Filling the flexibility gap

Realising the benefits of long duration electricity storage

A report for Scottish Renewables

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Riverswan Energy Advisory

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1. Summary

The 2020 Energy White Paper[1] has set out ambitious targets for the energy transition and for reaching Net Zero by 2050 while delivering affordable, secure energy to consumers. The Government's target for 2030 is to reduce greenhouse gas emissions from 1990 levels by at least 68% - this will be the fastest reduction in any major economy. The rapid expansion of renewable electricity output allied with electricity storage will be at the heart of this transition.

This paper evaluates how long duration storage projects can help enable this transition, and the market reforms that are needed so that these major investments may proceed.

The growth in renewable generation will have four important effects on future electricity markets.

1. Flexible energy resources will be needed when renewables are not available. Currently, fossil-fuel generators mainly provide this support, but they will need to be displaced by low-carbon alternatives over time.
2. Future market design and long-term price signals are uncertain. Future markets are likely to see near-zero marginal costs when renewables are available and unknown and increased price volatility when renewables are unavailable. Capacity and balancing markets do not provide adequate long-term price signals either. Uncertainty about future market design will deter large scale investments such as long duration storage.
3. Non-synchronous, intermittent renewables do not currently provide the critical security of supply ancillary services, such as inertia, voltage flexibility and restoration. These will have to be predominantly provided by dispatchable flexible resources, such as long duration storage, but again there are currently no long- term price signals for this capability.
4. Renewables located far from demand centres will drive an increase in network constraints. These constraints increase the potential for curtailment of renewables and additional balancing costs, which could be mitigated by long duration storage.

Future electricity markets should enable the timely introduction of new flexibility resources and the exit of fossil fuelled generation. An efficient future electricity market will need to attract all the necessary resources for continuous stable operation. These will include resources for flexibility, inertia, frequency response, reserve, voltage support and system restoration to displace those currently provided by fossil-fuel generators.

The optimum replacement for these resources appears to be long duration low-carbon synchronous generation or storage. This can be provided by several technologies including pumped storage hydro, liquid/compressed air, power generation with Carbon Capture Utilisation and Storage (CCUS), and hydrogen. If this is not enabled by electricity market price signals, then the total costs of the electricity customers will be higher than necessary.

The construction of long duration storage is constrained due to high capital costs, long construction periods and the lack of revenue certainty. For example, while independent analysis by Jacobs[2]

[1] https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[2] https://www.jacobs.com/sites/default/files/2020-10/Jacobs-Strategy-for-Long-Term-Energy-Storage-in-UK-August-2020.pdf

shows pumped storage projects are economic to construct and operate, the current fragmented design of electricity market mechanisms does not offer sufficient confidence to investors. Indeed, the existing 4GW of UK pumped storage projects UK were built when the industry was state-owned.

This paper has considered alternative market models for delivering long duration storage. It proposes a new market to derive an income floor for the provision of long duration flexibility services. This market would allow access to all technologies and would be overlaid on existing capacity, wholesale, and balancing markets to optimise resource provision.

The suggested market design would allow new long duration flexibility providers to bid for an income stabilisation floor in return for providing specified capabilities and performance commitments. This Government-backed floor would be based on income net of electricity purchases to ensure that the providers are incentivised to operate optimally in the electricity markets. The approach should provide security for investors and enable low-cost debt financing. This floor would only become active if the resources could not recover their revenues from the available markets.

Filling the 'flexibility gap' will be critical for enabling decarbonisation and utilising flexible technologies to achieve the energy transition in the most efficient way. Long duration storage projects can play a key role in filling this gap, but projects have long construction times and early decisions will be needed to initiate projects so they can contribute fully to enabling Net Zero. They should also benefit the wider Government aims of the 'Ten Point Plan for a Green Industrial Revolution[3]' and 'levelling up agenda' by delivering major new investment and job creation.

Next steps

BEIS and Ofgem will be updating their Smart Systems and Flexibility plan later in 2021. The following initiatives might usefully be considered:

- **Call for evidence** - BEIS and Ofgem should issue a call for evidence to industry about the potential costs and benefits from long duration storage, and the barriers to investment and how these could be addressed.
- **Identify flexibility needs and benefits** – the Electricity System Operator (ESO) should undertake analysis to identify major alternative long-term 'whole system' flexibility needs, benefits and options and prepare a potential specification for procurement of these long-term flexibility resources. This should define type and location of flexibility resources needed, specifying full-output duration, delivery year, and other key factors.
- **Design a new flexibility market** – BEIS and/or Ofgem should design how an income floor approach could work to identify long-term flexibility solutions. This should define the parameters for the selection of resources e.g., flexibility or storage volumes, costs, operational durations and delivery timescales, and how particular solutions may be selected.
- **Consider responsibilities and processes for future delivery** – BEIS should consider the responsibilities and resources for identifying and specifying flexibility needs, market operation, and ongoing performance and compliance.

[3] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

2. Introduction

This paper has been prepared for Scottish Renewables on behalf of the Pumped Storage Hydro Group by Riverswan Energy Advisory, an independent strategy, regulation, and investment advisory firm.

The rapid growth in renewable electricity generation to achieve 2050 Net Zero targets will require an accompanying increase in flexible and low carbon electricity storage, able to operate for extended periods alongside renewables. This paper examines the barriers to new investment in long duration storage and how they may be addressed if this resource is to be available to help decarbonise the future power system at least cost.

The paper is structured as follows:

- The need for long duration storage and the flexibility benefits it can bring to enable a decarbonised energy system,
- The barriers currently faced by investors and developers,
- The alternative market mechanisms that could remove these barriers,
- A comparison of these alternative mechanisms,
- Conclusions and recommendations.

The paper considers these issues from a technology neutral perspective, recognising that these capabilities may be provided by a range of low carbon technologies.

3. The need for long duration storage

In December 2020, the Energy White Paper set out the Governments plan for decarbonisation and significant growth in renewable electricity. The ambition is for a market framework to promote effective competition and deliver an affordable, secure, and reliable system to meet Net Zero targets. Intermittent renewable technologies would need to be complemented by low carbon alternatives such as clean hydrogen and long duration storage.

While the White Paper identified the need for long duration storage, it did not elaborate on what storage was needed or how much, nor how these resources would be included in the market framework. These issues are discussed below.

