Insight paper

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Ready and waiting:
Opportunities for energy storage

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Table of contents

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Foreword by DLA Piper

The Great Britain (GB) energy sector is, in response to the drivers which the climate agenda rightly provides, in transition. The significant structural shift from a fossil fuel-based system of energy production and consumption to renewable sources is necessary but not without challenge. One limit on the speed of transition is the often competing priority of energy security, an issue which has been brought to the fore by recent market volatility following the onset of conflict in Ukraine. It is in that context which energy storage plays a fundamental, critical, and pivotal role.

At its simplest, energy storage is the mechanic which overcomes the challenge presented by intermittent renewable energy sources; when the wind is blowing and the sun is shining excess energy can be captured and stored, to then be delivered later when conditions are less conducive to energy generation. This allows for flexibility, energy efficiency, and increased capacity in the electricity grid to which the stored energy contributes. Those features of energy storage are the essence of why it will play such a vital role in securing and accelerating an effective energy transition. Although the GB electricity storage sector faces various challenges, including supply chain vulnerability and the potential for revenue volatility, there also remain significant opportunities, particularly in the context of the growth of long-duration energy storage.

DLA Piper is one of the world's largest leading global full-service business law firms with over 80 offices in more than 40 countries across the world. At the heart of that business is an energy and natural resources practice which leads the market both in the legal services which it provides to all parts of the energy transition sector and the insight which its experience enables it to provide on the topics that matter to our clients.

With all of the above in mind it is our pleasure to present this Energy Storage Report, produced in conjunction with Cornwall Insight. We would be very happy to discuss any of the issues which it covers with you and encourage you to reach out directly with any queries.

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Executive summary

As the UK transitions towards net zero, the increasing share of the energy generation mix coming from renewables is resulting in greater intermittency of generation, leading to a growing system need for flexible dispatch solutions. With a range of different energy storage technologies that are, or could be, used in the UK to provide both short and long-term system flexibility, energy storage is set to play a central role in the energy system.

This shift is reflected in the significant recent growth in the development and investment into energy storage projects globally, with some of the most rapid growth taking place in the UK and the US. This report provides a background to energy storage and considers the main revenue streams and routes to market before going on to set out the challenges for electricity storage assets in Great Britain (GB) and concluding with the future opportunities and key considerations for investors. The focus is on the GB electricity market, with case studies included drawing insight from Ireland and Australia, two other island nations that will require significant energy storage and flexible dispatch solutions.

At present, GB electricity storage is dominated by Lithium-Ion (Li-Ion) batteries and pumped hydropower. The main revenue streams are:

- wholesale power arbitrage,
- the Balancing Mechanism (BM),
- frequency response services, and
- the Capacity Market (CM).

Shorter duration (0.5-1hr) battery assets have dominated the frequency response services, with longer duration (2-4hr) storage increasingly more active in the wholesale power arbitrage market and BM. Sophisticated trading strategies that stack multiple revenue streams are integral to optimising the business case for electricity storage assets and maximising returns. With market saturation of the frequency response services expected to substantially erode the value of this component of revenue stacks, we have observed a transition towards 2hr+ duration batteries, alongside pumped hydro and more novel technologies such as compressed air energy storage (CAES), with an increased proportion of revenue stacks from wholesale power arbitrage.

Looking forward, the co-location of energy storage assets with existing renewable generation could provide a valuable opportunity to overcome the long wait times new assets are currently facing to access a grid connection. However, there are still major questions around how to best optimise a co-located storage asset to reduce price cannibalisation for the renewable generator and avoid time periods when both assets require the ability to export to the grid over a limited connection capacity, thus constraining each other. For long-duration storage (>4 hours) there is currently a shortage of financial incentives to promote growth of this capability in GB. The development of the Pathfinder programme into a formalised market, or an equivalent of the Long-Term Energy Service Agreements (LTESAs) in Australia could prove crucial to the future roll-out of longer duration inter-day and ‘seasonal’ energy storage.

As an asset class, energy storage is very different from conventional renewable generation, and, along with the volatile and evolving nature of energy storage markets, there are a series of key considerations that need to be taken into account for investors and developers looking to get involved in the GB energy storage space:

Market access

It is important to know which markets offtakers have access to and experience trading in and what impact that has on the potential revenue stack for the asset. The track record of offtakers and optimisers is also very important, especially for battery assets. With the market saturation challenges discussed in this report, access to ancillary services is likely to be less important going forward.

Optimisation and risk appetite

The revenue stack will depend on which markets are the focus for the asset owner and offtaker, which in turn will be impacted by the risk appetite of the parties involved. The revenue stack and jumping between different revenue streams, with different degrees of revenue certainty, affects asset cycling and degradation, as well as having implications for raising debt or meeting required equity returns. In particular, investors and lenders will want to understand the certainty of (or contracted nature of any) revenues under any proposed revenue stack, and the trading strategies to mitigate any perceived merchant risk. The set up of the route to market arrangement will depend on the risk allocation between the offtaker and asset owner and who is taking on market risk, asset performance risk, legal risk etc.

Grid connection

How soon an asset can be connected to the grid and at what cost are key variables, with co-location providing an opportunity for quicker and cheaper grid connection for energy storage assets. The likelihood of curtailment and when any curtailment hours are likely to be are other important considerations.

Warranties

Warranties and performance system software are critical for electrochemical systems, particularly as system "wraps" can provide investors and lenders with long-term comfort on technology risk. The longevity of the warranty and whether it covers the intended cycling (charge and then discharge the stored energy) frequency are important characteristics to consider. Similarly, the extent to which warranties are dependent on the manner in which assets are maintained and the software that is used, and who the asset owners use to provide those services will all be key.

Supply chains

With many market players increasingly concerned with their wider impact on the world and society at-large, environmental, social and governance (ESG) considerations will be important for many. This is likely to require careful consideration being given to where materials are being sourced from and whether there are concerns about the treatment of workers or the geopolitical stability of those supply chains and the risks to which that gives rise, including, as DLA Piper Legal Director Elinor Thomas notes, ESG related litigation risk.

Source: Cornwall Insight

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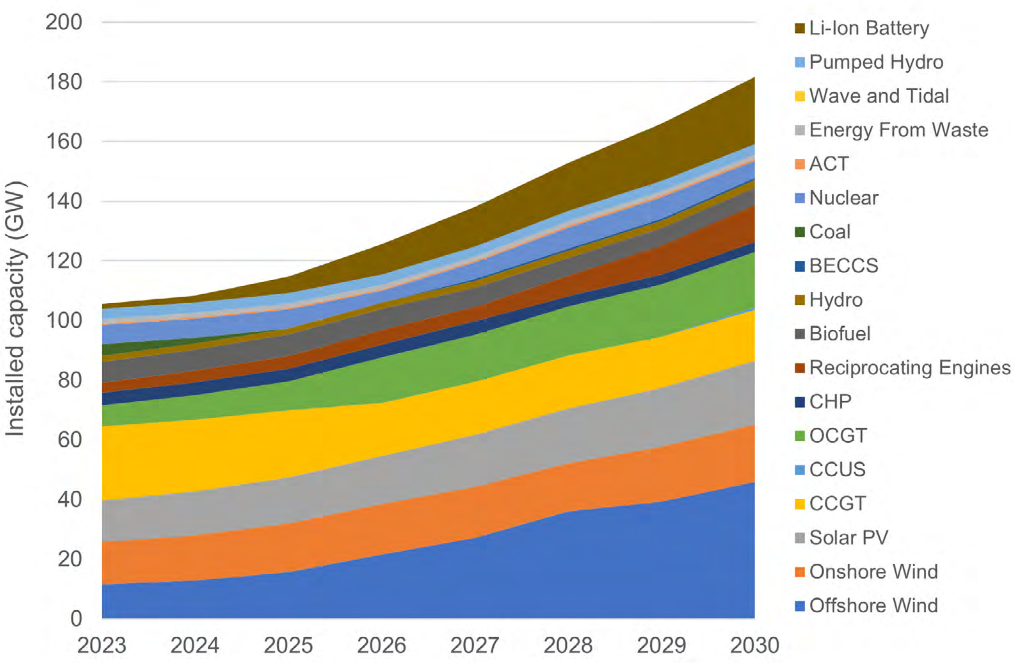
Background to energy storage

Background to energy storage

In December 2015, almost all global nations signed up to the Paris Agreement,[1] a legally binding treaty to limit global warming to 2°C relative to pre-industrial levels, with significant efforts made to limit the temperature increase to only 1.5°C. To meet the Paris Agreement, in June 2019 the UK government committed to reaching net zero by 2050,[2] whereby the amount of greenhouse gas released into the atmosphere is lower than, or equal to, the amount captured or removed. This net zero transition will require action across the UK economy, with the power sector targeting net zero, subject to security of supply, by 2035.[3]

Figure 1: Forecasted GB generation (and storage) capacity until 2030



Source: Cornwall Insight – Benchmark Power Curve (March 2023)

Cornwall Insight's latest modelling indicates that the GB electricity generation mix will be roughly double its current capacity by 2030, with an increasing share of the generation mix coming from renewable sources (Figure 1). As more renewables enter the mix, the intermittency of energy generation is increased and there is increasing need for flexibility. Energy storage is a key way to provide more short and long-term flexibility to the system and there are a range of different technologies that are, or could be, used in GB. An industry source highlighted that GB is moving from a system dominated by fossil fuels, where the storage is in the physical molecules (e.g. gas, coal), to one dominated by renewables, where the 'fuel' (e.g. sun, wind) can't be stored, so separate storage is needed for the renewable electrons.

