Department for
Business, Energy
& Industrial Strategy

Facilitating the deployment of large-scale and long-duration electricity storage: call for evidence

Closing date: 28 September 2021

July 2021

Any enquiries regarding this publication should be sent to us at: smartenergy@beis.gov.uk

Executive Summary

In April, the UK government announced a world-leading climate change target (the sixth Carbon Budget) to reduce emissions by 78% by 2035 compared to 1990 levels, on a pathway to net zero greenhouse emissions by 2050. Our success in achieving this will rest on a decisive shift away from unabated fossil fuels to using clean energy. Decarbonising our electricity supply is a key requirement for enabling an economy-wide reduction in emissions, and good progress has been made to date. In 2020, around 60% of our electricity generation was from low carbon sources.[1] Rapid integration of low carbon technologies is required to meet the net zero target. Within the decade, offshore wind will produce more than enough electricity to power the equivalent of every home in the country, based on current electricity usage, with our previous 30GW target boosted to 40GW.

To achieve this, we will need to make the best use of all available resources connected to the energy system. Flexibility, the ability to shift, in time or location, energy consumption or generation to balance supply and demand, will be essential. The need for flexibility will rise as we increase the volume of variable electricity (e.g. wind and solar power) on the system and electrify energy demand, particularly in heat and transport. As we transition to a greener economy, we will need to replace the flexibility currently provided by power generated from fossil fuels with low carbon sources of flexibility.

This call for evidence considers the role of large-scale, long-duration electricity storage in facilitating a net zero energy system, and seeks information on approaches that could be taken to support the deployment of more storage. We know that electricity storage is an essential source of low carbon flexibility, but evidence suggests that it faces barriers that limit its deployment. Electricity storage can help to integrate high volumes of renewable generation, and provide a range of services needed to manage a low carbon system. It can also play a key role in the efficient and cost-effective delivery of security of supply. Storage, across days, weeks, and months, could greatly reduce the costs of meeting net zero by storing excess low carbon generation for longer periods. Deploying smart and flexible technologies such as storage, heat pumps in buildings, and interconnection, could unlock savings of up to £10 billion per year by 2050.[2]

In this paper we discuss the role of large-scale, long-duration storage, that store power when there is a surplus of generation, and release it during generation shortages. We discuss the duration of storage these technologies can provide, and the benefits to the system. Whilst longer duration storage can provide system benefits, there is uncertainty as to how much is required. We also ask for evidence on the existing storage pipeline that could be built over the next 5 years. We then outline the challenges we have identified through recent engagement. A combination of factors including high capital costs, long lead times and, in some cases, lack of

[1] BEIS (2020), Energy Trends, table 5.1, https://www.gov.uk/government/statistics/%20electricity-section-5-energy-trends

[2] BEIS (2021), Smart Systems and Flexibility Plan, 2021, Appendix I: Electricity System Flexibility Modelling, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

track record associated with particularly novel technologies, alongside a lack of forecastable revenue streams underpins a financing challenge. As a result, large-scale, long-duration storage is not currently attracting enough investment and is not being built at the scale that may be needed to support the transition to a greener economy.

Changes within current markets may affect the investability of storage, and this call for evidence considers upcoming reforms, and asks for information to help assess the extent to which these changes could help more large-scale, long-duration storage to deploy. Beyond this, given the role large-scale, long-duration can play in driving cost-effective decarbonisation and maintaining energy security, we are seeking evidence on new mechanisms that may be necessary to address the financing challenge. We ask for information on options for addressing these barriers, including whether a bespoke de-risking mechanism to help bring forward investment in large-scale, long-duration is needed.

Information that we receive through this call for evidence will help us to:

- establish the need for large-scale, long-duration storage on the future power system;
- collect evidence on the potential pipeline of storage projects;
- determine whether there is a case for intervention;
- consider what sort of mechanism would be most appropriate; and
- identify appropriate and cost-effective mechanisms for intervention and associated risks.

Alongside this call for evidence, we have commissioned analysis to model and quantify the potential system need for large-scale, long-duration storage. This information will be used to help inform our decisions on whether further intervention is needed to support its deployment.

Contents

General information

Why are we issuing a call for evidence?

The government is seeking evidence on how to facilitate the deployment of large-scale, long-duration electricity storage.

Electricity storage is an essential technology for decarbonising the energy system, and large-scale and longer duration electricity storage could provide specific benefits, such as storing renewable power and discharging it over periods of low wind. Evidence from engagement throughout 2020 with academics and industry suggests that large-scale and long-duration electricity storage faces market challenges that mean it may struggle to deploy at scale.

This call for evidence seeks to gather information to help us understand in more detail the barriers within the current market, to inform the design of any potential future market intervention, and to map out risks that may be associated with potential interventions. Alongside this call for evidence, we are commissioning analysis to quantify and understand in more detail the system needs for large-scale and long-duration storage.

