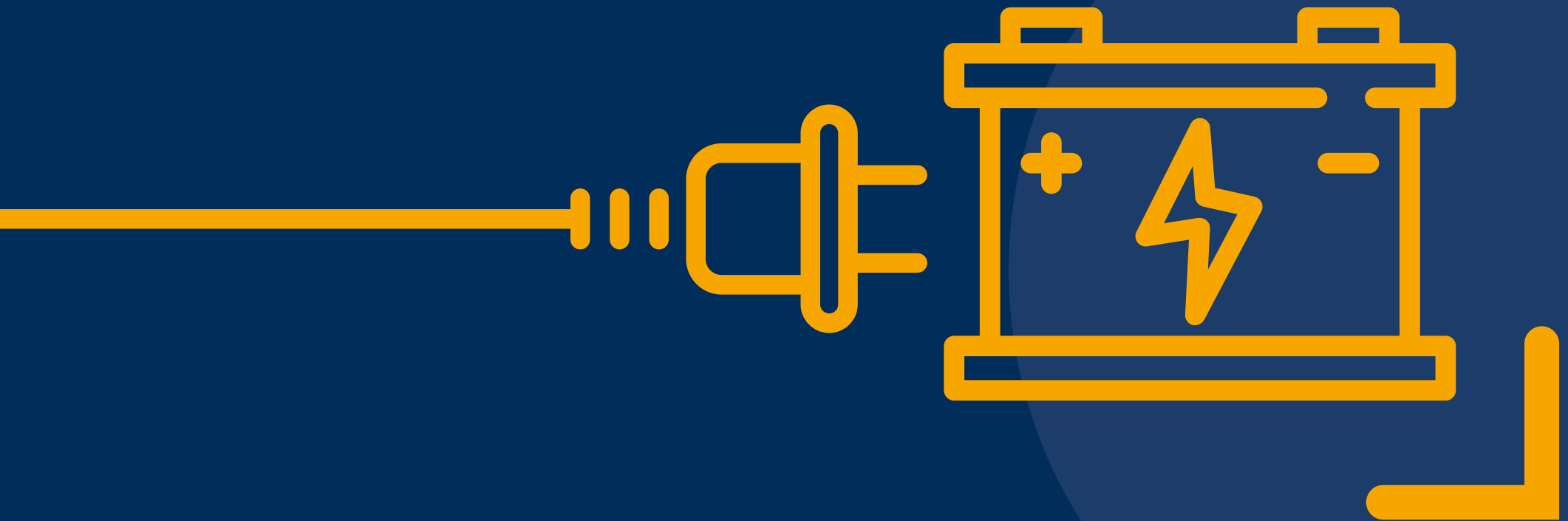


Is battery storage a good investment opportunity?

January 2021



Executive summary

In 2020 GB curtailed wind power on 75% of days, and over 3.6TWh of wind energy in total, largely due to network constraints. This clean energy could have been used to power over one million homes for the whole year had it been stored and used when needed.

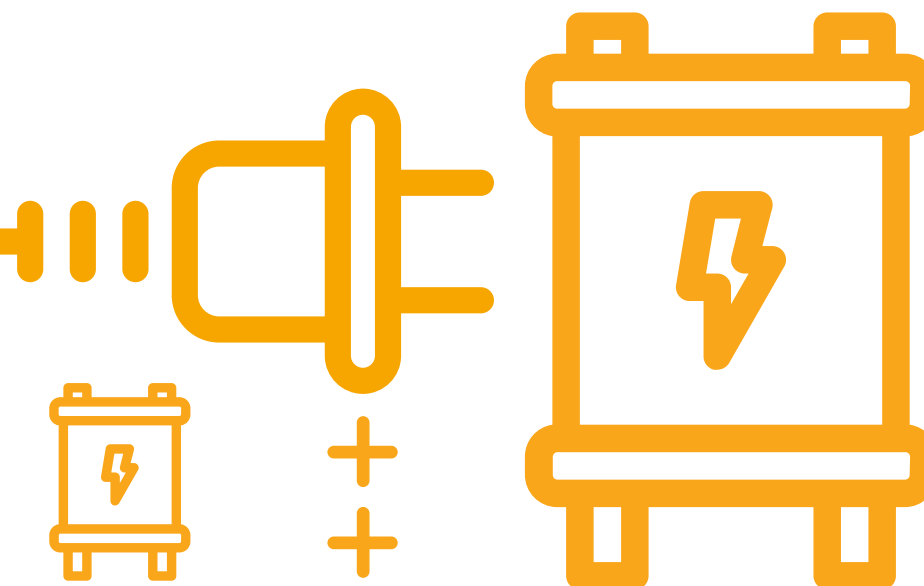
This is just one of the reasons there was significant renewed interest in the battery storage market in 2020, with favourable changes to planning regulations, lucrative Dynamic Containment (DC) contracts, Balancing Services Use of System (BSUoS) reforms, large scale acquisitions and demonstrated returns from multiple market participants all fuelling investors' appetites further in this asset class.