> "Energy storage is a key way to provide more short and long-term flexibility to the system.

1 UNFCCC
2 GOV.UK
3 GOV.UK

> “
> In GB, the electricity market is currently dominated by short-duration storage.

As a result of the UK's island-status and lower levels of interconnection to neighbouring markets than is typical in Europe, the energy storage markets are well developed, especially for short-duration or intra-day technologies. For the purpose of this report, only grid-connected energy storage is being considered, rather than captive or off-grid,[4] which would have different revenue opportunities and challenges. Grid-connected is the dominant form of energy storage encountered in GB but for other markets off-grid energy storage plays a more central role. For example, in Australia the East Coast has dominantly grid-connected energy storage whilst the West Coast has a much greater prevalence of off-grid storage, due to much lower amounts of electricity transmission infrastructure on the West Coast.[5] This dichotomy in Australia could provide valuable lessons for other parts of the world, including for the use of different types of energy storage within the same country.

Energy storage technologies

There are a wide range of energy storage technologies, including those that are currently operational and those in development to meet the increasing demand for system flexibility from the net zero transition. Broadly, energy storage assets can be considered as either short or long-duration. Short-duration is largely used to refer to assets which cycle (store and then discharge energy) on an intra-day basis, and long-duration can be further split into assets that cycle on an inter-day basis (12-48 hours) and on a 'seasonal' basis, where energy can be stored for weeks to months.

In GB, the electricity market is currently dominated by short-duration storage, but as renewable penetration increases, there will be an increased need for longer duration assets. Curtis VanWalleghem, CEO at Hydrostor, highlights this trend by flagging that storage starts to be required in markets as renewable penetration of total electricity generation reaches 20-30%, and becomes increasingly important as penetration increases, with the need for 'seasonal' storage arriving at 70-80% renewable penetration. To put this into perspective, in 2022, 56% of electricity generated in GB was from low-carbon sources,[6] which highlights the maturity of the GB market and the important role energy storage has to play.

Battery energy storage

Battery energy storage is the most commonly discussed and fastest growing energy storage technology in GB at present, with 2.5GW currently operational, 766MW of which was installed in 2022 alone.[7] Batteries are predominantly used for intra-day storage and cycling.

Batteries are charged using electricity from either the National Grid or an energy generation asset. This stored electricity can then be released at a

4 Distributed energy systems where on-site or nearby storage assets are connected to energy users and operate independently to any grid connection.
5 AEMO
6 GOV.UK
7 BESS analytics

later time in accordance with the chosen revenue stream(s), as discussed in section 2. Globally there are a wide variety of types of battery technologies, using a range of materials and techniques for storing energy electrochemically. In GB, most batteries are Li-Ion but there is increasing interest and development into flow batteries, which could provide a more scalable option when looking to provide energy storage for cities.

Pumped hydropower

Pumped hydro is the most prevalent form of energy storage globally, accounting for >94% of total installed capacity and is also the largest capacity energy storage technology in GB, with 2.8GW installed across four sites in Scotland and Wales.[8] Pumped hydro stores energy by using a two-tier reservoir system where energy is used to pump water from the lower reservoir to the upper reservoir. When the stored energy is required, the water can be released from the upper reservoir and the gravitational potential energy of the water is converted into electricity. Pumped hydro is particularly useful at long-discharge durations (4-8hrs) and has the benefits of a long lifetime and relatively low lifetime costs compared to other energy storage technologies. However, it is limited by locational constraints on where it can be installed.

Compressed air energy storage

CAES systems work in a similar way to pumped hydro, but instead of using excess energy to pump water from a lower to an upper reservoir, the energy is used to compress and store air, or another gas, in underground containers or caverns. The compressed air can then be heated up and expanded in an expansion turbine to generate power. Because the air has been compressed as part of the storage process, CAES turbines can generate roughly triple the power output as an equivalent sized natural-gas powered turbine. CAES is still at the early developmental stages as a technology in GB, but lessons can be learnt from the more extensive development in countries like Australia (Box 1).[9]

Box 1: CAES in Australia

In October 2022, the Australian Renewable Energy Agency (ARENA) announced the conditional approval of AUD 45 million in funding for the construction of a 200MW capacity Silver City advanced-CAES facility developed by Hydrostor in New South Wales. This project is expected to reach financial close in late 2023 and, once built, will provide at least eight hours of storage. As well as being one of the largest CAES projects globally, the Silver City project has the advantage over legacy CAES projects that the heat generated during the compression process is stored and used to re-heat the air during the expansion stage, rather than using fossil fuels to re-heat the compressed air.

CAES projects are viewed as a good alternative to pumped hydro projects for medium- and long-term energy storage, with Curtis VanWalleghem (Hydrostor) highlighting that CAES has lower space and water requirements than pumped hydro, giving more flexibility in site selection. Installing more grid-scale storage projects in remoter areas can help support the development of more renewable capacity in these regions.

8 International Hydropower Association
9 ARENA

Other long-duration storage

The Long Duration Energy Storage Demonstration programme (LODES)[10] is a competition launched by the UK government in March 2021, offering up to GBP 68 million in funding to help the commercialisation of innovative technologies for long-duration energy storage. LODES is separated into two streams, with the first stream offering around GBP 37 million for technologies at a technological readiness level (TRL)[11] of six or seven, and the second stream targeting less developed technologies at a TRL of four or five. There are a range of more nascent long-duration energy storage technologies supported through the LODES programme, including several novel flow battery technologies, CAES, and low-carbon hydrogen storage.

Beyond this support for early-stage technology development, which is designed for pathfinder schemes rather than rolling out at scale, there is currently a dearth of incentives to help the build out of long-duration storage technologies in GB, although the UK government has committed to designing new business models for low-carbon hydrogen storage by 2025.[12] Curtis VanWalleghem (Hydrostor) adds that, whilst batteries will likely dominate the intra-day markets, and pumped hydro and CAES can act in the inter-day market, there is not currently a clear technology for 'seasonal' storage that has proven to be both "commercial and cost competitive."

> "There is not currently a clear technology for 'seasonal' storage that has proven to be both "commercial and cost competitive."
>
> **- Curtis VanWalleghem,** Hydrostor

10 GOV.UK
11 *TRLs are a measure of the maturity of a technology, on a scale from 1 to 9. 4 – technology validated in a lab, 5 – technology validated in relevant environment, 6 – technology demonstrated in relevant environment, 7 – system prototype demonstrated in operational environment.*
12 GOV.UK

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Revenue streams and routes to market

“Understanding the different elements of the revenue stack is crucial for investors and lenders to build successful business cases for storage assets.

Revenue streams and routes to market

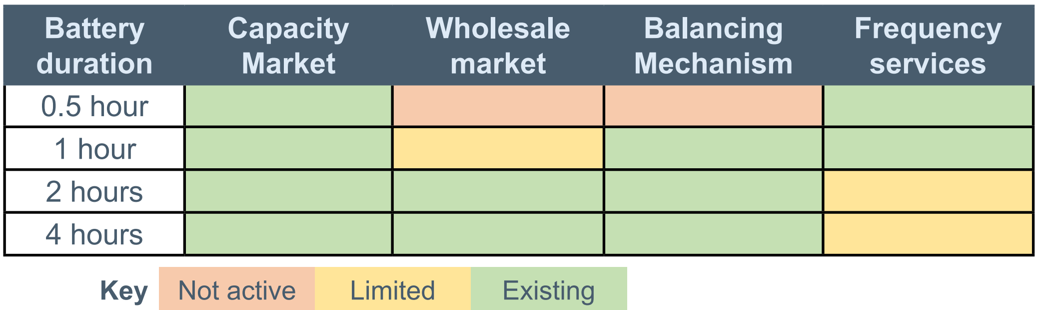
Revenue streams

There are a wide range of revenue streams which energy storage technologies can access in GB. Unlike for conventional renewable generation (solar PV, wind, etc.) many storage assets are looking to participate in, and to optimise and ‘stack’ across, multiple streams to maximise revenues. This stacking of revenues results in more sophisticated strategies in the storage space than for conventional renewable generation and understanding the different elements of the revenue stack is crucial for investors and lenders to build successful business cases for storage assets.

Jumping between different revenue streams is increasingly necessary to maximise asset use, particularly for short-duration assets. Not all revenue streams can be stacked together, for example, to ensure that assets are available when required, the system operator, National Grid Electricity System Operator (ESO), does not allow frequency response services to be stacked with wholesale power arbitrage and the Balancing Mechanism (BM). For investors and asset owners this means that careful consideration is required about which revenue streams to participate in at any given time to maximise their returns.

In general, shorter duration (0.5-1hr) energy storage assets tend to be more active in providing frequency response services for the ESO, and longer duration assets are more often deployed in the wholesale market, BM or Capacity Market (CM). Figure 2 indicates how use case varies for GB battery assets depending on duration.

