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Optimizing solar PV and battery storage retrofit for commercial buildings in the UK

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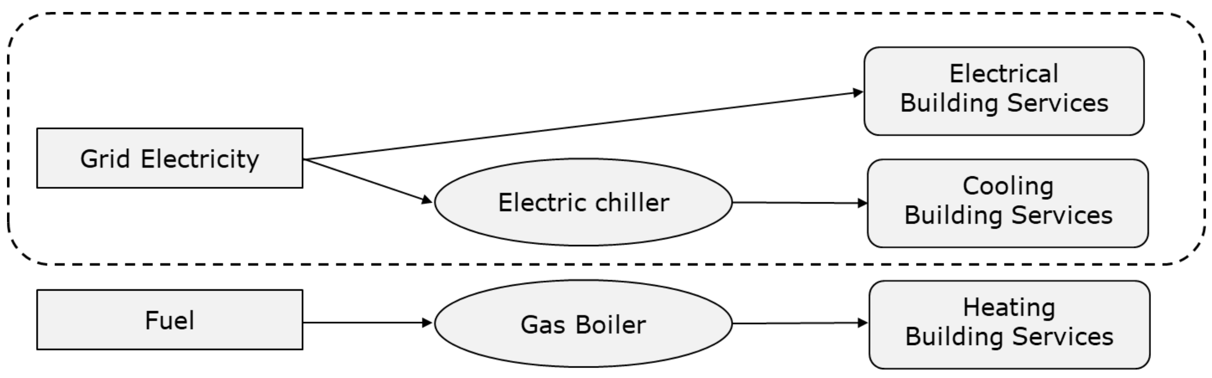
Objectives

- Develop a database of PV and battery storage technologies comprising of technical performances, and cost for grid-tied commercial PV installation.
- Identify relevant supporting polices for solar PV and battery installations in commercial buildings and incorporate them in the optimization model.
- Perform sensitivity analysis to quantify impacts of incentivising policies on the optimization results of PV and battery installations.

Background

Business-as-usual (BAU) features of operating a commercial building comprises of importing electricity from the grid, obtaining heat from running gas boiler, and supplying refrigeration load from electric chiller

Figure 1: Business–as-usual features of commercial buildings

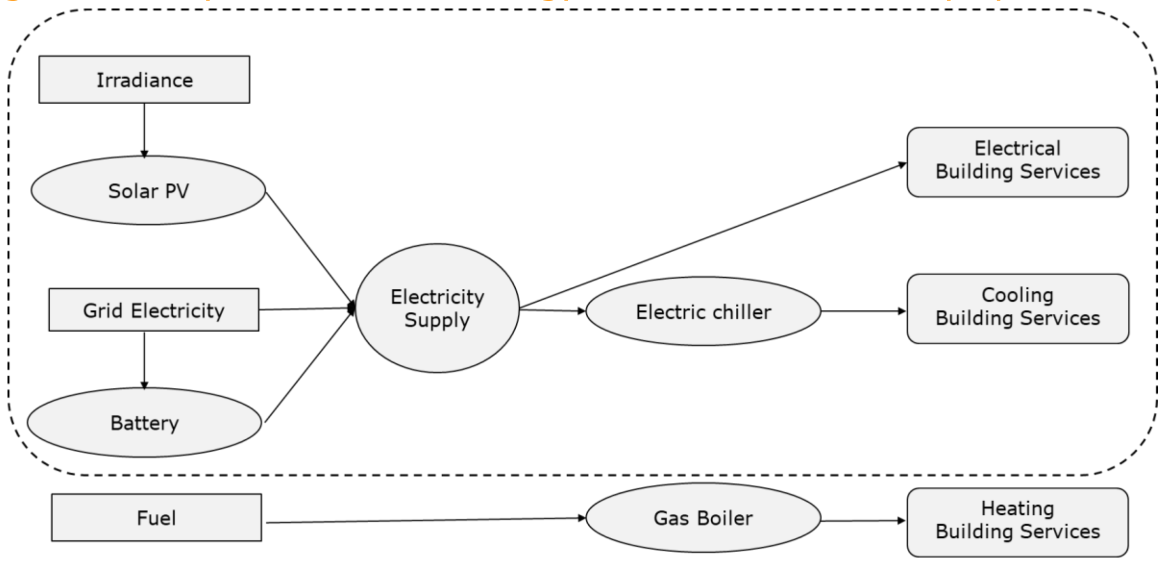


Case Study: Emerald Park distribution centre, Bristol, UK.