It is relatively simple to understand why battery storage is such an attractive proposition. They are currently earning significant revenues and the need for them is set to increase. In an increasingly intermittent system committed to decarbonising, a battery's ability to smooth and shift demand on sub second timescales is widely seen as crucial. And in a system with significant volatility, an asset that can arbitrage price spreads over the day is ideally placed to reduce risk exposure in portfolios and employ efficient algorithmic trading strategies which can capitalise on these opportunities.

But does this make batteries investable? Understanding the Return on Investment (ROI) potential of storage is an exceptionally difficult task. There are many levers which affect a battery project's potential, each of which come with large degrees of uncertainty. Competition from other flexible assets, policy and regulatory change, deployment of new storage technologies, uptake of electric vehicles, consumer behaviour, locations of new build assets, timescales of network reinforcements, and efficiency of trading – each of these levers can swing a battery project's potential from black to red.

It is also no secret that we have seen these bubbles of interest before. 2018 saw huge levels of battery storage interest driven by high value frequency response contracts and attractive Capacity Market (CM) de-ratings before the market corrected itself, leaving many battery asset owners out of pocket¹. With some areas of the market currently running at exceptional highs and with bullish investor appetite, are we simply repeating history?

In this report, we take an in-depth look at the fundamentals of the four key revenue streams available to batteries: arbitrage, balancing, capacity provision and frequency response. We analyse the opportunities available now and present our views of how these markets will develop. We're cautiously optimistic about the potential for storage in GB, and explain why we think there will be changes in both the sources of revenue for batteries and the trading strategies used.

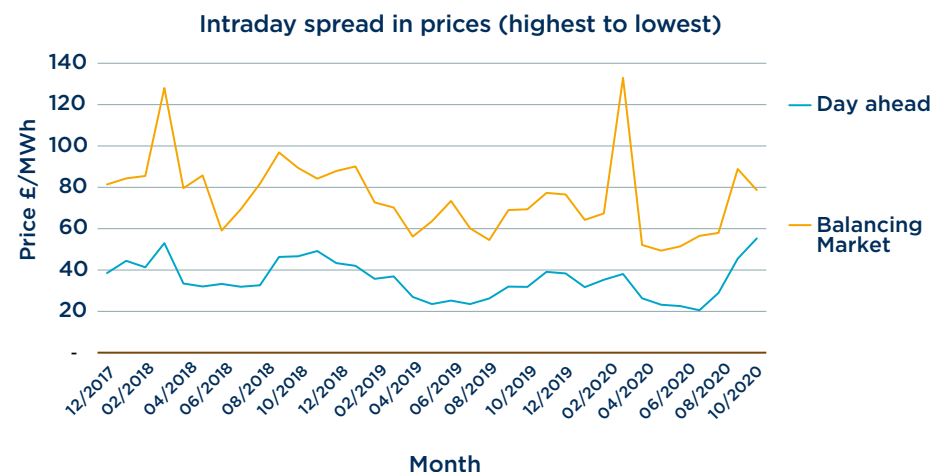


1. Modelling storage – what went wrong?: <https://www.lcp.uk.com/our-viewpoint/2019/04/modelling-storage-what-went-wrong/>

Arbitraging the market

Batteries make money in power markets through arbitraging the value between charging and discharging power. The greater the difference between high and low power prices across the day, the larger the profit for a battery asset. **Batteries can charge and discharge multiple times a day, but high levels of cycling have an impact on the lifetime of the battery asset itself, with most battery cells needing to be replaced after 6,000 - 10,000 full cycles.** A strategy involving high amounts of cycling may yield higher profits but will also reduce the expected lifetime of the battery.

We consider two key markets that batteries are likely to arbitrage, the Balancing Mechanism (BM) and the wholesale market. The day ahead auction is the most liquid of auctions and represents the earliest time a battery is likely to decide its initial running profile. The BM is one of the tools National Grid uses to balance electricity supply and demand close to real time. The BM consists of units submitting bids and offers to increase or decrease power output, and National Grid accepting some of these to resolve energy and system imbalances. This results in a 'cashout' price for each period representing the cost of these balancing actions. These prices tend to be more volatile than day ahead prices, and batteries can take 'Net Imbalance Volume (NIV) chasing' approaches to arbitrage the BM after they have submitted day ahead positions, so we consider the two together.



Power price spreads over the last few years in both the wholesale and BM have been attractive. There has been a suppression in these spreads recently, largely due to lower gas prices and Covid-19 reducing demand (although the increase in negative pricing events has provided some lucrative opportunities for batteries as well).

We expect these spreads to improve in the coming years (particularly in the wholesale market) as gas prices recover and push up peak power prices. **We've also seen the UK Government commit to boosting the deployment of offshore wind from 30GW to 40GW by 2030.** This, along with the rollout of other renewable technologies will increase the frequency of very low - including negative - prices which can help to increase spreads for storage technologies.

However, the outcome of proposed changes to the Contracts for Difference (CfD) regime would limit the occurrences of negative pricing in day ahead markets and hence the opportunities for batteries (for more on the changes, including the intended and unintended potential consequences, read our joint analysis with Frontier Economics)². And there are other threats too. Cannibalisation of price spreads from other battery storage assets presents a significant risk, particularly in the BM which has smaller overall volumes. In addition, the entry of competing sources of flexibility, such as interconnection and Demand Side Response (DSR), will also dampen spreads and reduce the opportunities for batteries.