Figure 2: Battery potential use cases by duration in GB



Source: Cornwall Insight

Rubayet Choudhury, Partner at DLA Piper, notes that energy storage assets tend to “need much more active management from investors,” particularly with regard to financing them. Choudhury added that the volatility of energy storage revenues makes them more appealing to “equity investors, who are willing to take informed risks” on future revenues by deploying well-thought-out trading and optimisation strategies. Given the wider macro trends around rising interest rates, this approach could well appeal to an increasing number of investors who may view potential volatility as an opportunity. Building on this, Natasha Luther-Jones, Partner, International Head of Sustainability and ESG, Global Co-Chair, Energy and Natural Resources Sector at DLA Piper, highlights that, whilst investors can outsource a lot of the trading and optimisation to third parties, energy storage assets are more complex to invest in than traditional generation.

Wholesale power arbitrage

Wholesale power arbitrage is the process of storing energy when it's cheap and then exporting it at times when it's more expensive, thus creating a price spread and generating a margin. A typical example of this would be importing energy from the grid during the night when demand and prices are low, and then exporting back to the grid during the evening peak. Energy can also be stored from co-located generation assets if excessive curtailment generates a large enough price spread and could also be exported to a behind-the-meter demand source to avoid importing from the grid during expensive periods.

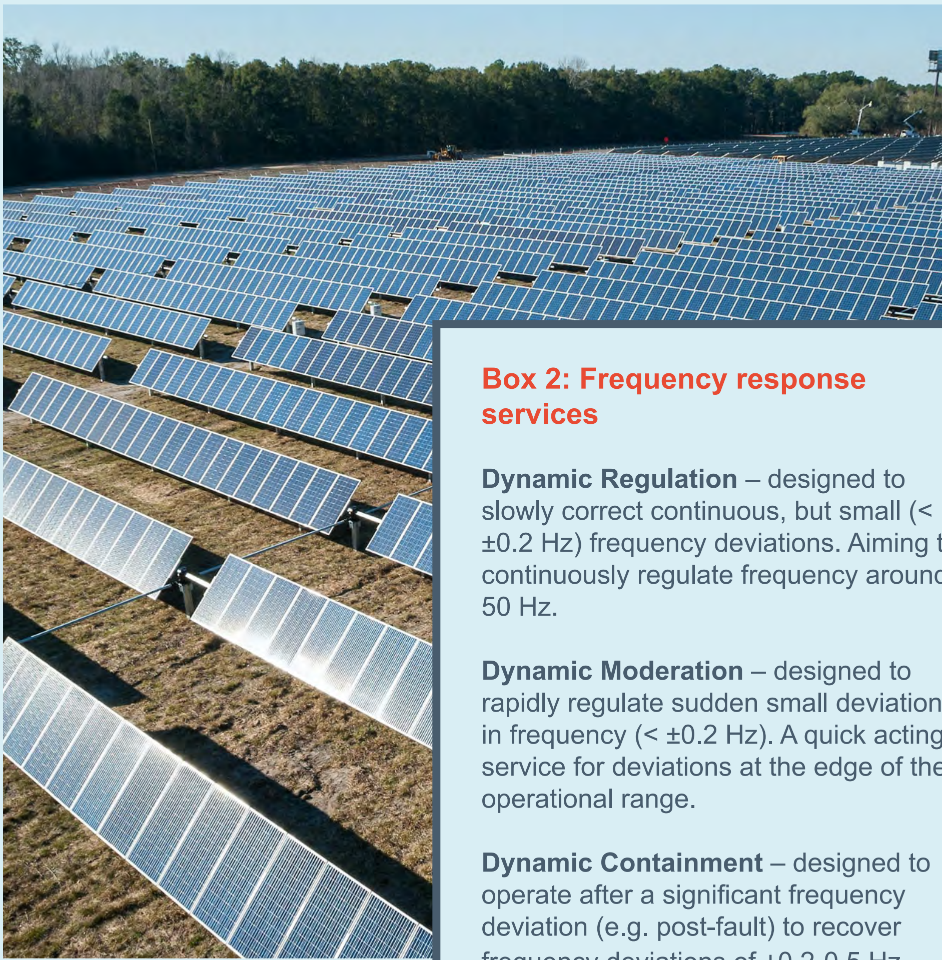
As more intermittent renewables come online the volatility in prices is expected to rise, with an increasing number of periods when oversupply of energy (e.g. high wind output combined with low demand) causes wholesale prices to be zero or negative. The increasing number of low or negatively priced periods creates additional arbitrage opportunities for energy storage assets alongside increased complexity in optimising energy storage and discharge cycles. Wholesale power arbitrage is a revenue stream that can be accessed across the full range of energy storage durations with an industry source noting that for longer duration storage, the focus shifts to optimising across days to match weather patterns, with charging and discharging decoupled from each other.

Balancing Mechanism

The BM is a key tool used by the ESO to balance the system and match supply and demand, and is obligatory for large (>100MW in England and Wales, >20MW in South Scotland, >10MW in North Scotland) GB generators to participate in. The ESO will assess supply and demand for each 30-minute window and pay participants to either increase or decrease supply to ensure the system is balanced. The BM is pay-as-bid, with two prices submitted, one to turn-up energy supply and one to turn-down.

Prices in the BM are more volatile than in the wholesale power market and so the BM can form a lucrative core component of the revenue stack for many energy storage assets. However, the revenues are more uncertain than for wholesale power arbitrage due to it not being a self-dispatch market, as the asset must be called upon by the ESO. Additionally, there can be a strong locational element. For example, high levels of renewable generation and relatively low electricity demand in Scotland, combined with significant grid constraints on the B6 (England-Scotland) boundary, mean that storage assets in Scotland are more likely to be called upon through the BM. Compared to wholesale power arbitrage, the BM therefore represents a higher risk, higher reward strategy and so its use within the revenue stack will depend on the risk appetite of the owner or operator.

As with wholesale power arbitrage, increasing intermittency from more renewable generation is likely to result in more BM actions needing to be taken by the ESO, increasing the opportunity for energy storage assets. Whilst both batteries and pumped hydro have been active in the BM, during 2022 it has provided a more lucrative revenue stream for the latter than the former.



Box 2: Frequency response services

Dynamic Regulation – designed to slowly correct continuous, but small (< ±0.2 Hz) frequency deviations. Aiming to continuously regulate frequency around 50 Hz.

Dynamic Moderation – designed to rapidly regulate sudden small deviations in frequency (< ±0.2 Hz). A quick acting service for deviations at the edge of the operational range.

Dynamic Containment – designed to operate after a significant frequency deviation (e.g. post-fault) to recover frequency deviations of ±0.2-0.5 Hz.

Frequency response services

Frequency response or 'ancillary' services are a suite of services which operate to maintain system frequency on a second-by-second basis and balance any deviations from 50.0 Hz (Box 2). The three main ESO-procured services which energy storage assets operate in are:

- Dynamic Regulation,
- Dynamic Moderation, and
- Dynamic Containment.

These services offer only short-term contracts and are linked to the inertia[13] of the system and the size of the largest potential generation or demand loss.

13 System inertia is a measure of how quickly system frequency would change if there was a change in generation, akin to the shock absorbers on a car. The turbines in traditional gas- or coal-fired power stations provide high system inertia by continuing to rotate for a period after a loss in power, slowing the decrease in frequency, whereas renewables such as solar and wind don't provide the system with this inertia. Periods of high renewable generation therefore have lower system inertia and would be subject to more rapid changes in frequency if generation drops, thus requiring a greater volume of ancillary services to be procured to manage system frequency.

> The speed of frequency response service requirements in GB and Ireland has helped promote "very advanced ancillary service products that other global markets don't have."
>
> **- Charlotte Johnson,** KrakenFlex

Box 3: DS3 in Ireland

As part of the EU's renewable targets, Ireland was set a target of procuring 16% of the country's total energy consumption from renewable sources by 2020. To reach this target, Ireland targeted generating 40% of electricity from renewable energy by 2020, with the DS3 programme introduced to allow the increased roll-out of intermittent or non-synchronous electricity generation sources without jeopardising power system security and efficiency. Renewable generation accounted for 43% of electricity in 2020 and the target has therefore been updated to 80% by 2030. A major part of the DS3 is the System Services, which contain fourteen ancillary services that can be accessed by energy storage assets. The current fixed tariff regime has meant that "access to contracts under the DS3 programme for ancillary services in an unrestricted way has been a key driver of revenues" for energy storage assets, according to William Marshall, Legal Director at DLA Piper. This tariff regime is currently under consultation and the outcome will impact on the revenues available to energy storage assets going forward.

In GB all the accepted volumes in the three dynamic services have so far come from battery assets. Frequency services have provided a key component of revenues for battery storage assets, making up ~74% of revenues for balancing mechanism registered assets in May 2023.[14] Dynamic Containment, in particular, has proven especially lucrative recently, averaging >GBP20/MW/hr, with a maximum of nearly GBP 80/MW/hr and making up ~70% of the battery revenues from ancillary services in 2022.[15]

Ancillary services have also been a prominent revenue stream for energy storage assets in the Irish market, as a result of promotion through the DS3 ("Delivering a Secure, Sustainable Electricity System") programme by the EirGrid Group (Box 3).[16] Charlotte Johnson, Global Head of Markets at KrakenFlex, highlights that the speed of frequency response service requirements in GB and Ireland has helped promote "very advanced ancillary service products that other global markets don't have." Johnson added that these more advanced ancillary markets are a key reason for the strength of the GB and Ireland energy storage, and particularly battery storage, markets.

