Antonin Samal

Battery optimisation for cost-effective net-zero microgrids

Supervisor: Dr Steve Cayzer

THE PROBLEM

National Grid

Growth of Variable Renewables needs Flexibility of Demand

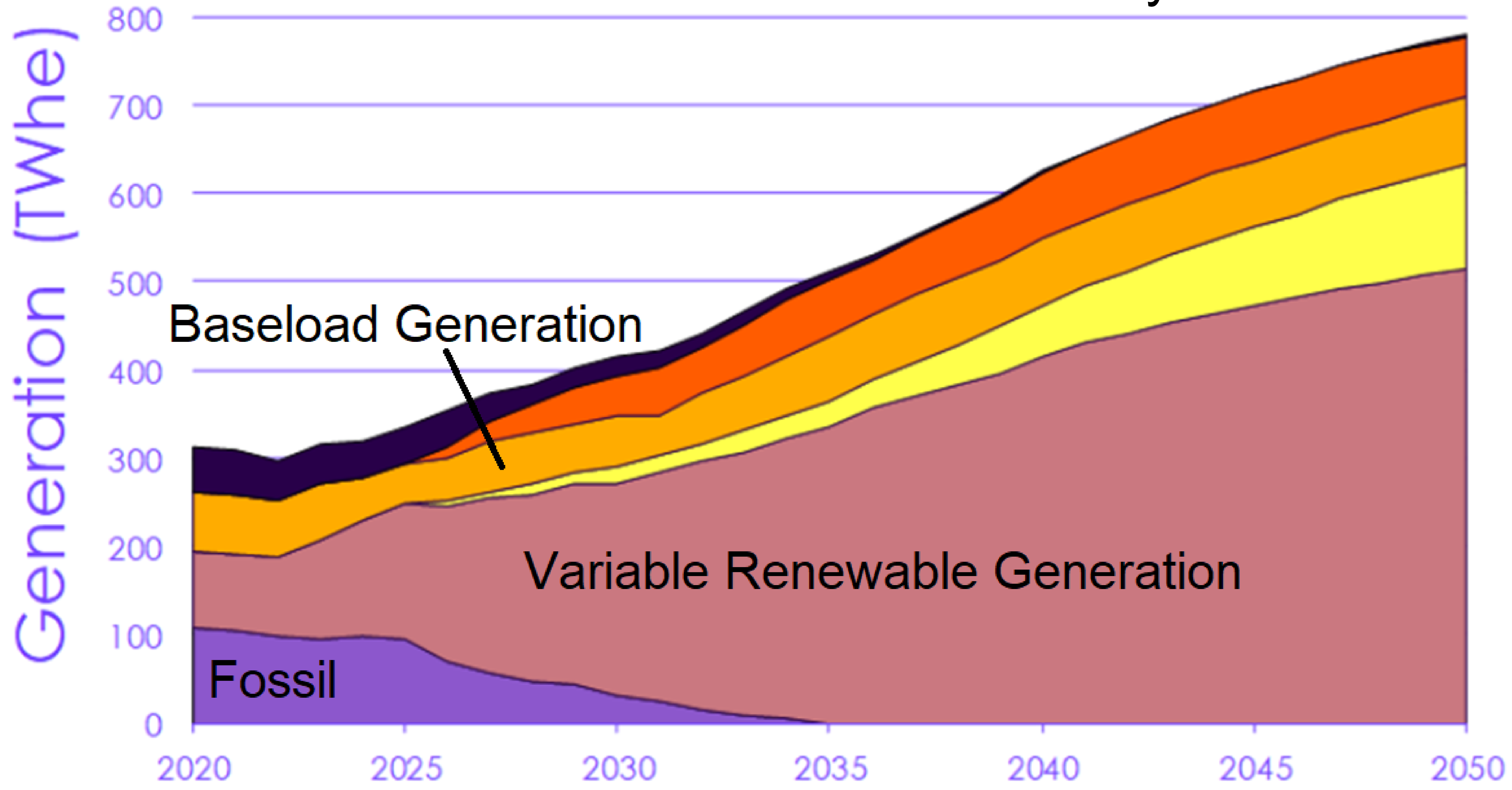

Fig. 1: UK national grid generation outlook to achieve climate targets [1]