Electricity system flexibility

The GB electricity system will be at the centre of the energy transition to Net Zero as the transport and heat sectors are increasingly electrified. But electricity systems must continually match power supply and customer demand. They must have essential operational resources continually available (and in reserve) to ensure the stability of the system. These resources are critical in ensuring security of supply, which is becoming more critical in a society dependent on the digital world.

These essential operational resources are often referred to as flexibility or ancillary services and are managed by the ESO through balancing services markets. They are:

- Power flexibility – capacity for ramping up or ramping down power output as needed to meet highly variable levels of demand, including holding output for use in reserve. Power flexibility is normally managed through wholesale market trading, but the ESO will manage real-time imbalance markets and ensure sufficient flexible output is always available,
- Frequency flexibility – providing frequency response through rapid changes in output, including holding capability in reserve,
- Stability flexibility – providing sufficient levels of system inertia, dynamic voltage control, and short circuit management to maintain stability, including holding capability in reserve,
- Voltage flexibility – providing the capability to generate or absorb reactive power to manage voltage levels, including holding capability in reserve,
- Restoration – black start capability to restore the power system.

Historically, power systems have been designed around fleets of large fossil-fuel synchronous generators that were obliged to provide many of these essential system services, normally without additional payment. These are being replaced by renewable generators that do not have the same requirements and capabilities. This creates a flexibility gap, both in terms of the operational resources and payment for these services.

To fill this gap, new sources of flexibility will be needed from storage, renewables, and flexible low carbon generation. Long duration storage can play a key role in absorbing and storing excess renewable generation. But new long and short-term price signals will be needed to drive investment and optimise operation. Furthermore, some flexibility requirements are locational in nature, so the price signals will need to reflect this.

The electricity system continually faces variable peaks and troughs of demand. This needs flexible generation or storage assets that can operate for different periods of time. These are often categorised as having short or long durations, namely:

- Short durations - less than 4 hours at full output. This would provide output or flexibility services over a short period, such as a high demand peak.
- Long durations - more than 4 hours at full output. This would provide output or flexibility services over several hours, days, or weeks when output from wind or solar resources is low.

In addition, not all storage assets will have the same flexibility capabilities. Whereas batteries are well suited to provide response and reserve services, they are less able to provide combined system stability services, such as inertia, reactive power, and manage short circuit levels. These capabilities can be delivered by storage technologies with synchronous generators such as pumped storage hydro or compressed/liquid air.

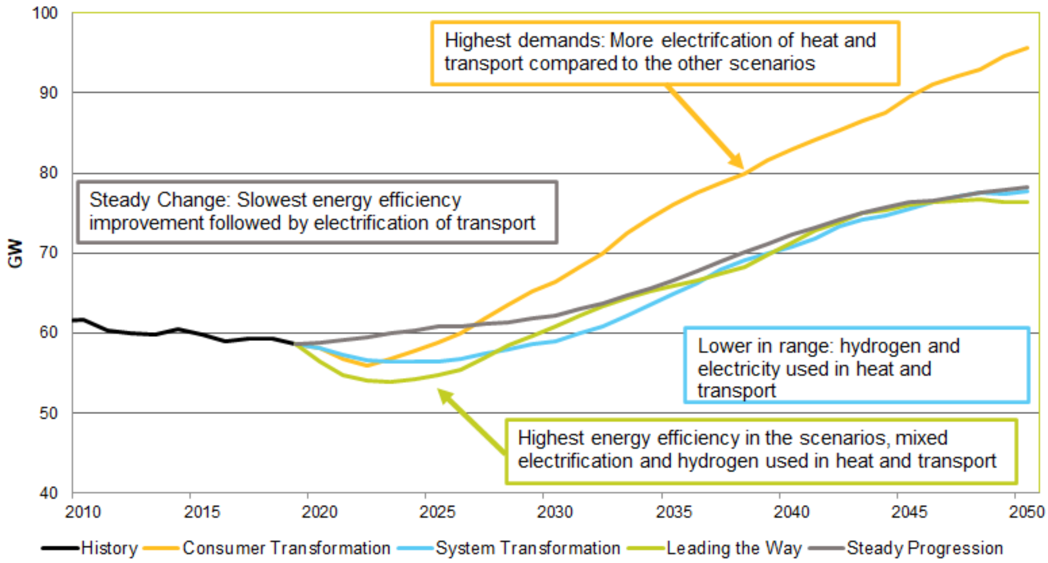
The impact of high renewable generation output

The high penetration of renewables is already having an impact on GB power system operability. For example, during the summer of 2020 lower demand due to Covid-19 coupled with high renewable output resulted in balancing costs that were circa 40% above expectations.[4] This included curtailing renewables and replacing them with synchronous, flexible fossil-fuel generators to maintain system stability.

While the 2020 demand profile appears exceptional, it does provide a glimpse into the future of the challenges of a high renewable power system facing the exit of fossil-fuelled generation. The ESO Future Energy Scenarios (FES) in Figure 1 below estimates that peak electricity demand will increase significantly from 2025 onwards. Government decarbonisation targets for 2030 mean that an increasing proportion of demand will be met by renewables. Without storage capacity, future renewable curtailment and high balancing costs may reflect the experiences of 2020.

[4] Ofgem review of March to July 2020 balancing costs of £718 million. https://www.ofgem.gov.uk/system/files/docs/2020/08/open_letter_spring_summer_review.pdf