14 BESS analytics
15 Cornwall Insight - Flexibility Markets Report
16 EirGrid Group

Capacity Market

The CM is a fixed payment made to suppliers to maintain long-term security of supply, with capacity procured through competitive auctions held four years and one year ahead of delivery. Contract lengths of one, three, and 15 years are available for different technologies and all assets within the CM are given a de-rating factor based on how much of a CM window that asset is expected to be available for. The de-rating factors for energy storage assets are highly dependent on the discharge duration (Figure 3). The CM is stackable with all previously discussed revenue streams and as such can form a base level of revenue for most energy storage assets.

Figure 3: CM de-rating factors for different storage discharge durations in the 2022 GB auction

Storage discharge duration	T-1 de-rating factor (%)	T-4 de-rating factor (%)
0.5 hour	9.30	5.95
1 hour	18.60	11.81
2 hours	37.02	23.63
4 hours	62.32	45.86
6 hours	95.25	58.97
8 hours	95.25	70.88

Source: National Grid ESO

The auction prices for successful assets have also been consistently increasing over the last four years, from GBP 6.44/kW for the T-4 auction for 2022-23 to GBP 63/kW for the T-4 auction for 2026-27.[17] The T-1 auction outturn prices have also increased from GBP 0.77/kW for 2019-20 to GBP 60/kW for 2023-24, with a maximum of GBP 75/kW for 2022-23.[18] CM participation can give comfort in contracted revenue certainty to investors and lenders by providing a stable, long-term, revenue stream, but is unlikely to justify a business case on its own so the viability of the rest of the revenue stack is still important. The CM can be effectively combined with other revenue streams as part of the revenue stack and is particularly valuable for longer duration storage assets that can secure higher de-rating factors. By way of demonstration, William Marshall (DLA Piper) comments that the Capacity Remuneration Mechanism provides a similarly valuable revenue stream in the Irish market, with 10-year contracts for new capacity forming an "attractive base revenue for many energy storage assets."

Routes to market

There are two main routes for energy storage assets to gain access to the market: (1) fully merchant market access through an optimiser or (2) as market participation with downside protection from an offtaker (e.g. as part of an optimisation and dispatch contract). The latter is the route that is most often pursued, particularly by battery assets, because of the complexity of the market, given the wide variety of structures, market access and offtaker offers to navigate. The complexities of trading and optimising energy storage assets, particularly for those looking to operate in a range of markets, means many energy storage developers will look to engage an industry specialist to optimise and trade on their behalf, with over 25

17 National Grid ESO
18 National Grid ESO

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Shared participation in trading and optimising between the asset owner and the offtaker... is for investors “who would like a share in the upside of asset optimisation, in return for taking some risk in the downside.”

- Andreas Gunst,
DLA Piper

offtaker or optimiser counterparties currently active in the battery storage space alone. However, Richard Braakenburg, Head of Equity Investments at SUSI Partners, notes that this is likely to consolidate more in the future, based on proven revenue cases.

Structure of route to market agreements

The structure of the route to market agreement between an offtaker and asset owner will vary depending on the risk appetite of the investor and their experience in energy storage markets. Whilst there are a range of possible investment structures, Andreas Gunst, Partner at DLA Piper, notes that “there are broadly two main types of dispatch and optimisation agreements active in the market at the moment.” The first of these is the ‘lease concept’ whereby the investor receives a fixed price for the asset and a third party is wholly responsible for the operation and optimisation of it and therefore comes with the least risk for the investor. The second is shared participation in trading and optimising between the asset owner and the offtaker. Gunst comments that this option is for investors “who would like a share in the upside of asset optimisation, in return for taking some risk in the downside.” These latter agreements are the dominant arrangement in the GB market and often include a floor price to enable the financing of the asset.

This second type of optimisation and dispatch contract structure, with shared participation in trading and optimising, is more frequent now, with the negotiations largely centred around where the risk lies between parties. Some of the key questions arise around the optimisation model and how that influences energy storage cycles and asset degradation, and the revenue sharing model, such as who’s taking the market risk and the asset-related performance risks, etc. A typical optimisation and dispatch contract will involve the offtaker or optimiser trading and optimising the asset in return for a percentage share on the returns (average of 7%), sometimes tiered for different profit ranges. The asset owner and the offtaker would agree on marginal costs and price triggers and these contracts are typically one to three years in length. It is also possible for assets to enter long-term (over seven years) optimisation and dispatch contracts, often with floor prices, to provide price certainty over a longer period and help finance new projects but these agreements tend to require stronger credit ratings from the parties involved.

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Challenges for energy storage

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A new stand-alone storage asset is unlikely to be able to access a grid connection before 2030.

Challenges for energy storage

Whilst it is clear that there are extensive opportunities open to energy storage assets in terms of accessible revenue streams, setting up an energy storage asset is not without its challenges. Broadly, these can be separated into two categories: firstly, physical constraints such as on grid and supply chains, and secondly, market and revenue challenges.

Grid constraints

A major obstacle to the roll-out of energy storage assets in GB, as well as many other global jurisdictions, is being able to access the grid. Currently, a new stand-alone storage asset is unlikely to be able to access a grid connection before 2030, and in many parts of the country is faced with a seven year wait from the application start date. A large part of this issue has arisen as a result of the ESO modelling of storage assets, which are assumed to be exporting coincident with maximum generation or importing concurrent with peak demand, when in fact the opposite is likely true. Another challenge to the existing system is that projects are queued by application date, and so projects closer to the front of the queue could be holding up projects that are already ready to connect and operate. The assumed extra infrastructure necessary to connect assets to the grid is likely to be greater in areas which are already the most constrained. Therefore, storage assets will be less likely to access the grid in these areas despite these being the areas which could most benefit from more system flexibility.

To counter the issues around grid access, the ESO has proposed initiating a range of short and long-term measures to change both the queue system and modelling assumptions currently used. For storage in particular, the reforms are aimed at allowing faster connection to the network, although with the caveat that they may be asked to turn off more frequently during periods of system stress, without initially being paid for this downtime, which could dent investor confidence by limiting access to, and certainty of, revenues. Related to this, Fredrik Lindblom, Partner at DLA Piper, suggests that allowing storage assets to freely access the grid at certain times of day could be another way to promote energy storage roll-out and system decarbonisation.

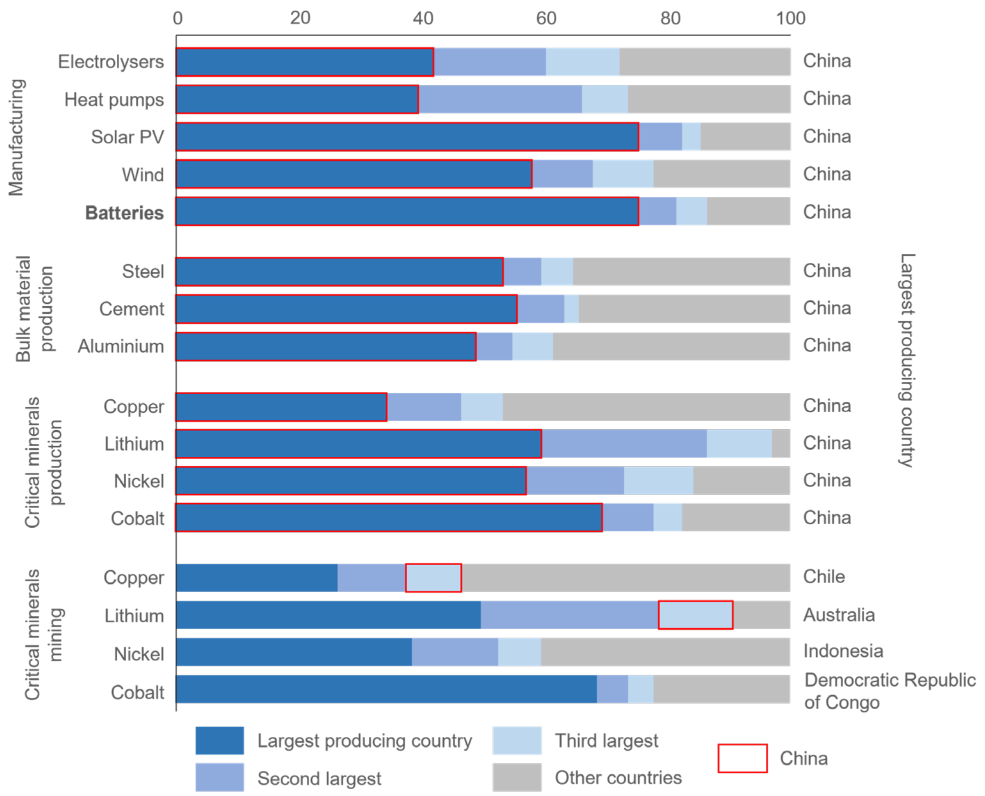
Supply chains

Another challenge to the roll-out of energy storage assets, and many other low-carbon technologies, is around supply chains. Supply chains for energy storage assets are currently facing constraints on three fronts:

- access to raw materials,
- manufacturing capacity, and
- labour and installation capacity.