Consultation details

Issued: 20 July 2021

Respond by: Midnight, 28 September 2021

Enquiries to:
Smart Energy Team
Department for Business, Energy and Industrial Strategy
1 Victoria Street,
London
SW1H 0ET

Email: smartenergy@beis.gov.uk

Consultation reference: Facilitating the deployment of large-scale and long duration electricity storage: call for evidence

Audiences: We are keen to hear from storage developers, generators, energy retailers, network operators, technology suppliers, flexibility providers, industry bodies, local enterprise partnerships, non-governmental organisations, academics, and anyone else with an interest in this area.

Territorial extent:

This call for evidence seeks views on the market for large-scale and long duration electricity storage in Great Britain (GB). This call for evidence therefore applies across GB, and to participants in GB markets.

How to respond

Your response will be most useful if it is framed in direct response to the questions posed, and with evidence in support wherever possible. Further comments and wider evidence are also welcome.

We encourage respondents to make use of the online e-consultation wherever possible when submitting responses as this is the government's preferred method of receiving responses. However, responses emailed to smartenergy@beis.gov.uk and hardcopy responses sent to the BEIS postal address will also be accepted. Should you wish to submit your main response via the e-consultation platform and provide supporting information via hard copy or email, please be clear that this is part of the same response to this call for evidence.

Respond online at: https://beisgovuk.citizenspace.com/clean-electricity/deployment-large-scale-long-duration-storage-cfe

or

Email to: smartenergy@beis.gov.uk

Write to:

Smart Energy Team,
Department for Business, Energy and Industrial Strategy
1 Victoria Street,
London,
SW1H 0ET

When responding, please state whether you are responding as an individual or representing the views of an organisation.

Confidentiality and data protection

Information you provide in response to this consultation, including personal information, may be disclosed in accordance with UK legislation (the Freedom of Information Act 2000, the Data Protection Act 2018 and the Environmental Information Regulations 2004).

If you want the information that you provide to be treated as confidential please tell us, but be aware that we cannot guarantee confidentiality in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not be regarded by us as a confidentiality request.

We will process your personal data in accordance with all applicable data protection laws. See our privacy policy. The government has been working closely with Ofgem to enable a joined up understanding of the policies in relation to large-scale, long-duration electricity storage technologies. **Responses gathered through this call for evidence will be shared with Ofgem, and this information will be used by the government and Ofgem to develop future policy under the Smart Systems and Flexibility Plan.**

We will summarise all responses and publish this summary on GOV.UK. The summary will include a list of names or organisations that responded, but not people's personal names, addresses or other contact details.

Quality assurance

This consultation has been carried out in accordance with the government's consultation principles.

If you have any complaints about the way this consultation has been conducted, please email: beis.bru@beis.gov.uk.

Strategic context: The role and value of large-scale and long-duration electricity storage in a net zero energy system

Flexibility is the shifting, in time or location, of energy consumption or generation to balance supply and demand. The need for flexibility will rise as we increase the level of variable, non-dispatchable generation (such as solar and wind power) on the system. Traditionally, fossil fuels have provided the majority of flexibility to the system; to achieve net zero by 2050 low carbon sources of flexibility will need to deploy rapidly to replace these. Deploying smart and flexible technologies such as short-duration storage, smart heating systems, smart electric vehicle charging and interconnection with other countries, could unlock savings of up to £10 billion per year by 2050.[3] This analysis did not explicitly include any longer duration storage, but showed the impact of hydrogen-fired generation in reducing system costs. We expect that long-duration storage could have similar system impacts to hydrogen-fired generation. We are working with Ofgem and industry to facilitate much greater levels of flexibility across our energy system, through delivering our joint Smart Systems and Flexibility Plan.[4]

Electricity storage will be an essential source of low carbon flexibility. The UK currently has around 4GW of storage in operation, 3GW of which is pumped hydro storage (PHS) and 1GW of which is lithium-ion battery storage.[5] There is a large pipeline of storage projects, including around 2GW of PHS and 8GW of battery storage, that are currently in planning stages.[6] Novel storage technologies are emerging. The illustrative scenarios in our analysis demonstrate that around 30GW of short duration storage and flexible demand may be needed in 2050.[7] This does not include longer duration storage that can store electricity across days, weeks and months.

In this call for evidence, we are considering the need for large-scale and long-duration electricity storage (LLES). Such technologies can help manage variation in renewable generation over longer periods of time. The precise technical parameters of storage that will be required are uncertain, but for the basis of this call for evidence we expect LLES projects would need to be able to store and discharge energy for over 4 hours, and up to days, weeks and months, and deliver power of at least 100MW when required. The larger the storage

[3] BEIS (2021), Smart Systems and Flexibility Plan, 2021, Appendix I: Electricity System Flexibility Modelling, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021
[4] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan 2021, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021
[5] National Grid Electricity System Operator (2020), Future Energy Scenarios, http://fes.nationalgrid.com/fes-document/
[6] BEIS (2021) Renewable Energy Planning Database, https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract
[7] BEIS (2021), Smart Systems and Flexibility Plan, 2021, Appendix I: Electricity System Flexibility Modelling, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

facility, the higher the volume of energy that can typically be stored. This in turn enables longer discharge durations or potentially higher power outputs, as not all types of storage are capable of achieving both.

