Mechanical Engineering Dissertation Defense

Integrated Solar Photovoltaic and Energy Storage [RM1.1][CJ1.2]Systems: Economic Feasibility and Grid Integration Using Real Demand Data from Phoenix-Area Facilities

School for Engineering of Matter, Transport and Energy

Cody Jenkins

Advisor: Ryan Milcarek

Abstract

Behind-the-meter solar photovoltaic (PV) and battery energy storage systems offer commercial and industrial facilities opportunities to reduce electricity costs, participate in demand response programs, and contribute to grid stability. However, economic viability varies substantially across facilities, and prior research, limited by simulated load profiles or small sample sizes, has been unable to identify generalizable predictors of profitability. This dissertation addresses this gap by using 910 real electrical load profiles from facilities in Phoenix, Arizona U.S.A., spanning 19 building sectors and representing approximately 8% of the local electrical grid. Mixed-integer linear programming is used to jointly size solar PV and battery energy storage systems for each facility under current rate structures. Results show that nearly every facility within the dataset achieves a discounted payback period of less than 10 years with an optimally configured system.

An Explainable Boosting Machine model is then trained on the optimization results to identify which facility characteristics and demand profile features most strongly predict economic outcomes. Facilities with low load factors below 0.3 and positively skewed demand distributions above 2 benefit the most from this technology. Optimal system sizing to minimize payback period while maximizing cost savings is approximately 2.4 kW of installed solar PV capacity per kW of the median facility demand, paired with an energy storage system sized below 10 times the median facility demand. Demand response participation decreases payback periods by approximately 17 years on average, shifting system sizing guidelines toward larger storage capacity and reduced solar PV.

Finally, grid-level impacts of widespread adoption are assessed by simulating technology deployment across all 910 facilities. Solar PV alone deepens the duck curve by reducing midday demand, while standalone energy storage provides modest but meaningful peak shaving. Integrated systems offer greater peak reduction while preventing net demand from falling below zero. Demand response leads to unintended grid consequences: off-peak demand nearly doubles compared to scenarios without energy storage. These findings suggest that demand response programs should either target specific facilities or reduce incentive levels to encourage appropriately sized systems to avoid shifting grid strain from current peak to off-peak periods.

March 2, 2026; 10:30am; ECG G315

Arizona State University