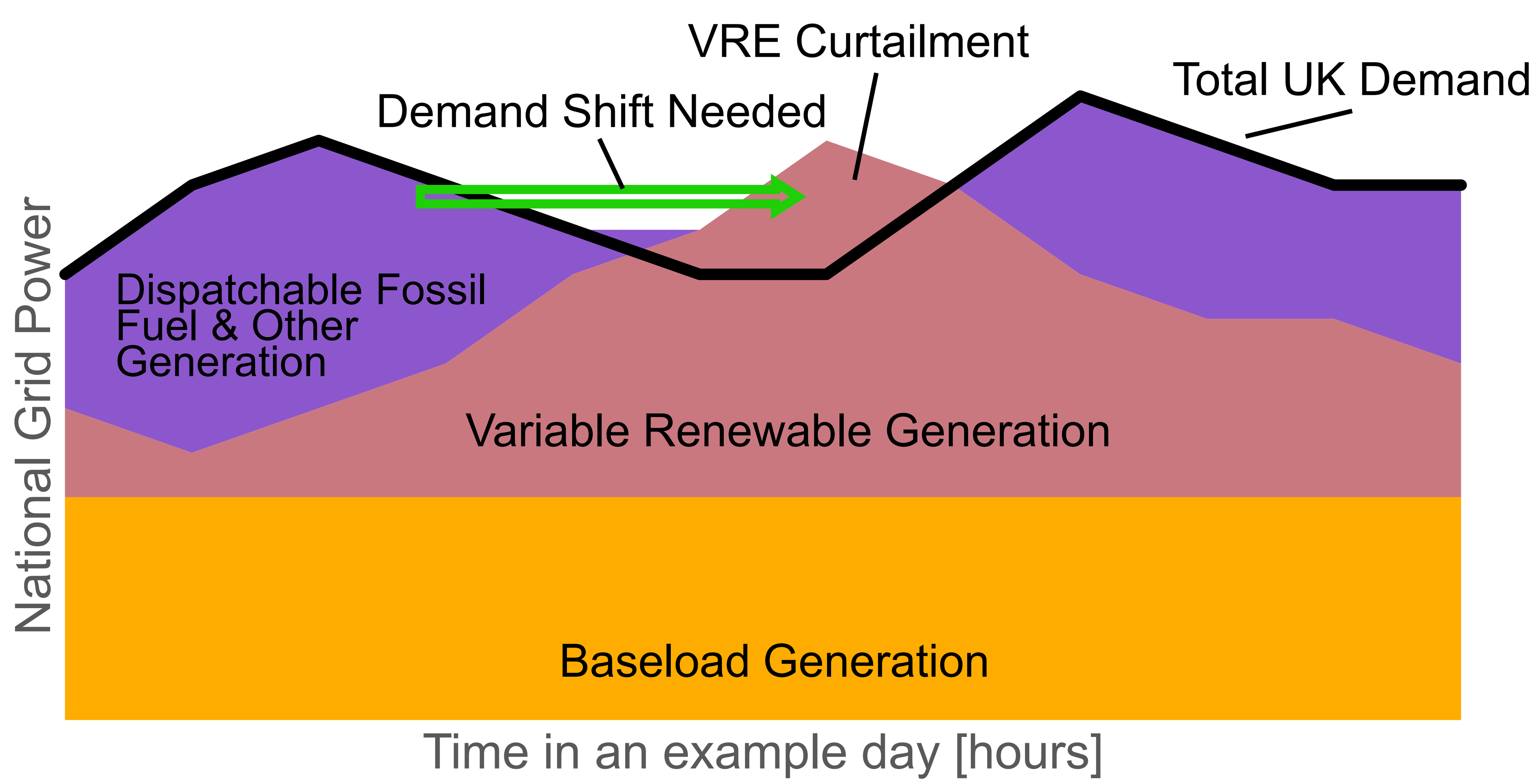

Fig. 2: Example of a day with a great need for grid flexibility; not real data

Owen Square Community Energy Microgrid in Bristol

Fig. 3: Community Centre with rooftop PV [2]

