LCPDelta

Value of long-duration BESS to the GB power system

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Contents

Executive summary

Long-duration BESS can play a crucial role in meeting Clean Power 2030 targets and reducing system costs

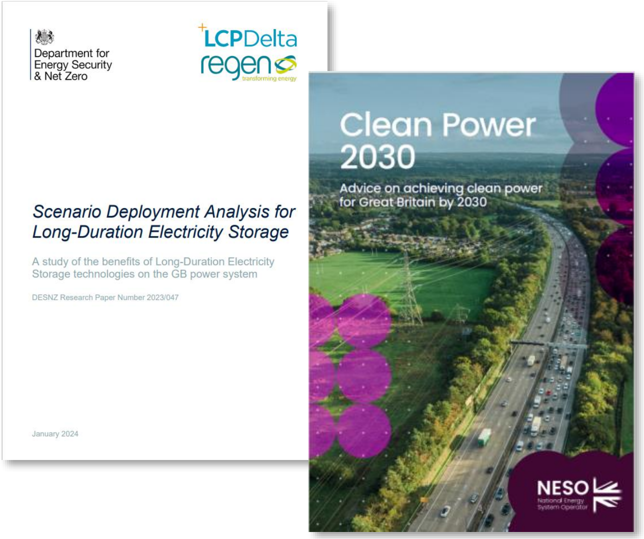
This report demonstrates the role that long-duration battery energy storage systems (BESS) can play in meeting the Clean Power 2030 ambitions, particularly in comparison to other long-duration energy storage technologies.

As the deployment of intermittent renewable generation accelerates, long-duration energy storage (LDES) becomes increasingly essential to ensure grid stability, flexibility, and cost-effectiveness over time. The UK Government's Clean Power 2030 roadmap[1], as outlined by the National Energy Systems Operator (NESO), highlights the necessity of **expanding LDES capacity from 3GW in 2023 to 5-8GW, and from 28 GWh to 81-99 GWh by 2030**. Furthermore, LCP Delta were recently commissioned by the Department for Energy Security and Net Zero (DESNZ) to assess the role and impact of a range of LDES technologies on the future GB power system, we showed that **building 20GW of LDES technologies by 2050 has a system benefit of over £10 billion**[2].

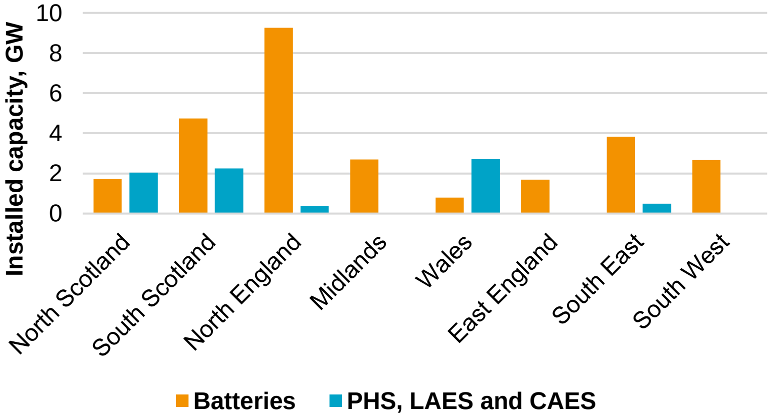
NESO's report on Clean Power 2030 emphasises that "the government's clean power mission must be about delivery". However, the delivery risk pertaining to the limited range of deployable technologies and the associated challenges must be addressed.

- Options being prioritised under Cap and Floor, including pumped hydro storage (PHS), compressed air energy storage (CAES), and liquid air energy storage (LAES), face significant limitations, such as location-specific deployment, lower maturity and high costs. These limitations can result in extended development periods that could impede the UK's ability to meet Clean Power 2030 targets.
- In contrast, long-duration BESS offers a compelling alternative, with a significantly lower delivery risk. Given the rapid and continuing decline in battery prices, we have conducted modelling with updated assumptions showing that BESS is not only more cost-effective but also a reliable solution that can play a pivotal role in reducing overall system costs.

[1] Clean Power 2030 | National Energy System Operator
[2] Based on the 'Established LDS Medium' scenario with medium LDES CapEx, *DESNZ LDES benefits report by LCP Delta and Regen*



Installed storage capacity in NESO's Clean Power 2030 "Further Flex" scenario



Our analysis demonstrates that long-duration BESS can deliver greater value than other LDES, provided it faces a level playing field

Finding #1 *1. C&F distorts incentives for short-duration BESS*

Incentivising **LDES through the Cap & Floor distorts signals for shorter-duration projects** by removing revenue opportunities, creating an uneven playing field.

Our analysis:

- Introducing a minimum duration into Cap and Floor **distorts incentives to build below the minimum supported duration**.
- Shifting build to longer durations leads to a **~10-12% lower operating margin for 2hr & 4hr BESS.**
- As a result, we would see an **8GW reduction in total 1hr, 2hr and 4hr BESS build**, outside of Cap and Floor.

Finding #2 *2. Cost effectiveness of long-duration BESS*

A system with long-duration BESS is a **more cost-effective** way to meet the requirements for long-duration energy storage than comparator technologies.

Our analysis:

- Long-duration BESS can provide the same system benefits as other technologies.
- However, due to considerably lower capital costs, this could amount to a **£17.8bn system cost saving NPV*.**
- This could **reduce the consumer cost of Cap and Floor by £2.22bn*** when returns are consistently below the floor**, reducing the risk of C&F for consumers.

Finding #3 *3. Long-duration BESS needs incentives*

While long-duration BESS is cheaper for the system**, market signals are not sufficient** for BESS projects to build at long durations without Cap & Floor (as is true for other LDES techs).

Our analysis:

- Even in a scenario with significant long-duration storage, additional BESS continues to provide a system benefit.
- **BESS at 6-8hrs and above requires support to be investable** and deliver those benefits.
- Without appropriate support, **the market will not provide signals for long-duration BESS**.

* (£2024, NPV 2025-2050)* calculated with a discount rate of 3.5%
** Assuming a floor return of 8% and actual returns of 6% between 2030 and 2050.

Scenarios considered in this analysis

We have considered three market scenarios which examine implications of different Cap and Floor design on LDES benefits and BESS investment

***Scenario 1**: No C&F*

Market continues to operate under current conditions without C&F incentivising additional LDES build.

- Moving from Scenario 1 to Scenario 2, **Cap and Floor is introduced** to incentivise LAES/CAES as well as some PHS.
- However, this distorts incentives for short-duration BESS investment, which would result in underinvestment.
- This could lead inefficient build of both LDES and shorter-duration storage.