For energy storage assets, and in particular batteries, sources of raw materials and manufacturing are geographically limited, with China dominating (Figure 4). The limited geographical spread of manufacturers makes supply chains more vulnerable to disruptions and raw material prices have displayed high volatility and increasing prices in recent years. Ben Brooks, Portfolio Management at Schroders Greencoat, adds that dependence on specific nations warrants a heightened focus on ensuring the materials and products have not come from areas or jurisdictions with known human rights abuse. This is likely to be an increasingly important topic with ESG becoming even more of a priority for many market players and because, as James Carter, Partner, Head of UK Energy and Natural Resources at DLA Piper, notes, of the increased ESG litigation risk to which businesses are exposed. Owners and lenders aren't simply focussing on delivering low-carbon solutions; they are also looking at the overall impact of their projects.

Figure 4: Geographic concentration of supply chain segments in 2021



Source: IEA Energy Technology Perspectives 2023, Cornwall Insight

These material and manufacturing constraints have been further compounded by a wider shortage of labour and skills, with the Confederation of British Industry identifying that a lack of skilled talent is the greatest obstacle to business growth across the UK economy.[19] Richard Braakenburg (SUSI Partners) also highlights this labour shortage, with a bottleneck currently in "credible and good plant contractors" and uncertainty over whether the contractor base will be able to meet the demand from pipeline projects; this will be a key factor for many investors who are seeking to

19 CBI

> "Dependence on specific nations warrants a heightened focus on ensuring the materials and products have not come from areas or jurisdictions with known human rights abuse.
>
> **- Ben Brooks,**
> Schroders Greencoat

> Biden's IRA is a game-changer. We are already seeing, both through a diversion of deal-flow and anecdotally, that investors are increasingly turning to the US in search of attractive tax credits.
>
> **- Rubayet Choudhury,** DLA Piper

participate in a meaningful pipeline so they can scale up their investments in line with their capital deployment requirements.

Long-term partnerships and targeted acquisitions could help build more resilient supply chains, with examples of this already seen in comparable segments such as the electric vehicle (EV) and offshore wind industries. One EV manufacturer has forged long-term agreements with mining companies in Brazil, China, and the Democratic Republic of Congo to provide a steady supply of nickel, cobalt, and lithium, all critical raw minerals for EV manufacturing. Similarly, a wind turbine manufacturer has announced a strategic partnership with a steel producer whereby the turbine manufacturer supplies low-carbon hydrogen and wind-generated electricity to allow the steel producer to produce 'green' steel which the turbine manufacturer will then purchase to produce turbines.

The vulnerability of global supply chains has also seen many governments developing initiatives to promote the development of domestic supply chains as well as improving security of supply for raw materials and critical minerals. The Inflation Reduction Act (IRA)[20] introduced in the US on 16 August 2022 contained a series of domestic content requirements for accessing subsidy funding to promote domestic supply chain growth.

Julian Jansen, Senior Director - Strategy, Market Development, Policy (EMEA) at Fluence, highlights that with the IRA in the US and the EU's Green Deal Industrial Plan (GDIP),[21] there is an increasing risk that the UK will not be able to attract investment across the value and supply chains for energy technology and assets. Rubayet Choudhury (DLA Piper) adds that "Biden's IRA is a game-changer. We are already seeing, both through a diversion of deal-flow and anecdotally, that investors are increasingly turning to the US in search of attractive tax credits. It will be interesting to see whether the EU and UK will respond with retaliatory protectionist measures or whether they will continue with the pragmatic approach taken under the GDIP."

The recently published (30 March 2023) "Powering Up Britain – The Net Zero Growth Plan"[22] in the UK included multiple mentions of developing and strengthening net zero supply chains. The UK government also published its "Critical Minerals Strategy"[23] in July 2022, with the subsequent Critical Minerals Refresh[24] published on 13 March 2023, to outline their strategies for growing the UK's domestic critical mineral projects alongside developing bilateral international partnerships. The policy and implementation details that would underpin these strategies are yet to be released.

20 The White House
21 European Commission
22 GOV.UK
23 GOV.UK
24 GOV.UK

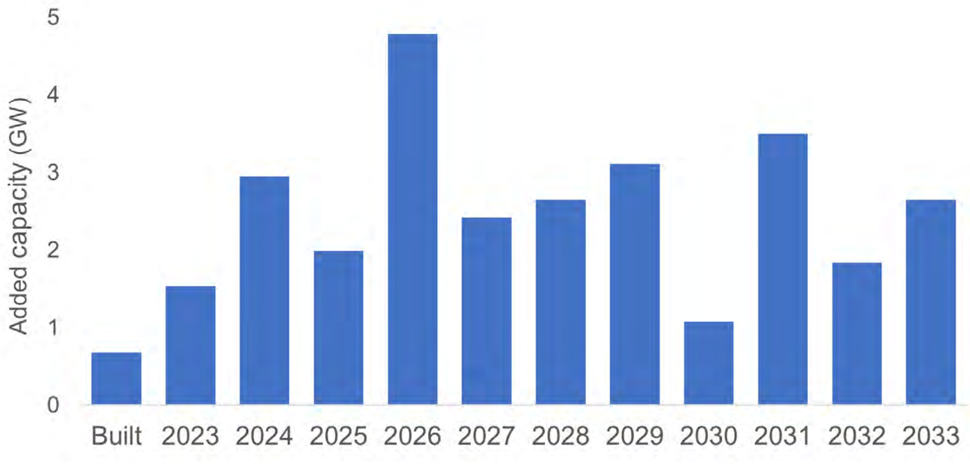
Alongside access to materials and labour, supply chains are also being increasingly stretched as a result of the rising cost of capital, with a recent report[25] from Cornwall Insight highlighting the scale and implications of this challenge on GB renewable generation. Additionally, Julian Jansen (Fluence) raises the point that as capital costs increase, there is the risk that investors will choose "weaker performing products that may not last their intended lifetime."

Market saturation

As discussed previously, ancillary services currently provide a lucrative component of the revenue stack in both the GB and Irish markets. However, with a substantial pipeline of energy storage projects due to come online this decade (Figure 5) there is an increasing risk of market saturation impacting on the available revenues. Cornwall Insight's recent Balancing Services Forecast (published February 2023) indicates that, as the market becomes oversaturated, prices for the Dynamic Containment ancillary service could fall to <GBP1/MW/hr. Concerns around market saturation of ancillary services mean that for new and existing energy storage projects it is likely that the other components of the revenue stack, particularly wholesale power arbitrage, will become increasingly important. However, Charlotte Johnson (KrakenFlex) adds that in the last two years the market has been particularly volatile and that investors should not "build a business case off the power arbitrage and ancillary revenues seen at the moment."

> "Market saturation of ancillary services means that the other components of the revenue stack will become increasingly important.

Figure 5: Capacity of stand-alone energy storage projects per year on the National Grid Transmission Entry Capacity (TEC) register for the next decade, as of 6 April 2023



Source: National Grid ESO, Cornwall Insight

Another concern around market saturation, according to an industry source, is that if the build out of renewable generation falls behind forecasted rates, then the revenue stack predictions used to finance energy storage assets

25 Cornwall Insight - WACC-A-MOLE - Implications of the rising cost of capital for the fifth round of the Contracts for Difference scheme

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> Investor confidence in energy storage will be dependent on a shift in mindset away from a focus on absolute power prices to a focus on market volatility.
>
> **- Richard Braakenburg,** SUSI Partners

could be impacted, with an increasingly saturated market reducing attainable revenues. The industry source added that revenue projections are currently based on a “build out of renewables that will be challenging to achieve.”

Revenue certainty

Linked to the challenge around market saturation is the certainty of contracted revenues, given the inherent volatility of most of the markets in which energy storage assets are active. Revenue certainty is a fundamental consideration for many investors and lenders and the degree of certainty is likely to be a key component in business cases. A key consideration is whether assets have access to the CM or if they are dominantly active in power arbitrage and ancillary services. Additionally, as pointed out by an industry source, with grid connection times over four years away, it is difficult for investors to have confidence in storage assets with so much uncertainty in the future revenue stack. DLA Piper’s Rubayet Choudhury adds that at the moment the majority of energy storage assets are equity funded, with the lack of contracted revenue certainty putting off certain lenders. However, more project-financed deals are now closing, proving that some players are getting more comfortable with sophisticated revenue stacks, although these are often underpinned by some form of contracted revenue. Richard Braakenburg (SUSI Partners) further notes that investor confidence in energy storage will be dependent on a shift in mindset away from a focus on absolute power prices to a focus on market volatility and getting comfortable with that volatility.

Greater familiarity with energy storage technology can help build investor confidence and offset some of the concerns around revenue certainty. Alex Murdie, Legal Director at DLA Piper, states that the transition to longer equipment warranties, from 5-6 year warranties to 10-15 year long-term service agreements, also supports and builds confidence in long-term investments in energy storage. Murdie adds that, for some projects, this has involved a separation of the storage asset from the rest of the project, thereby providing the energy storage asset suppliers with more confidence in providing a long-term warranty. Similarly, the operation and maintenance of certain storage assets, such as batteries, increasingly requires sophisticated strategies and software to try and extend asset life. Whilst it is too early to say whether those strategies and warranties have proven successful, these approaches can help make projects more attractive to investors.