To demonstrate how different strategies impact battery revenue and potential life expectancy, we look at how a battery asset could have performed historically using a 'perfect foresight and high cycling' strategy and an 'imperfect foresight and low cycling' strategy. Both strategies assume a 1-hour duration battery storage asset with a 90% round trip efficiency and an 80% depth of discharge, using the price spreads available over the past 3 years.

These strategies allow the batteries to optimise their behaviour in the day ahead market. With their positions locked in, we allow the batteries to further optimise their positions through the BM where they see additional opportunities.

2. Impact of negative pricing on renewable support: <https://www.frontier-economics.com/uk/en/news-and-articles/articles/article-17847-impact-of-negative-pricing-on-renewable-support/>

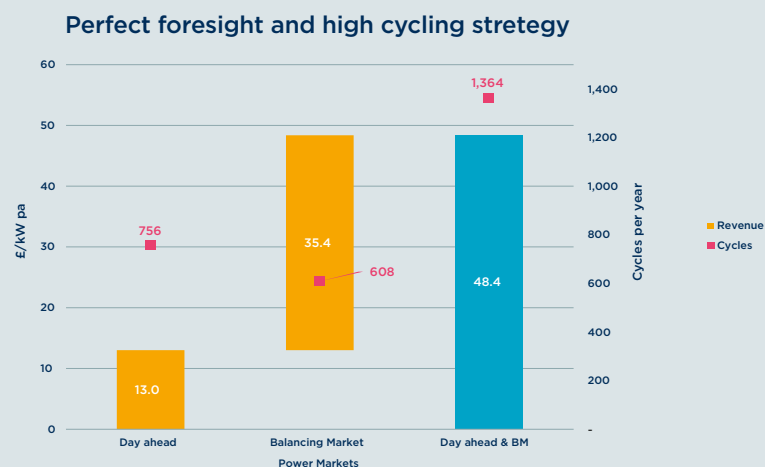
Battery trading strategies

Perfect foresight and high cycling strategy

For this strategy we have assumed “perfect foresight” so that all potential value is captured in the wholesale and BM. At this stage, it is worth highlighting that this approach is an upper revenue limit and that perfect foresight is particularly unrealistic in the BM, where direction of NIV and system prices are volatile and unpredictable. However, we have not included the additional value and hedging capabilities that would be available through intraday markets.

Applying this strategy, we see that batteries could have made returns of up to **£13/kW** pa in the day ahead market and **£35/kW** pa in the BM, representing significant upside potential for these assets.

But this strategy assumes a high number of cycles - almost 4 per day in total across the day ahead market and BM. As we mentioned earlier, batteries can cycle 6,000-10,000 times before they have to be refurbished. **If a trading strategy similar to this was used every day then the asset owner would need to plan to refurbish the battery after 4 - 7 years**, meaning that the Capital Expenditure (CAPEX) of this refurbishment becomes very important when looking at how to use the battery and how often you cycle it.

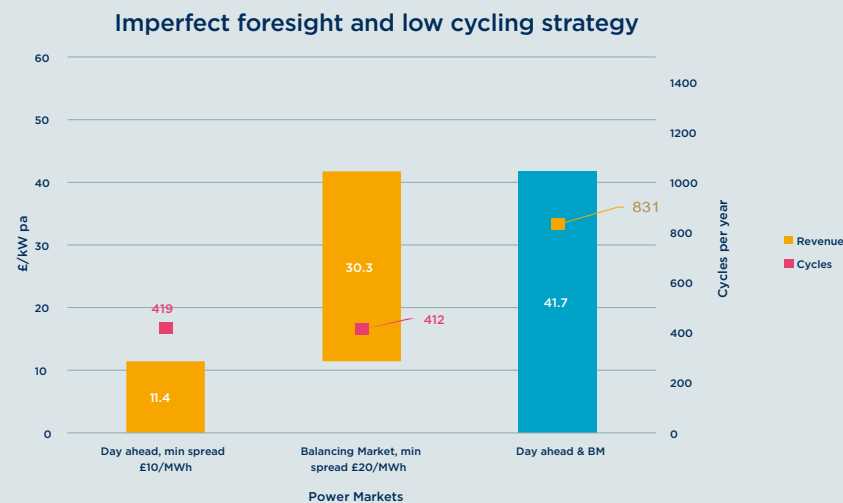


Imperfect foresight and low cycling strategy

For the second strategy we can instead assume that batteries only cycle to capture a minimum level of return, to avoid wear and tear and to avoid losing out due to imperfect foresight. We have assumed a minimum level of return of £10/MWh in the day ahead market, and £20/MWh in the BM (where prices are harder to forecast). This means that low margin cycles are reduced and cycles overall are reduced to 1 per day in each market. This represents a more realistic operating profile for a battery storage asset trading in today’s market.