***Scenario 2**: No BESS in C&F*

Long-duration BESS is not enabled through the Cap and Floor. LDES need is met through LAES/CAES and full PHS pipeline. This is the current DESNZ default position

- Moving from Scenario 2 to Scenario 3, **mitigations are put in place to prevent distortion of short duration BESS** e.g. including all BESS in Cap and Floor.
- This enables low-cost long-duration BESS investment without distorting market signals.
- This creates savings for consumers and the system.

***Scenario 3**: All BESS in C&F*

A scenario in which long-duration BESS is delivered without distorting market signals for other BESS.

Detailed assumptions for the three scenarios can be found in the Annex

Notes on scenario development

- Scenarios are based on LCP Delta's CP2030-compliant market scenario.
- Total LDES build is in line with DESNZ and NESO assessments of requirements.

- Each of the three scenarios consider a different mix of storage technologies and durations.
- Storage capacities in each scenario are set to maintain a similar level of system security and emissions across scenarios.
- This varies across scenarios based on the duration of assets.

Current Cap and Floor distorts incentives for short-duration BESS

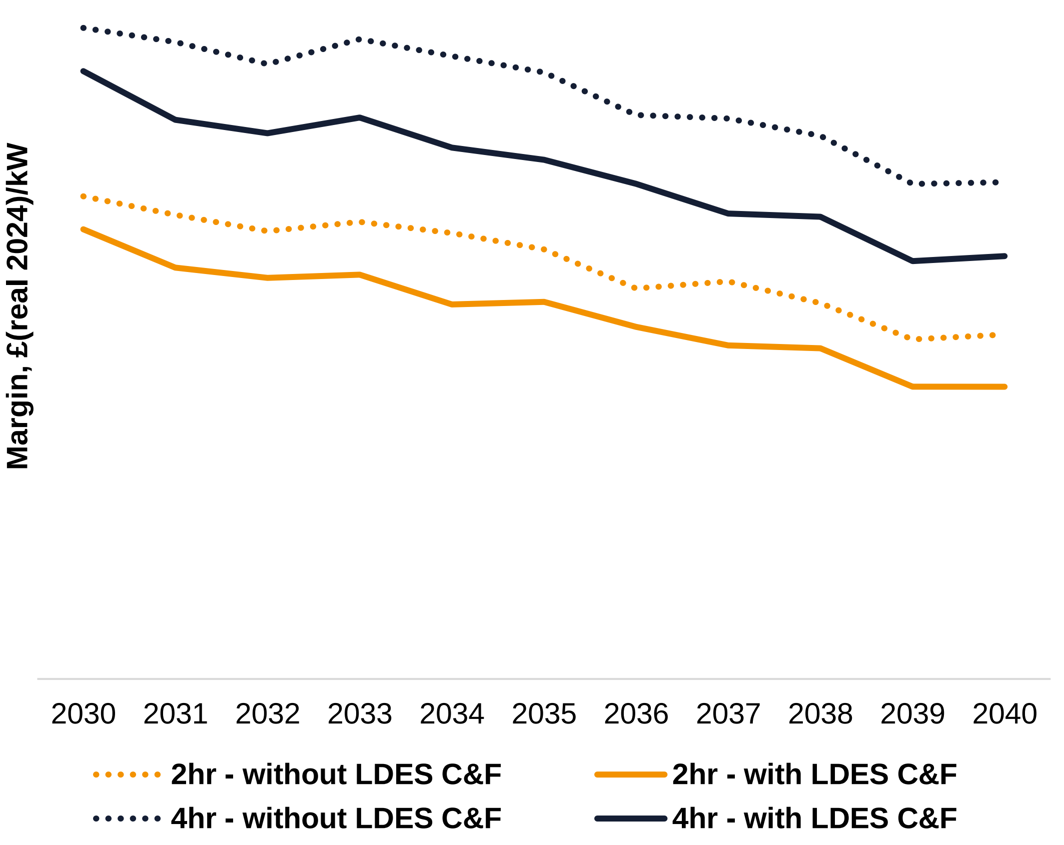
Current plans for Cap and Floor risks cannibalising revenues for shorter-duration BESS

Excluding all BESS from C&F distorts incentives for shorter-duration BESS, risking under-investment in 2hr and 4hr BESS.

- This chart shows margins achieved by BESS under Scenario 1 (without LDES C&F) against Scenario 2 (with LDES C&F).
- The change between these scenarios is that LAES and CAES, as well as some PHS, build due to the C&F incentive provided in Scenario 2 (with LDES C&F). In 2040, LAES & CAES build increases from 0GW to 6GW between scenarios, and PHS increases from 4.1GW to 7.3GW.
- Revenues available for shorter-duration assets are reduced when additional LDES is built, due to cannibalised price spreads and increased competition.
- This leads to a **~12% fall in operating margin** for both a 2hr and 4hr BESS asset, with a **~2% fall in rate of return**. The revenue reduction is evenly distributed across wholesale, intraday, balancing and frequency response revenues. We expect similar falls for 1hr duration assets also.

Operating margin refers to the annual operating profit (or net income from operations) on the asset. It is the total revenue the asset earns **minus** all operating costs (including TNUoS, other fixed O&M costs, and variable costs). This accounts for all costs and revenues except CapEx and associated financing costs.

Impact on shorter-duration BESS margin (degraded curve)



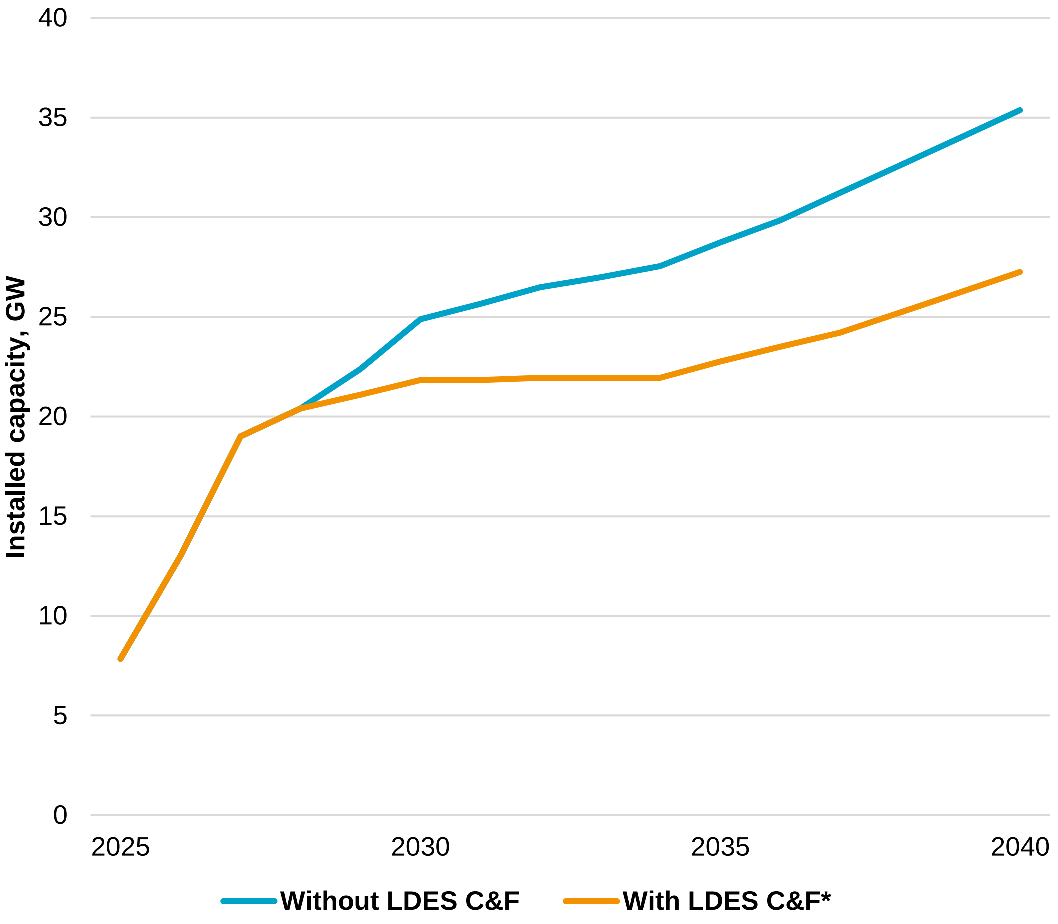
This distortion could lead to the market underdelivering on the system's need for short-duration storage

