An introduction: Revenue streams for battery storage

September 2017

CRA Charles River Associates

Introduction

Context

- Storage is critical in low emissions and renewable electricity systems, providing additional flexibility and reliability.
- As part of a move towards a smarter and more flexible electricity system, Ofgem, National Grid and government are seeking to reduce market barriers and enable storage.
- National Grid expects electricity storage capacity to grow rapidly in the next few years, nearing 6 GW by 2020 in all scenarios. Under the 2017 Consumer Power scenario, storage capacity reaches 10.7 GW by 2050.
- Storage growth in the next five years will be driven by both technology progress and improving commercial attractiveness, including decreasing cost, the increasing demand for flexibility and the growth of distributed resources.
- To optimise asset returns, investors need to understand how to monetise multiple potential sources of revenues.

About this document

- Overview of the business models and revenue sources for storage, particularly for Lithium-ion batteries.
- Summary of the current status, potential market changes and attractiveness of some of the main revenue streams to batteries.
- Estimate of the range of total revenues available to batteries from participation in the system services markets, capacity market and embedded benefits.

Target audience

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Outline

1. Battery business models and revenues
2. Review of battery revenue sources
3. Illustrative quantitative analysis

Business models

Energy storage is monetised through several business models and ownership structures:

	Location*		Owner**	
Revenue streams and benefits	Front of the meter	Behind the meter	Utility / investor	Consumer
Frequency response (e.g. FFR, EFR)	✓	✓	✓	✓
Reserve power (e.g. STOR, DTU)	✓	✓	✓	✓
Voltage support	✓	✓	✓	✓
Capacity market	✓	✓	✓	✓
Embedded benefits	✓	✓	✓	✓
Wholesale arbitrage	✓	✓	✓	✓
Grid upgrade deferral and congestion relief	✓	✓	✓	✓
Resiliency	✓	✓	✓	✓
Black start	✓		✓	
Peak reduction	✓	✓	✓	✓
Energy time shift	✓	✓	✓	✓
Renewable integration	✓		✓	
Back up power		✓	✓	✓
Off-grid / islanding		✓	✓	✓
Self consumption		✓		✓

** Front of the meter encompasses utility-sided, central applications; behind the meter comprises customer-sided, distributed applications.*

*** Network businesses are not included because they are not currently permitted to own storage assets. An Ofgem review is underway to facilitate proactive network management by DNOs, e.g. through ownership and operation of storage and DSR.*

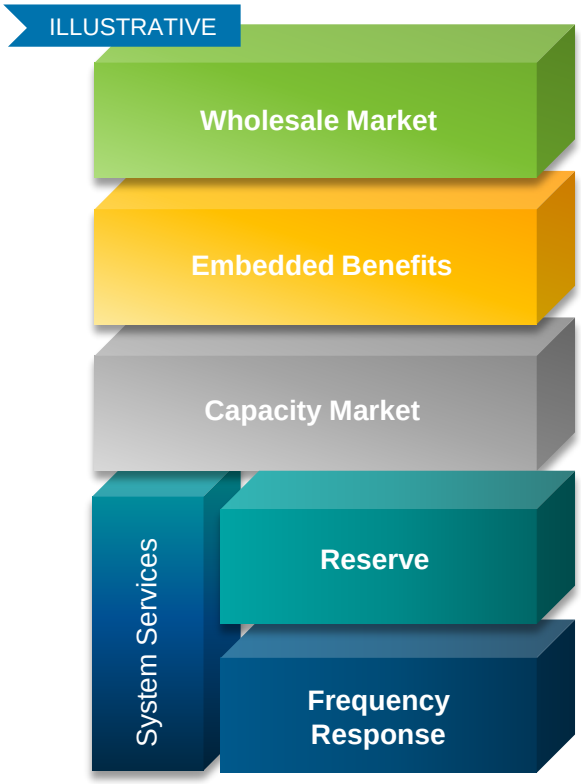
✓ Directly accessible

✓ Accessible primarily through an aggregator

Batteries can be developed as standalone assets (both behind and in front of the meter) or as part of an asset portfolio (for renewable energy integration and services such as demand-side response). This document focuses on investor-owned batteries located in front of the meter that may be developed by "stacking up" different sources of revenue.

Revenue streams

In the GB market, batteries have access to four distinct revenues streams:



Wholesale market: Price arbitrage, including intraday trading, is feasible but requires high spreads to justify the battery deterioration that follows from constant cycling.

Embedded benefits: Distribution-connected batteries are not liable for a number of generation network charges. Although significantly reduced, they can also secure payments for reducing suppliers' net demand and network charges.

Capacity market: Batteries can secure a capacity market agreement lasting up to 15 years for new build. Capacity market units are required to respond during system stress events.