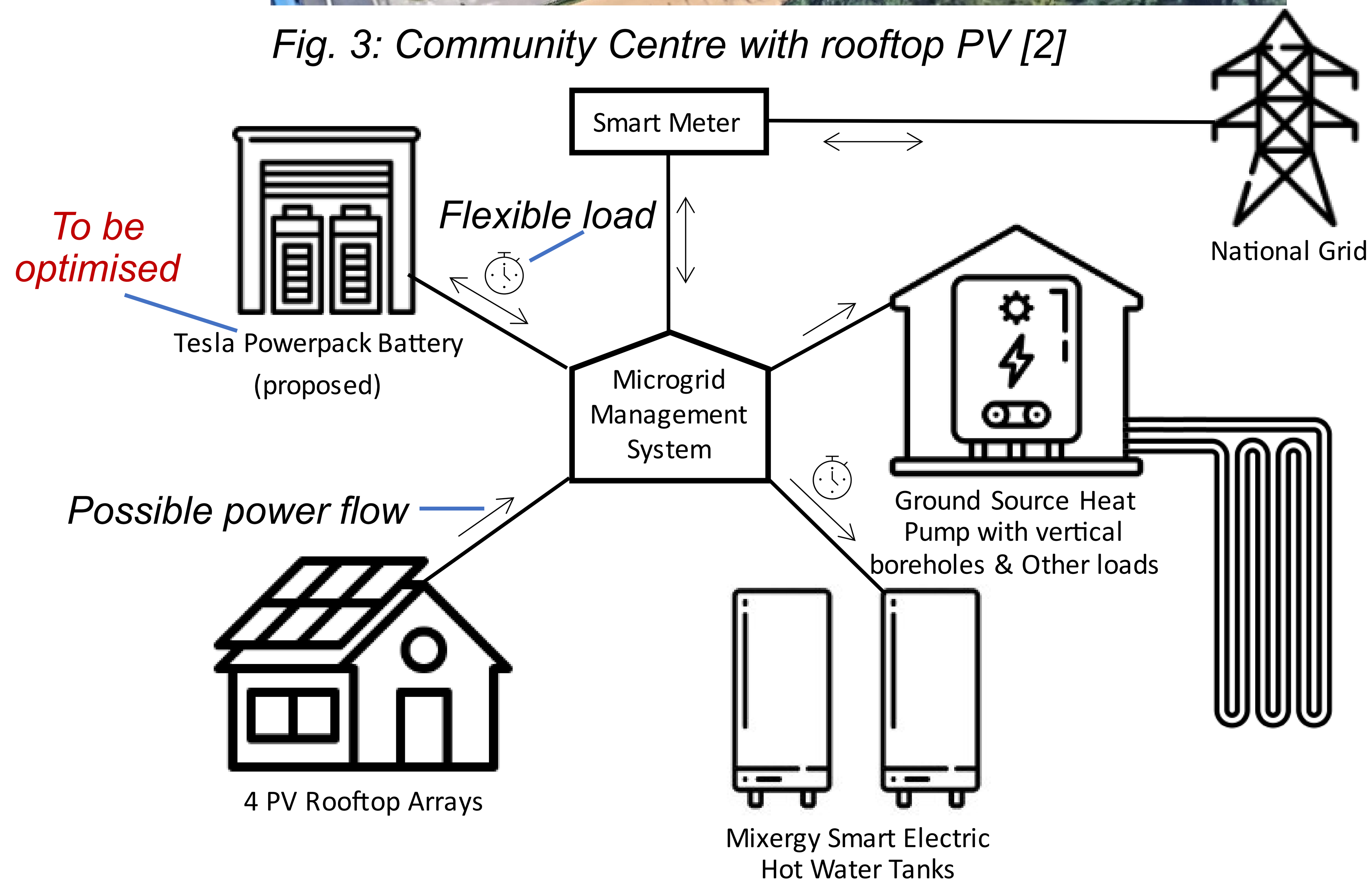

Fig. 4: Diagram of the microgrid's technologies. Icons from [3]