Longer duration storage can provide system security by ensuring that power that is generated when electricity is abundant, can be stored for times when renewable sources, such as wind and solar, are less available. As we deploy increasing volumes of variable renewable energy, there will be (windy, sunny, lower demand) periods when there are excess renewables on the system. If this electricity cannot be stored (or exported through an interconnector) then it may need to be paid to be curtailed. It would be better if this low-carbon electricity could instead be stored for when it is needed.

A range of technologies can provide large-scale, long-duration storage, including, but not limited to: gravitational storage, redox flow batteries, novel batteries such as copper and zinc, compressed or liquid air energy storage, pumped hydro storage (PHS), and power-X-power technologies. Different storage technologies can provide different durations of storage to the system.

The most mature LLES technology is PHS, which has been in operation in GB since the 1960s. It works by pumping water from a lower reservoir to a higher one when electricity is abundant, and letting it flow back down through a turbine when it is scarce – in doing so, generating electricity to help to balance the system. At a later time – usually when there is an abundance of renewable energy on the system, the water must then be pumped back to the upper reservoir. Some newer storage technologies do this by other means, for example compressing and decompressing air, or using gravity. Electrolysers use electricity to create hydrogen, and then reconvert the hydrogen back into electricity through combustion. The conversion of electricity (for example, into gases) for use in different sectors is often referred to as power-to-x. It allows surplus power to be utilised in different forms.

Since the publication of our 2017 Smart Systems and Flexibility Plan[8], we have worked closely with Ofgem to reform markets and remove regulatory barriers that have made the deployment of storage difficult in the past. As part of this, we have invested in innovation to support the development and testing of novel technologies and business models that could further grow the storage technology market. Innovation competitions are important for demonstrating how novel technologies and business models can work, and reducing the risks investors currently face. Following the Prime Minister’s Ten Point Plan[9] for a Green Industrial Revolution which announced new innovation funding to be delivered through the £1bn Net Zero Innovation Portfolio (NZIP), in May 2021 we launched an innovation competition, worth up to £68m, to support the commercialisation of first of a kind longer duration energy storage technologies.

The UK Government and Ofgem’s 2017 Smart Systems and Flexibility Plan and the 2018 Progress Update contained actions that have supported storage deployment at all scales. The

[8] BEIS and Ofgem (2017), Smart Systems and Flexibility Plan, https://www.gov.uk/government/publications/upgrading-our-energy-system-smart-systems-and-flexibility-plan
[9] UK Government (2020), Prime Minister’s Ten Point Plan for a Green Industrial Revolution, https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

2021 Smart Systems and Flexibility Plan sets out our next steps.[10] Our aim is for all storage technologies to be able to compete fairly with each other, and with low carbon generation. Evidence suggests this is currently not the case, with large-scale and long-duration electricity storage (LLES) technologies facing a financing barrier that limits deployment.

It is difficult to predict the exact mix of flexibility technologies that will be optimal for decarbonising the system in the long term. The need for LLES will be affected by how other sectors, such as heat, decarbonise, and which sources of renewable generation and shorter-term flexibility are available. We know that high levels of flexibility will be needed in a low-cost net zero system and qualitative evidence recognising the value of LLES is increasing. Further evidence is needed to quantify the types of assets that would be most valuable to the system over the coming years. Specifically, there is uncertainty about the precise system need for longer duration storage, including what the optimal use cases may be. To gather this evidence, we have commissioned analysis alongside this call for evidence that will model and quantify the potential need for LLES. This information will be important to help inform our decisions on whether further intervention is needed to support its deployment.

Alongside LLES, other technologies, including flexible demand, short-duration storage, interconnection, thermal generation with carbon capture, usage and storage (CCUS) and emerging hydrogen technologies, will be important in providing low carbon flexibility to the electricity system. Therefore, in the power sector, there is a degree of substitutability between these technologies and the development of each may affect the balance of technologies that will be needed in the future. However, it is expected that deployment of a mix of these technologies will be needed to meet our carbon reduction targets. There is also value in developing diverse sources of low carbon energy, so that we are not too dependent on individual technologies.

We know that, as a source of flexibility, LLES could:

- replace fossil-fuelled sources of flexibility including gas turbines and reciprocating engines and reduce the need for additional peaking generation by shifting excess supply from peak to off-peak, as well as managing periods when demand is lower than low carbon supply;
- reduce the need for additional low carbon generation by better utilising existing sources of renewable generation;
- support network constraint management, and reduce the volume and cost of network reinforcements by shifting supply from congested to uncongested periods;
- provide storage over different durations – intraday, inter-day and inter-seasonal, e.g. helping to balance the system across longer periods of lower generation (e.g. periods of low wind) or higher demand (e.g. colder periods when heating demand rises); and
- provide stability services, including inertia, frequency response and voltage.

[10] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan 2021, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

Questions

1. Do you agree with our definition of LLES as storage technologies that can store and discharge energy for over 4 hours and have a power capacity of at least 100 MW? If not, what alternative definition would be more suitable? Please provide supporting evidence where possible.