Solar PV and battery storage are retrofitted to a commercial building to reduce reliance on importing grid electricity and minimize building's carbon footprint associated from using grid electricity.

Electrical and cooling building services are now supplied by a combination of grid electricity, PV electricity and battery-discharged electricity

Figure 2: A representation of energy flow of PV and battery operation

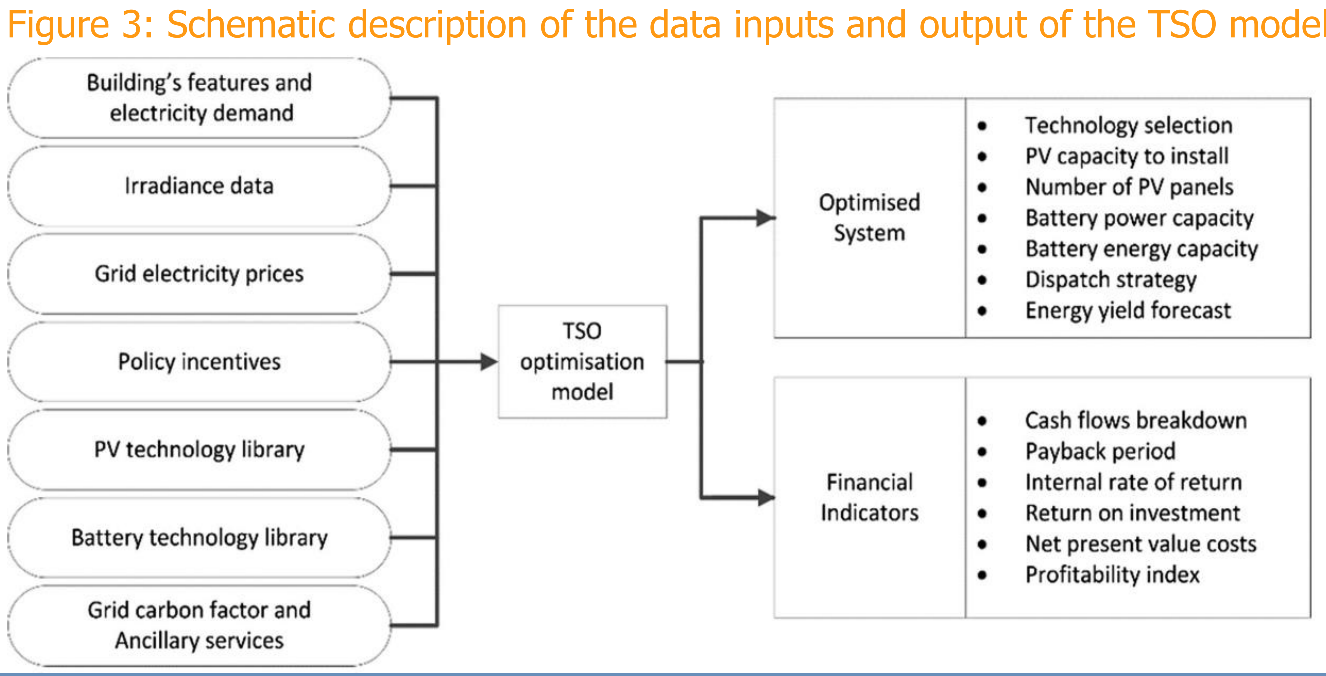


Methodology

Mixed-integer-linear programming (MILP) optimization model is developed with an objective of minimizing cost of supplying electricity supply for a commercial building

The model considers building's features and electricity demand, irradiance level, regional electricity price, policy incentives, PV and battery technology databases, and grid carbon factor and frequency response service. The model then optimizes for a configuration of PV and battery technology, their installed capacity, and battery dispatch strategy

Figure 3: Schematic description of the data inputs and output of the TSO model



Results (optimized system for current installation)

The optimization results show that the optimized system comprises only PV with installed capacity of 1700 kWp. The system is forecasted to produce 1.6 GWh of electricity annually or 29% of Emerald Park's energy use. The system can also gain revenue from exporting 0.19 GWh of excess electricity in the summer months or 12% of annual PV electricity generation.

