## HM Government – Written evidence (LES0015)

*Submitted by the Department for Energy Security and Net Zero*

### Introduction

The government welcomes the opportunity to provide written evidence to the inquiry of the House of Lords Science and Technology Committee examining how much long-duration energy storage will be needed and whether current government policies are sufficient to support its development.

We have drafted a response covering each of the Committee's questions. Our response covers a range of storage technologies including large-scale, long-duration electricity storage ('LLES') and hydrogen storage. To ensure energy security a combination of storage assets will be required to meet the varying needs of the energy system in the future.

### Questions

1. **How much medium- and long-duration energy storage will be needed to reach the Government's goal of a fully decarbonised power grid by 2035 and net zero by 2050, and by when will it need to be ready?**

Electricity demand and supply vary depending on many factors including human activity, weather profiles and plant outages. This means that flexible technologies are likely to be needed to help balance the system. Low carbon technologies that can adjust their supply or demand are likely to be crucial in a decarbonised power grid that relies on a high proportion of intermittent renewable generation. Future electricity systems are very likely to need storage operating on intra-day, inter-day, inter-seasonal, and potentially inter-annual timescales. The amount of each type of storage required for a low carbon emission system, at the lowest cost, depends on the wider generation mix and demand profile. The key factors influencing storage needs are; the

- amount of generation from variable renewables (solar and wind);
- demand profile from transport, heat, and industry;
- amounts of other flexibility options available;
- relative costs;
- charging and degradation efficiency of each technology;
- energy density of each storage technology; and
- electricity network capabilities and geological considerations.

We have modelled a set of scenarios that are compatible with a decarbonised power system in 2050. Our modelling indicates that Great Britain will need more inter-day and inter-seasonal storage - likely in the order of terawatt-hours (TWh), to avoid reliance on unabated natural gas to balance the network.[1] For the scenarios modelled in 2035, power storage capacity use over a year (with a duration of 4 or more hours) ranged between 15TWh and 1TWh, with additional hydrogen storage requirements of between 2TWh and 35TWh.[2] [3] When there

[1] Modelling of the Ability of a Mixed Renewable Generation Electricity System with Storage to Meet Consumer Demand, https://www.mdpi.com/2673-4826/3/1/2

[2] BEIS (2022), The Benefits of Long Duration Electricity Storage, https://www.gov.uk/government/publications/benefits-of-long-duration-electricity-storage

were lower levels of hydrogen storage modelled the required rate of power storage increased.

## 2. How sensitive is the amount of storage needed to assumptions about the future balance of supply and demand on the grid?

The need for flexibility will likely rapidly increase as variable renewable power replaces fossil fuel sources and we electrify heat and transport. Our 2021 Smart Systems and Flexibility Plan estimated that we will need about 30GW of short-term storage, interconnection capacity and demand side response by 2030.[4] This would be a three-fold increase on 2021's levels. Storage will preserve energy security by allowing the system to be more self-sufficient on indigenously generated electricity.

The storage capacity required is highly correlated with the amount of intermittent renewable generation capacity and the extent to which lulls in that generation can be filled by other assets (such as gas with carbon capture and storage (CCS)) and demand response to ensure supply and demand are balanced. There could also be scenarios where even more renewables are deployed which, even at low efficiencies in weather lulls, would reduce the need for energy storage.
In scenarios with very high deployment of solar and wind generation, there is a clear trade-off between additional storage and additional renewable generation. Increasing storage uses the intermittent generation more efficiently as it enables electricity storage instead of curtailment.

Scenarios with high degrees of dispatchable generation (including fossil fuels) will require fuel storage but less electricity storage, and in particular less longer duration electricity storage. This is because, pending fuel availability, these assets can be dispatched on demand, some on a continuous basis to cover low intermittent renewable generation periods.