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Future opportunities for energy storage

Future opportunities for energy storage

Whilst the rollout of energy storage is not without its challenges (as discussed in the previous section), with market saturation of particular concern for new projects and investors, there continue to be opportunities. Looking to the future, what key opportunities are available for the continued development of energy storage and what are the key considerations for new GB energy storage projects?

Pathfinders

National Grid ESO is currently running three "pathfinders,"[26] which seek to provide innovative solutions to the emerging issues with the evolving electricity system. The three pathfinders are:

- high voltage,
- stability, and
- constraint management.

All three pathfinders are location-specific but can offer an additional component of the revenue stack for energy storage assets, with Alex Murdie (DLA Piper) commenting that access to pathfinders has been "seen as an important objective" for future energy storage projects. Charlotte Johnson (KrakenFlex) adds that battery storage assets in the GB must already prove to National Grid that they can deliver reactive power and some stability services as part of their grid code, and so there is a growing body of assets that could provide pathfinder services if there is a market for it.

High voltage pathfinder

The high voltage pathfinder looks to cost-effectively absorb more reactive power, which has arisen from a drop in minimum power demand and power consumption on local distribution networks. Two tenders have been delivered through this pathfinder so far, offering 9-10 year contracts. A battery project has secured a contract as part of the first of these tenders, indicating that this is a potential revenue stream for energy storage assets.

Stability pathfinder

The stability pathfinder looks to address the falling inertia (faster rate of change in system frequency with a change in generation output) of the system as more intermittent renewables come online. Three tenders have been run so far, with successful projects wining 5-10 year contracts. As with the high voltage pathfinder, battery projects have been successful for the stability pathfinder, although the majority of contracts have been awarded to grid forming technologies (e.g. synchronous condensers).

The success of some battery projects indicates that it could provide value as an additional long-term component of energy storage revenue stacks in the future. Additionally, the ESO are currently investigating how to design and develop a stability market[27] to procure both short- and long-term stability through an open, transparent, and competitive market. The ESO is still currently exploring eligibility and contract structures as part of a potential market design, but it is possible that a dedicated stability market could allow energy storage assets to get greater certainty of revenues from stability services.

26 National Grid ESO
27 National Grid ESO

Constraint management pathfinder

The constraint management pathfinder aims to manage grid constraint, particularly on the B6 (England-Scotland) boundary, separately to the BM. Whilst this market is likely to grow until the "Eastern Bootstraps" (large undersea High Voltage Direct Current connections bypassing the B6 boundary) are in operation, it is likely that energy storage assets can get higher, although less stable/certain, value from access to the BM than as part of the constraint management pathfinder.

The ESO has noted that using energy storage exclusively for constraint management would be uneconomical and locating alongside an active export constraint would limit its access to other markets.[28] However, Ben Brooks (Schroders Greencoat) notes that transmission-as-a-service could become more of a revenue stream in the future, with the Netzbooster project[29] in Germany already an example of this, where "instead of laying additional high voltage lines, storage assets are placed at either end to increase the capacity of the existing line."

Co-location

An area of increasing interest in the last 12 months for investors and developers, in particular for GB battery storage assets, is co-location. Co-location can come in a wide variety of forms but for the purpose of this report we are only considering the situation where an energy storage asset and generation asset (e.g. a solar farm) share a grid connection but are separate assets behind that connection (i.e. not a hybrid system), with the assets either metered together or separately depending on the trading strategy and set-up. This is the most explored type of co-location in GB at present and allows the energy storage asset to benefit from lower costs and quicker connection to the grid if co-located with an existing generation asset, which is a particular benefit in light of connection times currently being beyond 2030 for a stand-alone battery asset. Tony McGuinness, Head of Origination, Market Entry and Storage at Aer Soléir, notes that this could be particularly beneficial for solar farms where yields and export capacity utilisation tend to be lower in GB and Ireland.

Co-location revenue streams

Co-located energy storage assets can access the same revenue streams as stand-alone assets, alongside the additional option of storing energy from the co-located generation asset. Storing energy from the co-located generation asset could be for power arbitrage purposes, to avoid curtailment, or to create an energy profile that is 'firmer' or better matches offtaker demand. However, Andreas Gunst (DLA Piper) states that, at present in GB, the "value for a storage asset tends to be much higher in trading and optimising than in

> "At present in GB, the "value for a storage asset tends to be much higher in trading and optimising than from storing renewable energy to avoid curtailment."
>
> **- Andreas Gunst,**
> DLA Piper

28 National Grid ESO
29 TransnetBW

> “
>
> Using storage to balance and avoid renewable generation curtailment could be an important market movement in the future.
>
> **- Natasha Luther-Jones,** DLA Piper

deriving revenue from storing renewable energy to avoid curtailment” and a co-located energy storage asset should therefore have a more sophisticated business case and trading strategy than just being turned on or off to avoid generation curtailment.

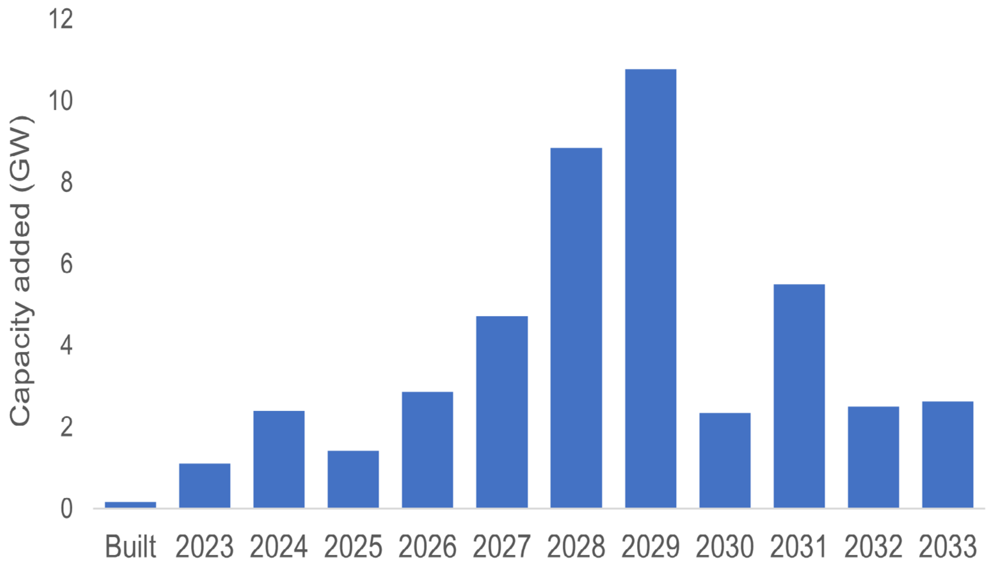
With the exception of highly curtailed renewable output due to grid constraints or negative pricing, there hasn’t been a strong business case in GB for storing energy from the co-located generation asset instead of from the grid. However, this is not the case for all jurisdictions, with an industry source noting that co-locating solar and storage with behind-the-meter demand has been successful in Western Australia. They added that this set-up was used to reduce consumer energy bills alongside participation in capacity and frequency response markets as a virtual power plant.

Natasha Luther-Jones (DLA Piper) highlights that, although currently storage and generation assets have been treated separately, with separate revenue streams and optimisation and dispatch contracts, using storage to balance and avoid renewable generation curtailment could be an important market movement in the future, particularly with market saturation impacting the attainable revenues in ancillary services. Andreas Gunst (DLA Piper) adds that larger energy storage assets than the battery sizes currently used in co-located projects would be needed to allow for “shaping and re-shaping of the generation volumes involved.” Ben Brooks (Schroder Greencoat) further notes that large corporates may be willing to pay a premium for storage assets to temporally shift generation to better match consumption and demand.

Challenges for co-location

A challenge to co-locating energy storage with a generation asset, especially if the generation asset is already built and operating with existing legal and contractual frameworks, is price certainty and cannibalisation. Stacking the individual business cases for the different assets is likely to place a constraint on one or other of the assets. Optimising co-located assets is crucial to ensuring that the cost and time benefits outweigh the losses from any constraints. The outlook for co-located energy storage assets appears positive (Figure 6), and as more projects come online there is increased clarity on which business cases work best and how to optimise the different assets.

Figure 6: Capacity of co-located energy storage projects for the next decade on the National Grid TEC register, as of 6 April 2023



Source: National Grid ESO, Cornwall Insight

> Without a massive increase in interconnection, inter-day and 'seasonal' storage will be crucial for the UK and Ireland to reach net zero.
>
> **- Ben Brooks,** Schroders Greencoat

More long-duration storage?

As discussed in the first section of this report, the GB energy storage market is currently dominated by short-duration storage focused on intra-day storage cycles and the accompanying market opportunities. Charlotte Johnson (KrakenFlex) comments that, with market saturation limiting the future value of ancillary services, there is a trend away from one hour batteries to investing in two hour batteries in order to better capitalise on wholesale power arbitrage revenues, but that there remains a gap in longer duration storage assets. Ben Brooks (Schroders Greencoat) adds that, without a massive increase in interconnection, inter-day and 'seasonal' storage will be crucial for the UK and Ireland to reach net zero.