- Reduced revenues for short-duration BESS due to additional long-duration storage will dramatically reduce investment in short-duration assets.
- The chart shows the resulting investment in 1hr, 2hr and 4hr BESS with and without the distortion introduced by current Cap and Floor described on the previous slide.
- There is a hiatus in investment in BESS in the early 2030s as market revenues are not sufficient to support additional investment. New build begins again in 2035 when returns improve.

Subsequently, lost revenue could reduce investment in short-duration BESS outside of Cap and Floor, reducing 2040 capacity by ~20% from 35.4GW to 27.3GW.

Note: that for the purposes of modelling the No BESS in C&F scenario both in subsequent sections, we have assumed that this reduction in BESS capacity does not happen, and BESS build remains the same across these two scenarios as set out in the Annex. This allows comparison of different LDES build scenarios against a consistent background of short-duration BESS.

Knock-on impact on Total 1,2 and 4hr BESS capacity

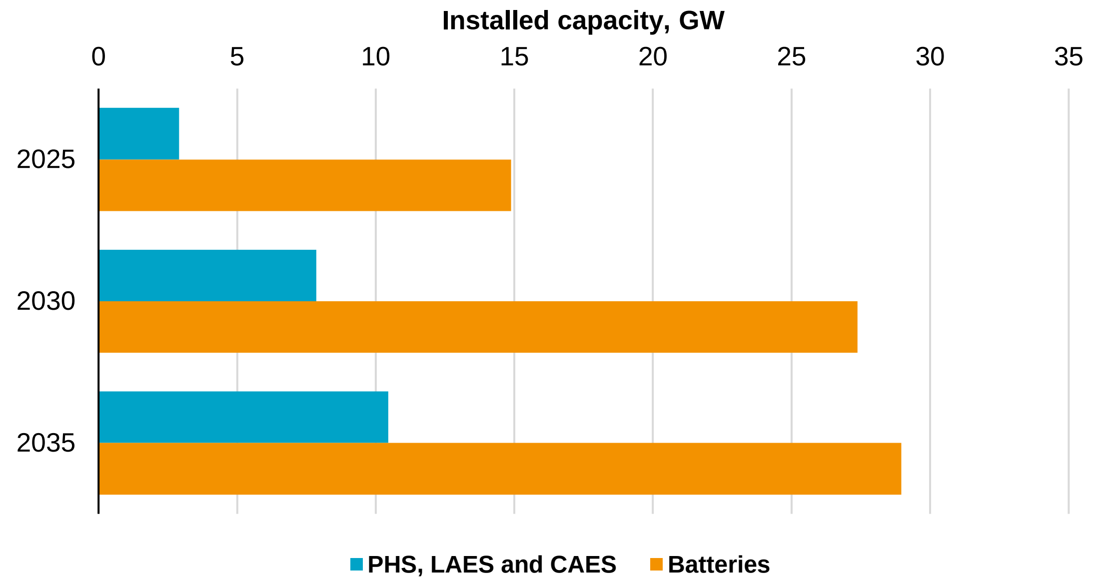


Without support or mitigations, there is inadequate investment in short-duration BESS which is needed in larger volumes than LDES

In NESO's Clean Power 2030 analysis, short duration BESS is installed in much larger volumes than LDES and is already the prevailing technology.

Cap and Floor would jeopardise this investment.

Installed storage capacity in NESO's Clean Power 2030 "Further Flex" scenario



Potential support or mitigation options could include…

Cap and Floor design should follow the principles of other Government policies whereby **supported projects should only be selected by NESO where existing market solutions are insufficient or higher carbon.** A similar example is the design of Dispatchable Power Agreements whereby a CCUS Gas plant receives an SRMC adjustment to operate at the cost of the most efficient unabated gas plant.

These measures could include:

- **Limitations on the types of bilateral agreements that C&F supported projects can enter** such as provision of services to NESO that current PHS provides.
- **Restrict participation in balancing services where the requirement is less than 1 hour.**

Cap and Floor design should consider how LDES can be supported in a proportionate manner which allows continued investment in shorter-duration storage as this is essential for achieving Clean Power 2030 and broader emission reduction goals at low cost.

Long-duration BESS is cost-effective against other LDES

CapEx assumptions at a glance

CapEx costs are a main driver of system costs. Due to technological advancements, economies of scale, and improved efficiencies CapEx costs for all technologies decrease over time.

LAES/CAES assumptions

- We have taken the start point of £4,000/kW[1] (£2020) from the DESNZ LDES report[1] and applied a learning curve equal to that which lithium-ion batteries have achieved[3]. This results in the CapEx cost of LAES/CAES being £3,250/kW (£2024) in 2025, which remains well below costs for known large scale LAES projects[4] which place these technologies at £6,000/kW.

