

Technical and Economic Evaluation of a Residential Solar Power Plant with Energy Storage

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Abstract

Photovoltaic (PV) system adoption in the residential sector has skyrocketed, driven by decentralized energy production, electricity price volatility, and environmental awareness. When combined with battery energy storage systems (BESS), PV systems can increase energy autonomy by storing excess solar energy for later use. Despite this, Portuguese public perception remains cautious regarding the affordability and viability of PV+BESS solutions. This thesis presents a technical and economic evaluation of residential PV+BESS systems under different Portuguese climatic and consumption conditions. An Excel-based simulation model was developed to analyze system configurations in Lisbon, Alto Minho, and Algarve, considering realistic and intensified demand profiles. Each scenario was optimized based on three cases: (1) maximization of Net Present Value (NPV), (2) maximization of Self-Sufficiency Rate (SSR) with positive NPV, and (3) maximization of NPV under 100% off-grid conditions. Additional financial and environmental metrics were also considered. Simulation results show that energy self-consumption has a greater impact on economic performance than grid exports. Intensified consumption scenarios consistently led to higher NPVs and SSRs. While regions with higher solar exposure yielded better returns, system sizing relative to load was a more decisive factor. Over-dimensioning PV or battery capacity reduced profitability, emphasizing the need for balanced design.

Keywords

Economical evaluation, residential energy management system, photovoltaic system simulation, battery energy storage, self-consumption, smart micro grid.