Proposed hybrid PV–Wind system to support Net-Zero Energy Building in tropical buildings

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Introduction

- West façades and roofs receive intense tropical solar radiation, increasing cooling loads and challenging institutional buildings' energy performance.
- Study analyzes west façade heat gain and evaluates hybrid PV–wind energy performance on façades and roof surfaces. (Hamzah & Go, 2023)
- Façade shading and rooftop hybrid systems reduce thermal loads, supporting NZEB goals consistent with prior tropical climate studies. (Rana and Rahman 2020)
- NZEBs are low-energy buildings that use renewable energy to offset annual energy usage (Ohene et al. 2024)
- Hot humid climate, where cooling loads dominate energy consumption due to high outdoor temperatures and humidity levels. (Halawa et al. 2018)

- systems enhance reliability and stability by combining complementary sources, such as solar and wind, which peak at different times, a consistent and stable power output can be achieved M. A. Mossa (2022)
- A BIPV double skin facade reduced energy demand by 35% and achieved near net-zero status (Abdou et al., 2021)
- High solar irradiation on west-facing facades and roofs in tropical buildings raises cooling demand, requiring reduced heat gain and optimized on-site renewable energy generation systems. D. K. Wardhani (2020)

sbcc 2025

Method

Component	Formula	Input Details	Load (W)	Reference
Wall Area	11.2 m × 2.8 m	West-facing only	31.36 m^2	Room dimensions
Wall U-value	-	Brick 2.64 $W/m^2 \cdot K$	-	Zaki et al., IOP Conf. Ser. Earth Environ. Sci., 2018
SHGF (June, 2 PM)	-	470 W/m^2 (west-facing, June)	-	ASHRAE Fundamentals
Shading Coeff.	-	1.0 (no shading)	-	ASHRAE default
Wall Conduction	U × A × ΔT = 2.64 × 31.36 × 9	ΔT = 9°C	744.18	Heat transfer formula
Solar Gain	A × SHGF × SC = 31.36 × 470 × 1.0	Peak solar radiation on brick surface	14,739.20	ASHRAE and field condition
Total External	Sum	-	**15,483.38**	

Site informations

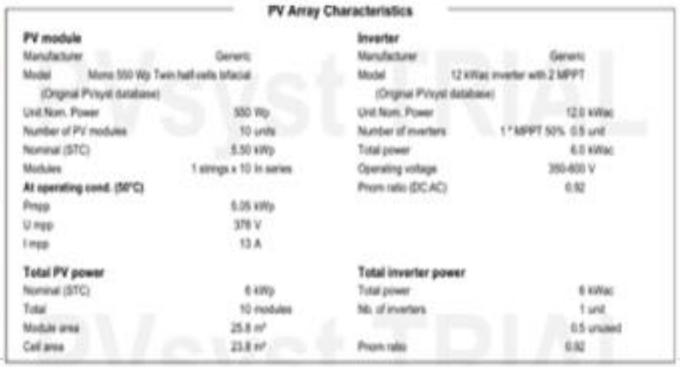
Building Name	Interdisciplinary Legal Research Center
Location	University of Indonesia
Total Building area	498 sqm
Number of garden lamps	27 used in 10 hours
Solar panel used	Centralized solar system

Simulation-based

Input
(1) Solar heat gain on a west-facing façade affects cooling load
(2) Hybrid PV–wind system for NZEB performance

Simulation
Simuat-
- Honeybee, Ladybug, ASHRAE CLTD method
- Rhino/Grasshopper
- PVsyst
- HOMER Pro

Output
Output
NZEB performance in a tropical institutional building



PV Array Characteristics

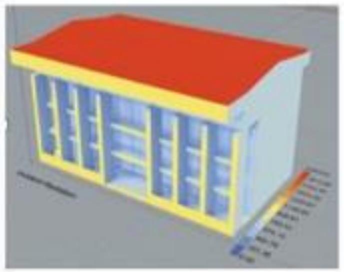
PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	Mono 550 Wp Twin half-cells bifacial (Original PVsyst database)	Model	12 kWac inverter with 2 MPPT (Original PVsyst database)
Unit Nom. Power	550 Wp	Unit Nom. Power	12.0 kWac
Number of PV modules	10 units	Number of inverters	1 * MPPT 50% 0.5 unit
Nominal (STC)	5.50 kWp	Total power	6.0 kWac
Modules	1 strings x 10 In series	Operating voltage	350-800 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	0.92
Pmpp	5.05 kWp		
U mpp	378 V		
I mpp	13 A		
Total PV power		**Total inverter power**	
Nominal (STC)	6 kWp	Total power	6 kWac
Total	10 modules	No. of inverters	1 unit
Module area	25.8 m^2		0.5 unused
Cell area	23.8 m^2	Pnom ratio	0.92

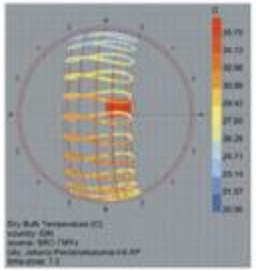
Data used

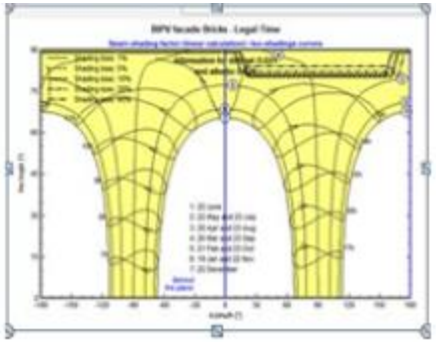
Item	Value
Number of turbines	6 units
Capacity per turbine	3 kW
Total wind capacity	18 kW
Average wind speed	3.5-4.2m/s(assumed, to be validated)
Output per turbine	2,950 kWh/year
Total wind output	17,700 kWh/year

Result and Discussion

- Simulation results show most of sun face west side (yellow color) and roof (red color)
- The iso-shading diagram visualizes how the west-facing BIPV facade reduces cooling loads while generating electricity
- Blocked radiation = less heat absorption = reduced air conditioning demand
- shading loss contours (1%, 5%, 10%) show where PV panels intercept sunlight, preventing it from heating the building, Blocks heat before it hits bricks reduces cooling load.

