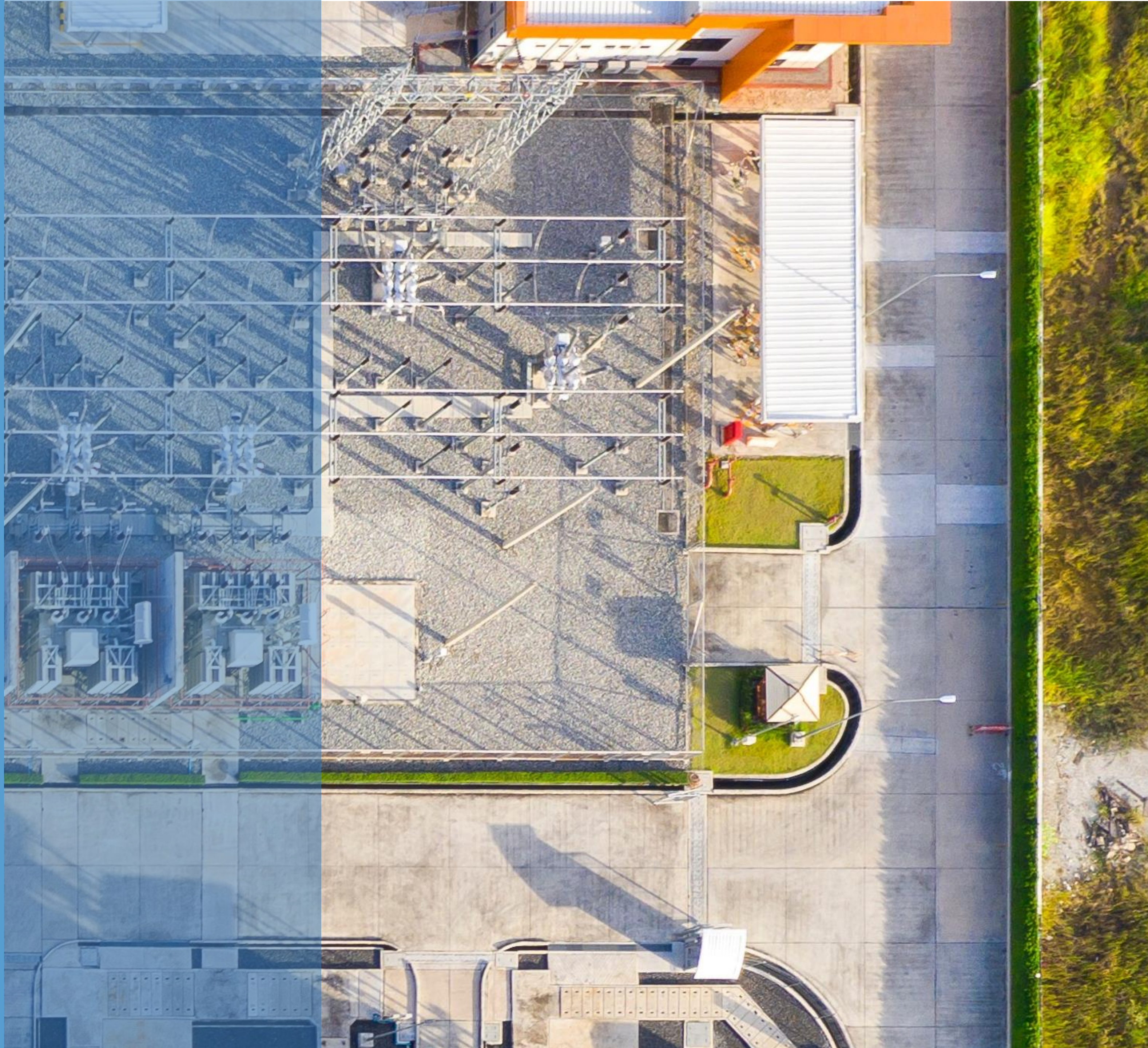
European battery investment wave

Understanding & quantifying battery value

Oct 2020



Timera Energy
Level 12
30 Crown Place
London EC2A 4ES

timera-energy.com
+44 (0) 207 965 4541

Contents

5 key takeaways

Europe on the cusp of a battery investment wave: Battery investment momentum has been accelerating in 2020. The UK is leading the charge given a relatively mature revenue stack. But other markets including Germany, Italy & Spain are now following. In this briefing pack we set out opportunities & challenges investors face in building a robust investment case.

Takeaway	Description
1. Europe needs new flex fast	• Thermal asset closures are outpacing renewables growth, causing a rapidly rising flex deficit across Europe. • We estimate a requirement for more than 50 GWh (€15 bn) of battery storage investment in Europe by 2030.
2. Wholesale markets drive investment cases	• The primary battery revenue driver is capture of wholesale & balancing price spreads. • Ancillaries & other revenue streams complement this, but face greater risk of cannibalisation.
3. Structural drivers support battery value	• Europe's changing capacity mix & flex deficit are structurally supporting battery price signals. • Steepening supply stacks & rising intermittency are set to drive up price shape & volatility.
4. Batteries complement renewable portfolios	• Co-location of batteries with the right PV asset can create genuine value uplift (e.g. 1.5 – 2.0% IRR). • Batteries can also diversify wind & solar project risk and can improve renewable portfolio risk/return profiles.
5. Building a robust investment case	• Robust battery valuation relies on realistic optimisation of battery flex across co-dependent revenue streams. • This means stochastic modelling & explicit capture of trading strategy (to cover price uncertainty & imperfect foresight).

Battery value drivers

Europe needs new flexibility fast

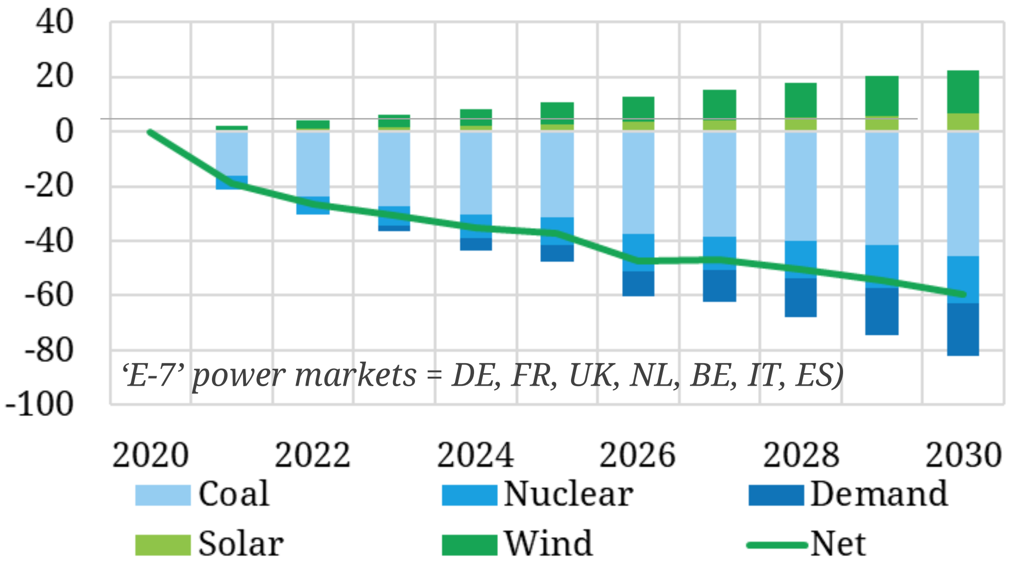
Europe facing a flex capacity deficit

- Top chart shows a rapid net reduction in de-rated capacity as coal & nuclear closures outpace wind & solar build in Europe:
  - 30 GW net capacity reduction by 2023
  - 60 GW net capacity reduction by 2030.
- Bottom chart shows a huge increase in intraday generation swings by 2030 as wind & solar capacity grows, e.g.
  - 100GW+ average intraday solar swing range by 2030
  - More than 100GW intraday wind swing potential.

How much battery investment is needed by 2030?