Figure 1: National Grid 2020 FES - peak demand scenarios

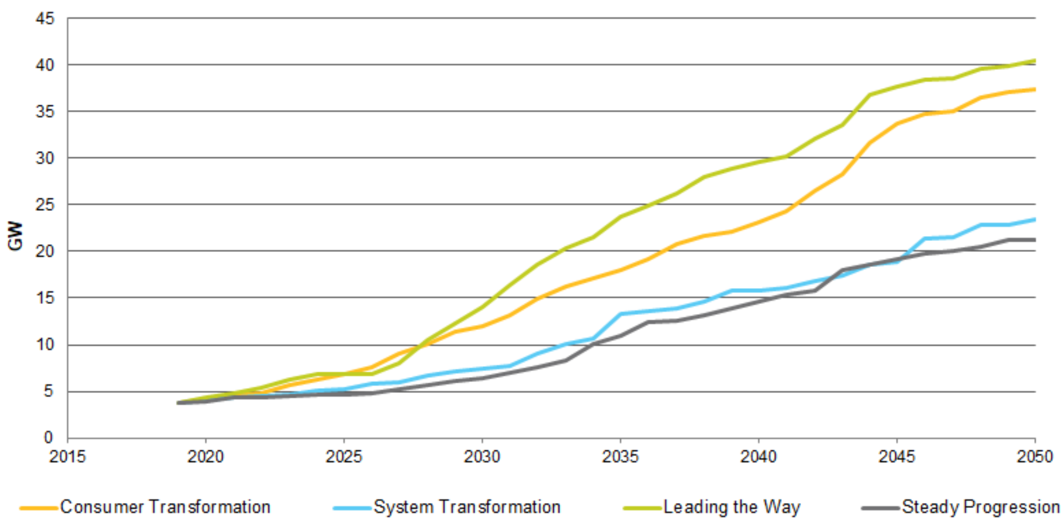


As decarbonisation and electrification increases, greater flexibility will be needed so the power system can operate with vastly increased levels of renewables. Some areas of the power system e.g., Scotland, already have limited flexible generation. Long duration storage can provide this flexibility – but construction periods of 5-8 years for technologies such as pumped storage hydro mean there will be a lead-time before these solutions become available.

Electricity storage forecasts

National Grid ESO's 2020 FES indicates that considerable growth in electricity storage is expected through to 2050. This is illustrated in Figure 2 below. Currently, the GB power sector has only 4GW of long duration pumped storage, all built several decades ago. The ESO's 'Leading the Way' scenario assumes a further 10GW of storage capacity will be needed by 2030, reaching some 40GW by 2050.

Figure 2: National Grid 2020 FES – Electricity storage scenarios



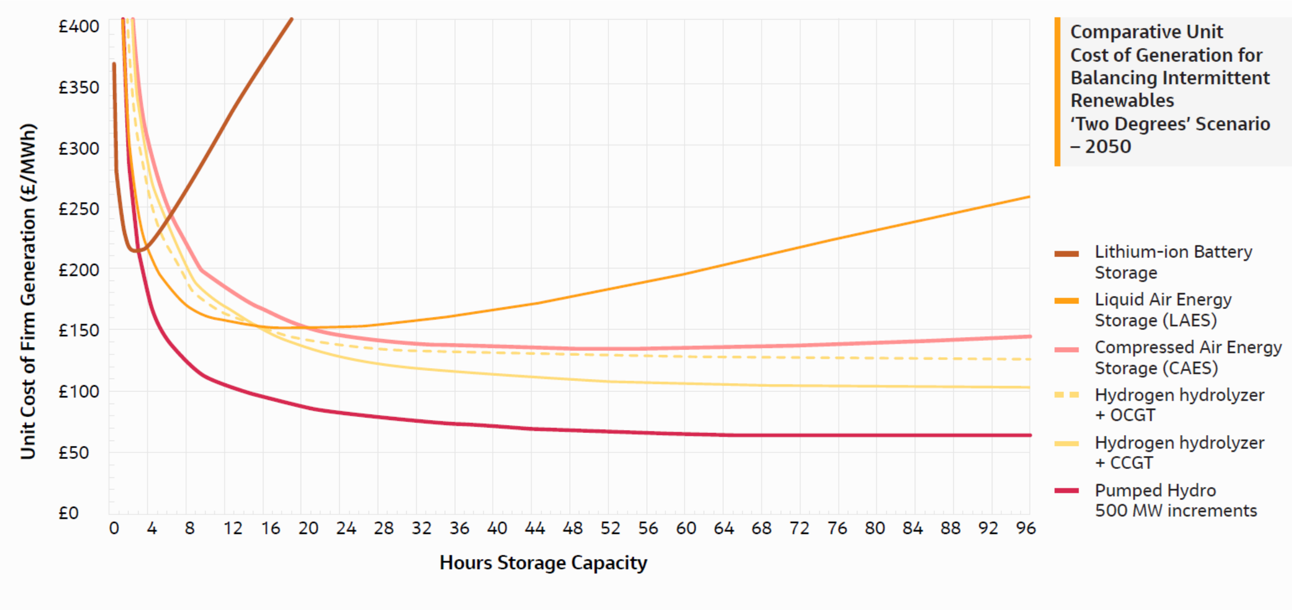
The FES indicates that this storage capability will be provided by both short and long duration storage resources, with long duration storage especially expected to be required as renewable penetration increases. However, construction periods of 5-8 years mean that early action is required if these resources are to be available by 2030.

Electricity storage costs

Jacobs[5] 2020 energy storage report compared the unit costs of several energy storage technologies with the equivalent unit cost of generation from other net zero carbon generation sources. The energy storage technologies examined are lithium-ion batteries, liquid and compressed air storage, and pumped storage hydro. These are compared with equivalent cost curves for green hydrogen OCGT and CCGT technologies, which can provide equivalent flexibility services.

The following figure 3 from the Jacobs report shows cost curves derived using the energy outputs from the daily balancing of baseload plant and intermittent renewable generation predicted for 2050. It combines the capital and operating costs (taken from BEIS analysis) for each technology to derive an approximate levelised unit generating cost against storage capacity.

Figure 3: Unit costs of generation and storage for different storage durations



The comparative unit cost of generation by technology type, for a typical plant of 500 MW installed capacity at a range of different storage durations from 1 hour to 4 days

The chart shows that lithium-ion batteries have the lowest cost of storage for durations of less than 4 hours, but that for longer durations there is a marked reduction in storage cost for the other technologies such as pumped hydro, hydrogen generation, compressed air, and liquid air. Pumped hydro has the lowest cost for durations of greater than 4 hours.

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[5] https://www.jacobs.com/sites/default/files/2020-10/Jacobs-Strategy-for-Long-Term-Energy-Storage-in-UK-August-2020.pdf

Benefits of long duration storage

Long duration storage is a valuable source of low carbon flexibility which can make a significant contribution to achieving the dual goals of decarbonisation and security of supply at least cost. The key benefits are:

- Increased renewable output by reducing the need for curtailment of renewables due to network constraints or at periods of low demand,
- Increased system stability and resilience by providing the full range of flexibility resources for power, frequency, inertia, voltage, short circuit levels and restoration,
- Whole system savings by reducing the need for additional network and generation capacity,
- Lower costs (especially pumped storage) than other long duration flexible technologies.