System services: Batteries can provide a number of system support services, such as frequency response, reserve and transmission constraint management. Their technical properties make them best suited for services procured on a short time scale. New system services definitions are expected in 2018.

The ability to "stack-up" these different sources of revenues will depend on both the operating parameters of the asset and the rules and requirements for participation in each market or service contract.

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Relevant system services

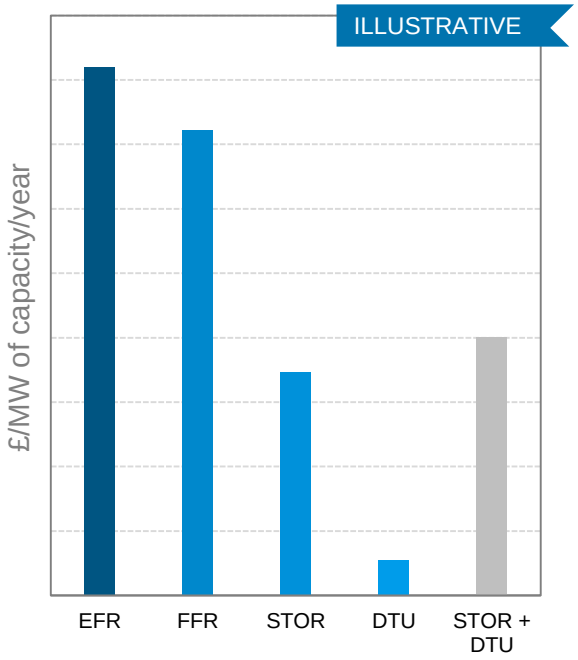
- National Grid currently procures over 20 different balancing services products across the categories of frequency response, reserve, system security and reactive power.
- Revenues from different system services can be cumulated as long as tendered availability windows do not overlap.
- The two key types of system services of relevance to batteries are frequency response (Firm and Enhanced Frequency Response – FFR and EFR) and reserve services (Short Term Operating Reserve and Demand Turn Up – STOR and DTU).
- National Grid has initiated a consultation to improve transparency and reduce complexity in this market.

Current service revenues

- Frequency response services currently provide higher revenues for batteries than reserve services; however, STOR and DTU revenues may be combined with some frequency response services.
- Competition for frequency response tenders is greater than reserve services.

Upcoming changes

- National Grid consultation results are due to be published in September 2017 and are expected to lead to:
  - Fewer products: inertia, frequency response (combining FFR and EFR), reserve, reactive power, black start;
  - Standardised key parameters (availability windows, contract terms); and
  - Increased transparency regarding tender assessment.



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Capacity market revenues

- Batteries can cumulate capacity market revenues with system services revenues and embedded benefits.
- In previous auctions, battery owners could have received up to £21.6/kW-year in capacity payments (clearing price £22.5/kW and 96% derating factor).
- However, BEIS and Ofgem are considering a change to battery derating factors that might both reduce capacity market revenues for batteries after 2018, and limit their ability to stack-up other revenues.

Changes proposed by BEIS and Ofgem

- Current proposals are to create several derating factors for storage depending on duration for which the battery can generate at full capacity without recharging (from 30mins to 4h). Beyond 4h, derating factors would remain at 96%.
- Shorter-duration storage would be derated according to Equivalent Firm Capacity (additional generation capacity that would be required to obtain the same Loss of Load Expectation on the system).
- National Grid will define final categories and derating factors at the end of its consultation (closed 8 September 2017).
- Changes will be implemented from next auction, scheduled for February 2018.

Reasons for changes

- Most installed batteries discharge at full capacity for 30mins-1h, but stress events last “up to two hours on average”;*
- Battery performance declines over time; and
- Batteries can participate in the balancing mechanism, triad avoidance and wholesale arbitrage: “security of supply challenges could arise if some of these batteries are not sufficiently charged before the start of a stress event and are therefore unable to deliver on their capacity obligations for the duration of the event”.*

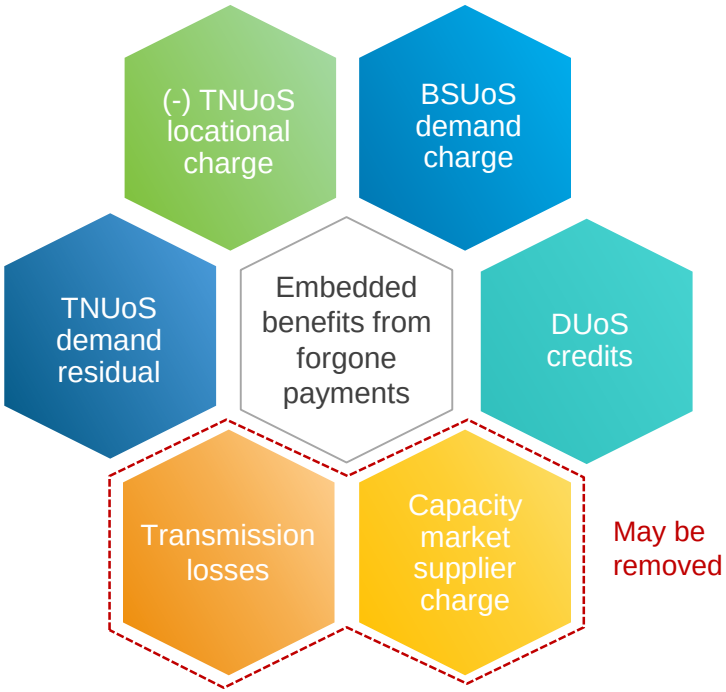
Source: BEIS (2017), “ Capacity market consultation – Improving the Framework ”, 23 August 2017