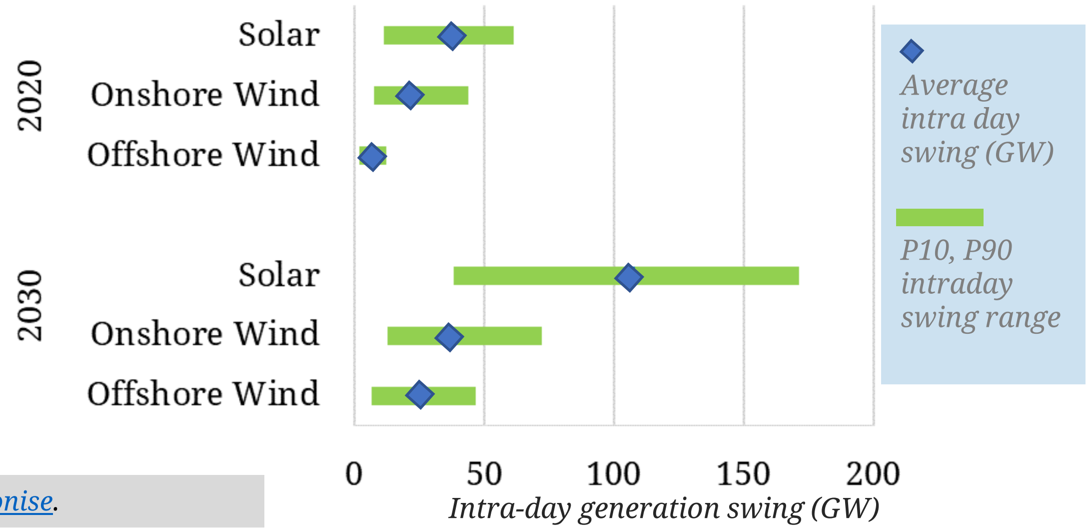
- Batteries are the primary source of scalable low carbon flex to replace closing thermal plants & balance rising variable wind & solar output.
- Policy makers have two main options to maintain security of supply:
  1. Allow a new wave of investment in gas-fired flex
  2. Increase policy support for batteries (& other storage).
- We think batteries will dominate, with more than 50 GWh (€15 bn) of battery investment required across European power markets by 2030.

E-7 changes in de-rated capacity (GW)



Source: Timera Energy

E-7 intra-day generation swings (GW)



For further analysis of Europe's rapidly growing capacity deficit see our briefing pack [The flexibility to decarbonise](#).

Battery investment landscape in Europe

The state of play

- The UK battery investment wave is already cresting, with a viable pipeline of GWs of investment across next 3 years.
- Germany, Italy & Spain are following… but more policy action is required.
- EU Green New Deal & revised RES & emissions targets are set to push storage policy reform into 'top priority'.

Market focus?

Battery investment is set to be focused on markets:

1. *Closing thermal capacity*
2. *Rapidly growing wind & solar*

This includes UK, DE, FR, IT, ES, BE, NL, IE, PT.

Market	Key investment drivers
UK	• Most mature revenue stack (wholesale / BM focus) • Established secondary revenue streams (e.g. ancillaries, capacity) • Constructive policy evolution (e.g. charging, new ancillaries, BM access)
Germany	• Strong fundamentals (rising price volatility & network stress) • Lagging policy framework (e.g. no capacity mkt, charging/network issues) • Current dependence on less liquid reserve markets
Italy	• Attractive capacity & ancillary revenue streams (to underpin energy) • Policy tailwinds & attractive PV co-location dynamics
Spain & Portugal	• Strong PV co-location opportunities (& growing merchant/PPA market) • Policy tailwinds (e.g. storage targets, colocation support) • But… early stages of policy evolution with much more clarity required
The Rest (e.g. France, Benelux)	• Capacity market revenue stream in France & emerging in Belgium • Current dependence on ancillary/network revenues (e.g. frequency) • Policy issues hampering progress (e.g. charging, clear support tools)

The battery investment case

Batteries role in providing flex

- Battery investment is focused on 1 to 4 hour duration L-ion projects.
- These provide short bursts of rapid flexibility response, ideal for balancing intraday swings in wind & solar output.
- Battery revenue streams can be grouped into 2 main sources:
  1. Energy margin – from responding to price volatility in wholesale & balancing markets
  2. Network services – from providing ancillary (e.g. frequency response), capacity or network related services (e.g. charge avoidance, constraints).
- An investment case relies on co-optimising across these revenue streams.

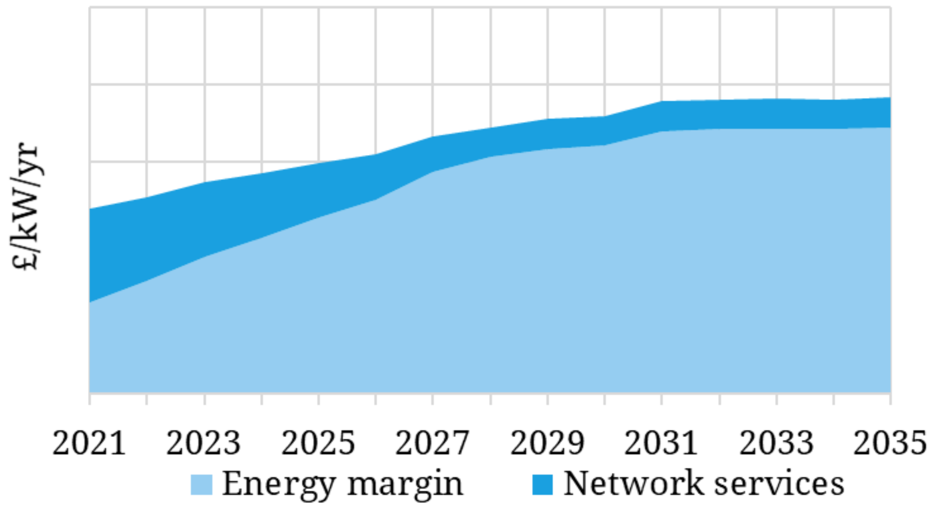
Power price volatility drives value

- Capturing price spreads in wholesale & balancing markets is the primary driver of battery returns for most battery projects.
- Network services can provide significant supplementary income, but face increasing risk of cannibalisation as battery volumes grow.

Building a viable battery investment case means getting comfortable with

1. Market drivers supporting battery revenue e.g. rising price volatility
2. Understanding & quantifying realistic battery revenue capture.

Battery margin evolution: UK case study



Source: Timera Energy

Battery investment case metrics

Cell + pack capex	€150/kWh (& falling)
Cycle rate	1.5 - 2.5 cycles per day
Cell replacement	8-10 years
Project IRR	8-12% (unlevered nominal)