Net revenues are reduced slightly to £11/kW pa for the day ahead wholesale market and £30/kW pa in the BM. **Although cycles are reduced by 45% in day ahead and 32% in the BM, net revenues are only reduced by 12% and 14% respectively.** This may mean a better return to the asset owner who will now have an asset that will last 3 - 5 years longer before needing refurbishment compared to the earlier scenario.

This analysis gives an indication of the value currently available to battery storage assets operating in the energy markets. But, if we look at the BM in more detail, we see that modelling it as a single market can significantly over or under estimate the value an asset can achieve.



Balancing the system

Beyond the arbitrage opportunities outlined above, the BM can offer a route for batteries to capitalise on their flexibility and secure additional revenue. Rather than chase the cashout price, a battery can look to be procured through the BM in the traditional manner, through having a bid or offer accepted.

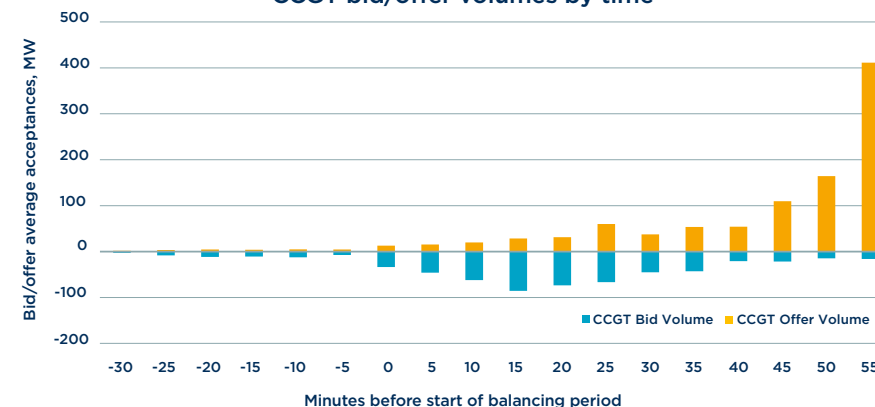
While the BM is technically a single market, with units competing with each other to provide balancing services, the BM serves two key functions. On the one hand, the BM is used by National Grid to resolve system issues, such as relieving constraints on the transmission network or ensuring the system has sufficient flexibility to cope with shocks. On the other hand, the BM is used to balance the overall level of energy on the system and ensure supply meets demand.

However, even within the energy balancing function of the BM, our analysis shows that there are effectively two markets operating over different time horizons. Units with longer response times and larger available capacities tend to be procured earlier, while assets capable of responding more quickly (such as batteries) see a greater proportion of acceptances closer to delivery.

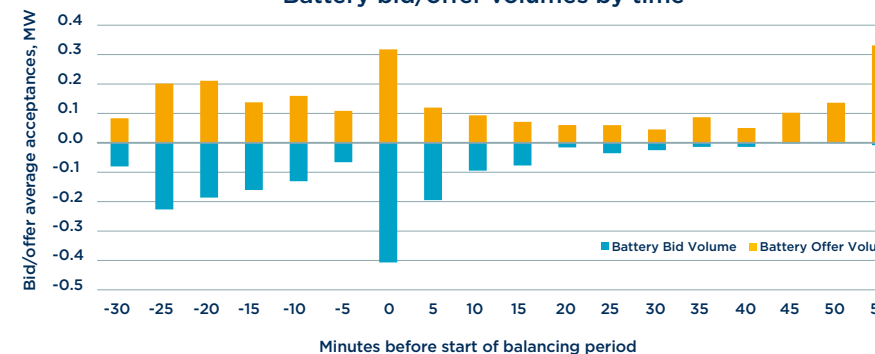
Currently, the majority of BM offers are accepted 45+ minutes before the start of the period. But there are material volumes that are first instructed close to or during the BM period. **Prices for accepted offers during the period are on average ~30% higher than earlier instructions, reflecting the scarcity of units able to respond at shorter notice.** Turn down prices follow a similar trend.

If the value available in the BM were assessed based on treating the BM as a single homogenous market, then the scope for highly flexible units could be understated because they are able to benefit from later instructions at higher prices. CCGTs capture most of their BM turn-up volume from instructions that are >45 minutes prior to the start of the BM period. Batteries do compete at these time horizons, but (relative to CCGTs) capture more of their instructed volume closer to delivery, and so can benefit from more favourable prices being accepted. However, it's worth noting that battery volumes in the BM have been small.