Key aims of a battery instalation

Current needs:	Carbon Net-Zero	Affordable energy
Shift power use to:	Low-carbon times	Low-spot price times

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Battery Operation Multi-objective Optimiser

THE SOLUTION

Input half-hourly datasets:
- Microgrid's imports and exports
- Day-ahead electricity prices
- South West England carbon intensity forecast

↓

Battery parameters → **Python Linear Programming Daily Optimiser** ← Carbon price
- using PuLP library
- developed from a hot water optimiser [4]

↓

Half-hourly battery operation

↓

Total microgrid's daily power use
- Carbon savings
- Actual spot-price cost savings

Objective function

$$min\left(\sum_{SP=1}^{OD}\left(i(SP)*\left(I(SP)+CP*C(SP)\right)+x(SP)*\left(X(SP)+CP*C(SP)\right)+b_e*CoT\right)\right)$$

- OD: Number of Supply Periods
- SP: Half-hourly Supply Periods
- $i(SP)$: Total imported power per SP [kWh]
- $I(SP)$: Day-ahead Import price with charges [p/kWh]
- CP: Carbon price input variable [p/gCO2eq]
- $C(SP)$: Carbon intensity of the grid [gCO2eq/kWh]
- $x(SP)$: Total exported power per SP [kWh]
- $X(SP)$: Day-ahead Export price with charges [p/kWh]
- b_e: Battery throughput (use) per SP [kWh]
- CoT: Cost of battery throughput parameter [p/kWh]