Battery revenues & capacity mix evolution

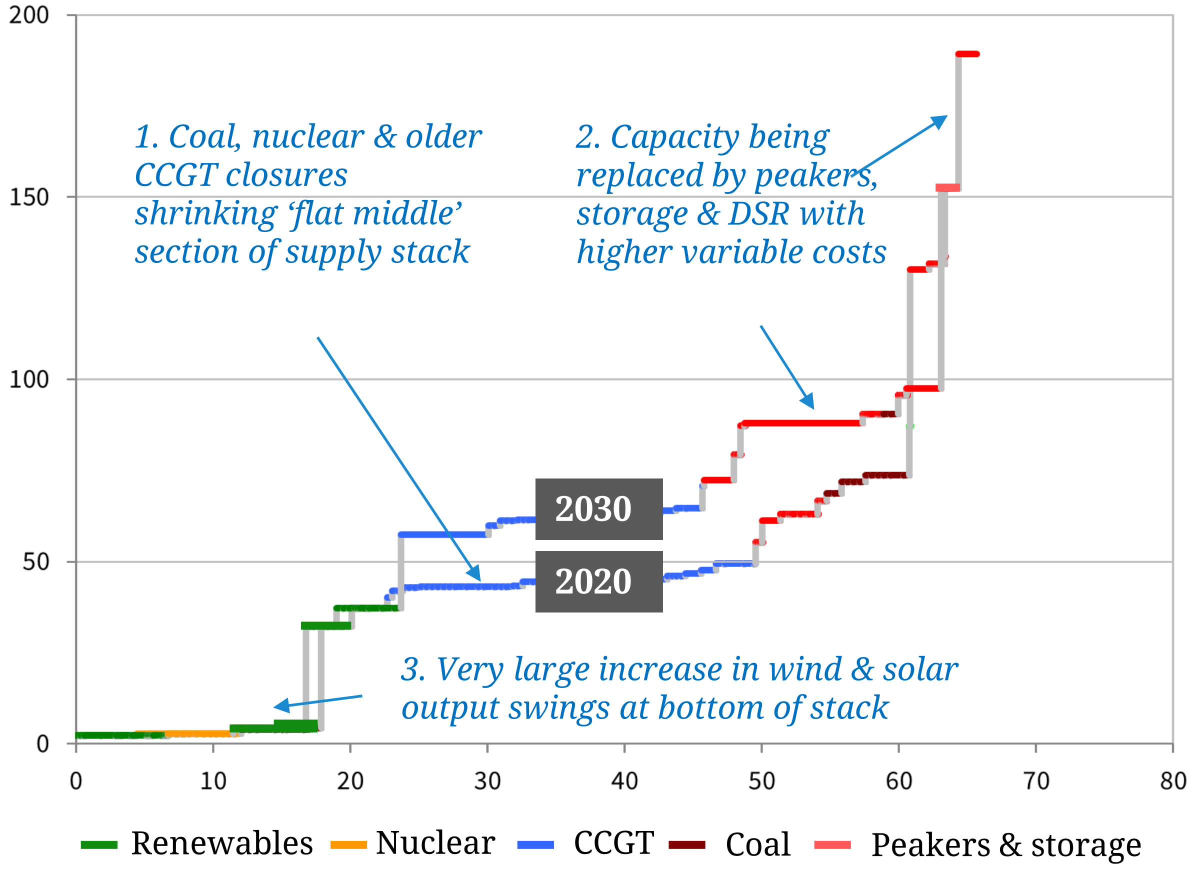
Supply stacks across Europe are changing

- The closure of coal, nuclear & older CCGT plants is rapidly reducing flexible capacity in the lower / middle section of supply stacks across European power markets.
- This capacity is being replaced by:
  1. Low variable cost & intermittent wind & solar capacity.
  2. Higher variable cost peaking capacity e.g. gas peakers, batteries & demand response.
- Capacity mix evolution is structurally changing pricing dynamics in favour of batteries.

Price shape & volatility set to increase

- Supply stacks are steepening (driven by 1. & 2. above).
- At the same time, rising wind & solar capacity is causing rapid increases in supply stack fluctuations (e.g. from high to low wind periods).
- The combination of these factors is set to significantly increase intraday price shape & price volatility.
- These sharper price signals are powerful tailwinds for battery revenues.

Evolution of supply stacks: UK case study (derated capacity)



Source: Timera Energy

Quantifying the rise in price shape & volatility

Batteries require stochastic supply stack analysis

- Market price volatility is the key driver of battery value and is largely driven by shorter term uncertainty around wind, solar & load patterns.
- Traditional Base / High / Low scenario supply stack modelling of power prices does not work for batteries.
- Robust battery valuation relies on stochastic simulation-based modelling of renewable output, load and power price evolution.
- This is achieved by running multiple (e.g. 500+) correlated hourly load, wind & solar profiles through a supply stack model.
- The output is a set of price distributions which show how price shape & volatility evolve with the capacity mix (see chart to right).

Flex price signals on the rise…

- As thermal plants close & renewables increases, there is rapid growth in:
  1. Low / negative prices – e.g. high wind / sun periods where renewable capacity sets marginal power prices.
  2. High prices & spikes – e.g. low wind / sun periods where high variable cost peaking capacity sets marginal power prices.
- This is set to drive a structural up trend in power price volatility, supporting battery value capture.
- Quantifying battery value relies on modelling realistic price dynamics.

Generation mix evolution (2025-2035)

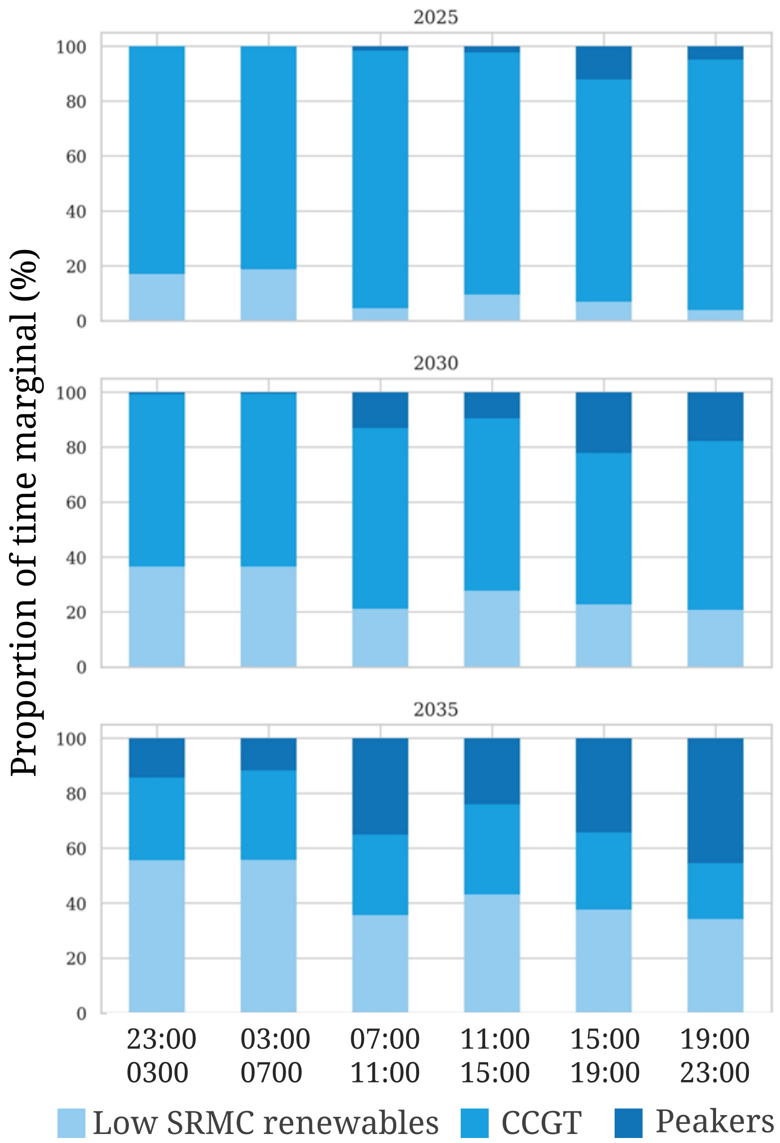


Chart shows the % of time different technology types set UK power prices across the day (2025 - 35).

In 2025, CCGTs dominate price setting, but with the impact of wind, solar & peakers growing rapidly.

By 2035, CCGTs only set <30% of prices, with >30% being set by:
(i) high SRMC peakers and storage and
(ii) low SRMC renewables

Source: Timera Energy

How do batteries make money?