Research performed by Carbon Trust and Imperial College London in 2016[6] set out the potential reductions in cost that could be delivered by effective competitive markets for flexibility, estimating this at between £17-40 billion by 2050 and around £8 billion per year up to 2030. Analysis by BEIS for the Energy White Paper[7] estimated that benefits from a decentralised smart energy system could be £12 billion by 2050.

[6] Imperial College and Carbon Trust (2016) Can storage help reduce the cost of a future UK electricity system?
[7] BEIS (2020), 'Modelling 2050: Electricity System Analysis', https://gov.uk/government/publications/ modelling-2050-electricity-system-analysis

4. Barriers to investment in new long duration electricity storage

Investment in long duration storage can reduce both the cost and risk of electricity system decarbonisation. Despite an evident need for these resources, and favourable long-term economics, these projects are not currently able to attract investment from capital markets. For potential storage investors, it comes down to two main and interrelated uncertainties, namely:

- uncertainty about future project revenues.
- uncertainty about the future market landscape.

These factors make it difficult for investors to gain the confidence necessary to raise and allocate large capital sums. This is not specific to long duration storage, it also applies to other high-value decarbonisation technologies such as nuclear, CCUS and hydrogen generation. The fact that the 4GW of existing pumped storage hydro projects in Great Britain were all built when the industry was state owned illustrates the challenges involved in realising this kind of investment on an entirely merchant basis.

What are investors seeking?

Investors and lenders for any type of new electricity (or any other) infrastructure project will seek to balance the following factors:

- the certainty of revenue including:
    - the percentage of contracted revenue throughout the operational life of the project,
    - the type of contracted revenue e.g., the creditworthiness of the counterparty,
- the asset type – whether it is a proven or emerging technology/type of asset,
- the amount of pre-construction cost at risk of not proceeding,
- the duration of construction e.g., 5-8 years for PSH,
- the certainty of costs for construction and during operation,
- whether the project IRR is acceptable for the risks involved.

To attract finance, electricity generation or storage projects with high development and construction costs and long asset lifetimes (such as nuclear, CCUS, PSH or CAES) will need to provide investors with confidence that future revenues will recover these costs and provide a return. Future revenue uncertainties will either increase the cost of capital or block investment altogether.

The issues that investors in long duration storage will want to be addressed are:

- **Policy confidence** – policy support for long duration storage, which recognises the value and the need for this resource,
- **Revenue confidence** – for a percentage of long-term revenue to be contracted or have revenue guarantees, and

- **Market confidence** – for future electricity market designs to enable long duration storage to compete equally with other technologies.

In recent years, new generation and storage projects with lower development and construction costs and shorter asset lifetimes (such as batteries, gas engines, and diesel generators) have been able to attract new investment from investors willing to accept significant merchant risk. But these risks are offset through fast development and construction times accompanied by greater confidence about near term market dynamics and price signals.

High value, long development timescale projects such as long duration storage cannot only rely on these near-term price signals for investment. Given their much longer lifetimes they are also much more exposed to future market design changes. Furthermore, by capturing market share, these merchant projects with shorter asset lifetimes will reduce the available revenue for lower unit cost resources such as long duration storage.

Policy confidence

The UK's Net Zero legislation, together with the Prime Minister's 10-point plan, the Energy White Paper, and the December 2020 UK National Commitment to reduce emissions by 68% by 2030, all provide confidence in the Governments ambition to decarbonise at pace.

The White Paper sets out the Government's plan to achieve a low cost, reliable, low carbon electricity system, to be composed predominantly of renewable electricity. This means renewables need to be complemented by technologies which provide power when the wind is not blowing, or the sun does not shine.

However, while the White Paper recognises the need for flexibility from long duration storage and other low carbon flexible technologies, there are no specific market mechanisms to ensure this can be delivered. The White Paper notes that further work is planned during 2021 to update the Smart Systems plan which may be expected to address policies for long duration storage.

Revenue confidence

The main sources of revenue confidence for low carbon generation projects are from Contracts for Difference (CfD), and previously from the Renewable Obligation or Feed-in-Tariff. These are not available to storage providers. GB electricity market revenues for long and short duration storage are available through four main avenues, namely:

- 'Twinning' agreements
- Wholesale markets
- Capacity markets
- Balancing markets run by the ESO, which include ancillary service markets

Storage projects will generally seek to build a merchant revenue stack from these different revenues. These are discussed in more detail below:

‘Twinning agreements’

‘Twinning agreements’ or storage capacity purchase agreements may be available between storage providers and either an energy supplier or renewable generator seeking to obtain ‘firm’ power for their own contractual commitments with their customers.

While these contracts could potentially provide a valuable source of revenue certainty to storage developers, energy suppliers or generators have little incentive to commit to long-term contracts for assets that are several years away from operation.

Suppliers are also facing an uncertain future from rapidly changing technology costs, customer demand, competition, and an unknown future market design and dynamics. Given these uncertainties, they are likely to want to continue to balance their customer commitments through existing wholesale and balancing markets.

Wholesale markets

Wholesale markets should provide generators and storage developers with price signals to help decide whether to invest in new capacity. They provide an opportunity for long duration electricity storage to arbitrage between high and low prices, particularly when renewables are not available.

For storage resources, arbitrage revenues are unlikely to offer sufficient certainty on their own – they need to be supported by other market revenues.

Looking forward, increased deployment of zero marginal cost renewables means that future wholesale prices will increasingly be close to zero or negative, making new investment in flexible generation or storage difficult to justify.

Capacity market (CM)

The CM aims to ensure resource adequacy at lowest cost and is open to generators, demand-side response, and storage technologies for one year ahead (T-1) and four year ahead (T-4) auctions. The capacity market competitions award 1, 3 or 15-year contracts to pay for firm power (MW) where providers must be available to respond with their agreed generation volumes or load reductions when called on by the ESO at times of system stress. All technologies are de-rated to an extent depending on their likely availability at these times.

The capacity market does not incentivise flexibility services, nor factor in carbon benefits. This means that existing fossil-fuel generators will have an advantage over new low carbon investments with high capital costs. In addition, the T-4 auction is not suitable[8] for projects where construction is greater than four years, which will exclude long duration storage projects with long construction times, such as pumped storage hydro.

Since it began, the capacity market clearing T-4 price has ranged between £8-22/kW. These levels are insufficient on their own to support new investments, which will need to be supplemented by revenues from other markets e.g., wholesale, and balancing markets, where revenues are not guaranteed.

