978. https://etasr.com/index.php/ETASR/article/view/4863
13. Department of Agriculture. (2019). Solar-powered irrigation system boosts rice production in Llanera, Nueva Ecija. https://www.da.gov.ph 63
14. Department of Energy. (2020). National Renewable Energy Program (NREP). https://www.doe.gov.ph/nrep
15. Department of Energy. (2022). Philippine energy plan 2020– 2040. https://www.doe.gov.ph/pep
16. Department of Energy. (2023). Philippine energy plan 2023– 2050. https://www.doe.gov.ph/pep
17. Department of Energy. (2023). Philippine power statistics. https://www.doe.gov.ph/energy-statistics
18. Department of Energy. (2026). Fuel price monitoring and oil price adjustments. https://www.doe.gov.ph/oil-monitor
19. Di Grazia, S., & Tina, G. M. (2023). Optimal site selection for floating photovoltaic systems based on Geographic Information Systems (GIS) and MultiCriteria Decision Analysis (MCDA): A case study. International Journal of Sustainable Energy, 43(1), Article 2167999. https://doi.org/10.1080/14786451.2023.216799
20. Friel, D., Karimirad, M., Whittaker, T., Doran, W. J., & Howlin, E. (2019). A review of floating photovoltaic design concepts and installed variations. In Proceedings of the 4th International Conference on Offshore Renewable Energy
21. (CORE2019). ASRANet Ltd.Gaikwad, O. D., & Deshpande, U. L. (2017). Evaporation control using floating PV system and canal rooftop solar system. International Research Journal of Engineering and Technology, 4(4), 2290–2294. https://www.irjet.net/archives/V4/i4/IRJET-V4I443.pdf 64
22. Gualtieri, C., Cimorelli, L., & Doria, G. P. (2023). Floating photovoltaic systems: Technological innovation and environmental perspectives. Renewable Energy, 201, 1166–1178. https://doi.org/10.1016/j.renene.2022.10.112

23. Gualtieri, G., Tina, G. M., & Orecchini, F. (2023). Floating photovoltaic plants: Performance analysis and environmental sustainability. Renewable and Sustainable Energy Reviews, 176, 113165. https://doi.org/10.1016/j.rser.2023.113165
24. International Energy Agency. (2022). Floating solar PV: A new frontier. https://www.iea.org/reports/floating-solar-pv
25. International Renewable Energy Agency. (2022). Solar photovoltaic systems. https://www.irena.org
26. Kichou, S., Skandalos, N., & Wolf, P. (2022). Floating photovoltaics performance simulation approach. Heliyon, 8, e03184. https://doi.org/10.1016/j.heliyon.2022.03184
27. Khoja, I., et al. (2025). A comparative review: Floating photovoltaic, agrivoltaics, and ground-mounted PV systems. IEEE Access, 13, 45853–45873. https://doi.org/10.1109/access.2025.3547438
28. Koondhar, M. A., et al. (2024). Reviewing floating photovoltaic (FPV) technology for solar energy generation. Energy Strategy Reviews, 54, 101449. https://doi.org/10.1016/j.esr.2024.101449
29. Kumar, M., Chandel, S. S., & Kumar, A. (2020). Performance analysis of a 10 MWp utility-scale grid-connected canal-top photovoltaic power plant under Indian climatic conditions. Energy, 204, 65 117903. https://doi.org/10.1016/j.energy.2020.117903
30. Lawale, F., Philbin, S., & Hosouli, S. (2025). Simulation and performance analysis of floating photovoltaic systems: A systematic review. Energies, 18(19), 5273. https://www.mdpi.com/1996-1073/18/19/5273
31. Lin, Y., Su, W., & Fang, C. (2022). Mooring system design and stability analysis of floating photovoltaic platforms. Ocean Engineering, 250, 110975. https://doi.org/10.1016/j.oceaneng.2022.110975
32. Manila Standard. (2025). One Meralco Foundation provides solar-powered irrigation pumps to Nueva Ecija farmers. https://manilastandard.net
33. Ministry of New and Renewable Energy. (2016). Canal top solar photovoltaic power plant: Design and implementation manual. https://mnre.gov.in