PHS assumptions

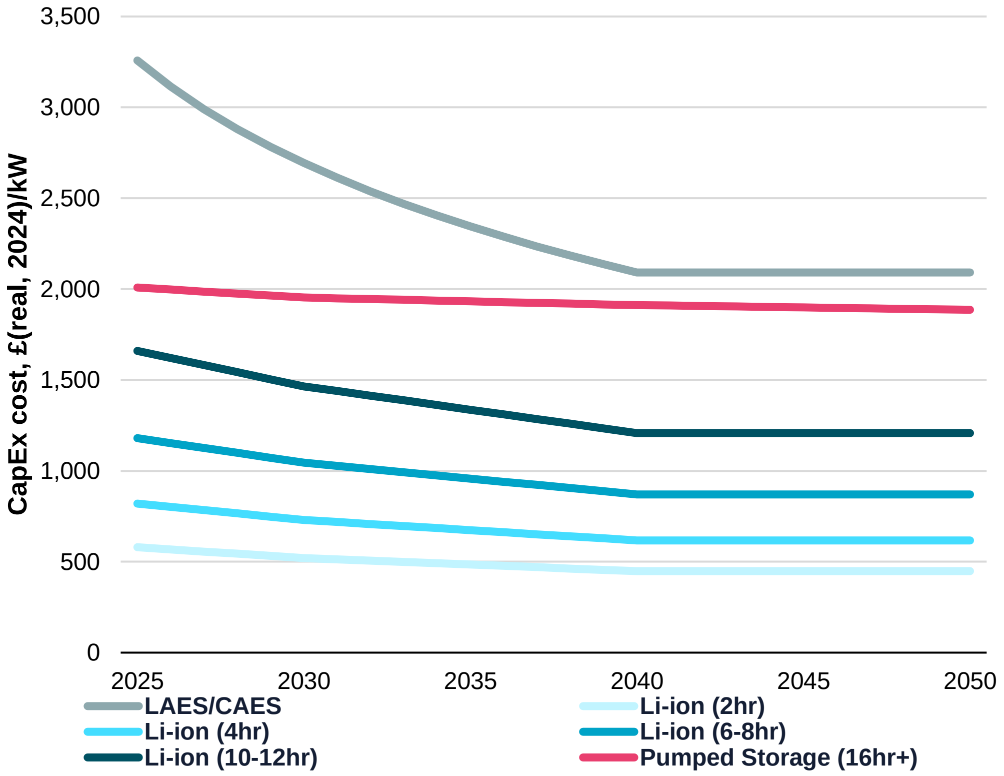
- For our pumped storage assumptions, we have taken the mid-point of the medium and high scenarios from the DESNZ LDES report[1] - the reason we have chosen this level of CapEx is twofold:
  - We do not replace the entire PHS pipeline with long duration BESS in the BESS in C&F scenario. Instead, we assume that the less cost-competitive projects are replaced and some lower-cost projects build. This assumption means that it is likely that the projects we are replacing have a higher-than-average PHS CapEx cost.
  - The price of materials associated with construction of PHS plants have risen dramatically since the DESNZ report[5]. In particular, the cost of concrete has increased by 34% since 2020, we don't expect these costs to reduce over time, especially given that they include embodied carbon costs, which will likely rise over time[6].
- Consistent with DESNZ assumptions, we have not assumed variation across durations for PHS.

Li-ion assumptions

- The CapEx assumptions for all lithium-ion battery storage come from our own internal storage assumptions (Q4 2024). However, according to a report by BNEF, BESS prices fell by a third during 2024 alone[7], this would place current projects well below the cost curves modelled. These costs are expected to fall by as much as 11% this year. If this rapid decrease in CapEx costs continues, the system benefits of BESS would be larger than our modelling estimates.

Further detail on our CapEx assumptions can be found in the Annex

CapEx costs across technologies and durations



[1] Scenario Deployment Analysis for Long-Duration Electricity Storage
[2] Energy Storage Technical Feasibility Assessment, NGESO
[3] Storage cost and technical assumptions for DESNZ report, Mott MacDonald
[4] UK Infrastructure Bank, Centrica & Partners Invest £300M in Highview Power
[5] Building materials and components statistics: February 2025 - GOV.UK
[6] Cost Estimating Guidance - GOV.UK
[7] Global Cost of Renewables to Continue Falling in 2025 as China Extends Manufacturing Lead: BloombergNEF | BloombergNEF

Lower CapEx for BESS results in a significant cost saving relative to other long-duration storage technologies

We examine the system costs associated with investment and fixed costs in assets and network.

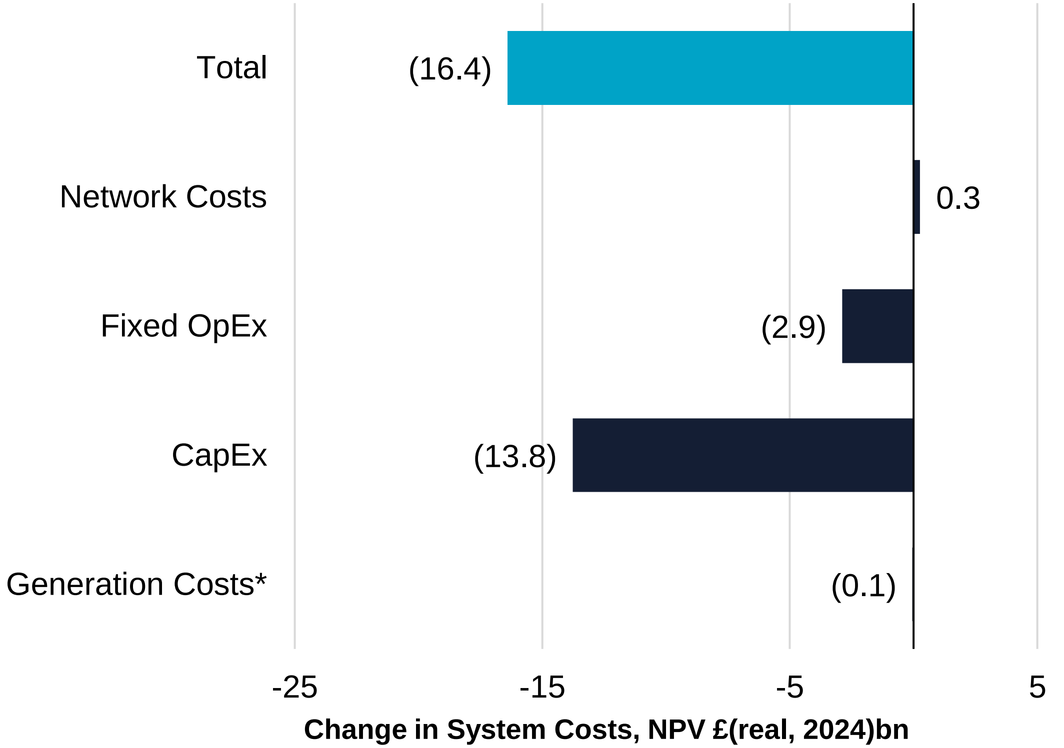
- This analysis reveals **a total cost reduction of £16.4 billion** in NPV** (real, 2024, 2025-50) terms.
- The transition from other LDES technologies to long duration BESS leads to a **reduction in CapEx costs by £13.8 billion**. This is due to the higher construction costs associated with CAES/LAES and PHS technologies. We find that there is a significant cost associated with these LDES technologies that results in large system savings in the All BESS in C&F scenario.