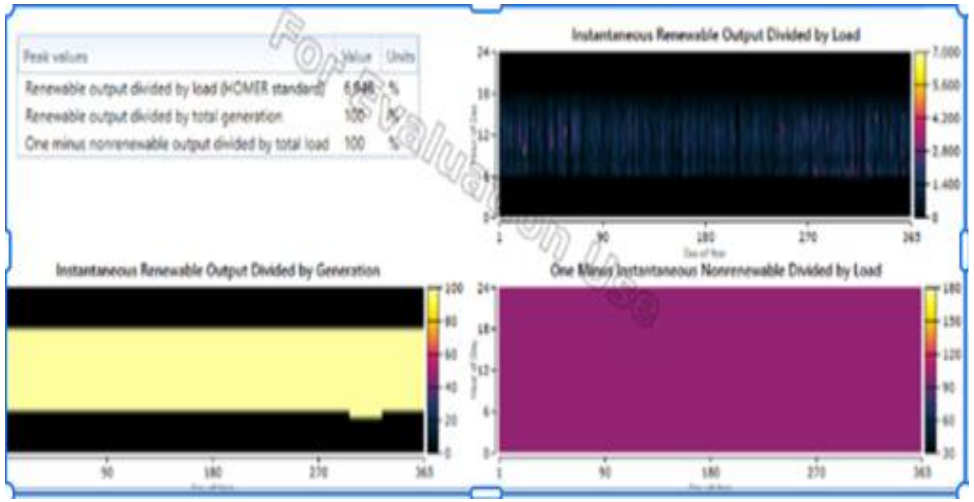


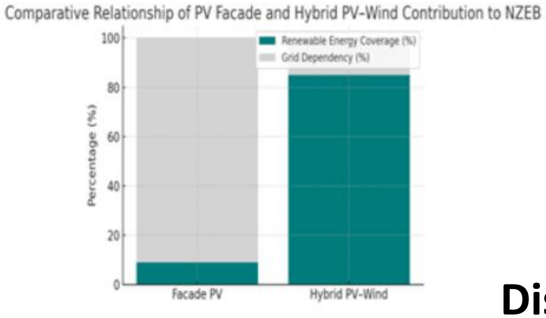




Scenario (source)	Shading loss (f)	Multiplier (1-f)	(Cooling load*{wall}* = *Q*{\text{wall}}(1-f)) (kW)	Reduction (kW)	Reduction (%)
Baseline (no shading)	0	1	15.48338	0	0.00%
PVsyst diffuse shading factor (diffuse only)	0.021	0.979	15.15823	0.32515	2.10%
Hypothetical — 5% shading (low contour)	0.05	0.95	14.70921	0.77417	5.00%
Hypothetical — 8% shading (mid contour)	0.08	0.92	14.24471	1.23867	8.00%
Irradiance-weighted (iso-diagram example) — computed from weighted SF (recommended)	**0.0952**	**0.9048**	**14.00936**	**1.47402**	**9.52%**
Hypothetical — 10% shading (upper contour)	0.1	0.9	13.93504	1.54834	10.00%

Result and Discussion





Component	Capacity	Annual Generation (kWh/year)	Share of Total Generation (%)
Rooftop PV	25 kWp	30,000	56.3%
Façade PV (BIPV)	13.32 kWp	4,068	7.6 %
Wind Turbines	6 × 3 kW	17,700	33.2 %
Total Hybrid	43 kWp	**53,275**	**≈ 85% coverage**

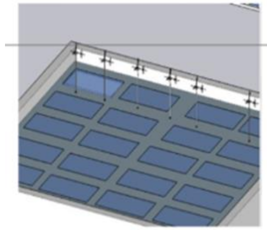
Application of Hybrid PV Wind energy gives the results that show almost of energy produced is from renewable energy (cream colour) and some few energy is from grid PLN

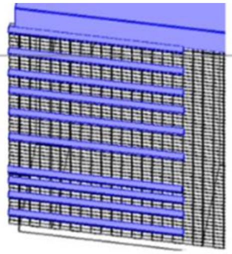
Discussion

- The façade results align with studies showing high afternoon heat gains on west-facing walls in tropical climates (Blanco and F. Convertino 2023)
- PV shading effectiveness agrees with research showing façade shading reduces thermal loads (N. Abdou.at,al 2021) Higher rooftop PV output matches findings that tilted rooftop modules perform better than vertical BIPV (S. Chen 2020).
- The strong hybrid PV–wind performance supports studies showing greater reliability from combining both resources (S. Chen 2020).

Conclusion

- This study aims to investigate how the solar heat gain of a west-facing facade influences the cooling load and interacts with the performance of a proposed hybrid Photovoltaic–wind system in supporting NZEB objectives. The research concludes that combining façade shading and a hybrid PV–wind system is an efficient means of enhancing the energy performance of buildings in tropical institutional environments.
- These results are most relevant for buildings that receive strong solar exposure, in particular west-facing façades and roof in warm climates.
- Future work will be centred on incorporating battery storage, maximizing PV orientation, and leading pilot studies in other building types and climates.





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