Systems with shares of large-scale nuclear power will still require significant storage to respond sufficiently to potential swings in electricity demand and supply. This would likely be made up of intra-day and inter-seasonal storage on the order of TWh. Our initial modelling suggests slightly less storage is required than in systems dominated by wind and solar. Deploying innovative smaller, more flexible nuclear reactors at scale might reduce the need for some storage, but further research is needed.

More interconnection might also reduce the need for longer duration storage. Further work is required to understand how nations with which the Great British power grid is interconnected are likely to behave as they have correlated weather and demand patterns.

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[3] Note that this analysis did not explore the cross-year storage requirements that may be required.
[4] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan (page 11), https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

A global trade in hydrogen or ammonia could reduce requirements for domestic energy storage, especially over longer timescales. There would likely still be a need for some domestic inter-seasonal storage, in addition to the intra-day and inter-day storage needs.

Systems with more demand side response (DSR) might need less intra-day storage. DSR usually operates on hourly or intra-day timescales and is therefore more likely to displace the need for storage with durations shorter than 4 hours. Although demand shifting away from power peaks can affect capacity requirements of other assets, this is unlikely to be significant on the scale of storage assets required.

Climate change is likely to shift our energy demand needs. We still expect winter peaks in electricity demand and demand for cooling is likely to increase in summers. The electrification of heating is likely to increase electricity demands in winter significantly and correspondingly increase the need for inter-day and inter-seasonal storage.

### 3. Which technologies can scale up to play a major role in storage?

Most medium and long duration storage technologies are not yet at technology readiness level (TRL) 9 for commercial deployment.

- Hydrogen storage, such as salt caverns and depleted fields, which could operate over inter-seasonal and inter-day timescales, have several components which are at TRL 8-9, but as an integrated storage system they are at TRL 6-7. Other hydrogen storage technologies exist but have lower TRLs or have smaller volumes, which makes them less attractive options to deploy at scale.
- Thermal storage, which could operate on inter-day and potentially inter-seasonal timescales, is at TRL 6-8.
- Flow batteries, which currently operate at intra-day timescales but are targeting inter-day, are an area of active innovation, with different chemistries and system configurations at TRL 4-8.

Technologies which can scale up include those currently being supported under the Department's Longer Duration Energy Storage (LODES) demonstration programme.[5]

Storage technologies which can operate over different timescales are in the table below.[6] Note technologies marked with * are currently deployed at scale in the grid.

| Intra-day | Inter-day | Inter-seasonal |
| --- | --- | --- |

[5] BEIS (2022), Longer Duration Energy Storage Demonstration Programme: successful projects, https://www.gov.uk/government/publications/longer-duration-energy-storage-demonstration-programme-successful-projects

[6] Hydrogen storage can operate over intra-day, inter-day and inter-seasonal timescales. Further evidence is required to determine the extent to which salt caverns, depleted gas fields and hydrogen carriers can be used on the intra and inter-day timescales.

| Intra-day | Inter-day | Inter-seasonal |
|---|---|---|
| Lithium-ion battery storage* | Liquid air storage | Synthetic e-fuels |
| Pumped hydro* | Hydrogen in tanks | Thermal storage in rock |
| Compressed air storage | Thermal storage | Phase change thermal storage |
| Liquid air storage | Flow batteries | Hydrogen stored in salt caverns |
| Supercapacitors | Pumped hydro | Hydrogen stored in depleted gas fields |
| Flywheels | Compressed air storage | |
| Flow batteries | | |
| Gravity storage | | |

In the 2023 Future Energy Scenarios (FES) report, National Grid ESO estimates 2030 hydrogen storage requirements ranging from 2-4TWh. This is the first step in a steep curve in the UK's hydrogen storage needs. FES estimates suggest we may need between 12 and 56TWh of hydrogen storage by 2050 to reach net zero.[7] This remains subject to uncertainty and is likely to change substantially depending on future policy decisions on hydrogen production and demand. Literature is consistent in indicating an increased need for hydrogen storage as the hydrogen economy grows.