Optimised Daily Operation of a Battery

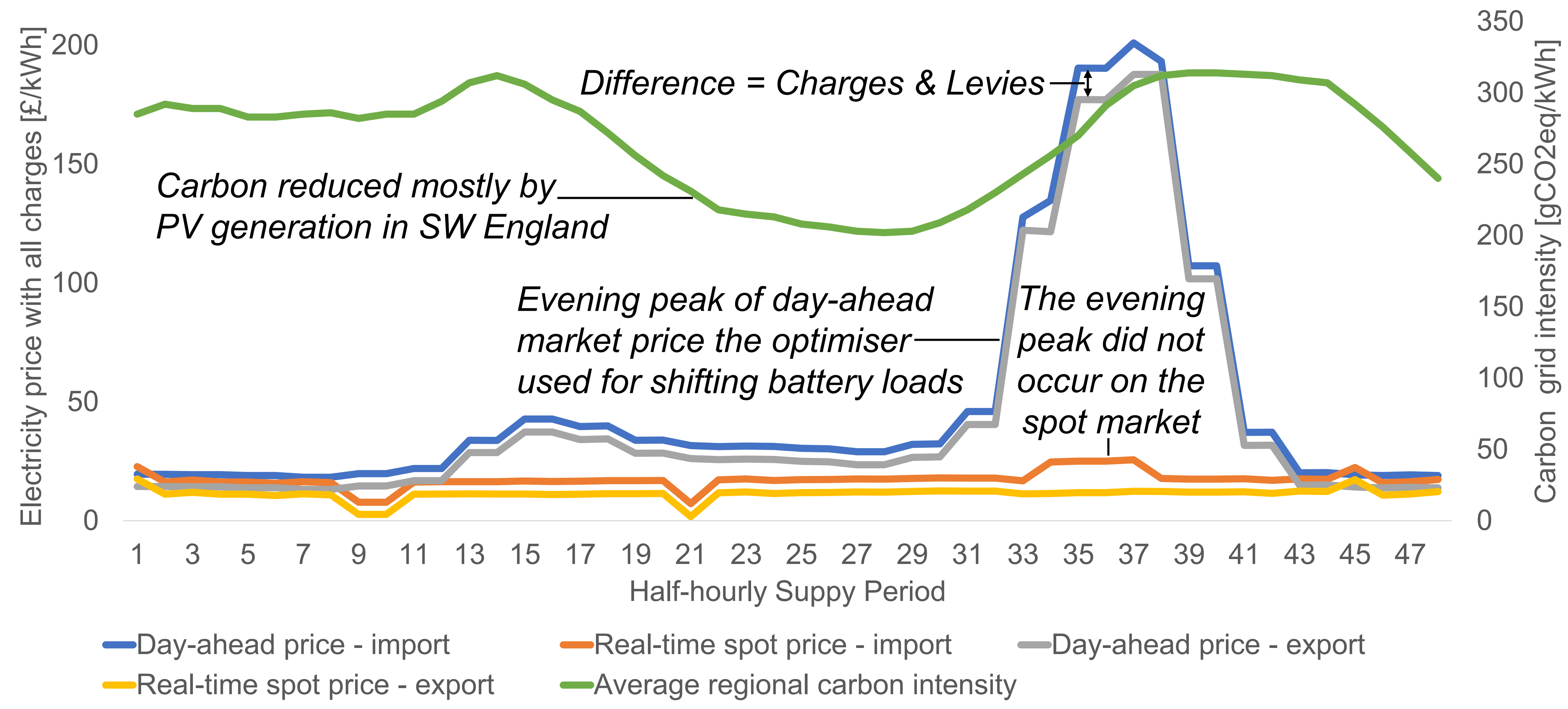

Fig. 5: National grid emissions intensity and import & export prices for 16/09/21