2. Do you agree that the electricity system requires, and will benefit from, LLES delivering the services outlined above? Are there any other important services that LLES can provide that are not covered here? Please provide supporting evidence where possible.

3. Do you think there will be a need for a range of different LLES technologies, alongside other technologies that may be able to deliver similar system benefits, such as hydrogen production and generation, and carbon capture, usage and storage?

As part of this call for evidence, we are seeking information from developers and investors to better understand what prospective LLES projects could be built over the next five years. This information, alongside details of the barriers that these projects are facing (see next section), will help us to design solutions best able to address these barriers.

Question

4. Please provide details of specific LLES projects that could begin development in the next 5 years. These details should include technology type (including intended use of fuel generated through sector coupling), MW and MWh capacity, the business model or route to market, efficiency and expected development, capital, operational costs and expected lifetime of projects.

Current market: Potential barriers to LLES deployment

Throughout 2020, we engaged with academics, developers, investors and industry bodies to understand more about the barriers that are preventing LLES from deploying in the current market.

This engagement highlighted challenges associated with financing large-scale storage in particular. A number of other high capital cost, low carbon technologies, such as renewable generation, nuclear power and interconnection, receive subsidies or other support designed to de-risk investment – which may reduce the relative attractiveness of technologies that do not receive such support. Stakeholders outlined that the high capital costs associated with some LLES developments, combined with long lead times and uncertainty over novel technologies, can make it difficult to attract investment in LLES when combined with a lack of bankable or forecastable revenues for these projects. In the wider context of alternative investment opportunities, these factors can make LLES less appealing to investors.

Key themes from our engagement are summarised in the table below, which lists barriers that are specific to LLES projects; we are aware there are additional barriers to all forms of flexibility (including LLES) which are discussed in our 2021 Smart Systems and Flexibility Plan.[11]

Table 1: Key challenges associated with financing LLES

Issue	Description
High upfront capital costs and long lead times	LLES projects often have high upfront capital costs, with costs varying across different technologies. Projects requiring significant civil engineering works, for example pumped hydro storage, can also involve long construction periods which can increase investment risk. Some technologies that provide long-duration storage are forecast to reduce in cost, although this may be dependent on global innovation funding and supportive regulatory environments.[12]
Lack of track record	Novel storage technologies face additional investment challenges compared to more mature technologies. There is a higher risk of investing in technologies where there is a lack of a track record for successful projects. Some of these technologies have not yet been demonstrated at scale, which can limit investor appetite.

[11] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan 2021, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

[12] Mott Macdonald (2020), Storage cost and technical assumptions for electricity storage technologies, https://www.gov.uk/government/publications/storage-cost-and-technical-assumptions-for-electricity-storage-technologies

Issue	Description
Revenue certainty	Electricity storage projects create value by stacking a range of revenues from across different markets. However, many of these revenues are currently contracted on a short-term basis in day-ahead or intraday markets. One exception is the Capacity Market (CM), which rewards contributions to security of supply and provides agreements of up to 15 years. To secure an agreement in the CM, a unit must be able to deliver capacity within 4 years. If a unit takes longer than 4 years to deliver, it may be able to take advantage of a long-stop date of up to a year, but this will reduce the length of revenue secured. If a unit takes longer than 5-years to deliver capacity, it would not be able to secure an agreement before construction commences. This would likely impact the investability. Projects with high up-front capital costs and long lead times generally require more visible long-term cash flows to secure finance and investment.
Market signals	Energy markets may not capture the full value of LLES projects, both new and existing. Long-duration storage could provide system benefits, as outlined above. However, the market currently tends to value short-duration storage, and there is little incentive to invest the extra capital needed for long-duration storage capacity (even for mature technologies e.g. lithium-ion and pumped hydro storage). Currently, price signals for inter-day or inter-week arbitrage are weak compared to intraday signals, so large-scale storage is incentivised to cycle multiple times per day rather than hold stored energy over longer periods (or operate in spin mode to provide grid stability services). Almost all new energy storage projects are therefore shorter duration, for example battery storage. Additionally, carbon emissions are not fully valued in flexibility markets, meaning low-carbon projects may be outcompeted by high-emitting assets for equivalent system services.

Questions

5. Do you agree that the issues outlined above are barriers to the deployment of LLES? Please comment on any issues that are particularly significant in your view.

6. Are there any other barriers impacting the deployment of LLES?

Our stakeholder engagement to date indicates that the commercial challenges listed above create a financing challenge for LLES projects, and that developers struggle to secure investment because the revenues for these assets are too volatile or uncertain.

Primarily, we understand this to be a challenge for those seeking to raise debt for large projects, as lenders require more secure revenue streams, with long-term visibility. Our understanding is that the majority of private investment currently going into energy storage projects is equity capital.

Our engagement to date indicates that investment in electricity storage as a whole is expanding, as more types of investors explore alternative investment opportunities in low-carbon infrastructure. However, whilst more capital may be materialising for smaller scale storage projects, it (either debt or equity) does not appear to be available, at least at sufficient scale, for larger-scale projects at longer durations (and novel technologies).