Incentives for long-duration energy storage

Currently there are no financial incentives in the GB market to promote growth of the long-duration inter-day and 'seasonal' storage. Curtis VanWalleghem (Hydrostor) highlights that CM revenues are likely to be the main component of the revenue stack for these longer duration storage assets, but that capacity payments are often capped by gas power plants or shorter duration batteries and not sufficient to incentivise long-duration assets. The LTESA (Box 4)[30] and the Capacity Investment Scheme[31] in Australia could provide examples of how more long-duration storage could

30 AEMO Services
31 Australian Government

Box 4: LTESAs in Australia

In 2020, the New South Wales Government set out its plan to transform its electricity system through coordinated investment in transmission, renewable generation, storage and firming infrastructure. A key component of this plan were competitive tenders to offer LTESAs for large-scale renewable generation, long-duration storage, and firming. The first of these tenders has now closed with the second (only open to firming infrastructure) currently underway. The LTESAs offer long-term contracts (up to 40 years, depending on the lifespan of the storage asset) with a cap-and-floor Contracts for Difference style scheme. LTESAs therefore provide long-term revenue certainties for long-duration storage assets.

be procured in GB. Similarly, a cap-and-floor regime[32] could be adopted as outlined in the UK government consultation response on the deployment of long-duration electricity storage that was published in August 2022.[33]

In June 2022, the Long Duration Energy Storage (LDES) Council published a report[34] outlining a wide range of potential ways that governments can help incentivise more long-duration storage, with "capacity market mandates or offsetting with grants or tax credits" identified by Curtis VanWalleghem (Hydrostor) as key mechanisms for enabling this. An industry source added that implementing a Contracts for Difference style scheme for long-duration storage not only provides the asset with revenue certainty, but also "incentivises energy storage to remove the volatility from the market."

32 A cap-and-floor regime for long-duration energy storage would provide an asset with a guaranteed minimum or 'floor' revenue, and a maximum or 'cap' revenue. When revenues fall below the floor they are topped up to the floor by consumers, and conversely, when revenues exceed the cap, those excess
33 GOV.UK
34 LDES Council

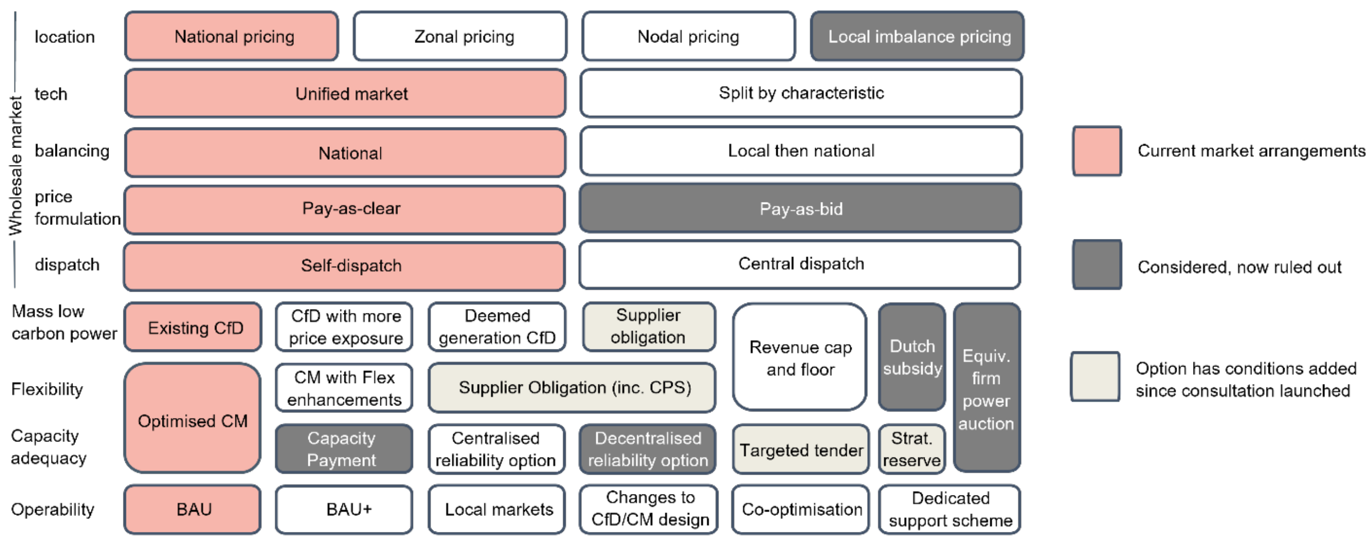
Policy risk or opportunity? - REMA

The Review of Electricity Market Arrangements (REMA) was announced as part of the British Energy Security Strategy in April 2022,[35] with the first consultation stage launched in July 2022[36] and the government response to this consultation published on 7 March 2023.[37] REMA is the government's review into all non-retail aspects of Great Britain's energy markets with the aim of ensuring these markets are fit-for-purpose in delivering upon the UK's net zero targets. At time of publication, there are still a large number of options being put forward, with relatively few ruled out after the first consultation (Figure 7), but the main high-level proposed changes involve splitting the wholesale market by technology type and locational marginal pricing (LMP).

Splitting the wholesale market

Splitting the wholesale market would likely involve two 'pools', one for dispatchable technologies (e.g. gas fired power stations, batteries) with prices based on short-term marginal costs and another for intermittent technologies (e.g. wind, solar PV) with prices based on the long-term marginal costs. It is likely that dispatchable assets will still be able to capture high prices and there could even be greater volatility, and therefore more opportunities for energy storage assets. Overall, split markets are unlikely to significantly impact on energy storage assets, although trading strategies and offtake arrangements may need re-visiting.

Figure 7: Summary of the REMA options following the first consultation



Source: GOV.UK, Cornwall Insight

35 GOV.UK
36 GOV.UK
37 GOV.UK

> “REMA is unlikely to “disrupt or bring about a meaningful reduction in the attractiveness or use of energy storage.”
>
> **- Andreas Gunst,** DLA Piper

Locational marginal pricing

LMP would propose to replace the current self-dispatch market with a central-dispatch market where prices are set on a locational basis (either zonal or nodal) in response to the balance of generation and demand and the constraints on grid infrastructure for the zone/node.

Whilst the full impacts of LMP cannot be predicted without the exact details of the LMP model under consideration, it is likely that generation assets located further south or closer to the major demand centres will see higher wholesale prices than those located further north and in generation dominated areas. Because storage assets earn revenues from market volatility, locational variations in absolute wholesale prices are less likely to impact revenues. However, assets that are more flexible on siting (e.g. batteries) may be more able to benefit from any locational differences in volatility resulting from LMP than long-duration energy storage assets such as pumped hydro or CAES, which are less flexible on where they can be located.

REMA will have a significant impact across the GB energy markets for at least the next few years as decisions are made to firm up which options will be adopted going forward. At present it looks likely that energy storage assets will not be substantially negatively impacted by REMA, with Andreas Gunst (DLA Piper) noting that storage assets will “still be used to optimise trading opportunities in the market” and that REMA is unlikely to “disrupt or bring about a meaningful reduction in the attractiveness or use of energy storage.”

Key considerations

Key considerations

As an asset class, energy storage is very different from conventional renewable generation, and, along with the volatile and evolving nature of storage markets, there are therefore a series of key considerations (Figure 8) that need to be taken into account for investors and developers looking to get involved in GB energy storage markets.

Figure 8: Key considerations for investors and developers

Market access

It is important to know which markets offtakers have access to and experience trading in and what impact that has on the potential revenue stack for the asset. The track record of offtakers and optimisers is also very important, especially for battery assets. With the market saturation challenges discussed in this report, access to ancillary services is likely to be less important going forward.

Optimisation and risk appetite

The revenue stack will depend on which markets are the focus for the asset owner and offtaker, which in turn will be impacted by the risk appetite of the parties involved. The revenue stack and jumping between different revenue streams, with different degrees of revenue certainty, affects asset cycling and degradation, as well as having implications for raising debt or meeting required equity returns. In particular, investors and lenders will want to understand the certainty of (or contracted nature of any) revenues under any proposed revenue stack, and the trading strategies to mitigate any perceived merchant risk. The set up of the route to market arrangement will depend on the risk allocation between the offtaker and asset owner and who is taking on market risk, asset performance risk, legal risk etc.

Grid connection

How soon an asset can be connected to the grid and at what cost are key variables, with co-location providing an opportunity for quicker and cheaper grid connection for energy storage assets. The likelihood of curtailment and when any curtailment hours are likely to be are other important considerations.

Warranties

Warranties and performance system software are critical for electrochemical systems, particularly as system “wraps” can provide investors and lenders with long-term comfort on technology risk. The longevity of the warranty and whether it covers the intended cycling (charge and then discharge the stored energy) frequency are important characteristics to consider. Similarly, the extent to which warranties are dependent on the manner in which assets are maintained and the software that is used, and who the asset owners use to provide those services will all be key.

