Vehicle Integrated Photovoltaic (VIPV) Systems

H. Samadi, G. Ala, M. Alqtish, A. Di Fatta, A. Imburgia, S. Licciardi, P. Romano, F. Viola

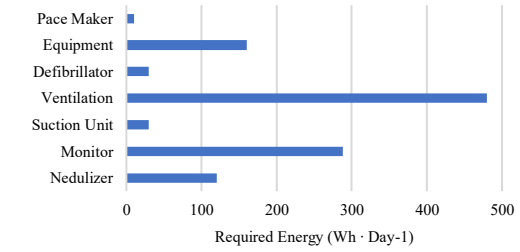
DI – Dipartimento di Ingegneria, Università degli Studi di Palermo
Viale delle Scienze, Edificio 9, 90128 Palermo

Vehicle-Integrated Photovoltaics (VIPV) represent an innovative approach to sustainable energy generation by converting the typically unused surface of vehicles into mobile solar power units. Vehicles are usually exposed to direct sunlight, making their surfaces ideal for integrating photovoltaic (PV) cells. Advances in PV technology now allow these systems to be embedded into vehicle bodies, partially or fully meeting their energy needs. Beyond mobility, the energy generated can serve other purposes, particularly in disaster scenarios, where power outages make energy access critical. In such cases, VIPV systems act as mobile power sources, capable of generating and storing electricity for essential equipment like medical devices.

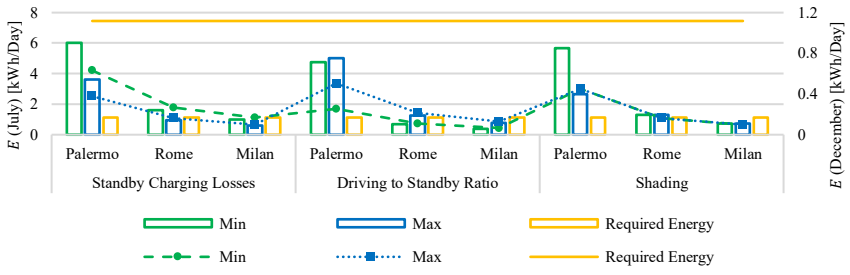
Case Study 1: Evaluating the Role of VIPV Systems in a Disaster Context

In this context, we evaluated the feasibility of integrating PV modules onto the roof of an electric ambulance to power essential ICU medical equipment. Simulations were conducted under varied environmental and operational conditions, including standby charging losses (0–700 W), driving-to-standby ratios (40–80%), and shading levels (0–80%). To verify its effectiveness under worst-case scenarios, the minimum daily energy generated in each month was compared with the required load of vital equipment. Figure 1 illustrates this comparison, with bar charts for July and line graphs for December. July and December were used as representative months for high and low solar output, respectively. Results show that even under challenging conditions, the system could supply energy for medical devices from 1 to 15 hours per day.

(a)



(b)



(c)

Figure 1. (a) The electric ambulance equipped with VIPV, (b) energy demand of ICU medical equipment, and (c) minimum daily energy production in July and December under various parameters and locations.

Case Study 2: Evaluating the VIPV Contribution for a Minibus in UNIPA campus

This study presents a framework for analyzing VIPV systems by combining optical, thermal, and electrical models, adapted from fixed PV methodologies. A case study was conducted using a minibus at the University of Palermo (UNIPA) to validate the model. Figure 2(b) shows the annual energy output of different solar modules placed on various vehicle surfaces. Two operational scenarios were compared: continuous operation from 08:00 to 15:00 with 21 daily cycles (approx. 29 kWh/day consumption), and hourly operation with 7 cycles/day (approx. 10 kWh/day). Based on the energy balance, the number of days each month that VIPV can meet the minibus's energy demand was calculated and is shown in Figures 2(c) and 2(d) as monthly contribution percentages.