We are interested in collecting further evidence on the investment landscape for energy storage and LLES, and whether challenges apply only to raising debt capital or also equity, and the extent to which the depth or breadth of available capital is a challenge.

Questions

7. What types of capital are available for LLES and from what types of investors?

8. Do the financing challenges LLES projects face primarily concern raising debt, or also equity?

Addressing barriers to the deployment of LLES

Market reforms: Current routes to market and potential reforms

LLES currently participates in a number of energy markets, and largely, developers need to stack several revenue streams to build a viable investment case. The table below summarises our understanding of current routes to market for LLES assets in GB and how these revenue streams contribute to the investability of energy storage assets.

Table 2: Assessment of current routes to market for LLES

Revenue stream	Impact on investability for storage
Wholesale market (arbitrage trading)	Fairly reliable revenue stream (based on day-ahead / intraday volatility) but less likely to be bankable at present; equity investors can invest but not lenders. Uncertainty over future levels; arbitrage opportunities likely to increase due to increased renewables and heat and transport electrification, but there may be competition with other flexible assets.
Power Purchase Agreement/floor (private contract)	Some utilities have begun offering revenue floor contracts to storage developers similar to power purchase agreements. This improves financeability, and in exchange the off-taker receives a share of profits. Only a few examples of this; availability currently limited.
Balancing Mechanism	High value revenue stream at present due to rising costs of balancing the grid. Forecast to increase further in the future, however highly unpredictable.
Ancillary services	Various ancillary services contracts are available to storage, including frequency response and reserve services. Many of these markets are well understood, however some are undergoing reform and competition for contracts is high. Generally, these are short-term contracts, but can provide a case for equity investment.
Capacity Market (CM) (15-year agreements)	15-year CM agreements can provide bankable revenue for storage assets. Short-term storage projects are de-rated according to their contributions to security of supply, which is limited due to their short duration, so the value of their CM agreements are relatively low. For some technologies, e.g. PHS, the 5-year period between the CM auction and delivery may not be long enough to allow an agreement to be secured before construction commences, which may impact investability. Some novel storage technologies do not face these challenges, however higher technology costs mean they may not be able to compete on cost with conventional sources of capacity.

A number of markets that LLES participates in are undergoing reforms that could be beneficial to these assets. There are several areas under development that may help provide a route to market for LLES, some of which are outlined below. Our engagement to date suggests that any of these new opportunities would need to be stacked along with other revenue streams, rather than providing a new route to market on its own.

- **Stability Pathfinders and other ESO services**: The ESO is trialling various new services for grid stability and network constraints, including the Stability Pathfinder and Constraint Management Pathfinder projects, which energy storage assets were eligible to bid for. These pilots have included multi-year revenue contracts, which may support financing for LLES projects.
- **UK Investment Bank**: Government is establishing a new national infrastructure bank. As part of its mandate, the Bank will support the UK's net zero target by investing in low-carbon infrastructure projects, which could include LLES projects. Financing support from the Bank could help attract private investment to LLES projects.
- **Capacity Market:** We will shortly publish a call for evidence on the Capacity Market (CM). This will gather evidence on how we might support the participation of new build projects that have construction times which are longer than the time between the main capacity auction and delivery (approximately four years), for example pumped hydro storage. It will also request views on how the CM can better align with our net zero commitments.
- **Network competition**: In the Energy White Paper, the Government committed to legislate to enable competitive tenders for building, owning and operating onshore electricity network assets. This will allow entities who are not incumbent network owners to compete for onshore network projects. These could potentially include LLES projects where these provide a cost-effective alternative to traditional network assets.
- **Network charging:** Ofgem is considering the role that network charges will play in ensuring efficient network usage in the future and, as part of the broader work on access and forward looking charges, Ofgem will consider how demand and generation charges should be applied where storage is acting in a way that benefits the system.
- **Transmission Constraint Licence Condition:** Ofgem has published an open letter[13] clarifying how storage is treated under the Transmission Constraint Licence Condition, which aims to reduce any uncertainty that could dampen the incentive for storage assets to locate behind, and alleviate, a network constraint.

In addition to the above, our new Smart Systems and Flexibility Plan[14] outlines other areas for potential future reform that could affect the business case for LLES, including work that

[13] Ofgem (2021), Applicability of Transmission Constraint Licence Condition to generators that are importing power, https://www.ofgem.gov.uk/publications-and-updates/applicability-transmission-constraint-licence-condition-generators-are-importing-power

[14] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan 2021, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

considers how we can address the carbon intensity of flexibility markets, and how wider system impacts could be taken into account in the Contracts for Difference scheme.

As these reforms will affect markets that LLES participates in, we would like to understand the extent to which these changes could contribute towards improving the investability of LLES. To be clear, these changes do not involve widescale market reform, but consist of adjustments within current frameworks.