The UK has set an ambition of 10GW of low carbon hydrogen production capacity by 2030[8], subject to affordability and value for money, with at least half of this coming from electrolytic hydrogen. In the 2030s we anticipate a significant increase in demand as the hydrogen economy establishes and expands. Hydrogen could make up over a third of total energy consumption in 2050. We have set out a comprehensive approach to developing a thriving UK hydrogen sector that can provide energy storage, resilience, and flexibility for the power system alongside decarbonising vital industrial sectors, heavy transport, and potentially heat.[9] Given the nascency of the market, long-term supply and demand for electrolytic hydrogen across different end-use cases, including storage, remain highly uncertain.

We are developing a hydrogen production delivery roadmap in 2023, taking forward recommendations made in the *Independent Review of Net Zero* and the

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[7] National Grid ESO (2023), Future Energy Scenarios 2023 (page 192), https://www.nationalgrideso.com/future-energy/future-energy-scenarios/documents
[8] BEIS (2022), British Energy Security Strategy (page 22), https://www.gov.uk/government/publications/british-energy-security-strategy
[9] BEIS (2021), UK Hydrogen Strategy (page 12), https://www.gov.uk/government/publications/uk-hydrogen-strategy

Hydrogen Champion report. We will set out a 'hydrogen networks pathway' of our vision of the next steps for the development of hydrogen transport and storage infrastructure.[10]

**4. What policy support is currently in place to support deployment of storage technologies? Is it sufficient to support deployment at scale?**

Electricity storage

We have been working closely with Ofgem and industry since 2016 to remove barriers and reform markets to facilitate the deployment of storage and the 2021 Smart Systems and Flexibility Plan sets out actions to enable this. This built on the government and Ofgem's joint 2017 Smart Systems and Flexibility Plan and 2018 Progress Update.

In 2021 we commissioned external analysis on the benefits of long duration storage. It was found to add significant value to the system of £13bn – £24bn between 2030 and 2050 (2019 prices, discounted to 2030), compared to where just short duration storage was available.[11] This came through reduced network constraints, reduced fuel costs and cheaper management of seasonal imbalances. The longer the duration of the storage, the greater the potential benefits could be. The potential for long periods of high/low wind suggests very long duration flexibility options (thermal capacity via hydrogen or CCS gas) was cheapest at providing long duration flexibility. We must also consider the benefits that supporting LLES technologies may have for enabling a diverse portfolio of technologies, whilst mitigating risks for technology delivery and supply chains. It diversifies our technology mix and provides optionality for meeting our ambitious 2035 power sector decarbonisation targets.

LLES however faces significant barriers to deployment under the current market framework due to its high upfront costs and a lack of forecastable revenue streams. We have committed to putting in place an appropriate policy framework by 2024 to enable investment in LLES, with the goal of deploying sufficient storage capacity to balance the overall system.[12] We anticipate further consultation with stakeholders on an appropriate policy approach later this year.

Changes to the grid

A central aim to any policy to enable investment in long duration storage will be to deploy technologies where they have greatest benefits to the system. Where these assets are located requires careful balancing of different considerations including the operational needs of the technologies themselves. Further analysis is required to understand these trade-offs fully. We are committed to accelerating network delivery, as reaffirmed in Powering Up Britain, to support the grid to connect to and utilise new technologies. We have taken action to improve strategic planning and speed up consenting and regulatory approvals.

[10] BEIS (2022), Independent Review of Net Zero, https://www.gov.uk/government/publications/review-of-net-zero

[11] BEIS (2022), Benefits of long-duration electricity storage (page 75), https://www.gov.uk/government/publications/benefits-of-long-duration-electricity-storage

[12] DESNZ (2023), Powering Up Britain: Energy Security Plan (page 42), https://www.gov.uk/government/publications/powering-up-britain

Ofgem has accelerated the delivery of nearly £20bn of strategic transmission projects,[13] and we are supporting them to enable strategic investment in their regulatory frameworks, as set out in the Strategy and Policy Statement, the consultation for which has recently closed.

