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Design and Implementation of a low-cost and compact real-time monitoring tool for battery life calculation

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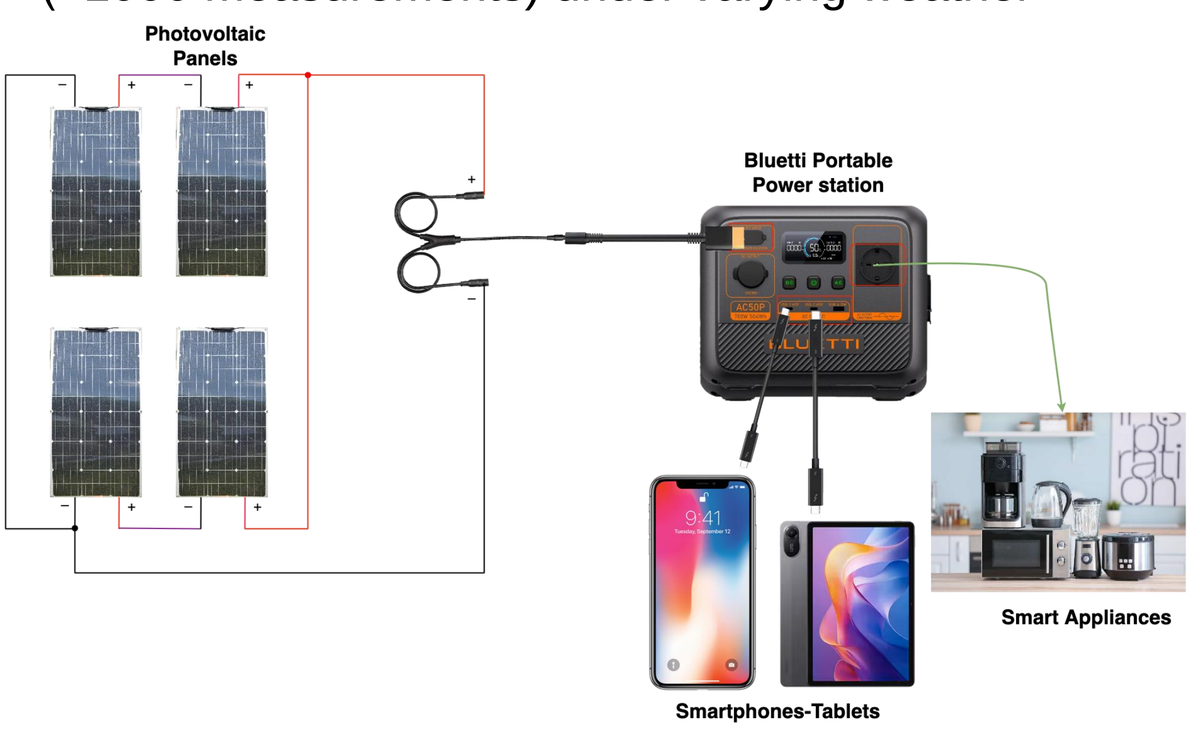
INTRODUCTION & AIM

- Buildings consume ~30–40% of global energy (~36% CO_2), with windows causing ~30% of heating/cooling load.
- Flexible PV panels can retrofit windows, providing shading while generating power.
- Local battery storage ($LiFePO_4$) stores daytime solar output to maximize self-consumption
- This project explores a dual-purpose solution: using flexible PV panels to simultaneously generate clean energy and provide passive shading, reducing the need for air conditioning.
- **Aim:** Demonstrate a low-cost PV+storage system with real-time battery monitoring (SoC/SoH) to improve home energy autonomy and comfort.