Questions

9. To what extent will the reforms outlined above support the investability of LLES? Please comment on any specific reforms that, in your view, hold potential to support the investability of LLES significantly.
10. Do you have any views on further reforms that could take place in current markets to improve the investability of LLES?
11. Are you aware of any proposed market changes (and/or system changes) that could make it more difficult to finance LLES within current markets?
12. Considering your answers to questions 9, 10 and 11, do you think further intervention is needed to de-risk investment in LLES?

Rationale for further intervention to de-risk LLES, and potential approaches

Based on the challenges identified through stakeholder engagement over 2020/2021, as set out above, we recognise that LLES faces a financing challenge impacting investment and that markets are not fully capturing all of the potential system benefits.

Market signals do not currently create a strong enough incentive to facilitate the storage of electricity for longer durations. Furthermore, where LLES is built, current market signals may incentivise it to cycle daily and provide shorter duration storage. It is important to note that the mechanisms outlined in this call for evidence will not address these signals for longer duration storage. We expect that these price signals will strengthen as renewable deployment increases and gas generation declines in the 2030s. Some stakeholders also see the need for broader market reforms in order to meet net zero; this is discussed in the Smart Systems and Flexibility Plan.[15]

Even though more work will be needed to ensure LLES is rewarded for storing electricity for optimal durations, we are seeking evidence on whether it will be beneficial to accelerate deployment in the medium term, so that it is available to contribute to the system in the latter

[15] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan 2021, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

half of this decade. At present, the challenges LLES faces in attracting the investment it needs to deploy could prevent storage at this scale from being built in the short-term, meaning that it is not an option for tackling the reduction in gas generation and significant increase in variable renewable generation needed by the mid-2030s.

Our view is that working to address the challenge of financing LLES could be an optimal approach as:

- Due to longer construction times, waiting for stronger market signals to materialise may mean that LLES is not able to deploy in time to meet the challenges of increased variable wind and reduced gas generation in the 2030s;
- Flexibility from LLES will still benefit the system even if it is more likely, in the short term, to store electricity for shorter durations.

Questions

13. Do you think that it is necessary to try to accelerate the deployment of LLES, even if stronger signals for longer duration storage may not develop until the late 2020s / 2030s?

14. Are other reforms needed to markets to ensure long-duration storage assets are providing the maximum value to the system? If yes, please provide detail of what reforms could be needed.

Stakeholders have suggested a range of mechanisms that could help bring forward investment in LLES. The table below briefly describes some of the options available:

Table 3: Examples of mechanisms that could be considered for de-risking LLES

Mechanism	Description
Regulated Asset Base (RAB)	This is the model employed by Ofgem for regulated energy networks in GB (the “RIIO” framework) and widely used in other sectors / jurisdictions. A regulator or other authority approves expenditure and determines a reasonable return on investment, capping prices or revenues to ensure investability of the asset whilst protecting consumers (with incentives to ensure effective delivery and performance). This model effectively guarantees investors that capital they invest will be recouped over the life of the assets, plus a reasonable return (provided minimum performance standards are met). It can encourage a low cost of capital and in GB has brought forward significant investment in energy networks and other sectors. This model significantly shifts risk from investors to bill payers.
Cap & Floor mechanism	Ofgem developed the Cap & Floor regime to encourage investment in electricity interconnectors, which allow trading between GB and neighbouring energy markets. Operators of electricity interconnectors earn money by

Mechanism	Description
	(primarily) auctioning cable capacity to traders who buy and sell energy across markets. The Cap & Floor regime provides a minimum revenue allowance to help developers secure financing. When operator revenues fall below this floor, they are topped up by consumers. Conversely, when revenues breach a revenue cap, excess returns are passed on to consumers. The cap and floor levels are calculated based on project costs including financing costs (at the floor) and a return to equity (at the cap). The Cap & Floor regime duration is 25 years for interconnectors. A variation of this approach would involve setting a floor, without a cap. This could provide further incentive for investors and developers to optimise operation of the storage assets but would mean consumers do not benefit when returns are higher than expected. Another option could be for profits above an agreed cap to be shared between investors and consumers.
Contract for Difference (CfD) framework	The CfD mechanism provides support to low-carbon forms of energy generation. It provides price stabilisation, increasing revenue certainty and widening the pool of available capital for low-carbon generation. When the market price for electricity generated falls below the generator's Strike Price, payments are made by the Low Carbon Contracts Company (LCCC) to the generator to make up the difference. Conversely, when the reference price is above the Strike Price, the CfD Generator pays LCCC the difference. Through the competitive auction process the CfD framework has encouraged falling strike prices and cost reductions, including on the cost of capital. The CfD is a 15-year agreement between the generator and the LCCC. The CfD framework is also being adapted to support CCUS generation projects. BEIS has consulted on a Dispatchable Power Agreement (DPA) to provide developers and investors with the revenue certainty necessary to secure investment whilst retaining the incentive to dispatch at times that are most beneficial to the market. The DPA is based on the CfD contractual framework but the proposed payment mechanism consists of an availability payment and a variable payment. The availability payment provides the revenue certainty necessary to secure finance but investors will need to consider how the assets operate in the wholesale electricity market and other markets such as those for balancing and ancillary services when building a business case. The variable payment is designed to incentivise the plant to generate ahead of equivalent unabated generation assets, by compensating for the difference in short-run marginal cost between the CCUS plant and an equivalent but unabated reference plant. It is envisaged that the DPA would be a 15-year contract between the developer and the LCCC.