REMA

The Review of Electricity Market Arrangements (REMA) is reviewing all electricity-related (non-retail) markets. A key priority for REMA is ensuring these markets send the right signals, both operational and investment, to incentivise deployment of low carbon flexibility across the electricity system as it decarbonises.

The delivery of projects, infrastructure and bespoke support mechanisms to unlock investment in initial 'first of a kind' (e.g. CCUS and hydrogen) and long duration storage technologies is out of scope of REMA due to the need to consider the requirements of each individual project. REMA will consider how reform to the wholesale market, balancing services and capacity market can facilitate deployment and efficient operation of all types of low carbon flexibility in the medium-long term.

Hydrogen storage

To support the development of hydrogen storage, the Net Zero Hydrogen Fund and Low Carbon Hydrogen Agreement,[14] will provide limited funding for costs of associated transport and storage (T&S) infrastructure for hydrogen production projects. We have run several innovation competitions through the Net Zero Innovation Portfolio (NZIP) which have supported DEVEX and/or CAPEX of hydrogen T&S infrastructure.

To unlock private sector investment and remove market barriers we are developing business models for hydrogen T&S infrastructure, to be designed by 2025, and are seeking the necessary enabling powers in the Energy Bill.[15]

We are also developing our approach to strategic planning for hydrogen T&S infrastructure and will set out key next steps for this in a 'hydrogen networks pathway' to be published alongside the Hydrogen Production Roadmap later this year.

**5. How well developed is the UK industry across different storage technologies, such as hydrogen or redox flow batteries? How does the UK compare to global competitors in these industries?**

Hydrogen

[13] Ofgem (2022), Decision on accelerating onshore electricity transmission investment (page 14), https://www.ofgem.gov.uk/publications/decision-accelerating-onshore-electricity-transmission-investment

[14] DESNZ (2022), Low Carbon Hydrogen Production Business Model: Heads of Term (page 7) https://www.gov.uk/government/publications/hydrogen-production-business-model; DESNZ (2022), Low Carbon Hydrogen Production Business Model: Heads of Term (page 7), https://www.gov.uk/government/publications/hydrogen-production-business-model

[15] DESNZ (2023), Hydrogen transport and storage infrastructure: minded to positions, https://www.gov.uk/government/consultations/proposals-for-hydrogen-transport-and-storage-business-models

Several technologies could be adopted for hydrogen storage at scale, each at different levels of maturity. Novel approaches to hydrogen storage could also emerge in the future. Onshore salt caverns are currently considered most promising. The UK has one operational hydrogen storage facility in Teesside where hydrogen is being stored in salt caverns. Elsewhere in the UK, salt caverns are also used to store natural gas and these stores can potentially be repurposed for hydrogen.

Further research and development (R&D) into hydrogen storage technologies is required, particularly for innovative technologies to explore the storage opportunities they possess, increase their TRL and encourage investment. Examples of government support include the HySecure Project, which demonstrated the deployment of grid-scale storage of hydrogen in a salt cavern. We have also supported R&D into innovative hydrogen storage technologies through NZIP.

Projections of hydrogen storage growth differ across the world. All countries acknowledge the need to further develop strategies and policies for hydrogen T&S, including commercial and regulatory frameworks. Across most countries, strategies and policies to support hydrogen transport are more developed than for hydrogen storage due to the potential for repurposing existing gas networks.

The Hydrogen Sector Development Action Plan[16] sets out actions government, industry and others are taking to ensure we have the right skills in the right place at the right time to support the growth of the hydrogen economy, maximising direct and indirect UK jobs. We are engaging with overseas markets to scope demand and opportunities for UK hydrogen exportation.

<u>Redox Flow Batteries</u>[17]

Redox Flow Batteries (RFB) store energy in tanks of electrolyte fluid held separately from the battery itself. This fluid is then mixed in the battery cell where a chemical reaction occurs that generates power. From 2011-2021, the UK ranked 7th globally for total publications and patents filed on RFB but ranks 2nd globally for research impact based on number of citations, below Australia. Commercialisation of RFB research in the UK has been supported by £84 million across 20 deals.