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[8] Projects with longer construction periods can participate in the CM market but would need to undertake construction risk for the period until the project reaches the T-4 deadline and then take the risk that an acceptable CM would be obtained.

Balancing markets

These markets are run by the ESO to manage supply/demand imbalances and to procure ancillary services for system frequency and voltage stability, including reserves for all credible system failures.

Historically, power system balancing services have been provided by synchronous fossil-fuel generators designed to offer these services alongside power output. Non-synchronous generators such as wind, solar and interconnectors are not currently designed to offer services such as inertia and voltage support.

Flexibility or ancillary service markets run by the ESO have the following features:

- Many of the flexibility services are provided by synchronous generators or, in the case of voltage support, by network companies at no additional charge, so the market requirements are difficult to predict,
- The markets are mostly for short term contracts, mainly for day or month ahead,
- Markets are segmented into separate products and procurement processes meaning that is difficult to win contracts across all markets at the same time,
- Many of the flexibility services are determined by capacity constraints on the transmission network which can be difficult to predict, and
- Demand for some flexibility services may be substituted by construction of new transmission networks. The evaluation of these projects may not consider whether a flexibility resource such as storage might provide a lower cost alternative.

The value of the balancing market is expected to increase significantly over time as more flexibility resources are needed. But current balancing markets provide few long-term price signals and little long-term revenue certainty. The ESO's forward plan sets out an ambition for 'competition everywhere', and their strategy is to increase the use of short-term auctions e.g., day-ahead, for more ancillary services. This short-term focus does not provide the long-term price signals needed by long duration storage projects.

The failure of the balancing markets to offer long-term price signals for flexibility resources (alongside gaps in other market mechanisms) presents a barrier to investment and is likely to lead to higher than necessary costs in these markets as otherwise economic investments are deferred. This environment is better suited to the development of more costly short-term storage solutions such as batteries which can access these markets more readily.

Overall, this revenue environment is particularly challenging for long duration storage developers despite having economic projects. Long-term twinning agreements are not available, future wholesale market prices are expected to fall, capacity market contracts are not available before start of construction, and balancing market design favours other solutions. This is not just a challenge for long duration storage developers, it will also apply to other flexibility providers such as hydrogen or CCUS generators, although in the latter case BEIS seems willing to provide CfD contracts, thereby de-risking revenues.

Market design confidence

Electricity markets have evolved since privatisation, from the initial 'Pool' arrangements which rewarded generators for available capacity, but which led to high generation costs, to the supplier-led wholesale and balancing markets of today. Recent years have seen overlays of new market mechanisms and subsidies to drive rapid growth in renewable and other low-carbon generation.

The independent Helm Energy Review in 2017[9] suggested a future landscape where the growth in renewables would result in future wholesale market marginal costs moving towards zero. Demand would become more active and storage would be needed alongside subsidy-free renewables. Storage technologies would reduce the problem of meeting peaks in demand and dampen wholesale price volatility and wind intermittency.

The capacity market was created to provide capacity investment signals, but it does not provide signals for low-carbon capacity, for long-duration flexibility, or cater for projects with longer construction periods.

There are several reform initiatives (led by BEIS, Ofgem, and the ESO) underway to improve efficiency of electricity markets, including:

- Retail market competition - smart meter rollout, settlement reform; enabling greater competition in retail markets,
- Distributed energy – enabling access to wholesale/balancing markets by a wider group of market participants,
- Smart systems plan – addressing future flexibility, including distribution and storage initiatives,
- Low carbon generation – incentivising delivery through CfDs for renewables, RAB model for nuclear, CCUS incentive regime

All of these will impact the available future markets and price signals for long duration storage. For example, distributed energy resources such as batteries and demand response are expected to compete over short duration peak demand periods with highly volatile price signals. But these resources have limited operating durations – and will need to be replicated at additional cost to be available for longer duration demand shoulders or off-peak periods. Without clear market signals, these short-duration flexibility assets may cannibalise revenue streams open to more efficient long duration storage and have the unintended consequence of crowding out this flexibility resource.

Carbon Capture Utilisation and Storage (CCUS) - As mentioned earlier, the 2020 Energy White Paper makes clear that flexible technologies will be needed when renewable output is not available. CCUS is one of these potential future technologies, together with hydrogen-fuelled generators. Both these technologies are at early stages of development and face similar financing challenges to long duration storage.

9 https://www.gov.uk/government/publications/cost-of-energy-independent-review

BEIS is currently seeking views on a potential revenue support model for power CCUS. This model[10] proposes that top up payments are made in addition to revenues earned from wholesale markets, ancillary services, and capacity markets. These additional payments would be a fixed amount for generator availability and a variable amount which would enable the plant to operate in a dispatchable mode alongside other technologies.

The availability payment is designed to provide a revenue floor and provide confidence to investors. The variable payment should incentivise a CCUS generator to react to market prices i.e., to generate at times of high prices and demand and reduce output at times of low prices and demand. The variable price would be set at a level such that the CCUS generator would displace fossil-fuel generation but not low cost, low carbon generation capacity such as renewables or nuclear. The model does not appear applicable to long duration storage which has different operating characteristics and costs.

<u>Enabling a high renewable power system</u> - alongside the White Paper, BEIS have called for evidence about changes needed to future electricity market design. This paper highlights that CfD supported renewable generators do not currently respond to market price signals and falling wholesale marginal prices are expected to impact future CfD support costs.

Options are being considered to expose renewable generators to more market price signals and requirements to provide flexibility (including co-location with storage). But co-location of storage with renewables is not always practical or the most cost-efficient option. The provision of long-term price signals to stand-alone long duration storage resources is not addressed.

Overall, market design principles under consideration for the development of energy transition assets appear to cover a wide spectrum, ranging from agreements between market participants to Government guaranteed floor prices to secure low-cost financing. Clarity over future market design will be important to secure investment in new assets.

Looking forward, if the forecast £8 billion a year savings for 2030 are to be realised, then a 'whole market' approach will be needed to ensure that the market price signals are driving the most economic long-term solution. This will require clear leadership of market reforms, clarity over roles and responsibilities, and effective co-ordination.

Uncertainty about the future direction and speed of market design presents a barrier to the development of long duration storage and other flexible generation projects.

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946561/ccus-business-models-commercial-update.pdf

5. Alternative market mechanisms

To attract new investment, future energy markets need to provide both long- and short-term price signals to address the expected shortfall in flexibility assets. They should enable the most economic long-term solutions to achieve Net Zero whether that be short or long duration storage, or other flexibility solutions.