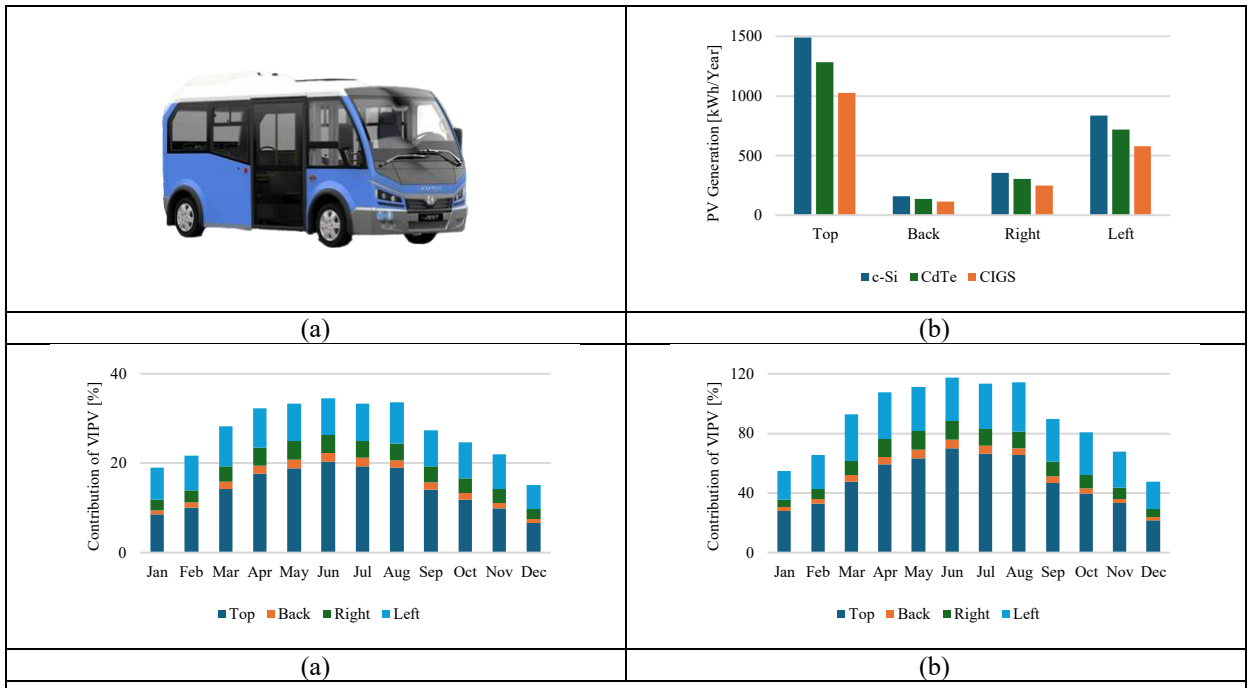


Figure 2. (a) The VIPV-equipped minibus, (b) annual energy production from different module placements, and monthly VIPV contribution under (c) continuous and (d) hourly operation scenarios.

References

[1] Samadi, H., Ala, G., Lo Brano, V., Romano, P., & Viola, F. "Investigation of effective factors on vehicles integrated photovoltaic (VIPV) performance: a review". World Electric Vehicle Journal, 14(6), 154, MDPI, (2024).

[2] Samadi, H., Ala, G., Lo Brano, V., Romano, P., Viola, F., & Miceli, R. "Potential and Methods of Integrating Solar Cells into Vehicles". In 2023 IEEE International Conference on Clean Electrical Power (ICCEP) (pp. 715-720).

[3] Samadi, H., Ala, G., Imburgia, A., Licciardi, S., Romano, P., & Viola, F. "Evaluating the Role of Vehicle-Integrated Photovoltaic (VIPV) Systems in a Disaster Context". World Electric Vehicle Journal, 16(4), 190, MDPI, (2025).

[4] Samadi, H., Ala, G., Brito, M. C., Traverso, A. Imburgia, M., Licciardi, S., Romano, P., Viola, F. "A Novel Model Chain for Analysing the Performance of VIPV Systems". (In preparation).