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Economic modelling of rooftop photovoltaic and battery storage for affordable low-emission energy transitions

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Abstract: South Australia has one of the highest rooftop photovoltaic (PV) penetrations globally, with 53.3% of dwellings equipped with solar PV panels—equivalent to one in two homes. The primary motivation for this adoption is the reduction of electricity bills, as South Australians face some of the highest retail electricity prices in the world. Recently, the Federal Government introduced a subsidy for household battery storage systems, lowering installation costs to around AU $250/kWh and providing new opportunities for households to enhance their energy independence. This research investigates whether the declining cost of battery energy storage systems (BESS) has crossed a breakeven point for typical households in Adelaide with existing PV installations.

A techno-economic optimisation framework was developed in MATLAB, employing a genetic algorithm to minimise annual energy cost by optimising battery capacity. The analysis considered a household in Adelaide with an average daily load of 13.42 kWh and a 6.6 kW rooftop PV system, generating approximately 1,742.7 kWh per installed kW annually. A time-of-use (TOU) tariff from a South Australian retailer was adopted, with peak (AU 56.23 ¢/kWh), off-peak (AU 20.38 ¢/kWh), and shoulder (AU 20.38 ¢/kWh) rates, alongside a feed-in tariff of AU 5 ¢/kWh.

The results clearly demonstrate that under current conditions, including the subsidy-driven reduction in battery cost, the breakeven point for BESS integration has been surpassed. The optimisation identified an optimal battery size of 9.5 kWh at a unit cost of AU $250/kWh, yielding the lowest annual cost of energy. For the reference household, the PV-BESS configuration minimised annual energy cost by 57.6% compared to PV-only systems and by 81.5% compared to grid-only supply. These results confirm that residential PV-BESS integration provides a viable pathway to substantially reducing household energy costs. Importantly, this reduction addresses the growing risk of energy poverty, where households are forced to limit essential consumption or compromise on other basic needs due to escalating electricity prices. By enabling more affordable access to clean energy, PV-BESS systems can alleviate financial stress, enhance household resilience, and contribute to a more equitable energy transition.

This research highlights that the economic viability of BESS is strongly dependent on PV system size, household load profiles, tariff structures, and battery price trajectories. By framing the analysis within an economic modelling approach, the study provides a practical tool for evaluating household-level investment decisions in low-emission technologies, ensuring both affordability and resilience. The methodology can be adapted to households with varying consumption patterns, offering insights into how distributed renewable energy such as PV integration contributes to cost-effective and equitable energy transitions. Future work will extend this framework to consider the impact of electric vehicles on household energy economics, reinforcing strategies for a sustainable, low-emission energy future

Keywords: *Rooftop Photovoltaics, Battery Energy Storage Systems, Time-of-Use Tariff, Cost of Energy, Economic Modelling, Optimisation, Low-Emission Energy Transition*