There appear to be five main alternative future market models that could be adopted to address the current investment barriers and attract investment into the most economic flexibility solutions. These are:

1. **Maintain existing market arrangements** – this would retain the existing price signals and market framework.
2. **Reform existing capacity and balancing markets** to give clear flexibility investment signals.
3. **A new flexibility obligation** for intermittent generation, requiring the provision of flexibility services, either through self-provision or through third-party contracts.
4. **A new 'income floor' flexibility market** for long duration storage and other flexibility resources, offering income stabilisation to provide investor confidence.
5. **Regulation of long duration flexibility assets** through a regulated return on a Regulated Asset Base (RAB).

These options are discussed in more detail below and are then evaluated in the following section.

1. No change - Maintain existing market arrangements

As today, new long duration flexibility providers would base their investment case on future forecasts of a stack of potential revenue streams. These may include revenues from wholesale market trading, capacity market contracts, and from balancing and ancillary service contracts with the ESO. The wholesale market and the balancing mechanism would continue to focus on optimising short term price signals.

Key advantages would be that:

- this model would not require reform to existing market arrangements,
- it would maintain the known market dynamics for investors,
- ongoing initiatives should improve liquidity and competition in retail and short-term balancing markets.

Key disadvantages would be that:

- the various elements of the revenue stack are difficult to forecast and long-term contracts are either not available or are of limited scale,
- potential funders of major capital projects find it challenging to gain confidence in a merchant revenue stack that is out of step with the longer funding, construction, and operational timescales of large-scale flexible generation or storage projects,

- The absence of long-term price signals means that larger scale storage is being crowded out of these markets by short-term storage or flexibility solutions which have lower up-front capital costs but higher lifetime costs than long duration storage. This will lead to higher overall energy prices for consumers.

The current merchant market model presents a significant barrier to the development of large-scale, long duration energy storage projects.

2. Reform existing capacity and balancing markets

This approach assumes that existing market arrangements are modified to provide additional revenue certainty to long duration storage projects.

The following key reforms are suggested:

- **Capacity market redesign** to include a long-term price signal for low-carbon flexibility resources. For example, this could be designed to incentivise long duration, low carbon flexibility resources that could provide power, stability, frequency, and voltage flexibility. The capacity market lead time would need to increase from 4 years to allow long duration storage to participate.
- **Balancing market redesign** to incentivise increased operation of low carbon long duration flexibility resources in existing balancing markets through a suitable price signal.
- **Whole system optimisation** – to allow low carbon long duration flexibility from storage, generation, or demand resources to compete directly with new transmission network reinforcement projects. This could be enabled through reform of the ESO Network Options Assessment regime to provide long term congestion mitigation contracts as a lower cost option to network investment.

Wholesale and retail market arrangements would be unchanged. The low carbon CfD support mechanisms are assumed to continue as planned.

Key advantages would be that:

- it would provide some new long-term price signals for new low carbon flexibility investments,
- it would open up a new ‘whole system’ market that could be accessed by flexibility resources including storage.

Key disadvantages would be that:

- it requires significant change to current capacity and balancing market arrangements, which would be complex and will take time to implement. Changes such as prioritising low-carbon resources would need to address legacy commitments, including to EU State aid rules,
- there are significant locational differences in flexibility resource needs, and the capacity market would not reflect this, unless it was redesigned accordingly. This could lead to reliance on short-term price signals,

- revenues would still be obtained from stacking across different markets with different procurement timescales and different contract lengths,
- short- and long-term price signals from capacity and balancing markets would still be subject to the volatility of market dynamics, with associated revenue uncertainty.

These reforms may be able to offer some longer-term price signals to long duration storage projects, but significant uncertainty would remain.

3. A new flexibility obligation for low carbon generators

This approach addresses the decline in flexibility resources that are currently mandated from fossil-fuel generation by requiring these services to be provided by renewable generators. This could be enabled through an obligation on either energy suppliers or on generators, requiring them to provide flexibility services for power output, frequency, inertia, and voltage. This could be applied to all, or only to new renewable generation.

All other market mechanisms would continue unchanged. The balancing market would optimise these flexibility resources in the short-term markets.

Key advantages would be that:

- it could provide some 'market-led' long-term price signals for new low carbon flexibility investments. Non-flexible generators (or suppliers) would be incentivised to sign 'twinning agreements' with flexibility providers,
- the existing balancing markets would optimise the cost of flexibility services.

Key disadvantages would be that:

- this approach is reliant on suppliers and generators being able to commit to long-term investment contracts for long duration flexibility. This is unlikely to be possible. Suppliers will seek to contract on a short-term basis and generators will seek contracts that align with their individual revenue horizons. This approach may lead to increased procurement of less economic short-duration storage, resulting in higher overall energy prices for customers,
- this would distort the market signals for renewable generation. By mandating a requirement for all renewable generation (existing and new) this will impose an additional unexpected cost that could undermine confidence in renewable generation investments,
- a market-wide mechanism is likely to lead to an excess of flexibility resources being procured with an associated cost penalty being passed to investors and consumers,
- a market-wide mechanism may not be efficient, as it will not signal the location or type of flexibility resources that are needed,
- the impact of this intervention across balancing, wholesale and capacity markets, and across technologies would be unclear, adding to market and revenue uncertainty,
- it will require significant change to existing market arrangements which will be complex and take time to implement.

In theory, this obligation could directly replace the flexibility capabilities currently provided by fossil fuel generators through contracts with flexibility providers. But it will be difficult for suppliers or generators to make long-term commitments for long duration storage.

Overall, it will be complex and difficult to implement. It is likely to lead to higher costs for consumers and may undermine incentives to develop renewable generation.

4. Income floor

This model proposes that a new flexibility market could be overlaid on the existing wholesale, balancing and capacity market structure. The aim of this market would be to provide long-term income stabilisation to new low carbon flexibility assets.

An existing mechanism used for a similar purpose is the CfD market - these long-term contracts are procured during regular tender rounds. They enable a renewable generator to stabilise its revenues at a pre-agreed floor level (the Strike Price) in £/MWh for the contract duration. CfD top-up payments above wholesale market prices are funded by electricity suppliers and ultimately by customers. This approach appears unlikely to be suitable for storage investments as it would incentivise an inefficient outcome i.e., the storage asset could seek to maximise output rather than respond to market signals in an efficient manner.