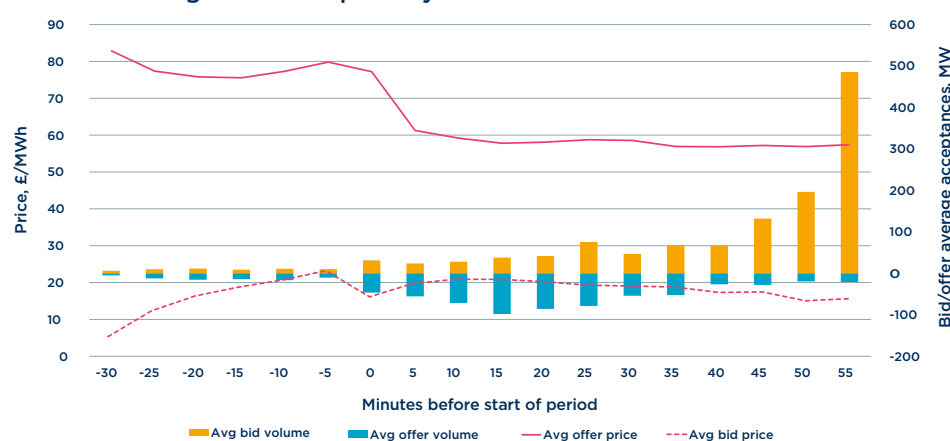
CCGT bid/offer volumes by time



Battery bid/offer volumes by time



Average volume & price by time of first instruction 2018-2020



Balancing the system *continued*

The BM certainly represents an opportunity for battery assets, but how will this opportunity grow over time? There are conflicting factors at work here. As renewable deployment increases, the volatility of the system and magnitude and frequency of system imbalances will grow. However, forecasting capabilities (for demand, solar and wind) are also improving, mitigating the risk of particularly large imbalances caused from forecasting error and intermittent output. While we do see overall imbalance volumes growing, they do not grow at the same rate as expected battery storage deployment. As such, from an energy balancing perspective, the BM is a shallow market. There is a cap on the amount of capacity that will ultimately be required, putting a ceiling on the opportunity available through the BM.

However, with a large proportion of BM volume also being accepted for system constraint reasons, strategically located assets may be able to extract more value from the BM than they otherwise could. Scotland, the North East and the South East particularly are regularly constrained areas, being limited by the network infrastructure available to flow power to other regions. Assets that are able to offset the need to turn down expensive units, such as curtailing policy-incentivised wind, stand to benefit from much more attractive prices being taken through the BM.

Capacity provision

Another key component of a battery's revenue comes from the Capacity Market (CM). The CM ensures security of electricity supply by providing a payment for reliable sources of capacity. Each technology is assigned a de-rating factor which is calculated based on the technology's contribution to system security.

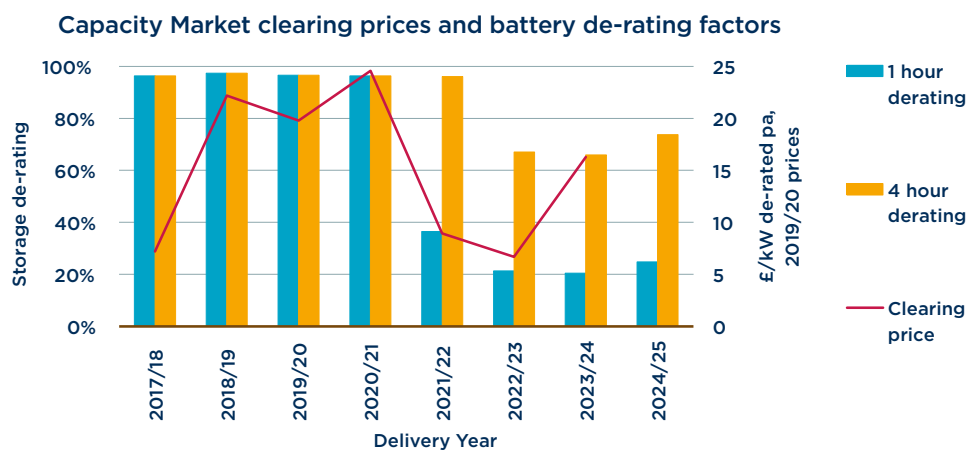
In the first three T-4 CM auctions, all storage was de-rated at 96%, which, coupled with relatively high clearing prices, resulted in lucrative 15-year contracts for new storage assets. However, in 2017, National Grid updated their approach to more accurately capture the contribution from limited duration storage. This resulted in much lower de-ratings for storage with short durations (e.g. less than 4 hours), who are unable to contribute as much firm capacity during longer system stress events.

LCP provide the models that National Grid use to calculate these de-ratings, and in the longer term we expect to see these de-ratings to fall further, due to:

- System stress events increasingly being driven by low periods of wind generation (rather than just peaks in demand), meaning that **stress events will be longer in duration but less frequent (for the same LOLE standard)**. This results in short-duration storage providing less value to the system in securing electricity supply.
- As more batteries connect to the system, **the marginal contribution of an additional battery (which determines the de-rating) will fall**. This is because the batteries will be restricted during the same longer stress events.

Although the CAPEX of building longer duration batteries is greater, the higher de-ratings mean that we expect these may be preferred in the future, when coupled with higher earnings through the other markets. Longer duration batteries are able to capture higher wholesale revenues, and as discussed, we expect these to make up an increasing share of a battery's revenues as wholesale market price spreads increase. Longer durations are less suitable for frequency response services, but the volume required in these markets is limited.

Offsetting the lower de-ratings, we expect the clearing prices in the CM to increase in the future (relative to the low prices seen in recent years), to account for the 'missing money' required in a system with ever increasing volumes of intermittent renewables. For new build units, the 15-year agreement provided through the CM still provides the revenue certainty that's needed to help secure finance for the project.