Mechanism	Description
Reformed Capacity Market	The Capacity Market is a security of supply mechanism that ensures there is enough capacity available to meet peak demand. The revenue stream is a fixed payment based on installed capacity (kW/Year) in return for delivering capacity during a notified CM System Stress Event. It is not dependent on a capacity providers load factor in the period of support (outside of a CM System Stress Event). A CM Agreement can range in length from 1-year in duration, up to 15-years, based on capital expenditure criteria. Since publishing our five-year review into the Capacity Market, government ambitions on carbon reductions have increased, as demonstrated through the Energy White Paper and adoption of the CCC recommendations on Carbon Budget Six. The next full review will take place by 2024 and will ensure that the mechanism acts in concert with other markets to incentivise investment in the right type of capacity, at the right time. In the interim, we intend to return to some of the issues and improvements identified through the Five-year Review, particularly those which can help ensure the CM is better aligned with our Net Zero ambition, such as reviewing the arrangements on agreement lengths, considering the role of split auctions, and reviewing evidence on the way in which technologies with long-build times, such as PHS, can better participate in the CM. We will shortly publish a call for evidence on the Capacity Market, to start gathering stakeholder views on the longer-term future of the scheme in the context of net-zero

The mechanisms above may, to differing extents, help to mitigate the challenge of financing LLES. Any potential mechanism should also be designed to be cost-effective, and to ensure value for money for consumers.

We want storage to:

- be incentivised to respond to varying price signals, and
- provide flexibility when it is needed i.e. in times of scarcity and surplus.

A RAB, and the CfD for low carbon generation, would be less likely to incentivise developers to operate storage in this way. The CfD mechanism incentivises generators to maximise output, which is not suitable for storage.

In principle, the DPA, consulted on for CCUS generation is an example of how the CfD framework could be adapted to incentivise optimal dispatch of flexible generation assets whilst providing revenue certainty for investors. However, we do not currently believe there is evidence for the need for an availability payment for LLES, or to change its position in the merit order using a variable payment. Our view is the economics of the Cap & Floor approach is a more suitable approach for intervention.

A Cap & Floor has proven effective for interconnectors and in principle, a mechanism similar to that in place for electricity interconnectors, may prove effective for LLES technologies. This is because:

- It retains an element of merchant exposure, meaning developers are incentivised to optimise the storage assets in a way that generates the most value, as they are exposed to returns between the cap and the floor.
- It also retains a developer-led approach. Energy system users would share in the upside of projects in exchange for having de-risked the downside, but with lower risk of supporting stranded assets.
- The cost of the Cap & Floor to consumers could be low as this option will not necessarily pay out a subsidy, depending on the economics of individual projects.

We are less clear on the extent to which a Cap & Floor mechanism may potentially be suitable for bringing forward power-hydrogen-power projects at present. Hydrogen can play a role in the power system in various ways, including providing system flexibility through electrolysis. These technologies currently face a different set of risks: there is currently no hydrogen market to which an intervention could apply, and hydrogen projects are likely to require a range of interventions in the long term across the value chain. The challenges hydrogen faces at this stage are not the same as the financing challenges faced by other LLES technologies that currently have a clearer route to market. In addition, given that hydrogen storage is a mature technology, but one that is not well demonstrated as an option to deliver grid scale electricity storage, it may face additional innovation barriers in addition to the eventual financing challenges that stakeholders describe for some other LLES solutions.

There may be some merit in a Cap & Floor for hydrogen storage in the long term, once a hydrogen market is in operation, but this will depend on how other parts of the hydrogen value chain develop. Information gathered through this call for evidence and the system need analysis we have commissioned alongside this will help to clarify how best to address hydrogen.

Another option could be to reform the CM. This could be an effective approach because:

- The CM reduces merchant risk, by providing a steady, guaranteed revenue stream, whilst allowing a capacity provider to maximise its revenues external to the CM (for example in wholesale markets or ancillary services).
- It retains a developer-led approach through a technology-neutral competitive auction. Whereby developers are incentivised to only bring forward projects with economic value, reducing distortions on wider energy markets.
- The CM also takes a technology-neutral approach, which means that it could potentially accommodate a variety of storage technologies, including novel technologies.
- Some aspects of the CM framework could cause difficulties in bringing certain types of technologies to market. We are considering how we can best bring changes forward to the CM to ensure that it remains a robust mechanism for supporting suitable capacity at

least cost to the consumer. We will provide detail of these considerations, and seek stakeholder views in our upcoming 2021 CM Call for Evidence.

Questions

15. Which intervention, in your view, has the most potential to be appropriate for addressing barriers to help bring forward investment in LLES, including novel storage technologies? Are there any other mechanisms which might be appropriate to consider? Please provide evidence to support your response where possible.