METHOD

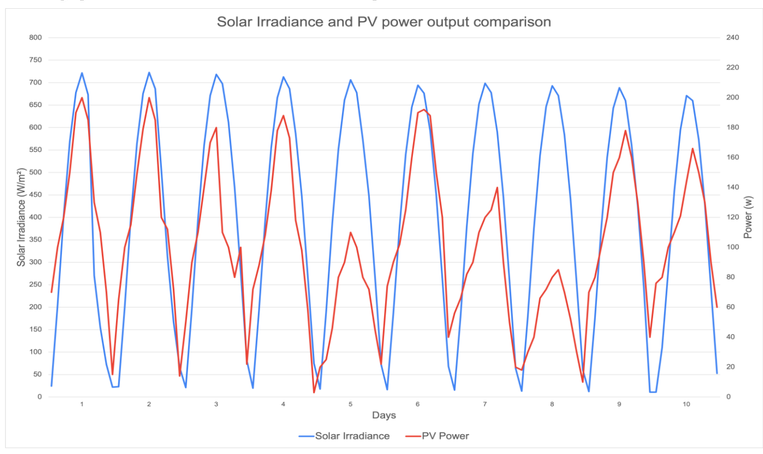
Hardware

- **PV:** 4×50W 12V PlusEnergy flexible PV panels (ETFE, 3 mm) installed on a glass door (series-connected to form a 24V, 200W array)
- **Storage:** BLUETTI AC50P portable power station (504 Wh $LiFePO_4$ battery, 3000 cycles, 700W inverter) collects panel output
- **Monitoring:** Collected data include solar irradiance, PV power, battery SoC, and indoor/outdoor temperatures (using HY02B05 thermostat and Xiaomi Mi Monitor)
- **Test:** Deployed on an apartment in Athens (Peristeri); monitored continuously for 10 days (≈1000 measurements) under varying weather

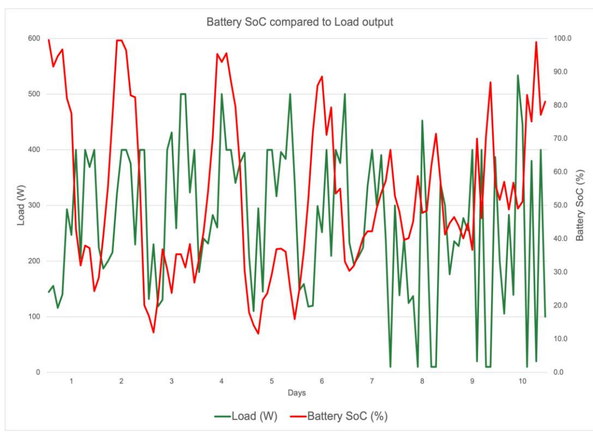


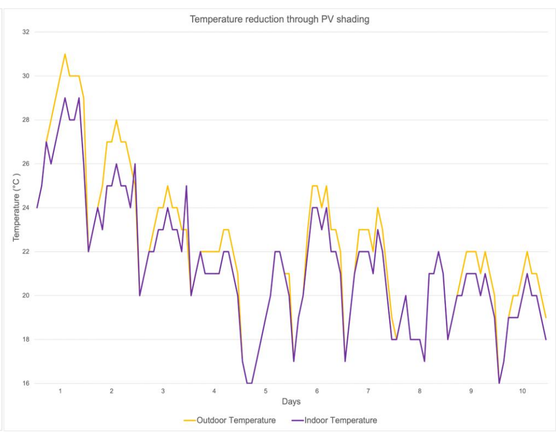
RESULTS & DISCUSSION

- ✓ **PV Output:** 11 kWh generated over 10 days (0.55–1.45 kWh/day) with Peak PV power ≈200 W around midday



- ✓ **Battery:** Net charging on most days. On highest-load day (Day 1), the battery discharged ~379 Wh (SoC ↓ 75%).
- ✓ (**Thermal Comfort:** The window-mounted PV array reduced indoor temperatures by 1–2 °C during peak sun, confirming effective shading.
- ✓ **Economics:** Every kWh displaced grid use. Measured ~€2.5 saved in 10 days (~€90/year at €0.22/kWh).





CONCLUSION

1. The system harvested solar power while also acting as passive shading, confirming dual benefits of renewable generation and thermal comfort.
2. battery efficiently buffered excess PV generation: on most days ending With SoC > start-of-day, safely operating within 20–90% range to prolong battery life.
3. The prototype was robust and user-friendly. Results confirm feasibility of an inexpensive PV–battery monitoring tool for residential energy savings and autonomy.

FUTURE WORK / REFERENCES

Future Work: Scale up energy storage (1–2 kWh) to capture more solar; conduct techno-economic analysis for larger deployments; field-test in diverse apartment settings; develop smart dashboards/apps for real-time SoC/SoH feedback; integrate bidirectional/grid-tied inverter for demand response and smart-home control.

References: Rimpas *et al.*, Eng. Proc. (2023); Li *et al.*, *J. Clean Prod.* (2021); Ito & Lee, *Appl. Energy* (2024). (Additional references in-text.)