Vanadium RFB batteries are at a high TRL for long duration grid-scale energy storage, with several plants deployed globally. Further improvements in electrolytes, electrodes, and cell design will give the UK a stake in the global RFB market.

Several global vanadium RFB companies have sites in the UK, including two with manufacturing activity, and one that is active in R&D research. Several companies are conducting industrial R&D in the UK, two of which received

[16] BEIS (2022), Hydrogen Sector Development Action Plan, https://www.gov.uk/government/publications/hydrogen-sector-development-action-plan

[17] GO-Science (2022), Rapid Technology Assessment – Novel Batteries, https://www.gov.uk/government/publications/rapid-technology-assessment-novel-batteries#:~:text=Details,with%20a%20range%20of%20experts

support from the Energy Entrepreneurs Fund (EEF), and three received funding from the LODES programme (totalling £17m across five projects).

Other industrial R&D activity in the UK on batteries for longer duration storage includes Zinc metal batteries, Copper/Zinc batteries, and sodium-ion batteries, with two projects that have been awarded funding in the EEF, and two projects funded under LODES. These technologies are currently at a lower TRL than most RFB technologies for long duration grid-scale energy storage applications and would have export potential once developed.

**6. Beyond the cost of deploying long-duration energy storage, what major barriers exist to its successful scale up (e.g. the availability of a skilled workforce, the ability to construct the necessary infrastructure on time, or safety concerns around new technologies)?**

Stakeholder responses to our 2021 Call for Evidence indicated there are significant barriers preventing private investment into LLES projects. The issues highlighted were high upfront capital costs, long build times, lack of track record, lack of revenue certainty and lack of market signals.[18]

More widely lengthy connection timelines are being offered across the country, which is impacting, or would impact, long duration storage projects. We are working with Ofgem and network companies to release network capacity and improve the connection process.

The Electricity System Operator (ESO) is considering options for longer-term connection reform, following a consultation which closed on 28 July.[19] We will publish a connections action plan (jointly with Ofgem), building on the industry-led work to provide direction on further actions to accelerate connections.[20]

UK hydrogen storage faces some technical barriers to overcome to enable successful scale up. Salt caverns and depleted fields are geologically constrained as they require specific geological formations. Some locations and industries will therefore need access to extensive hydrogen networks to access suitable geological storage sites and may need to rely on other solutions (such as above ground tanks) if such networks are not available.

Other technical barriers include concerns around the risk of hydrogen contamination by other gases in the store and microbial activities that can produce hydrogen sulphide in salt caverns. However, these issues are not considered insurmountable.

[18] BEIS (2022), Facilitating the deployment of large-scale and long-duration electricity storage: government response (page 11), https://www.gov.uk/government/consultations/facilitating-the-deployment-of-large-scale-and-long-duration-electricity-storage-call-for-evidence

[19] National Grid ESO (2023), Connections Reform, https://www.nationalgrideso.com/industry-information/connections/connections-reform

[20] DESNZ (2023), Powering Up Britain: Energy Security Plan (page 45), https://www.gov.uk/government/publications/powering-up-britain

7. **What steps should the Government take now to ensure this storage can come online later in the current decade?**

Government is facilitating the deployment of electricity storage at all scales through the joint government and Ofgem 2021 Smart Systems and Flexibility Plan. We have committed to putting in place an appropriate policy framework by 2024 to enable investment in LLES, with the goal of deploying sufficient storage capacity to balance the overall system. As part of the process to enable investment in LLES, we have considered approaches taken in other countries. The nature of electricity storage technologies is such that, often, the different system needs and different geographies of different countries are not directly comparable. We are planning further consultation on an appropriate policy approach later this year.

On 31 August we published minded to positions for business models for hydrogen transport and storage infrastructure, as well as on regulatory arrangements and strategic planning to support its development. The necessary enabling clauses for the business models have been tabled in the Energy Bill.

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