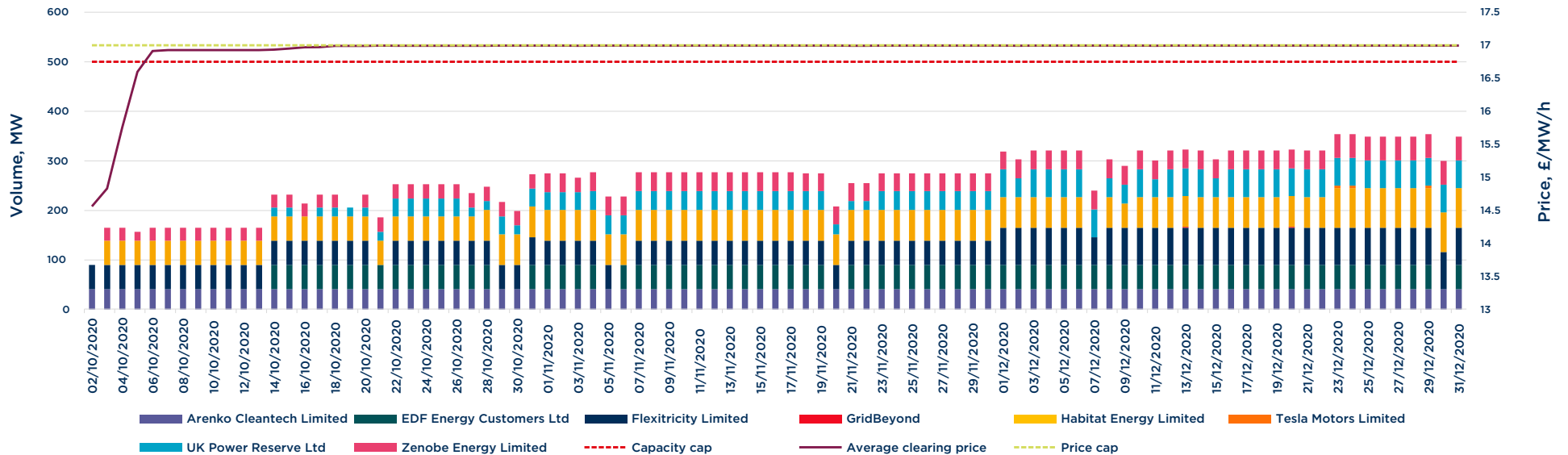
Frequency response

Since the blackout of 9 Aug 2019, significant attention has been drawn to the need for fast acting reserve that can stabilise system frequency during stress events³. National Grid's Dynamic Containment (DC)⁴ was launched at the start of October 2020 and is designed to operate post-fault, i.e. for deployment after a significant frequency deviation in order to meet our most immediate need for faster-acting frequency response. This product requires participants to provide power in under 1 second when the frequency deviates from 50Hz by more than 0.2Hz (currently DC is only for low frequency events, but this will be rolled out for high frequency events in the future). Two more products, **Dynamic Regulation** and **Dynamic Moderation**, will also be launched soon, and will be pre-fault mechanisms.

The stringent technical requirements of the product have meant that only battery storage can really compete. This has resulted in low levels of supply and competition relative to demand and only ~300MW of capacity is currently clearing auctions to date (below the current auction cap of 500MW). **This has resulted in the average availability fee accepted remaining at the price cap of £17/MW/h (or £150/kWh annually) - proving extremely lucrative for battery storage units.** With the addition of more dynamic markets aimed at batteries, and the cap for DC expected to increase to 1GW, battery owners can expect to continue to receive these prices for the near future while there is not enough supply to meet demand.

DC was called upon immediately on 2 Oct 2020 when a 1GW trip on the IFA1 interconnector caused a frequency deviation of over 0.4Hz. The assets called upon responded immediately and the event was managed with no disconnections or blackouts.

Dynamic Containment clearing volumes and prices



3. What caused the blackout?: <https://www.lcp.uk.com/our-viewpoint/2019/08/what-caused-the-blackout/> 4. National Grid Dynamic Containment frequency response service: <https://www.nationalgrideso.com/industry-information/balancing-services/frequency-response-services/dynamic-containment>