Margin capture driven by price spreads

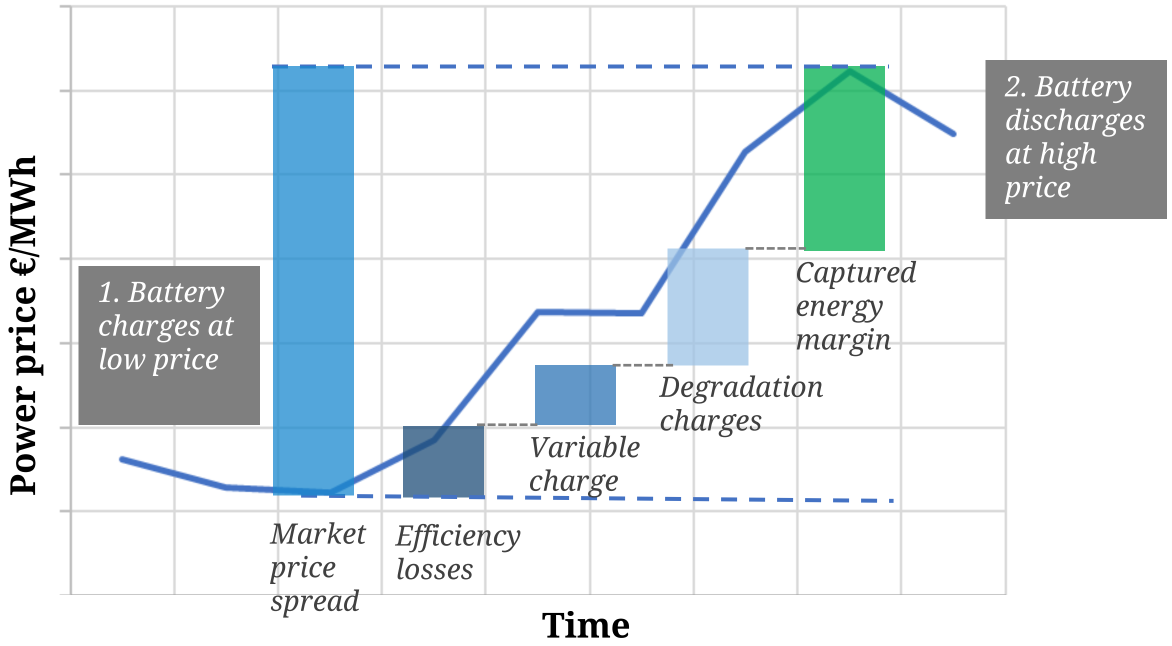
Batteries are options

- A battery is effectively an option to move power from lower price periods (charging) to higher price periods (discharging).
- As such, the primary exposure of batteries is to price spreads, not price levels.
- Battery optionality can be profitably exercised if a market price spread exceeds the variable cost of cycling the battery (the ‘strike’).
- Variable cycling costs drive this option strike (see breakdown in the chart).

Battery value capture

- Battery optionality can be exercised against various wholesale & balancing price signals e.g.
  - Day-ahead – relatively liquid, lower risk, but lower volatility
  - Within-day – less liquid, higher risk, somewhat higher volatility
  - Balancing prices – high volatility but high forecast / dispatch risk.
- A battery operator needs to co-optimise these wholesale & balancing revenue with other value streams (e.g. ancillary & network services).
- An optimisation case study is shown across the next 3 slides.

Indicative cycle margin breakdown (€/MWh)



Option ‘strike’ cost components:

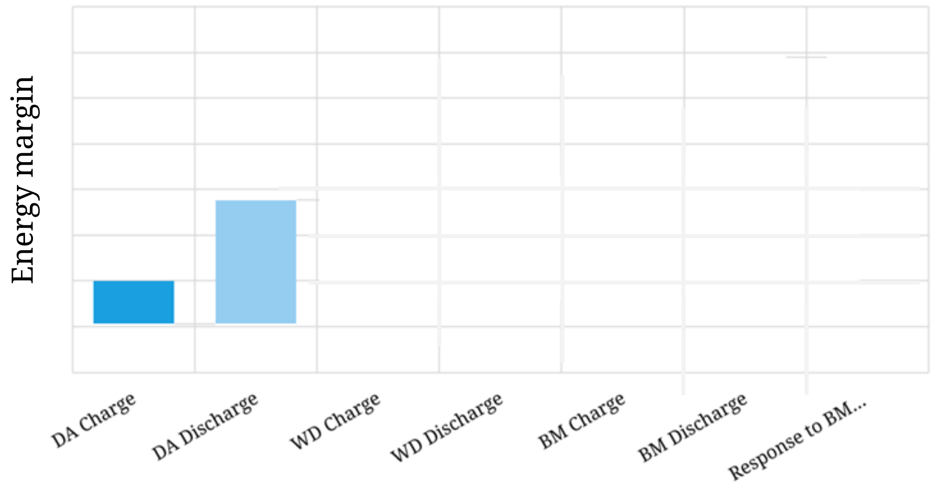
1. *Efficiency losses: energy loss from cycling battery*
2. *Variable charge: e.g. to cover variable network charges*
3. *Degradation charges: the ‘shadow cell cost’ from degradation for each cycle*