Note: this result is sensitive to the assumptions on CAES/LAES CapEx which are very uncertain, as well as PHS which are project specific. However, assumptions would need to change substantially to change the conclusion of the analysis. More detail on our CapEx assumptions can be found in the Annex.

- In much the same way, when we move from the No BESS in C&F scenario to the All BESS in C&F scenario, we see a **reduction in fixed OpEx costs of £2.9 billion**. This is due to lithium-ion storage having a lower fixed OpEx cost than pumped storage and compressed air/liquid air energy storage.
- When we move from the No BESS in C&F scenario to the All BESS in C&F scenario there is a slight increase in network costs of **£0.3 billion** as more capacity is connected, however, this is a relatively small change.
- There is a minor change in generation costs between the two scenarios. This is expected as we are keeping security of supply and carbon emissions consistent between the two scenarios. The very small benefit comes from the higher efficiency of long duration BESS compared to the other LDES technologies.

Note: the potential to deliver long-duration BESS by adding duration to existing BESS sites could substantially reduce the network costs.

Total system cost changes from long-duration BESS



£ **These savings reduce the returns underwritten by consumers through Cap and Floor**. In a scenario where LDES has a floor rate of return at 8% and the market provides 6%, these savings **translate into a £2.06bn saving for consumers (NPV 2025-50, 3.5%).**

In this scenario, consumers would save £122 million per year.

*Generation costs in this result are the costs associated with electricity generation dispatch including generation costs, interconnector costs and balancing costs

**NPV calculated with a discount rate of 3.5% per year in line with DESNZ CBA approach

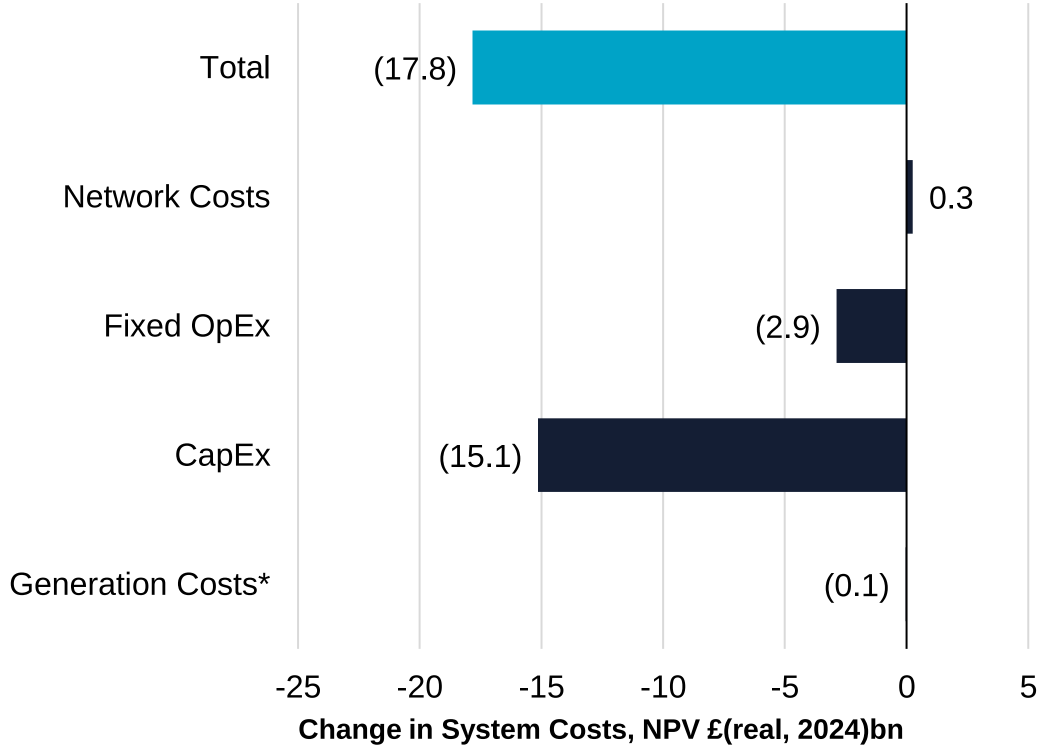
If CAES/LAES lifetime were reduced to 20 years, then the benefits of long-duration BESS increase further

We include a further scenario to address the underlying uncertainty in lifetime assumptions of CAES/LAES.

- In this scenario, we reduce the lifetime assumptions of compressed air and liquid air assets to 20 years.
- This change results in the CapEx saving of long-duration BESS assets being more apparent. In this scenario we have a total cost reduction of **£17.8 billion** in NPV**(2025-50 real, 2024) terms.
- The change in total cost differences between the No BESS in C&F scenario and the All BESS in C&F scenario is entirely down to having to replace CAES and LAES assets earlier than in the other scenario. The total cost savings due to lower CapEx of BESS assets increases to **£15.1 billion**.
- It is important to consider this scenario in our analysis of the value of long-duration BESS because, in comparison to BESS assets, there is a large amount of uncertainty around the lifetime that a compressed air, or liquid air asset can achieve.

For reference, the **total system cost for the No BESS in C&F scenario is £5,881 billion**, showing an overall system cost saving of **0.3% over the period 2025-2050.**

Total system cost changes from long-duration BESS



£ **These savings reduce the returns underwritten by consumers through Cap and Floor**. In a scenario where LDES has a floor rate of return at 8% and the market provides 6%, these savings **translate into a £2.22bn saving for consumers (NPV 2025-50, 3.5%).**

In this scenario, consumers would save £131 million per year.

*Generation costs in this result are the costs associated with electricity generation dispatch including generation costs, interconnector costs and balancing costs

**NPV calculated with a discount rate of 3.5% per year in line with DESNZ CBA approach

Long-duration BESS needs support to maximise its benefit

In this phase of the analysis, we look at the benefits and investment case for marginal long-duration BESS in 2030 in the No BESS in C&F scenario

The questions we are answer in this phase are:

- Does the market reward long-duration storage for its system benefits?
- Does long-duration BESS provide system benefits, even with high volumes of LDES?
- Does long-duration BESS need support to be investable?

Our approach to modelling these benefits and revenues

We **use the No BESS in C&F scenario** as the baseline market scenario.

For each duration of BESS, we **forecast the behaviour of an additional 1MW of storage** over the lifetime of the project.

Each 1MW replaces the need for:

- Thermal peaking generation, to maintain system security, accounting for derating.
- Offshore wind, to reduce emissions.

We replace this capacity and record the cost saving.