A key feature of flexibility resources is that availability is valued as well as utilisation. Flexibility resources will often be held in reserve such that they may be called on in the event of sudden changes to generation or demand, or network failures. Also, requirements for different types of flexibility resource e.g., response, reserve, reactive power, or inertia, will differ significantly for the system operational characteristics over time, and by location. A new flexibility market (income floor) would allow procurement of flexibility resources to be targeted to meet expected long-term temporal and locational requirements.

A key issue to be addressed in the design of a revenue stabilisation mechanism for long duration storage such as pumped hydro is that the business will purchase electricity for pumping and receive revenues from electricity sales and flexibility services. The income floor stabilisation mechanism should incentivise the asset owner to participate in existing markets to optimise costs and revenues in the most efficient way and deliver these benefits to consumers.

Because of the complexity involved in designing a revenue stabilisation mechanism that accounts for the variability and unpredictability of the costs involved in operating storage assets, stabilisation based on income after electricity purchases[11] appears most appropriate for flexibility assets. This could be a defined as an income floor, perhaps for a 20-year term. If the annual income fell below the floor level, then recovery of top up payments to this level could be socialised similar to CfD costs. This should provide confidence to investors in these assets and enable lower-cost debt financing.

All other market mechanisms would be unchanged. The wholesale and balancing market would optimise these resources in short-term markets. While a corresponding income cap could be

[11] Annual revenues from electricity markets less electricity purchases (or cost of sales).

introduced alongside a floor, this could disincentivise the optimisation of the asset and cause market distortions. It is also likely to be more complex to design and implement.

The Cap and Floor regime currently used to stabilise new interconnector revenues guarantees a long term regulated revenue floor and a cap on investor return. The cap and floor levels are derived by Ofgem from capital and operating costs and allowed return. The cap is in place to protect consumers from the risk of excessive outturn profits from this ex-ante regime.

Applying this cap approach to a merchant storage asset would require a gain share mechanism to be developed to incentivise efficient trading operation. It may be difficult to design a regulatory regime that appropriately incentivises the asset owner to optimise performance e.g., an operator may seek to optimise against regulatory incentives instead of optimising market performance. A cap may be unnecessary because the risk of excessive profits will be mitigated by competition for revenues in short term markets and through additional long duration resources being triggered through regular tender rounds.

It is suggested that an income floor value would be identified for individual long duration flexibility resources through a competitive tendering process. It could be similar to a CfD tender except that instead of a strike price for MWh of output, the contract would be for an annual income floor value in £m/MW terms, conditional upon the availability of flexibility resources including MWhs of storage, MVArs of reactive power, and a frequency response/inertia capability. Due to the scale and lead-time associated with these assets, the number of participants in tender or gateway processes may be limited. If this is the case, then it may be appropriate for a floor value to be set by BEIS or Ofgem through an administrative process similar to that used for interconnectors.

Key advantages would be that:

- certainty about a minimum income level would enable investment funding at a lower cost of capital and a lower cost to customers,
- lower cost longer duration flexibility expenditure would reduce costs to consumers,
- the design of the tender process would enable these resources to be targeted where needed at least cost,
- the tenders could be open to all technologies meeting the specification, allowing alternative solutions from demand, and generation to be considered,
- the income floor would be derived through a commercial tender, ensuring that bidders seek to optimise the floor level with other elements of the revenue stack, providing a fair balance of risk between investors and customers.

Key disadvantages would be that:

- this would require the development of a new market mechanism for a complex mix of resources, which may give rise to investor uncertainty until the mechanism is proven,
- the market would need to differentiate between low carbon flexibility resources and fossil fuel flexibility resources.

An income floor model provides revenue certainty and should attract investment capital for the development of large-scale, long duration storage investments.

5. A regulated return

This would provide a long-term regulated revenue payment for long duration flexibility resources identified through a competitive tendering or gateway process. All other market mechanisms would be unchanged. The asset owner would optimise these resources in short-term markets.

This is most similar to the Regulated Asset Base (RAB) model being considered for major new nuclear projects, where a long term regulated return would be provided to investors to help mitigate construction cost risks. This model proposes that Ofgem will regulate returns ensuring a fair sharing of risks between customers and investors.

If applied to long duration storage, the RAB model could give a guaranteed return on investment assuming that operational performance obligations were met. Investors would assume construction and operation risk and could be incentivised through a gain/loss sharing mechanism to optimise the performance of the asset in the merchant revenue stack.

Key advantages of the RAB model would be that:

- revenue certainty would enable investment funding at a lower cost of capital and a lower cost to customers,
- lower cost longer duration flexibility assets would reduce costs to customers,
- a tender process would enable these resources to be targeted where needed,
- the RAB ongoing regulated returns would be derived through a regulatory assessment.

Key disadvantages would be that:

- this would require the development of a new regulatory regime for long duration storage. It may be difficult to design a regulatory regime that appropriately incentivises the asset owner to optimise performance, ensuring efficient dispatch e.g., an operator may seek to optimise against regulatory incentives instead of optimising market performance,
- due to information asymmetry about regulated assets, a higher degree of risk may be taken by consumers,
- the market would need to differentiate between low carbon flexibility resources and fossil fuel flexibility resources.

A regulated revenue model provides revenue certainty and should attract investment capital for the development of large-scale, long duration storage investments.

6. Evaluation of alternative market models

This section provides a qualitative evaluation of how these alternative market models for flexibility resources could impact the development of long duration storage projects. The evaluation considers the following criteria:

- **Net Zero policy fit** – will the market design fit with Government policy aims for decarbonisation and security of supply for Net Zero?
- **Whole system** – will the design deliver the right flexibility resources in the right place, at the right time, for the optimum whole system solution?
- **Investor confidence** – will the design provide confidence to investors, including the risk mitigation necessary to secure low-cost debt finance?
- **Efficient Market Operation** – does the model enable efficient dispatch in electricity markets? Will it minimise market distortion?
- **Extent of reform** – what change is needed to the existing market framework? Are there any unintended consequences? Is it deliverable and how long will it take?
- **Customer benefit** – will customers benefit from lower costs than might have been the case without intervention?

The following table provides a high-level summary evaluation of the alternative market models against these criteria.