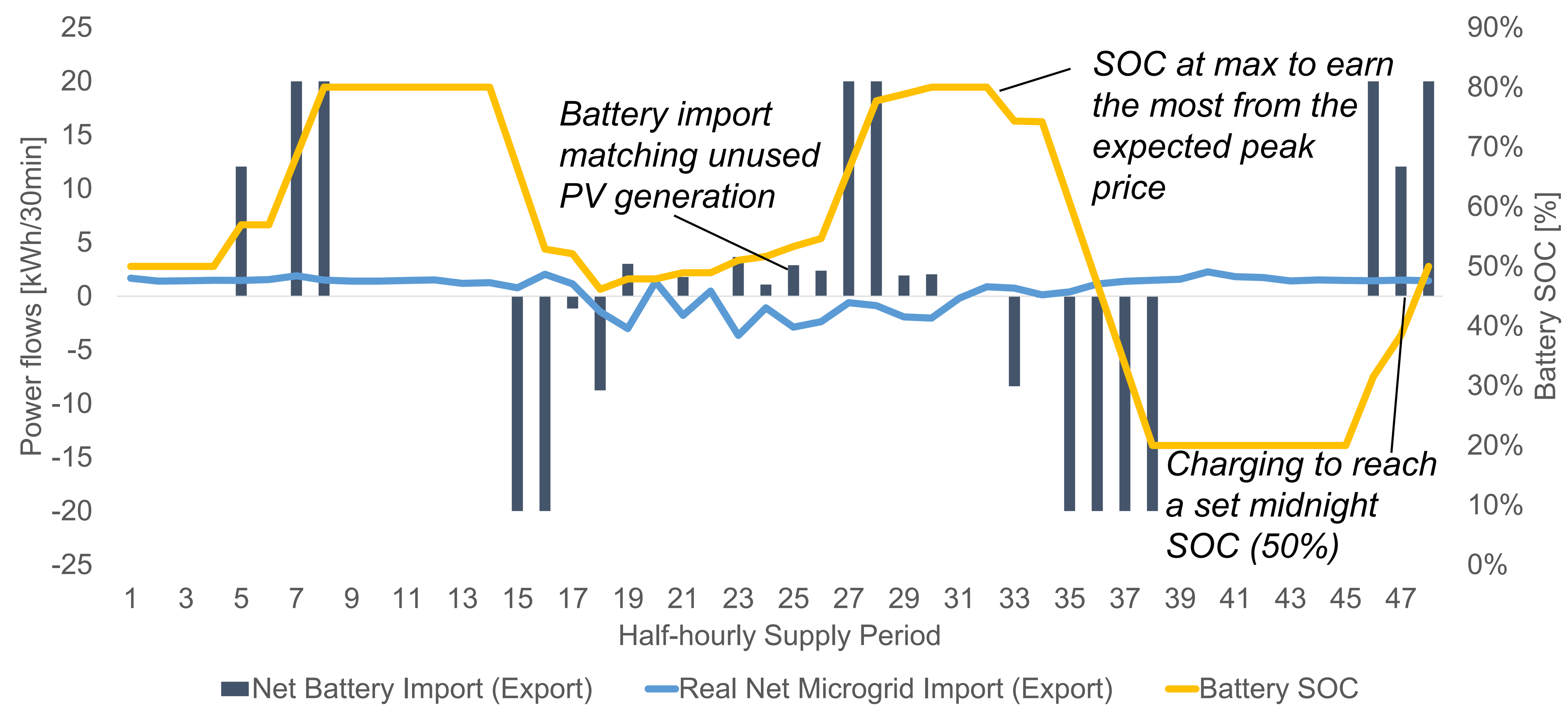

Fig 6.: Microgrid's actual historical net power exchange with the national grid and optimised battery operation for 16/09/21. Battery charges during forecasted low-price times and discharges during forecasted high price. Also tries to avoid charging at high carbon intensity times.