We **simulate the market before and after the addition of storage** and measure:

- Storage operating margin
- Change in system cost, including build costs and generation costs

We have assessed the marginal benefit and cost of BESS at different durations in the No BESS in C&F scenario

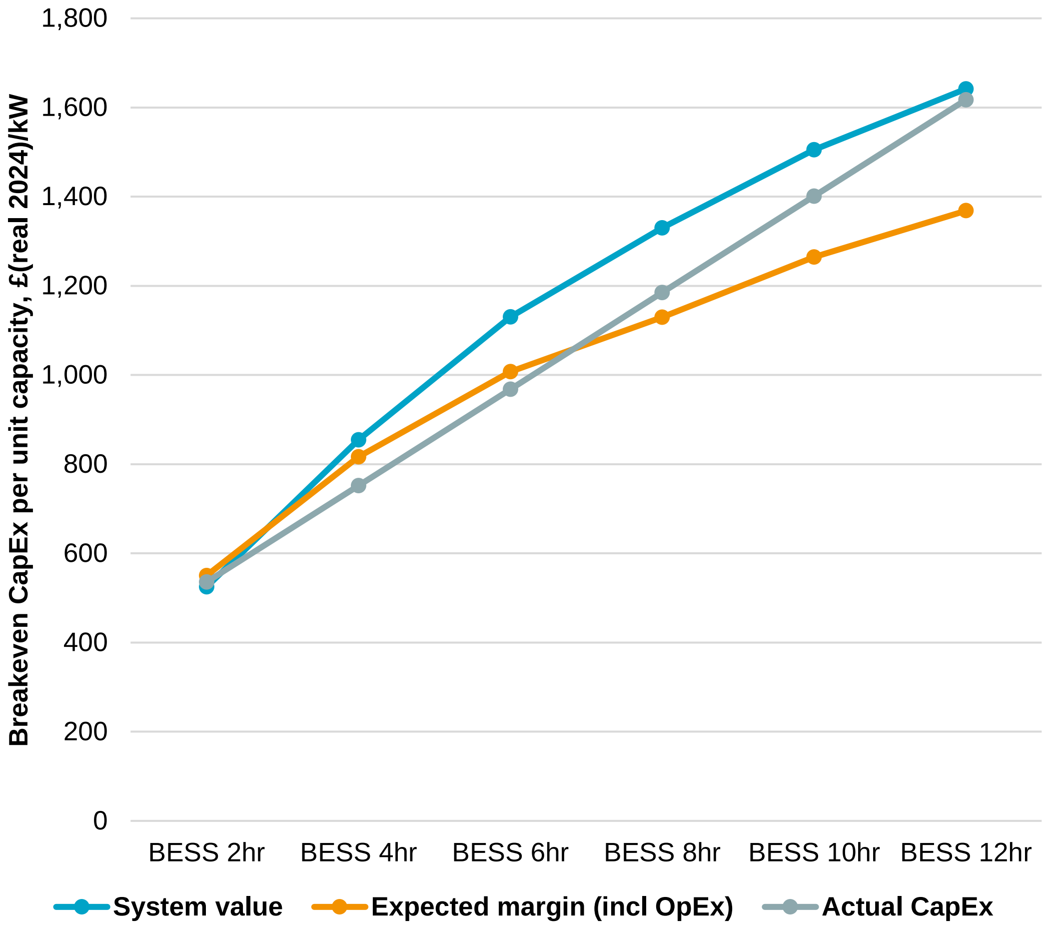
We have calculated three metrics to demonstrate the value that BESS of different durations provides to the system and the ability of the market to support investment in those assets.

- **Actual CapEx:** LCP Delta's estimate of 2030 CapEx for BESS at different durations. We have assumed that the cost of additional kWh is constant up to 12hr duration.
- **Expected margin (incl. OpEx):** the modelled operating margin (the total revenue the asset earns minus all operating costs) per unit of capacity, on a lifetime NPV basis (discounted at an assumed hurdle rate of 12%) including OpEx. If the margin exceeds the CapEx value, then BESS is investable at that duration in this scenario without further support.
- **System value:** the system benefit, in terms of system cost reduction, per unit capacity on a lifetime NPV basis (discounted at the social discount rate of 3.5%). If the system value exceeds CapEx, then building additional BESS at this duration is beneficial to the system.

In this analysis, **we consider the marginal benefit of BESS at different durations in the No BESS in C&F scenario**.

This uses the same system cost metrics as the comparison of the No BESS in C&F and All BESS in C&F scenarios in the previous section. However, it instead calculates how additional storage would change the capacity mix by displacing thermal build for system security and wind build to maintain emissions, alongside generation cost reductions.