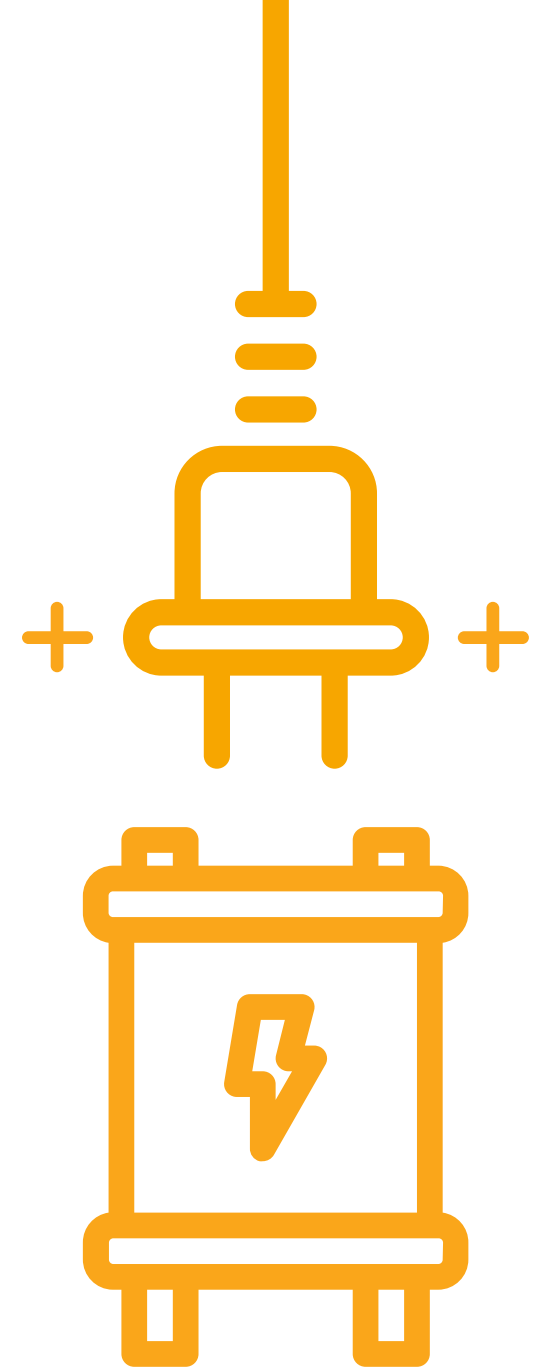
Frequency response continued

An additional benefit of procuring an ancillary service contract is that the asset is being paid for its availability, and so is paid to be held out of the other markets, while the likelihood of actually being needed is relatively low. This means that the cycling rate is reduced significantly. This increases the life of the asset, providing even more value to the asset owner.

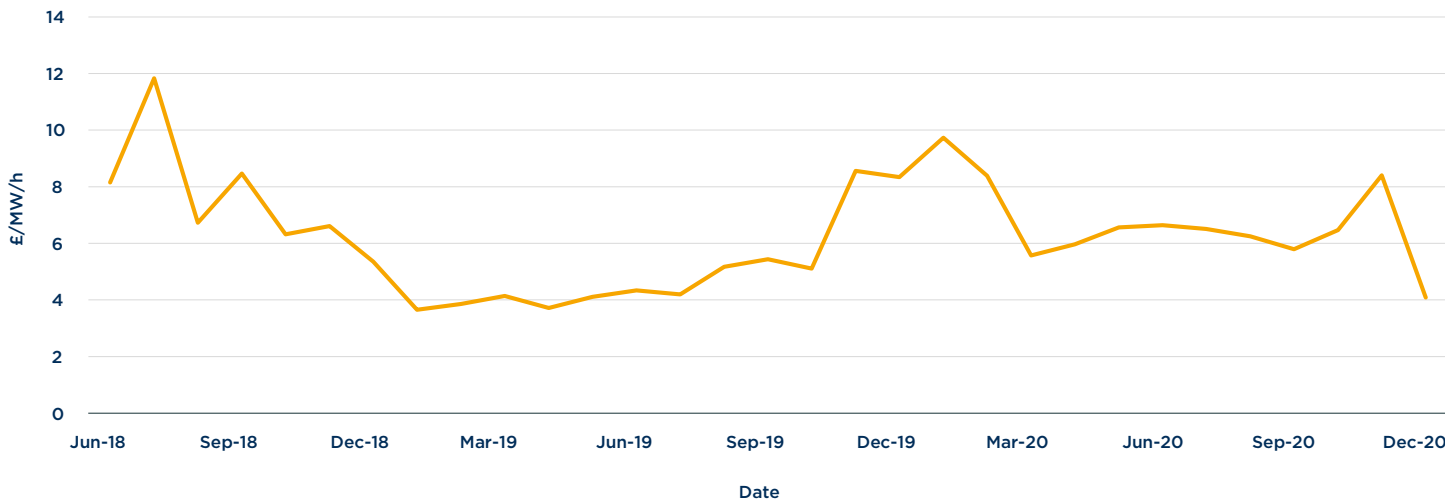
Currently, the DC market is an overwhelmingly attractive proposition for battery assets, and a large contribution to the current appetite for storage deployment. However, these outsized returns should be taken with a pinch of salt. Lucrative frequency response contracts due to undersupply such as these are a fleeting opportunity - they will only stay at these levels while there is insufficient competition to drive the price down to a level that reflects the value of the service and the

opportunity cost of not participating in other markets. As such, these opportunities should be capitalised on where available, but shouldn't be simply projected forwards as a reason to wholly finance a new project.

We only need to look back to 2018 to see the risks of investing in near term attractive ancillary contracts. The dynamic frequency response market was clearing at £12/MW/h so the market went all in to capitalise on these returns. This, in turn, cannibalised these margins and brought the price down to £4/MW/h. With current DC prices even more inflated, at nearly 50% higher than the peaks of dynamic Firm Frequency Response (FFR), it is certain we will see DC prices brought down as supply levels increase.