Optimisation UK case study
Step 1 – Day Ahead

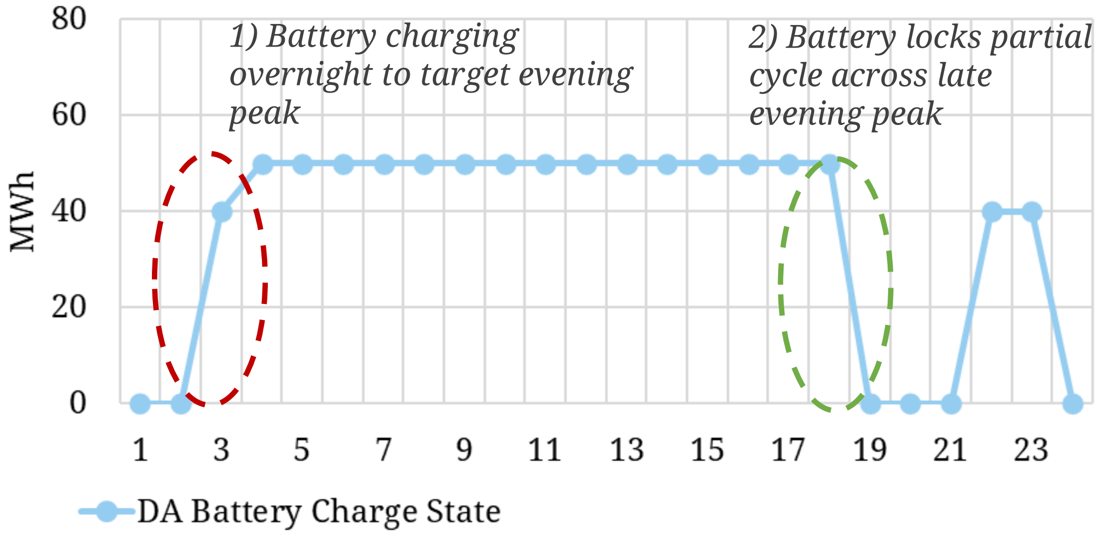
Optimisation steps

1. Battery is optimised at the DA stage, locking in two cycles against auction prices (creating base layer of revenue)

Value impact of each re-optimisation step



Battery cycling optimisation



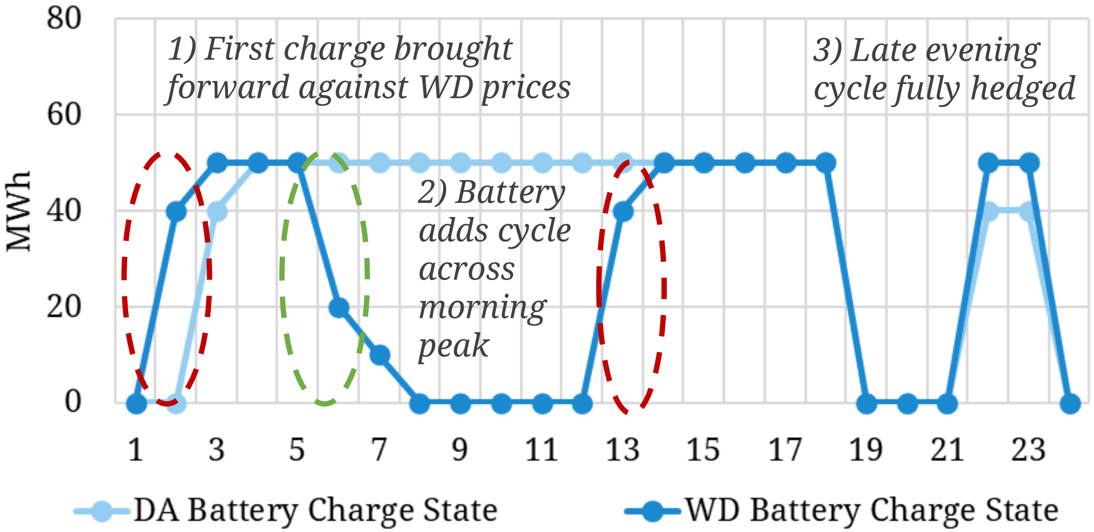
Number of full cycles: 1.8

Optimisation UK case study
Step 2 – Within Day

Optimisation steps

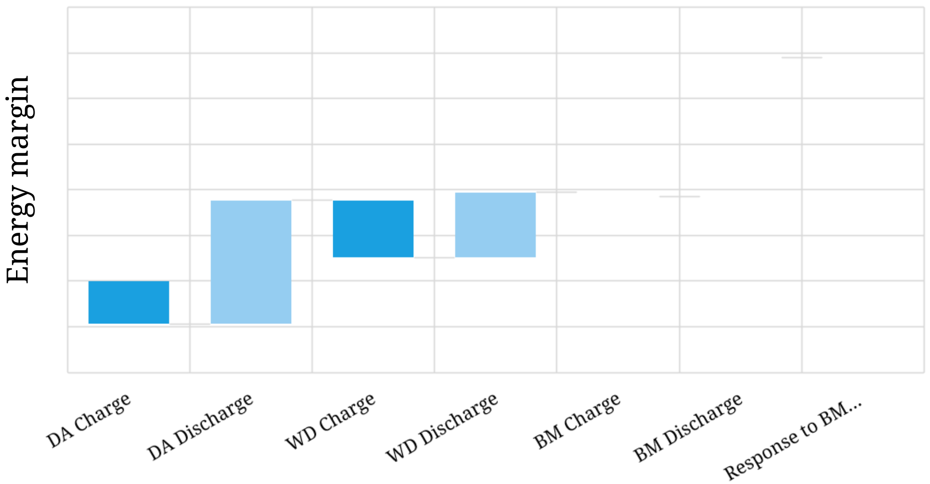
1. Battery is optimised at the DA stage, locking in 2 cycles against auction prices
2. Battery is re-optimised within-day, shifting forward first charge and adding additional cycle across the middle of the day

Battery cycling re-optimisation



Number of full cycles: 3.0

Value impact of each re-optimisation step

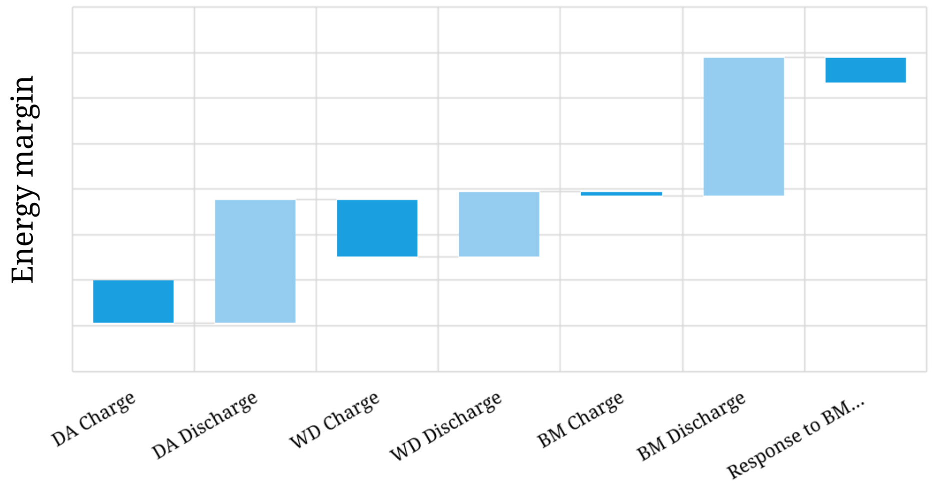


Optimisation UK case study Step 3 – Balancing

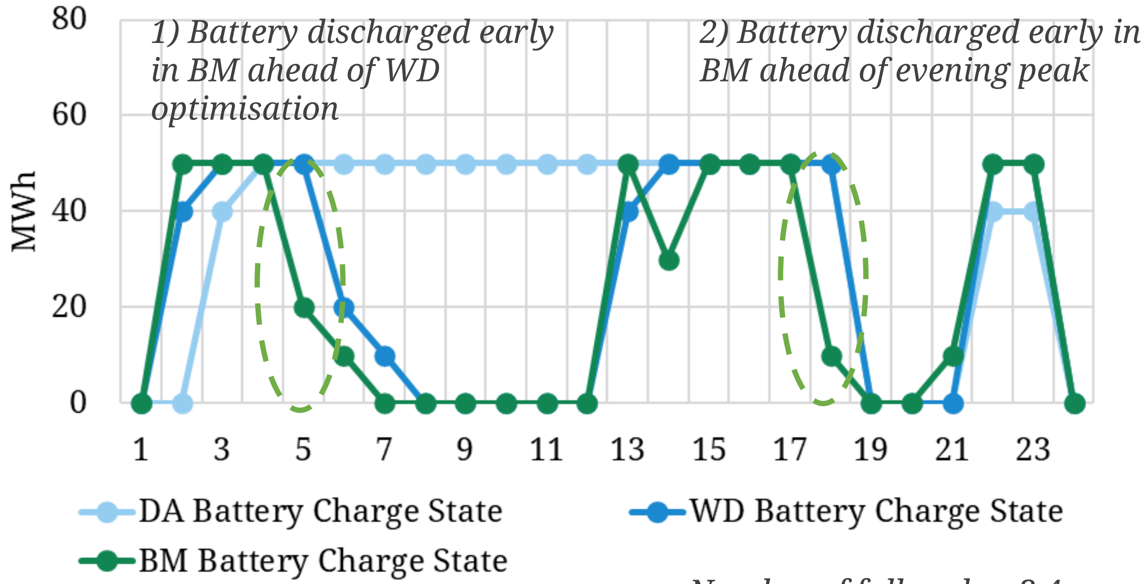
Optimisation steps

1. Battery is optimised at the DA stage, locking in 2 cycles against auction prices
2. Battery is re-optimised within-day, shifting forward first charge and adding additional cycle across the middle of the day
3. Balancing Mechanism (BM) re-optimisation: discharging earlier in the overnights, discharging in the early afternoon & then buying back in the WD market and increasing charge & discharge volumes across the end of the day

Value impact of each re-optimisation step



Battery cycling re-optimisation



Number of full cycles: 3.4

Combining batteries with renewable assets

Battery co-location value drivers

Co-location shares fixed costs

- Investment momentum behind battery co-location with solar & wind is growing rapidly, particularly in the UK, Italy & Spain.
- Co-location savings come from sharing existing grid connections and avoiding network charges.
- Solar & wind assets can incur high connections costs, but typically only use the connection for a relatively low portion of time (e.g. ~10% for solar, ~20-30% for onshore wind).

Co-located batteries are operated independently

- Co-located batteries are normally optimised independently of solar & or wind output.
- But the battery is constrained by the grid connection size and renewable generation profile (which has preferential access).
- These constraints are managed by appropriately sizing the battery to operate around the renewable output profile.
- As renewable price cannibalisation grows, batteries are less likely to want to export across high renewable periods, reducing the constraint value of co-location.