Embedded benefits (for distribution-connected assets)

Distribution-connected assets can:

- Receive payments for reducing net demand from suppliers at the GSP, thereby reducing liability for network charges;
- Face the inverse of TNUoS demand locational charges for generation during Triad;
- Avoid generation charges associated with being connected on the transmission system.

Payments to embedded generators



Evolution of embedded benefits and network charging

- CMP264 and 265 significantly reduced the value of the TNUoS demand residual, from £45.33/kW to £1.62/kW.
- BEIS is minded to remove the capacity market supplier charge payment to embedded generators.
- The CMA energy market inquiry recommended the application of transmission losses to generation, which would suppress this embedded payment.
- Other relevant changes:
  - National Grid is looking into removing double charging of TNUoS demand residual and BSUoS on electricity taken from storage facilities (respectively CMP280 and 281).
  - Ofgem has launched a Significant Code Review to reform residual charging for transmission and distribution. However, the review does not cover some embedded benefits available to smaller embedded generation.

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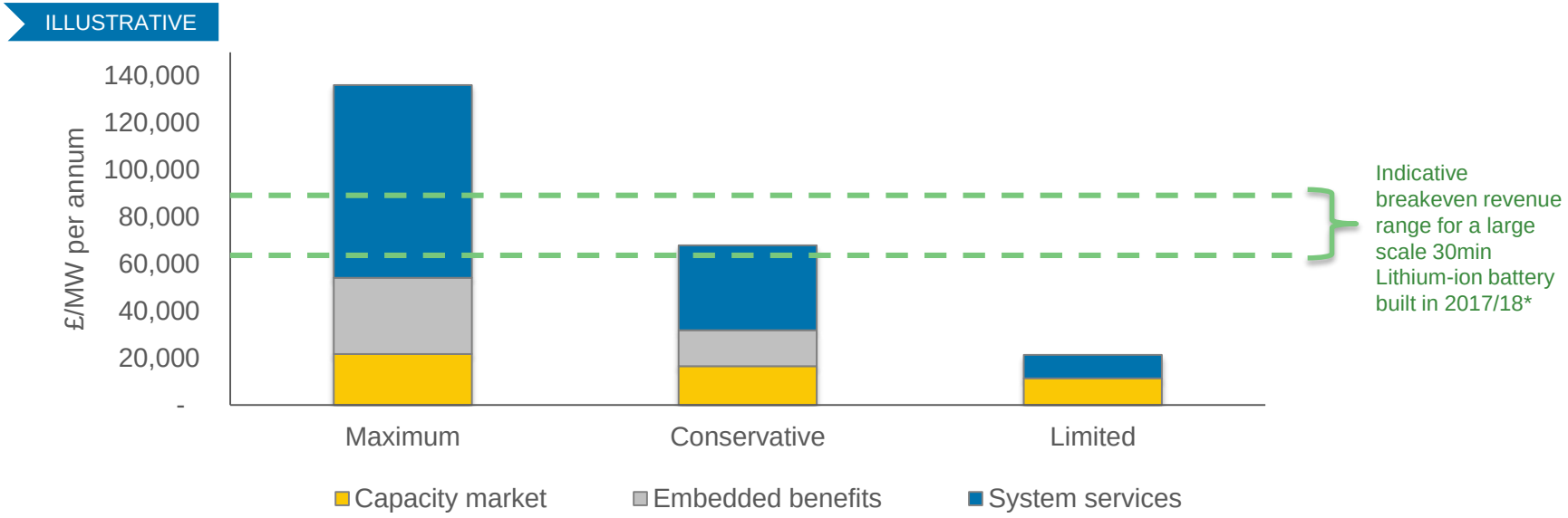
Revenue breakdown for Lithium-ion batteries, excluding wholesale energy market

- Revenue scenarios for Lithium-ion batteries based on 2017 available services:
  - Maximum: High capacity market derating factor, maximum revenue from embedded benefits, high remuneration for frequency response;
  - Conservative: Medium capacity market derating factor and embedded benefits, conservative remuneration for frequency response; and
  - Low: Low capacity market derating factor, no embedded benefits, participation in reserve services;
- Different combinations of capacity market, embedded benefits and system services revenues can provide between £20/kW-year and £135/kW-year, **in addition to potential revenues available from participation in energy markets**.
- In comparison, make-whole revenue requirements can range from £60/kW-year to £85/kW-year for 30-minute batteries, with substantial cost savings projected in coming years.