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RESULTS

Annual run of daily optimisations

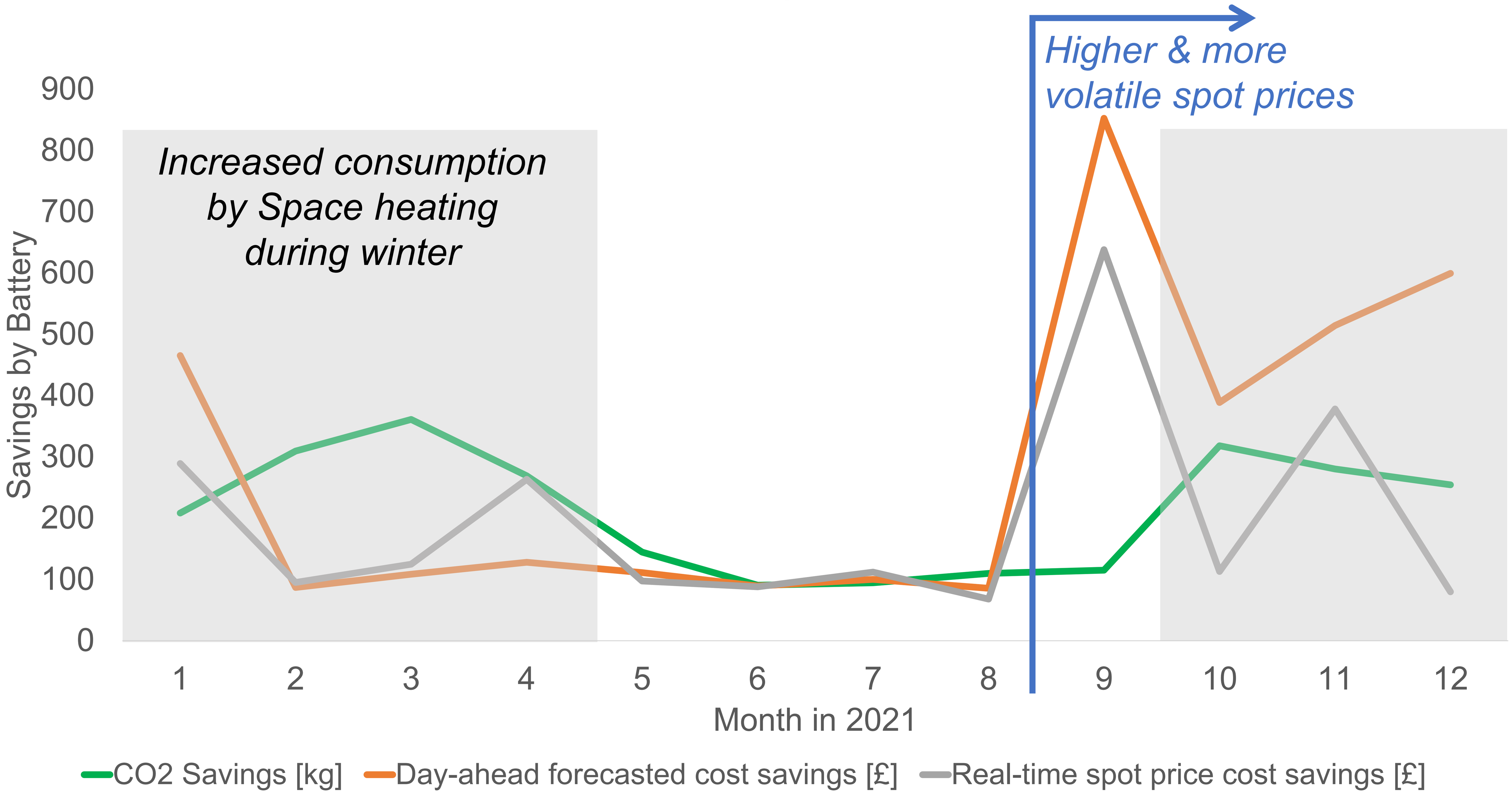

Fig. 7: Monthly sums of cost & carbon savings by 24h battery optimisations

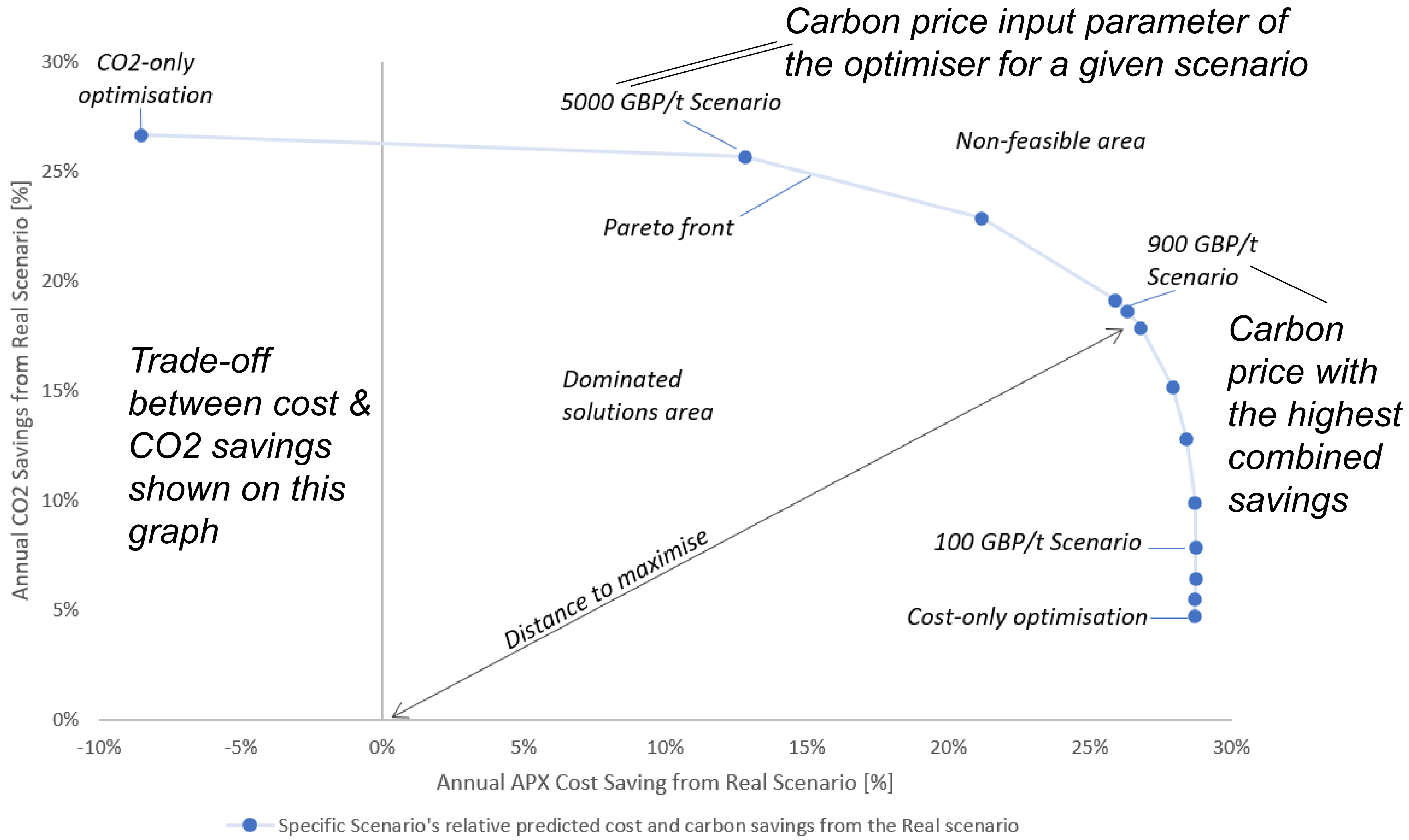

Fig. 8: Pareto criterion graph of multiple solutions' results with a varying input carbon price. APX = day-ahead forecasted electricity price

Final model input operational parameters

SOC range	Cost of use	Carbon price	Efficiency
10 – 90%	7p/kWh	900 £ / tCO2eq	85% roundtrip

160kWh Tesla Li-ion battery operation summary

Estimated Capacity Degradation Lifetime 16.5 years [5]	Embodied CO2 12.2 tCO2eq [6]	Purchase cost £84,320
	CO2 Savings p.a. 2.6 tCO2eq	Revenue p.a. £5,670

Key outcomes

- Optimised battery significantly lowered electricity cost & carbon
- Operational limits crucial to its lifetime effectiveness
- Tesla Powerpack achieved carbon payback of 4.7 years
- Monetary payback: before modelled lifetime; longer than desired

Nomenclature

VRE = Variable Renewable Energy
APX = Electricity cost based on day-ahead market price
SOC = State of Charge of the Battery
HH = Half-hourly

Bibliography

[1] The CCC, 'The Sixth Carbon Budget The UK's path to Net Zero', Committee on Climate Change, 2020.

[2] 'Google Maps', *Google Maps*, 2022. https://www.google.com/maps/@51.4611816,-2.5630854,58a,35y,17.32h,54.34t/data=!3m1!1e3 (accessed Apr. 27, 2022).

[3] Freepik and Smashicons, *Flaticon*, 2022. https://www.flaticon.com

[4] S. Vetterlein, 'Microgrid-supply cost optimisation using stratified thermal storage', 2021.

[5] A. Samal, 'NMC vs LFP battery lifecycle GHG emissions estimation based on a battery degradation model; Student Internship project', Imperial College of London, 2021.

[6] ANL, 'EverBatt | Argonne National Laboratory', 2018. https://www.anl.gov/amd/everbatt (accessed May 02, 2022).

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