Co-location cost breakdown

	Stand-alone	Co-located
Battery costs	Full	Full
Balance of system costs	Full	Shared
Grid connection	Full	Shared / sunk
Network charges	Full	Shared / sunk
Optimisation	Unconstrained	Constrained by renewable output
Clipped power	No	Yes – depending on coupling and inverter arrangement
Losses	Losses on charging and discharging	No losses on on-site charging from wind/solar
Overheads	Full	Shared rent, rates, security, insurance

Co-location value uplift: UK case study

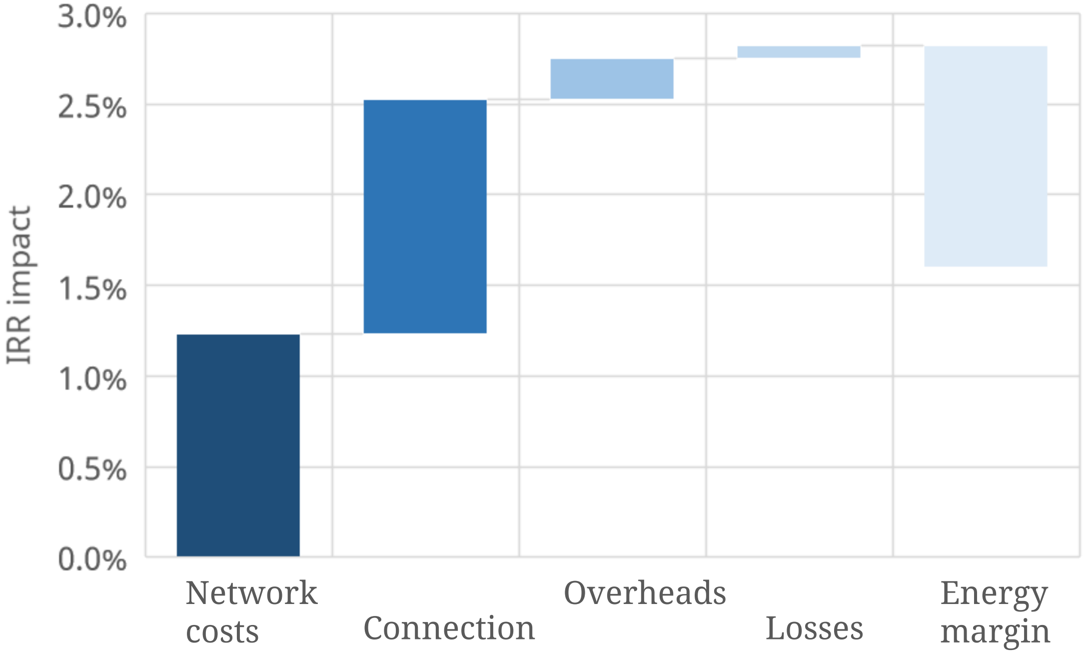
Co-location value uplift drivers (vs standalone battery)

Project economics vary significantly between sites depending on location, market and size

1. **Network costs:** Network charges are typically levied based primarily on capacity. Co-locating a battery with solar or wind allows the battery to piggy-back on the existing export capacity.
2. **Connection costs:** High one-off connection costs can weigh down investment cases, particularly when in remote locations. Co-locating allows the battery to either share or avoid these costs entirely.
3. **Overheads:** Co-locating allows the sharing of project overheads across both the renewable and battery project. E.g. see economies of scale with rent, rates, security & insurance.
4. **Losses:** Direct on-site charging of a battery from renewable generation can save losses on both the export & import of power.
5. **Lost energy margin:** Co-location relies on sharing a single grid-connection to reduce costs. Effective sizing reduces the impact of sharing a single connection, however some interference to battery optimisation from inflexible renewable output is inevitable.

Balancing the size of the battery against grid connection and renewable profile is key to maximising value and minimising battery constraints (see next slide).

Indicative IRR uplift: UK case study



Indicative IRR breakdown calculated for a 1hr transmission connected UK battery. IRR uplift is project dependent and can vary based on location, battery sizing, efficiency, connection fees and project costs.

Source: Timera Energy

Effective battery sizing key for co-location

Efficient battery-solar ratio

Batteries should be sized to maximise grid connection utilisation while limiting constraints from renewable output:

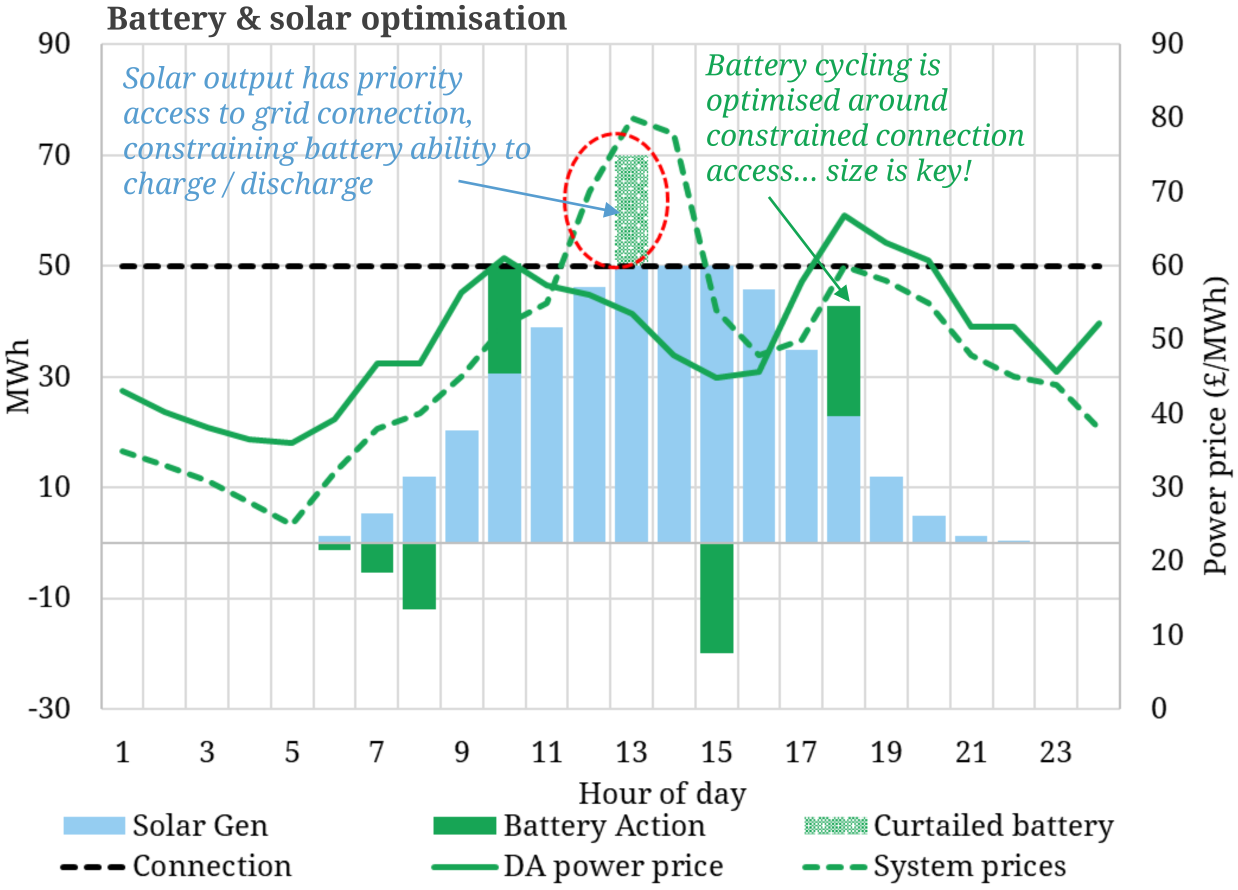
- Higher battery-solar ratio allows greater capture of market price spreads, but with greater curtailment by renewable output.
- Lower battery-solar ratios will be less curtailed by renewable generation but will fail to maximise the utilisation of the grid connection, effectively leaving value on the table.

Balancing battery sizing

- A battery-renewable ratio is efficient when energy arbitrage revenues exceed the impact of curtailment by the grid connection and the cost of battery cells.
- Project specific battery sizing depends on the site solar profile, grid connection and the coupling arrangements.

Modelling constraints

- Modelling co-location adds another layer of complexity to battery revenues.
- Over-simplifications of solar profiles can undervalue the impact of co-location of optimisation and lead to inaccurate margin projections.
- Stochastic battery optimisation against correlated power price and renewable profiles is required to model realistic value capture.

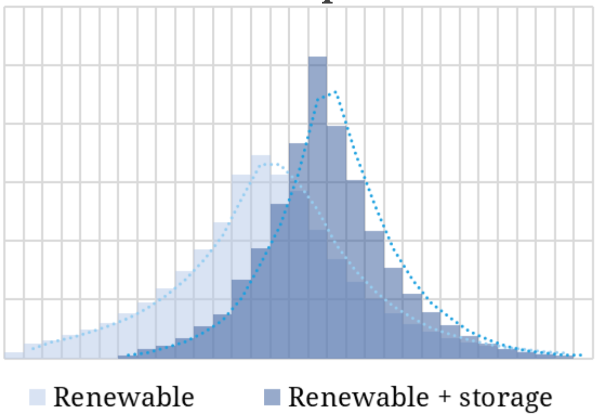


Diversifying renewable portfolios with batteries

Battery interaction with renewable portfolios

- Across Europe, renewable portfolio exposure to wholesale & balancing prices is increasing.
- Batteries can diversify some key renewable portfolio risks e.g. price cannibalisation (see table below).
- Adding an appropriately sized tranche of batteries to a renewables portfolio can:
    1. Reduce portfolio downside i.e. tighten value distribution
    2. Increase expected portfolio returns
- Stochastic analysis can be used to quantify optimal battery volume & impact on portfolio risk/return.