Measures of 2030 BESS value and cost for different duration assets

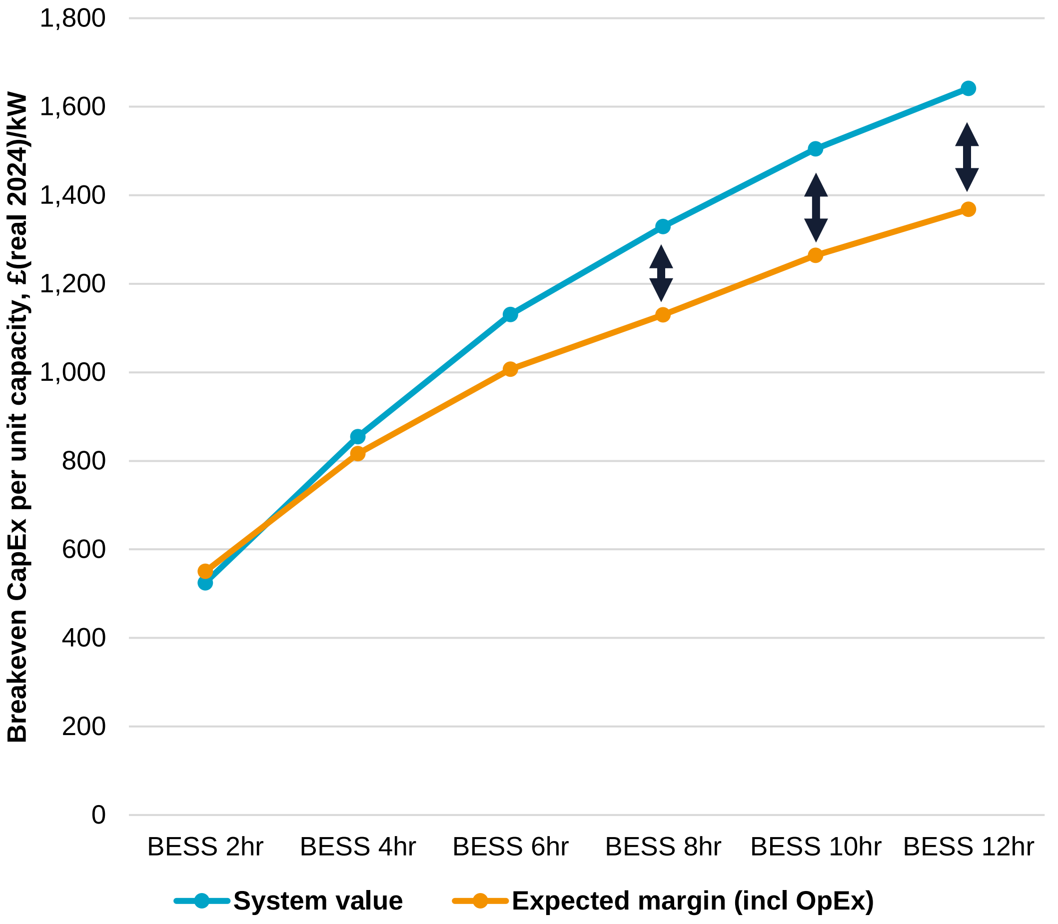


The market does not accurately reflect the value of BESS at longer durations

The market signal to long-duration BESS does not reflect its value to the system.

- **As duration increases, the system value per kW increases** as storage offsets more investment in thermal capacity to maintain system security.
- It can also offset a greater amount of renewable generation, while maintaining carbon emissions.
- Market revenues also increase, due to greater opportunities to capture price spreads and higher CM revenues.
- However, **margins do not increase by as much as system benefit**, creating a disparity between the value of storage and what it can earn from the market.
- Therefore, without appropriate support, the **system may not efficiently deliver the right assets** to maximise a system benefit.

Measures of 2030 BESS value and cost for different duration assets

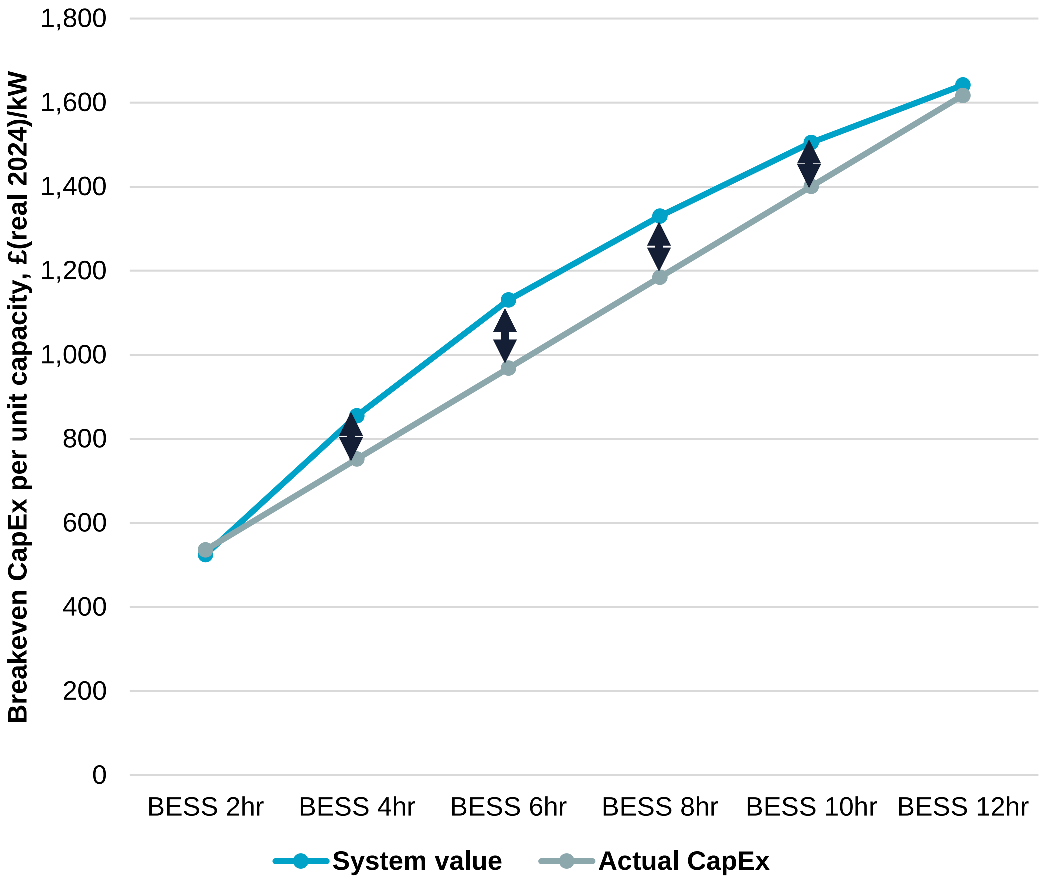


Long-duration BESS continues to provide system benefits at higher durations

£ **Long-duration BESS continues to provide benefits to the system with high deployment of long-duration BESS.**

- The **system value of storage exceeds the CapEx cost at all durations** between 2hr and 12hr in 2030.
- At shorter durations, this benefit is smaller because of higher competition from other storage, and because the total cost per kWh is higher.
- The initial **benefit of additional kWh (e.g. between 2hr and 6hr) exceeds the additional CapEx cost**. This benefit is due to higher CM deratings, offsetting thermal plant build, and greater ability to reduce generation costs, including emissions.
- While the marginal benefit of additional kWh is lower at 10hrs and 12hrs, **these assets still provide a benefit and meet the system's fundamental need for long-duration storage**.