Subject to assumptions on costs, battery sizing, required returns, WACC and other key parameters, not accounting for potential wholesale market revenues. Revenues for reserve services have been adjusted to reflect the maximum participation possible with a 30-minute battery.
Source: CRA analysis

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How CRA can help

- System services markets, capacity markets and embedded benefits are complex enough on their own. Understanding how generation and storage assets can maximise the potential value from all of these markets is particularly challenging in an environment with constantly changing rules and policies.
- CRA can help investors understand the interactions of these markets, the regulatory risks, the likely policy evolutions and evaluate all potential sources of revenue for battery assets.

Why CRA?

Deep electricity market knowledge

We have deep expertise in electricity markets, capacity markets and system services markets. CRA experts have helped shape some of the most sophisticated electricity markets in the world and understand policy and regulatory risks.

Proven market analysis and valuation experience

Our team has conducted revenue forecasts, financial analysis and asset valuations. Investors and financial institutions often retain CRA to value investments and analyse the risk and value drivers of power markets.

Modelling expertise

CRA has extensive expertise modelling electricity markets and projecting financial models. We can provide flexible, dynamic tools that will enable you to evaluate and value investments.

Investment and operational expertise

Our team has experience investing in, and attracting investors to, a wide range of power markets. We can help you shape or review your business plans, identify optimal investors and negotiate.

How our team can help

- Assessing the optimal combination of feasible revenues
- Market and revenue scenario analysis
- Asset valuation
- Portfolio analysis
- Independent evaluation of your internal analysis
- Third party challenge to investment assumptions and forecasts
- Developing a bidding strategy for auction markets (including the capacity market or auctioned system services)
- Developing a business case
- Assisting in negotiations with investors and developers

Battery storage system modelling:

A comprehensive assessment of your project returns

Market analysis and value stacking

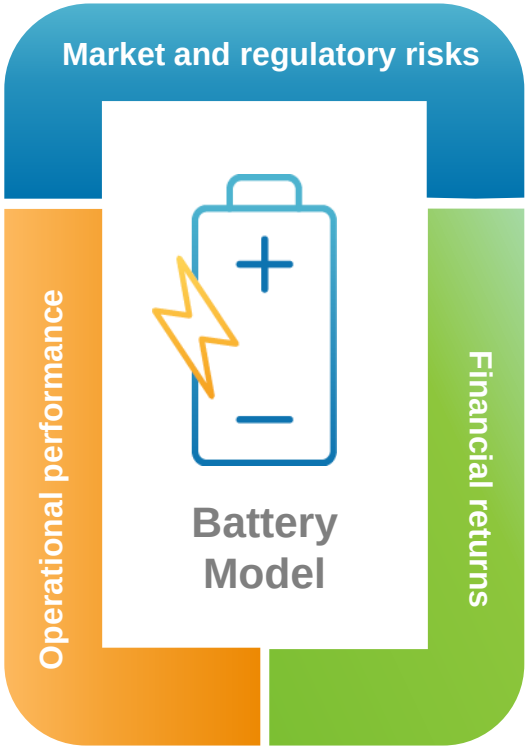
- How much value each revenue stream holds
- Which revenue streams can be combined
- What assets can be combined to capture most revenue
- Bidding strategy
- Competitor analysis and benchmarking

Regulatory analysis and evolution

- How the regulation will evolve in the near future
- How it will impact your project
- Key regulatory risks

Project costs and asset technical assumptions

- £/kW and £/kWh price curves
- Battery efficiency
- System energy (kWh) to power (kW) ratio
- Depth of Discharge and State of Health assumptions
- Battery lifetime assumptions
- Dynamic asset degradation



Design evaluation and propositions

- Battery capacity allocation for maximum value capture
- Charge / recharge cycle duration
- Stochastic forecasts for battery operations
- Battery usage and respective degradation
- Capacity warranty contract and cycling effects on performance
- Assessment of bundling energy storage with a conventional asset
- Optimal battery sizing

Financial returns and capital structure

- Optimal project capital structure
- Relevant project return parameters (e.g. NPV and IRR)
- Financial risks and hedging strategies
- Portfolio financial performance and optimisation
- Cash flow profiles
- Evaluation of revenue and operational performance scenarios
- Business model and stakeholder structure assessment
- Potential investor's exit strategies

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