34. Mohd Azmi, N. S., Othman, M. Y., & Sopian, K. (2014). Performance analysis of floating photovoltaic and conventional photovoltaic systems. Journal of Sustainable Manufacturing and Technology, 1(1), 1– 7. https://ejournal.upsi.edu.my/index.php/EJSMT/article/view/10
35. National Grid Corporation of the Philippines. (2025). Transmission development plan. https://www.ngcp.ph
36. National Irrigation Administration. (2021). Solar-powered pump irrigation projects in San Isidro and Peñaranda, Nueva Ecija. https://www.nia.gov.ph
37. National Irrigation Administration. (2023). Irrigation systems profile and performance. https://www.nia.gov.ph/irrigation-statistics
38. National Irrigation Administration. (2025). Solar-powered irrigation program accomplishments. https://www.nia.gov.ph/programs-projects 66
39. National Renewable Energy Laboratory. (2021). Solar radiation basics. https://www.nrel.gov
40. One Meralco Foundation. (2025). Solar-powered mobile irrigation pumps for farmers. https://onemeralcofoundation.org
41. Philippine Information Agency. (2026, January 26). PhilRice underscores proper water management to ensure healthy rice, quality yield. https://pia.gov.ph/news/luzon/cl/philrice-underscores-proper-watermanagement-to-ensure-healthy-rice-quality-yield/
42. Philippine Star. (2026). Hunger and Hormuz. https://www.philstar.com/business/2026/04/22/2522592/hungerand-hormuz Rahman, M. M., & Karim, M. A. (2021). Structural analysis of floating solar photovoltaic systems under environmental loads. Renewable Energy, 170, 1148–1160. https://doi.org/10.1016/j.renene.2021.02.058
43. Ravichandran, N., et al. (2022). Floating photovoltaic system for Indian artificial reservoirs—An effective approach to reduce evaporation and carbon emission. International Journal of Environmental Science and Technology, 19(8), 7951–7968. https://doi.org/10.1007/s13762- 021-03686-4 Rappler. (2026). PH fuel supply and energy crisis updates. https://www.rappler.com
44. Sahu, A., Yadav, N., & Sudhakar, K. (2022). Floating photovoltaic power plant: A review. Renewable and Sustainable Energy Reviews, 66, 815– 824. https://doi.org/10.1016/j.rser.2016.08.051 67
45. Sananse, N. M., et al. (2023). The canal top solar power generation project. International Journal for Research in Applied Science & Engineering Technology, 11(4), 188– 193. https://doi.org/10.22214/ijraset.2023.51144
46. Sazali, M. A., Lam, H. L., & Mashori, M. (2025). Development of floating solar panel efficiency and their maintenance. Progress in Energy and Environment, 21, 15-28https://publisher.uthm.edu.my/periodicals/index.php/peat/article/view/ 19611
47. Sharma, R., Tiwari, G. N., & Sharma, D. (2022). Performance evaluation of floating solar photovoltaic systems. Solar Energy, 227, 228– 239. https://doi.org/10.1016/j.solener.2021.09.032

48. Trapani, K., & Redón Santafé, M. (2015). A review of floating photovoltaic installations: 2007–2013. Progress in Photovoltaics: Research and Applications,23(4),524–532. https://doi.org/10.1002/pip.2466
49. United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. https://sdgs.un.org/2030agenda
50. Vasuki, S., Levell, J., Santbergen, R., & Isabella, O. (2025). A technical review on the energy yield estimation of offshore floating photovoltaic systems. Renewable and Sustainable Energy Reviews,216,115596. https://doi.org/10.1016/j.rser.2025.115596
51. World Bank. (2019). Where sun meets water: Floating solar handbook for practitioners. https://www.worldbank.org/en/topic/energy/publication/where-sun- 68 meets-water
    Yang, Y., Li, X., Zhang, Q., & Xu, H. (2022).
52. Impacts of a floating photovoltaic system on temperature and water quality in a shallow tropical reservoir. Limnology, 23(3), 467–478. https://doi.org/10.1007/s10201-022-00698-y