Table 1: Evaluation of alternative market models

	1.No Change	2.Market reform	3. Flexibility obligation	4. Income floor	5. Regulated return
Net Zero Policy fit	No	Yes	Yes	Yes	Yes
Whole system	No	Some	Some	Yes	Yes
Investor confidence	Low	Medium	Low	High	High
Efficient Market Operation	Medium	High	High	High	Medium
Extent of reform	Low	High	High	Medium	Medium
Customer benefit	No	Yes	Some	Yes	Some

Overall, this comparison of different market models suggests that an income floor for long duration flexibility would be the most effective way of achieving the Government's Net Zero policy aims. These options are discussed further below.

1. No change

This approach assumes no significant change from the current market model. Long duration storage will rely on a stack of merchant revenues across mainly short-term markets, with few (and uncertain) long-term price signals. This will impact negatively on investor confidence and projects are unlikely to be able to be financed. Policy aims and consumer benefits in terms of lower cost decarbonisation are unlikely to be realised.

This model retains the existing market design. It maintains a technology discrimination in that fossil-fuel generators are obliged to provide flexibility capabilities without additional charges, but renewable generators are not.

2. Market reform

This approach assumes that changes are made to the capacity and balancing markets to incentivise the provision of low carbon flexibility resources and long-term 'whole system' contracts are available to attract long duration flexibility resources. This should improve the long-term revenue confidence for investment capital to be secured. However, this confidence will be limited due to the uncertainty about securing revenues through capacity, wholesale, balancing and long duration flexibility markets.

Significant redesign of all markets will be required, which will impact other most other market participants and is likely to take several years to implement. Long duration storage will compete for contracts alongside other technologies to ensure the most efficient outcome is obtained. This approach should allow policy aims and consumer benefit to be realised.

3. Flexibility obligation

This approach assumes that fossil fuel flexibility resources are replaced by long duration storage and other flexible technologies through a new low-carbon flexibility obligation on renewable suppliers or generators, requiring them to procure or install this capability for the lifetime of their assets. These resources would then participate in existing wholesale, balancing and capacity markets. This should mean that renewable generators will seek to sign 'twinning agreements' with long duration storage developers, thereby providing the revenue confidence necessary to secure investment.

This obligation is unlikely to deliver investment in long duration storage as neither suppliers nor generators are likely to be able to enter into long-term contracts with flexible resources. If implemented, it would have a significant impact on the costs of existing and new renewable generators and additional costs would probably have to be funded by existing support schemes. The key disadvantage of an industry-wide approach is that it would be difficult to target the flexibility resources to where they are most needed, and this could lead to oversupply and additional costs. While being aligned with policy aims, there is a risk that costs to customers would be higher than necessary.

4. Income floor

This approach assumes that long-term low-carbon flexibility solutions are specified in a new long duration flexibility procurement process. The requirements would be specified by the ESO and the most cost-efficient whole system solutions would be gained through a competitive tendering process. The tendering process would seek bidders to propose a Government-backed income floor for their project, which would only be required if revenues from capacity, wholesale and balancing markets were below this level. This approach should provide the necessary investor confidence to attract finance.

This approach is an overlay on existing market arrangements and is technology neutral. It should be able to deliver the optimum whole system resource solutions through existing markets, aligning with policy aims and delivering benefits for consumers.

5. Regulated revenue

This approach assumes the revenue is regulated as a return on assets. This approach can provide a high degree of investor certainty and deliver the flexibility assets. It could use a competitive process to identify the levels of return and gain some efficiency benefits.

However, the key disadvantages are that it may provide weak incentives for optimising performance in electricity markets and may distort competition and efficient dispatch in these markets. It is likely to require technology-specific decisions to be made. Overall costs to consumers may be higher as a result.

7. Conclusions and recommendations

Conclusions

To reach renewable electricity generation targets for Net Zero, flexible power, frequency, inertia, and voltage resources currently provided by fossil fuel power stations will need to be replaced by the lowest cost low carbon alternative including long duration storage. But the current wholesale, capacity and balancing markets do not provide effective price signals for investment in these assets. Furthermore, potential revenues are being cannibalised by market designs which drive investment in more expensive technologies when whole system costs are taken into account.

Future electricity markets will need to give both long- and short-term price signals for investment in the resources that are needed, and to optimise operation. If they do not provide clear pricing signals then the market risks becoming increasingly inefficient, putting Net Zero and security of supply at risk, and consumers will be paying more than they need to.

This paper has considered alternative market models for delivering low-cost long duration storage including regulated asset models, market obligations and reform of existing markets. It has concluded that a new market for the provision of long duration flexibility services appear to be the best solution. This new market would seek bids from developers for a long-term Government-backed income floor for their provision of defined flexibility capabilities. It would be overlaid on existing capacity, wholesale and balancing markets, allowing them to continue to optimise resource provision in the short term.

Technology fairness and widening market access will be important. This paper has considered how flexibility markets might be designed in a technology neutral way, allowing long and short duration storage technologies to compete fairly with each other, and with other providers of flexibility.

The suggested market design would allow these new long-term flexibility providers to seek a net income floor guarantee for their solution, thereby providing security for investors. This floor would only become active if the resources were not able to recover these revenues from other markets.

Recommendations

Filling the 'flexibility gap' will be critical for enabling decarbonisation and utilising flexible technologies in the most efficient way, the following initiatives are suggested:

- **Call for evidence** - BEIS and Ofgem should issue a call for evidence to industry about the potential costs and benefits from long duration storage, and the barriers to investment and how these could be addressed.
- **Identify flexibility needs and benefits** – BEIS and Ofgem should ask the ESO to identify major alternative long-term 'whole system' flexibility needs and benefits and prepare a specification for procurement of these long-term flexibility resources. This should define type and location of flexibility resources needed, full-output duration, delivery year, and so on. This might be similar to the approach used by the ESO to identify black start resources in different regions.

- **Design a new flexibility market** – BEIS and Ofgem should explore how the income floor could work to enable investment in long-term flexibility solutions. This should define the parameters for the selection of resources e.g., flexibility or storage volumes, costs, operational durations and delivery timescales, and how particular solutions may be selected.
- **Consider responsibilities and processes for future delivery** – BEIS should consider the responsibilities and resources for identifying and specifying flexibility needs, market operation, and ongoing performance and compliance.

Such initiatives should commence through the Smart Systems and flexibility plan due to be published later in 2021. They should make a valuable contribution to the UK meeting its Net Zero targets while ensuring least cost and secure electricity supplies.

Riverswan Energy Advisory

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