Average Dynamic FFR Price



In summary

It is understandable why there is so much interest around batteries: they can operate across a number of markets, have unique characteristics which make them intrinsically useful to the system, and the need for them will grow as we deploy more renewable technology. However, it is important to consider the markets that they operate in, how susceptible they are to cannibalisation, and how the dynamics of these markets will change going forwards. Here's our view on how each market could change in the future:

Arbitrage - The future looks positive for price arbitrage strategies, particularly when considering the wholesale market. Spreads are forecast to grow in the future as gas prices recover and the increase in renewable generation creates more low and negative pricing periods. The wholesale market is also considered a deep market and is, therefore, less susceptible to market cannibalisation.

Balancing services - The level of imbalance is forecast to increase as the level of renewable generation grows, meaning that this market will continue to provide value. However, due to the BM being a relatively shallow market (when compared to the wholesale market) we expect increased competition, from new batteries and other flexibility providers, is likely to cap the potential for returns in the long term.

Capacity provision - CM clearing prices are forecast to increase in the future to account for the 'missing money' that's removed from the wholesale market by renewables - which will continue to grow. Longer duration storage will also benefit more from higher de-rating factors and will, therefore, achieve higher revenue compared to shorter duration batteries.

Frequency Response - These services will continue to provide an important source of revenue for batteries. DC is set to expand, with the capacity it procures increasing from 500MW currently to 1GW next year. Until this volume cap is hit, operators may continue to make lucrative returns such as the £17/MW/h prices recently observed. However, this is another shallow market, and value is likely to reduce as the market becomes saturated as competition increases. Once the capacity cap is reached, we expect to see the different markets interact much more closely, with operators looking at the opportunity costs between participating in different markets to drive their bidding decisions.

Bringing all of this together, we'd expect trading strategies to shift in the future, from currently focussing on the ancillary markets to more of a fluid strategy between the wholesale, balancing and ancillary markets. As all of these markets now operate on similar time horizons, the ability to change strategy dynamically has emerged, and there will be a need for investors to ensure the traders and optimisers managing their assets can maximise the ability of a battery to participate in and switch between the markets available.

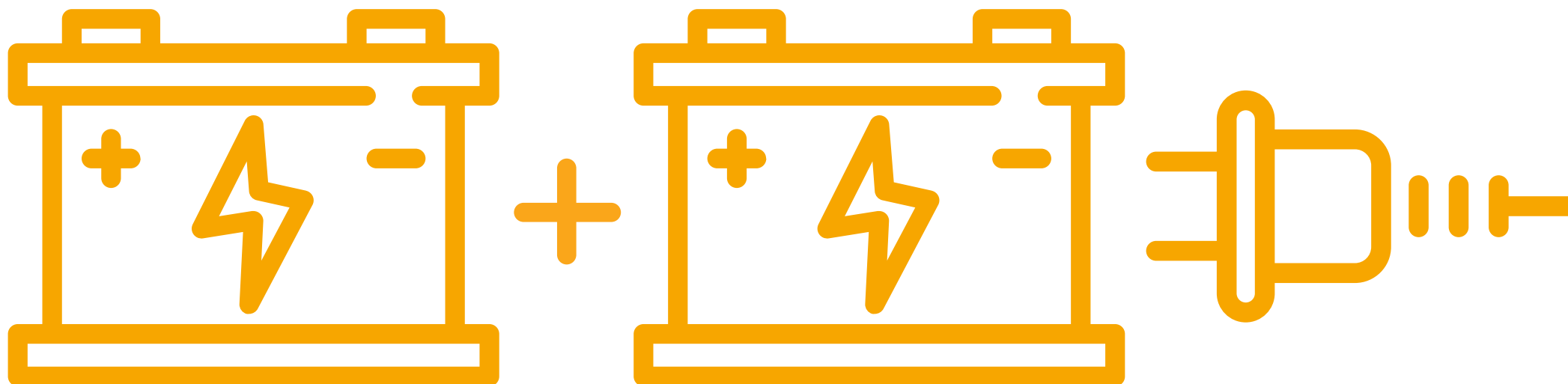
Overall, we are cautiously optimistic about the investment case for battery storage in GB. Executed correctly, batteries represent an exciting opportunity for investors to capitalise on an increasingly complex market.



How we can help

Understanding the revenue stack for battery storage assets in an ever changing regulatory and competitive backdrop has never been more complex. LCP's modelling framework has been used extensively by industry and key decision makers for over a decade in understanding the revenue potential for assets across markets and how markets will evolve. Our work includes providing the UK Government with their primary long term energy forecasting models, providing the modelling National Grid ESO use to set the capacity market deratings, and supporting £1bn+ M&A transactions.

- We provide extensive support to numerous parties looking to develop or acquire battery assets, both existing and new build. Our close relationship with traders through our real-time Enact platform has also allowed us to consider trading strategies and efficiencies in our long term forecasts, and demonstrate how markets are beginning to interact with each other.
- If you would like to hear how we help our clients with their battery assets, from investor due diligence to real time trading, get in touch with us at www.lcp.uk.com/contact-us/



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