The system has total investment cost of £1.36 m. It will provide 5-year NPV saving of £171k and 7 year payback period. The system will contribute 27.8% of carbon emission reduction from BAU scenario.

Table 1: Technical and financial results of optimized system in 2021

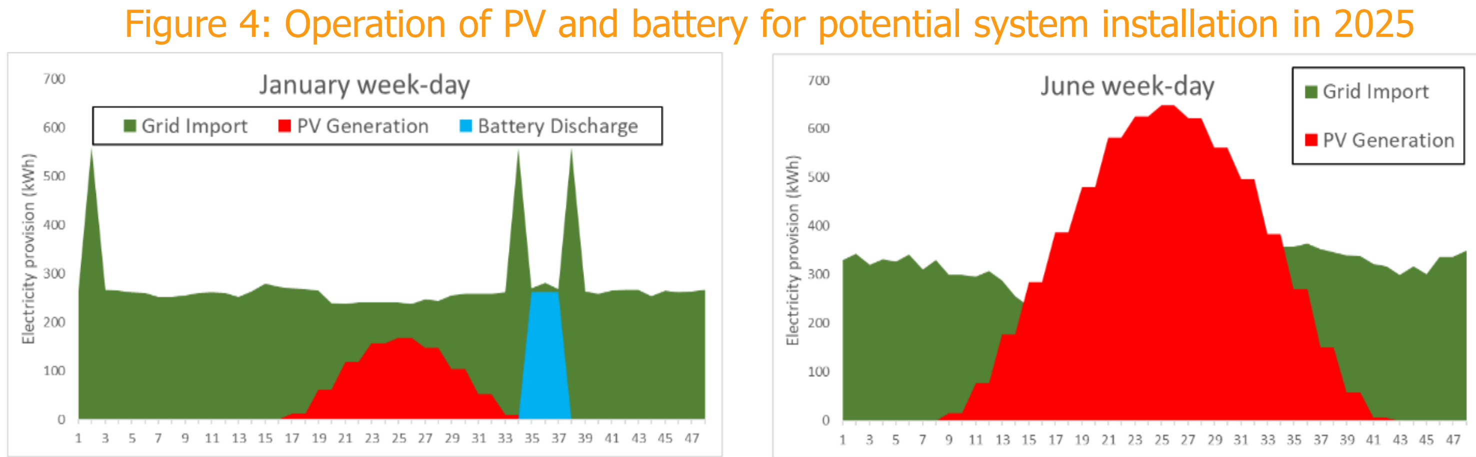
Optimized configuration	
PV technology	Polysilicon
Number of panels	6800
Capacity (kW_p)	1700
Yearly PV generation (GWh/yr)	1.60
Yearly PV electricity export (GWh/yr)	0.19
Peak half-hour PV generation (kWh)	459
PV investment (£)	£1.36 m

Outputs	BAU	PV - SEG
PV (poly-Si, kWp)	-	1700
Battery (Li-ion, kWp)	-	-
Initial investment (£m)	-	£1.36 m
5-year NPV costs (£m)	-£3.19 m	-£3.02 m
5-year NPV savings (£m)	-	£171 k
Payback period (year)	-	7.0
IRR (%)	-	14.2%
PI	-	1.69
ROI (%)	-	235%
CO2 emission (tCO_2e)	2,853	2,059
Carbon reduction (%)	-	27.8%

Discussion (Battery integration in 2025)

The optimization result shows that battery system will be an attractive investment in year 2025 based on forecast reduction in battery prices. Using 2025 polysilicon PV system price of £700 per kWp and 2025 price forecast of lithium-ion of £386 per kWh, the optimized system comprises of 2,401 kWp of PV (41% bigger than optimized system in 2020) and 1175 kWh of lithium-ion battery (accounting for 96% of electricity demand during energy triad) During the triad, all of the battery electricity will be discharged for self-consumption.

Figure 4: Operation of PV and battery for potential system installation in 2025



Conclusion

PV technology can be an attractive investment a of current when the installed capacity is optimized based on building's features, electricity import and export cost. However, an attractiveness of battery investment at present is questionable. The optimization results indicate lithium-ion battery will be best integrated with poly-silicon PV in 2025 based on lithium-ion system price reduction of 5.5% per year.

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