16. Please provide suggestions for how the most effective intervention, in your view, could be structured to ensure value for money and affordability.

17. Do you think that hydrogen storage that will provide flexibility could face the same financing barriers discussed in relation to LLES above? Please provide evidence where possible.

18. Do you agree that it is not yet appropriate for a Cap & Floor mechanism to be considered for hydrogen storage? If so, what other approaches might be appropriate to consider?

Understanding risks

Government has a range of options for addressing the financing challenges LLES faces, through bespoke mechanisms that would involve varying degrees of intervention. However, any market intervention carries a risk of introducing new distortions, and adds to a wider risk that the variety of government interventions active at once will exacerbate complexity. Interventions to improve the investability of LLES could give a competitive advantage to some technologies over others. This could increase the risk of assets being underutilised or stranded. One risk of government intervention is that technologies that benefit from additional support do not turn out to be as valuable as anticipated. For example, new technologies could develop which provide alternative cost-effective sources of low carbon flexibility, lowering the requirement for LLES. Within LLES, some technologies have greater cost reduction potential than others.

There is also a risk that addressing the financing challenges of LLES assets may not be enough to deliver more longer duration storage while underlying issues concerning market signals are not addressed. Incentives for LLES to operate in short duration mode may continue to outweigh those for providing longer duration flexibility, even as signals to provide the latter increase. Associated with this, introducing a de-risking mechanism to improve the investability of LLES could result in these projects directly competing in markets with shorter duration flexibility assets such as batteries or flexible demand. For example, if LLES assets compete in the same markets as short-duration storage assets and other flexibility assets, there is a risk that supported projects could crowd out other assets in these markets.

In general, there is a risk relating to adding further complexity to the energy system, through intervention to support a specific suite of technologies and services. We think it is important to design any mechanism in a way that enables the intervention to subside as market signals improve.

Although we have identified the Cap & Floor mechanism as potentially being an effective approach for intervention, we will need to be mindful of any risks that a support mechanism for LLES could introduce, to avoid overcorrecting current market distortions.

Questions

19. What are the key risks in intervening to support LLES, and what risks might arise from a Cap & Floor specifically?
20. How might a Cap & Floor mechanism distort the market for short duration flexibility and nascent technologies? Please provide evidence where possible.
21. How could any intervention, such as a Cap & Floor mechanism, be designed and implemented to enable the benefits to outweigh risks?

Summary of questions

Strategic context: The role and value of LLES in a net zero energy system

1. Do you agree with our definition of LLES as storage technologies that can store and discharge energy for over 4 hours and have a power capacity of at least 100 MW? If not, what alternative definition would be more suitable? Please provide supporting evidence where possible.
2. Do you agree that the electricity system requires, and will benefit from, LLES delivering the services outlined above? Are there any other important services that LLES can provide that are not covered here? Please provide supporting evidence where possible.
3. Do you think there will be a need for a range of different LLES technologies, alongside other technologies that may be able to deliver similar system benefits, such as hydrogen production and generation, and carbon capture, usage and storage?

Current market: Understanding the storage landscape

4. Please provide details of specific LLES projects that could begin development in the next 5 years. These details should include technology type (including intended use of fuel generated through sector coupling), MW and MWh, the business model or route to market, efficiency and expected development, capital, operational costs and expected lifetime of projects.

Current market: Potential barriers to LLES deployment

5. Do you agree that the issues outlined above are barriers to the deployment of LLES? Please comment on any issues that are particularly significant in your view.
6. Are there any other barriers impacting the deployment of LLES?
7. What types of capital are available for LLES and from what types of investors?
8. Do the financing challenges LLES projects face primarily concern raising debt, or also equity?

Addressing barriers to the deployment of LLES

Market reforms: Current routes to market and potential reforms

9. To what extent will the reforms outlined above support the investability of LLES? Please comment on any specific reforms that, in your view, hold potential to support the investability of LLES significantly.
10. Do you have any views on further reforms that could take place in current markets to improve the investability of LLES?
11. Are you aware of any proposed market changes (and/or system changes) that could make it more difficult to finance LLES within current markets?
12. Considering your answers to questions 9, 10 and 11, do you think further intervention is needed to de-risk investment in LLES?

Rationale for further intervention to de-risk LLES: Considering approaches

13. Do you think that it is necessary to try to accelerate the deployment of LLES, even if stronger signals for longer duration storage may not develop until the late 2020s / 2030s?
14. Are other reforms needed to markets to ensure long-duration storage assets are providing the maximum value to the system? If yes, please provide detail of what reforms could be needed.
15. Which intervention, in your view, has the most potential to be appropriate for addressing barriers to help bring forward investment in LLES, including novel storage technologies? Are there any other mechanisms which might be appropriate to consider? Please provide evidence to support your response where possible.
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Understanding risks

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This Call for Evidence is available from:

www.gov.uk/government/consultations/facilitating-the-deployment-of-large-scale-and-long-duration-electricity-storage-call-for-evidence

If you need a version of this document in a more accessible format, please email enquiries@beis.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.