Batteries can 'tune' portfolio IRR



How do batteries complement renewable portfolio returns?

Market driver	Wind/Solar	Batteries	Summary
Low average wholesale prices			Solar & wind revenues fall with wholesale prices. Battery revenues are largely uncorrelated to wholesale price levels
Price cannibalisation			Wholesale prices are negatively correlated with wind & solar output, cannibalising revenues. This correlation benefits batteries e.g. make money when L/H wind & sun
Rising intraday price shape			Price shape is increasingly correlated to renewable output. Cannibalisation reduces solar & wind revenues, but increases battery returns
Rising price volatility			Rising volatility increases renewables balancing exposure. Battery returns benefit from higher balancing price volatility

Red indicates a net negative asset margin impact. Grey indicates a net neutral margin impact. Green indicates a net positive margin impact

Building a battery investment case

5 key challenges valuing batteries

Battery valuation pitfalls

- The biggest threats to realistic battery valuation are shortcuts and oversimplification.
- Two examples of flawed approaches to modelling battery value are:
  1. Trying to use a generation supply stack model to forecast battery margins
  2. Calculating battery margin based on an empirical relationship to a forecast market volatility index
- These approaches may be convenient to execute and explain, but they are the analytical equivalent of making up numbers.
- The table summarises 5 key challenges in producing a robust battery valuation

Battery asset optionality is complex (like hydro).

If you don't confront that complexity, it is unreasonable to expect you will get your money back.

5 battery valuation challenges

Challenge	Description
1. Trading strategy	Battery valuations need to explicitly reflect the practical trading strategy adopted by the asset operator
2. Uncertainty	Traders do not have perfect foresight and this lack of price visibility needs to be realistically captured in a model
3. Degradation	Degradation from each cycle brings forward battery cell replacement and needs to be dynamically modelled as a variable cost
4. Volatility	Stochastic price simulation is needed to capture the realistic evolution of price volatility - scenario or stack modelling doesn't cut it.
5. Margin codependence	A battery valuation model needs to dynamically co-optimise margin across multiple margin streams (e.g. day-ahead, within-day, balancing, ancillaries)

Realistic modelling of battery value

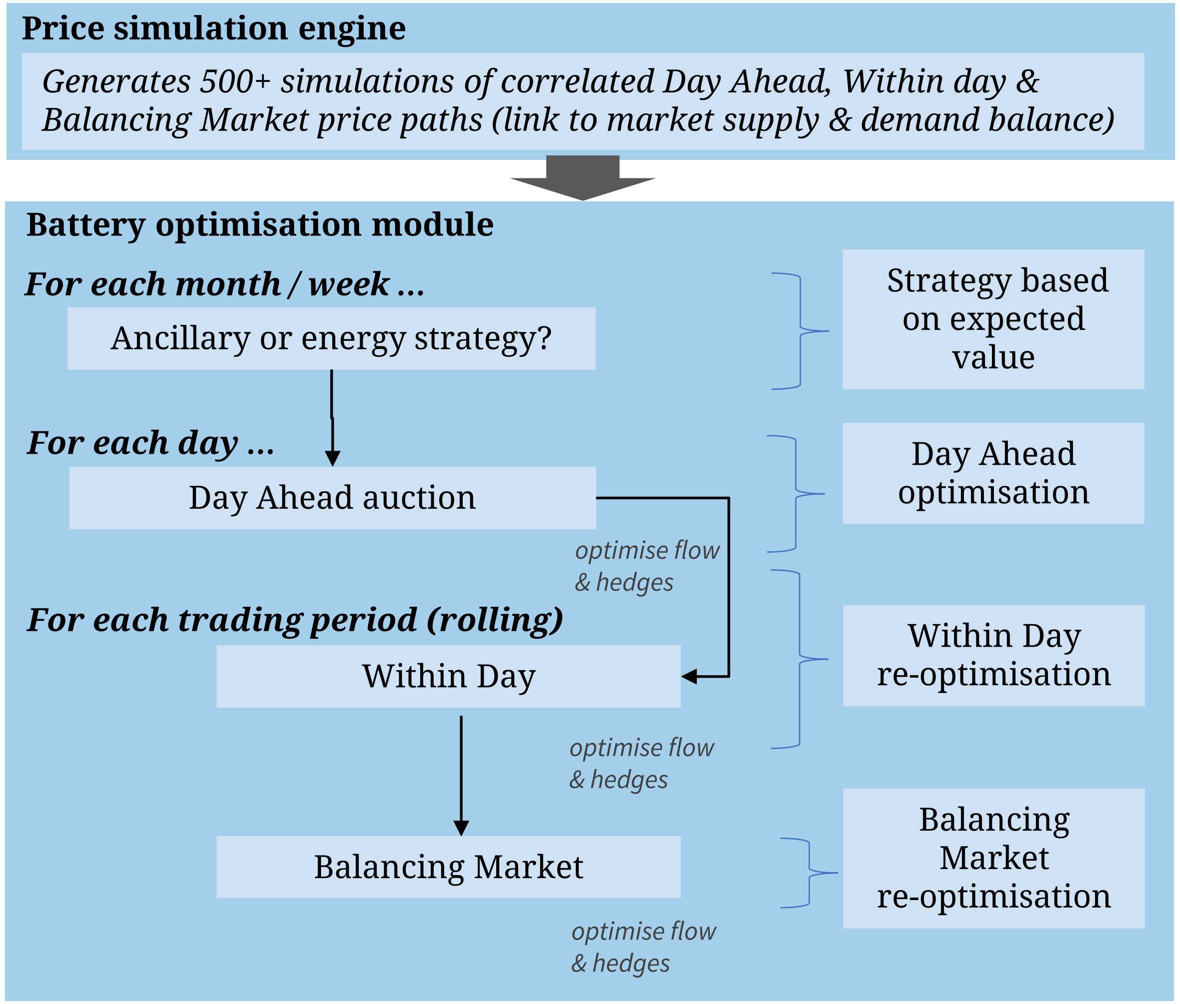
How does Timera model battery value?

- Batteries share many value dynamics with other established energy storage assets e.g. hydro & fast cycle gas storage.
- We have developed an in-house battery valuation model which draws on these existing stochastic techniques for analysing storage margin.
- Our approach is consistent with those used by established battery operators (e.g. EDF, Statkraft, Centrica).

Realistic value relies on replicating battery optimisation

- Our stochastic battery optimisation model produces:
    - Wholesale, balancing & ancillary margin numbers
    - Variable costs (e.g. charges, losses) & cycling / degradation data.
- Key battery optimisation steps are illustrated in the diagram.
- Across each time step, the model reflects the practical decision making process that a trader faces when dispatching a live asset.
- Importantly, we replicate both the trader's imperfect foresight & the costs associated with re-balancing a battery.
- The focus of the methodology is producing margin results that can be achieved in reality.
- We work directly with several leading European trading desks that are optimising batteries to ensure our approach is robust.