Supply chains

With many market players increasingly concerned with their wider impact on the world and society at-large, environmental, social and governance (ESG) considerations will be important for many. This is likely to require careful consideration being given to where materials are being sourced from and whether there are concerns about the treatment of workers or the geopolitical stability of those supply chains and the risks to which that gives rise, including, as DLA Piper Legal Director Elinor Thomas notes, ESG related litigation risk.

Source: Cornwall Insight

The UK has seen substantial growth in energy storage, particularly batteries, in recent years, with a greater number of investors becoming confident with the sophisticated trading strategies needed to optimise business cases. The large pipelines of assets being developed highlights that this is a market that will continue to grow. However, this growth will face challenges from grid access, supply chains, and market saturation. The latter of these is likely to result in a trend away from revenue stacks dominated by ancillary services to a greater focus on wholesale power arbitrage and the BM. As part of this shift there will be a greater focus in energy storage assets with 2-4hr duration, as opposed to the 0.5-1hr duration assets that are currently prevalent in the market.

Going forward, there will be increasing interest from investors and developers in designing and optimising co-located systems for energy storage alongside renewable generation, which could provide a valuable opportunity to speed up grid access and lower costs for assets. Other key developments that could have significant impacts on the energy storage market are REMA and the potential development of a formalised market for long-duration electricity storage.

Given the complexity and rapidly evolving nature of the energy storage market in GB at present, there are a range of key considerations that need taking into account for entities looking to get involved, as highlighted in Figure 8. Get in touch with Cornwall Insight or DLA Piper for further information on how we can help your business get to grips with the intricacies of the energy storage market.

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About Cornwall Insight

Getting to grips with the intricacies embedded in energy and water markets can be a daunting task.

There is a wealth of information to help you keep up-to-date with the latest developments, but finding what you are looking for and understanding the impact for your business can be tough. That's where Cornwall Insight comes in, providing independent and objective expertise.

You can ensure your business stays ahead of the game by taking advantage of our:

- **Publications** – Covering the full breadth of the GB energy industry, our reports and publications will help you keep pace with the fast moving, complex and multi-faceted markets by collating all the "must-know" developments and breaking-down complex topics
- **Market research and insight** – Providing you with comprehensive appraisals of the energy landscape helping you track, understand and respond to industry developments; effectively budget for fluctuating costs and charges; and understand the best route to market for your power
- **Training, events and forums** – From new starters to industry veterans, our training courses will ensure your team has the right knowledge and skills to support your business growth ambitions
- **Consultancy** – Energy market knowledge and expertise utilised to provide you with a deep insight to help you prove your business strategies are viable
- **Research** – Creating new knowledge and insight in markets that are rapidly evolving, leveraging our in-depth knowledge and expertise in the energy sector to design thought leadership campaigns to suit your needs.
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We also offer a range of subscription and bespoke consultancy products specifically within the energy storage space:

Flexibility Markets Service – Gain an in-depth, real time understanding of the commercial flexibility landscape. Policy and regulatory coverage, forecasting, and routes to market insight. Regular analysis reporting and interactive monthly forum monitoring developments in GB.

Archetype Storage Revenue Curves – Quarterly report providing a forecast of revenue streams and costs for typical battery storage assets in Great Britain, covering a 20 year horizon. A range of asset configurations are provided, varying by location, duration, capacity, and connection type. Revenues are provided annually on a GBP/kW basis, along with expected cycle rates.

Bespoke Battery Storage Modelling – Using Cornwall Insight's in-house modelling capabilities, a 20 year forward view of revenues achievable from an optimized battery storage asset can be provided, tailored to your requirements. There are a range of customisation options available to accurately model your specific asset, as well as a broad variety of detailed data outputs including revenues and volumes split by revenue stream.

For more information about us and our services contact us at 01603 604400 or enquiries@cornwall-insight.com

Glossary

Glossary

B6 boundary: separates the transmission network at the SP Transmission and National Grid Transmission interface running along the border between England and Scotland.

Balancing Mechanism (BM): a mechanism that enables the Electricity System Operator to instruct generators and suppliers to vary electricity production or consumption, in real-time, in order to balance the system.

Cap-and-floor regime: a route to market where payments have a pre-agreed mechanism for providing a minimum guaranteed revenue (the 'floor') and a limit above which revenues are capped. This regime is used for GB interconnector revenues and is also often seen in Power Purchase Agreements.

Capacity Market (CM): manages the long-term security of supply by providing payment for reliable sources of generation capacity, alongside their electricity revenues to ensure they deliver energy when needed. Capacity is procured through competitive auctions held four years and one year ahead of delivery.

Captive/off-grid: an electricity generation or storage asset located at a consumers site (eg a large industrial or commercial energy user) primarily for their energy consumption. The asset may have no connection to the electricity network and so be unable to export any generation not needed by the consumer.

Contracts for Difference (CfD): a generator signed up to a CfD is paid the difference between the 'strike price' – a price for electricity generated reflecting the cost of investing in a particular low-carbon technology – and the 'reference price'– a measure of the average market price for electricity in the GB market. When the market reference price is higher than the strike price, the generator with the CfD pays the difference back to the Low Carbon Contracts Company (LCCC). When the market reference price is lower than the strike price, the generator with the CfD receives the difference up to the strike price (from the LCCC).

Curtailment: the reduction in electricity output compared to what could have been produced as a result of a constraint.

Cycling: the act of charging and discharging electricity. Cycling timescales can vary substantially from assets that charge and discharge many times within a single day to assets that charge up one day and then discharge days or even weeks later.

De-rating factor: the percentage of a Capacity Market window that an asset is anticipated to be available for, with more intermittent or weather dependent assets receiving a lower de-rating factor.

Dynamic Containment: ancillary service designed to operate after a significant frequency deviation (eg post-fault) to recover frequency deviations of ±0.2-0.5 Hz.

Dynamic Moderation: ancillary service designed to rapidly regulate sudden small deviations in frequency (< ±0.2 Hz). A quick acting service for deviations at the edge of the operational range.

Dynamic Regulation: ancillary service designed to slowly correct continuous, but small (<±0.2 Hz) frequency deviations. Aiming to continuously regulate frequency around 50 Hz.

"Eastern Bootstraps": these are large undersea High Voltage Direct Current connections by passing the B6 Boundary.

Electricity System Operator (ESO): the licensed operator of the GB electricity transmission system. Primary role is to ensure supply and demand are matched and the transmission system is planned for and operated within safe and secure engineering limits.

Frequency response (or ancillary) services: services that operate to maintain system frequency and balance any deviations from 50.0Hz on a second-by-second basis.

Green Deal Industrial Plan (GDIP): a wide range of legislative and regulatory reforms in the EU aiming to remove the barriers to net zero and promote net zero investment in the EU, whilst also boosting domestic supply chains.

Inertia: a measure of how quickly system frequency changes in response to a change in generation, akin to the shock absorbers on a car. Traditional coal- and gas-fired power plants provide high system inertia, and therefore slow changes in system frequency, due to the continued movement of the turbines for a period after generation has stopped. Whereas renewables (eg solar PV and wind) provide low system inertia.

Inflation Reduction Act (IRA): a US federal law passed in August 2022 that allocates USD 369 billion in funding over a period of 10 years to incentivise investment in clean energy. Includes 'local content requirements' to boost domestic supply chains in clean energy technologies.

Locational marginal pricing (LMP): a market mechanism proposed under the Review of Electricity Market Arrangements consultation whereby prices are set on a locational basis (either zonal or nodal). Prices would therefore be based on the local balance of generation and demand and take into account constraints on the grid infrastructure for the zone/node.

Long-Term Energy Service Agreements (LTESAs): a mechanism introduced in New South Wales, Australia, which provides a long-term contract for renewable electricity generation projects with a fixed minimum price for electricity generated. These agreements are competitively tendered and are designed to provide long-term revenue certainty to help drive investment in new renewable projects.

Offtaker: an entity which contracts for power generated.

Pathfinder programmes: a series of projects run by the Electricity System Operator to find solutions to the challenges in the electricity system. The three Pathfinder projects are aimed to address: (1) regional high voltage issues, (2) the need for system inertia to maintain grid stability, and (3) network constraint issues.

Pay-as-bid: bidders receive the price that they bid in with, and so prices will likely vary between bidders.

Price cannibalisation: the depressive influence on wholesale electricity prices at times of high output from intermittent, weather-driven generation (eg solar, wind). The greater the proportion of generation coming from these sources, the greater this effect becomes.

Revenue stack: the process whereby an asset earns revenues from a range of different markets. These different markets could be entered sequentially or simultaneously. For example, an electricity generator could receive payments for selling electricity into the wholesale market, whilst also gaining revenues from providing balancing services to the Electricity System Operator, and alongside receiving regular payments from the Capacity Market.

Review of Electricity Market Arrangements (REMA): the UK Government's review into all the non-retail aspects of the GB electricity markets, with the aim of ensuring these markets are fit-for-purpose in delivering the UK's net zero targets.

Technological readiness level (TRL): measure of the maturity of a technology, rated on a scale from 1 to 9, where a score of 1 shows basic principles observed and 9 means the actual system has been proven in an operational environment.

Wholesale power arbitrage: the process of storing energy when its cheap and exporting it when its expensive, generating revenue from the delta between the import and export

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