Timera's battery valuation model summary

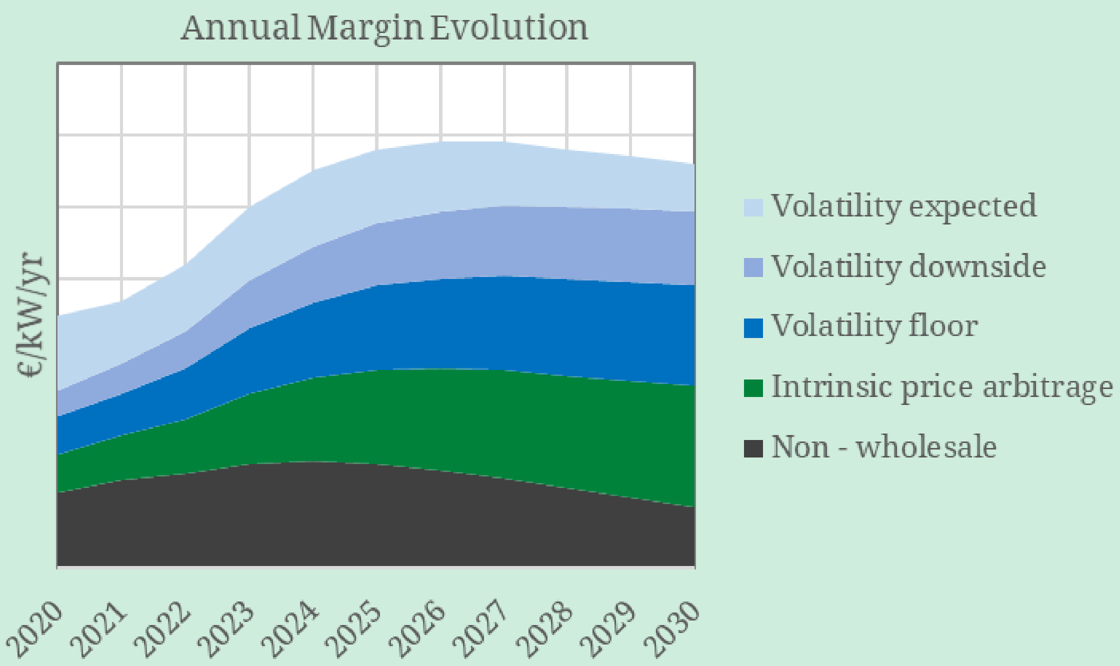


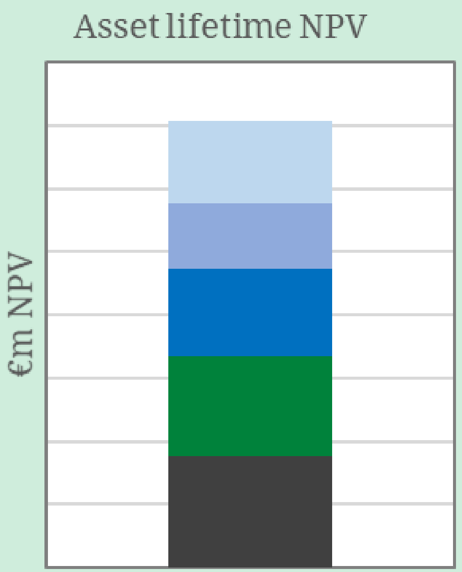
Benchmarking battery value

Building confidence in modelled value

- There is no substitute for sophisticated market & asset modelling of battery value (see previous slide).
- But… how can I sense check the model? How do I get comfortable with value downside if the model is wrong?
- Equity & debt investors are becoming more comfortable with flex asset risk. Transparent benchmark analysis & backtesting helps.

Benchmarking a battery margin stack: Value can be transparently benchmarked in tranches to challenge model results (e.g. vs breakeven, P10, Base cases)





Margin Tranche	Description
Volatility expected	Incremental value from 'expected' volatility case
Volatility downside	Incremental value from 'downside' volatility case
Volatility floor	Incremental value from inherent 'floor' level of volatility from RES/load swings
Intrinsic arbitrage	Value that can be captured against intrinsic price shape
Non - wholesale	Ancillaries / network / capacity value streams

5 factors behind a robust battery investment case

We finish with 5 investment case considerations from our work supporting battery investors & owners:

Takeaway	Description
1. Understand market requirement	• A battery investment case is underpinned by linking strong market fundamentals & policy tailwinds to tangible value. • This means analysing market requirements for storage flex as the capacity mix evolves (e.g. duration, competition).
2. Commercially optimise project	• Battery project configuration (e.g. size, duration, connection type) is a commercial optimisation problem. • Asset configuration can be ‘tuned’ by modelling how battery flex interacts with the market over time.
3. Co-optimise revenue stack	• Realistic battery valuation requires dynamic co-optimisation of wholesale / balancing / ancillary revenues. • Valuation modelling needs to explicitly capture the impact of a realistic trading strategy with imperfect foresight.
4. Use a stochastic model	• Batteries are options and require a stochastic valuation model… Shortcuts result in ‘hypothetical’ valuation & unseen risks. • Robust simulation of market prices & realistic monetisation assumptions across co-dependent revenue streams are key.
5. Quantify portfolio effects	• Co-location can create value uplift. But the trade off between cost savings & lost revenue needs quantifying… • … as does the portfolio diversification benefits of combining storage with renewables (i.e. risk/return impact).

Timera offers expertise on value & risk in energy markets

Specialist energy consultancy

Focus on LNG and European gas & power assets

Extensive industry expertise

Practical knowledge from senior industry roles

Pragmatic commercial focus

Investment, value monetisation & market analysis

Strong client base

leading energy companies (producers, utilities, funds)

Leading industry blog

15,000+ regular readers, publications, conferences

Our clients include

Relevant recent power credentials

Project	Client	Description
1. Storage investment	**RES Fund**	Comprehensive analysis of multiple European battery project options & margin projections
2. Storage investment	**RES Fund**	Market and revenue stack analysis of UK standalone & co-located storage development projects
3. Flex monetisation	**Utility**	Trading strategy & optimisation advice for large portfolio of UK batteries & engines
4. Flex co-location	**RES Fund**	Analysis of value & risk benefits of co-locating storage & engines with solar/wind portfolios
5. UK battery analysis	**Investor**	Analysis of market evolution & battery revenue stream modelling for large UK flex platform
6. Storage investment	**Fund**	Commercial DD advisor & valuation analysis for bid on 2GW UK battery portfolio
7. Battery valuation	**Aggregator**	Value capture & optimisation analysis for operational UK portfolio of batteries
8. PPA / market access	**Fund**	Advising on competitive selection process & structure for UK flex asset PPA & market access
9. Market analysis	**Fund**	Analysis of impact of battery, peaker & DSR roll out on NW European power market evolution
10. Flex management	**Aggregator**	Structuring advice on PPA contracts to support battery & engine flex services

Timera power team members

Our team members have extensive senior industry experience and practical commercial knowledge.

David Stokes: Managing Director

20+ years energy/commodity market experience
Expert in investment/monetization of flex power assets
Industry roles with Origin, Williams, JP Morgan

Olly Spinks: Managing Director

20+ years energy industry experience
Expert in flexible power asset valuation
Ran BP’s gas, LNG & power commercial analytics function

Rosie Read: Director

10 years industry energy industry experience
Storage optimisation & commercial analysis expert
Analysis, strategy & power trading industry background

Steven Coppack: Director

8 years European energy industry experience
Trading, optimisation and fundamental analysis expert
Analysis, operations & trading industry background

Nick Perry: Senior Advisor

30+ years industry experience (Enron, Exxon, Amoco)
Expert in commercial & risk management strategy
Board level experience (Enron Europe, Teesside Power)

Tommy Rowland: Analyst

5 years European energy industry experience
Strong power, risk and data analysis expertise
Commercial & risk analysis roles at Smartest Energy

What does Timera do?

Our power asset class expertise

- Conventional generation
- Battery & hydro storage
- Renewables
- Interconnectors
- Distributed flex / EVs

Our power related services

A. Investment

- asset valuation
- commercial due diligence
- transaction support
- investment targeting
- portfolio strategy

B. Value Management

- flex asset monetisation
- contracting & optimisation
- risk management
- business model structure
- analytical capability development

C. Market Analysis

- scenario analysis
- stochastic stack modelling
- LNG/gas/power integrated modeling
- asset value implications
- capability development

Contact Us

David Stokes — david.stokes@timera-energy.com
Managing Director — +44 (0) 7957 656 337

Steven Coppack — steven.coppack@timera-energy.com
Director — +44 (0) 7817 916 581

Address: L12, 30 Crown Pl, London, EC2A 4ES, UK
Tel: +44 (0) 20 7965 4541

www.timera-energy.com