Measures of 2030 BESS value and cost for different duration assets

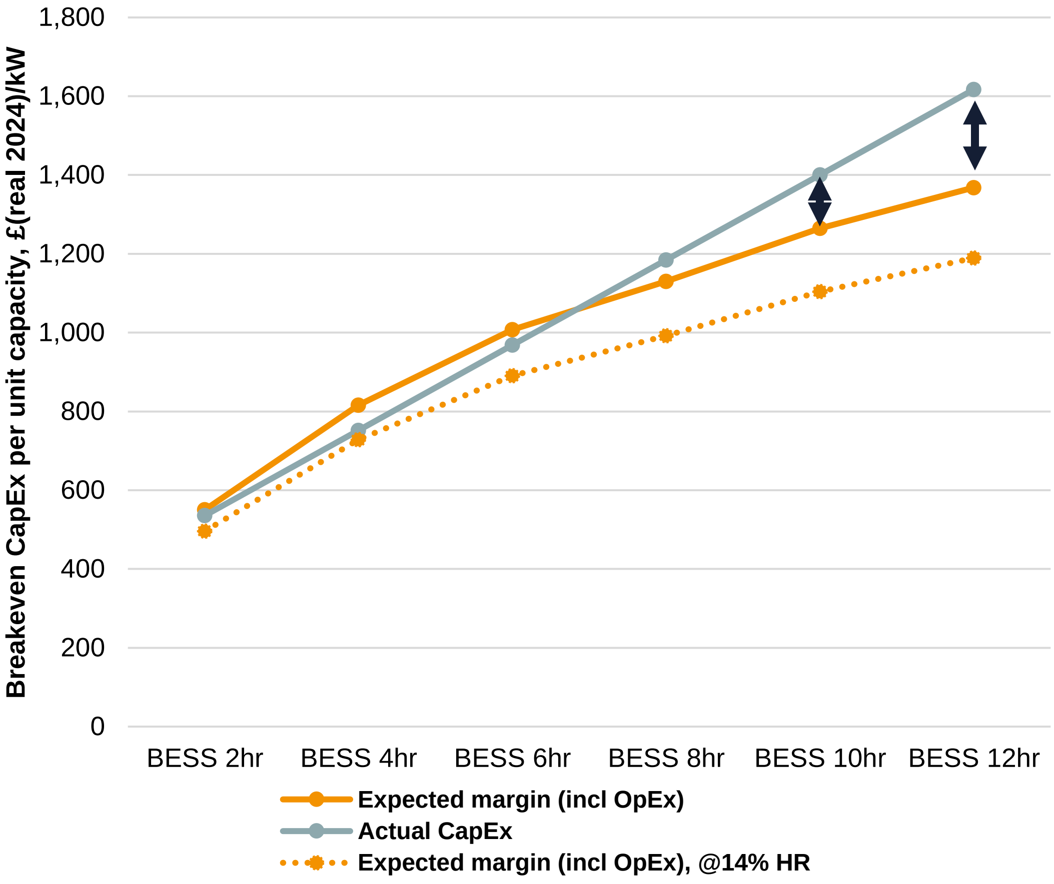


Despite providing a system benefit, the market will not deliver long-duration BESS without support

Without support, BESS at 8hrs and above is not investable despite its system benefit. At a higher hurdle rate (14% rather than 12%), this is also true at 6hrs.

- At lower durations, BESS can make a return which covers its capital costs without support.
- However, at durations above 6 hours, the market does not accurately reflect the value of BESS.
- This means that **long-duration BESS will not build without support**.
- **For example, if BESS were included in Cap and Floor, then the cost of capital would be reduced, making BESS investable at longer durations.**

Measures of 2030 BESS value and cost for different duration assets



Annex A - Scenarios

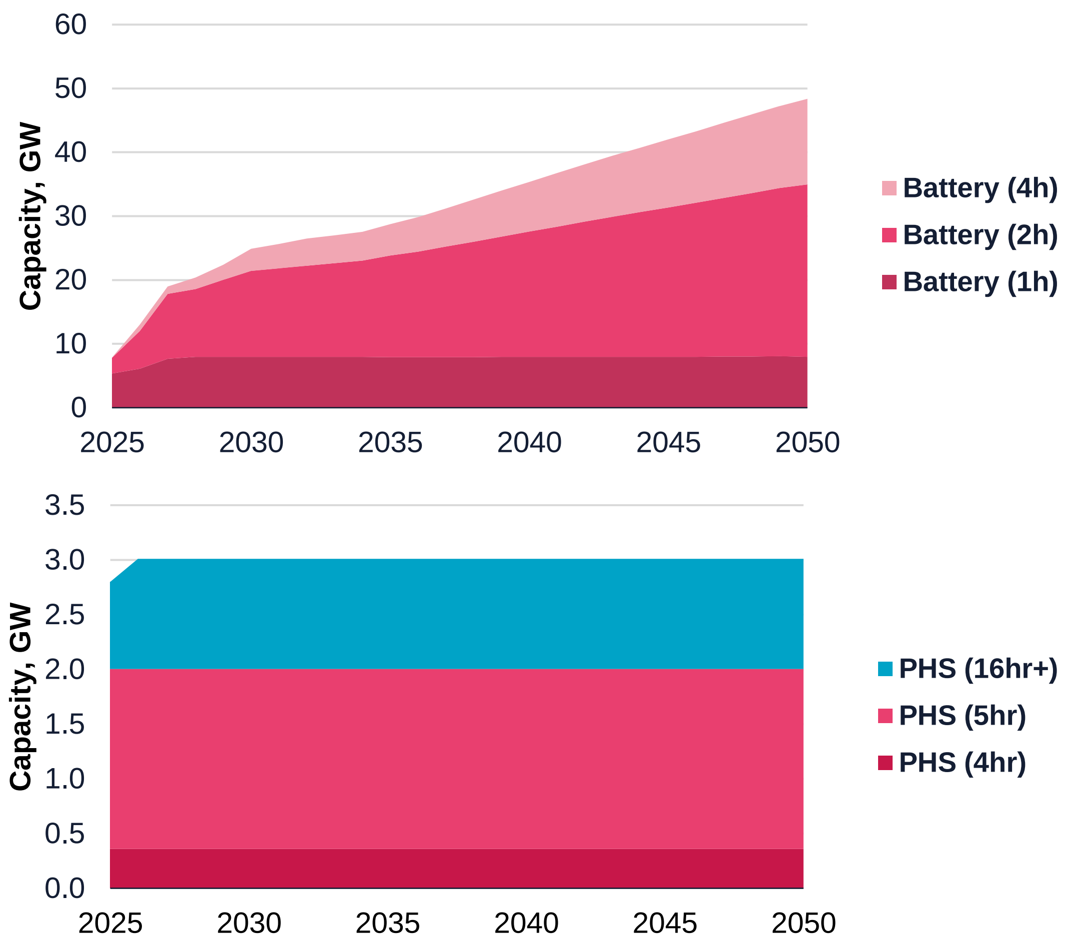
In the No C&F scenario, there is no incentive for long duration BESS and LDES buildout post-2030 and

Under the No C&F scenario we see the following buildout of battery storage and LDES technologies:

In this scenario we assume that there is no Cap and floor, and that the market continues to operate under current conditions without C&F incentivising additional LDES build.

- **Battery buildout:** in this scenario, we see 1hr, 2hr, and 4hr battery capacity build in line with the Clean Power 2030 ambitions. There is no buildout of long-duration BESS, or LDES technologies beyond the current pipeline due to a lack of incentive due to there being no C&F. The battery capacity reaches 25GW in 2030, increasing to 35GW in 2040, and reaching 48GW in 2050.
- **Pumped Hydro Storage:** without the incentive provided by C&F, pumped storage capacity only reaches 3GW by 2030, as only PHS projects that are existing or under construction build. Following this, the scenario considers no further buildout.
- **Compressed Air and Liquid Air Energy Storage:** CAES and LAES do not build in this scenario as there is no incentive provided by Cap and floor.

Storage breakdown under the No C&F scenario



In the No BESS in C&F, LAES/CAES and full PHS pipeline meet LDES requirements

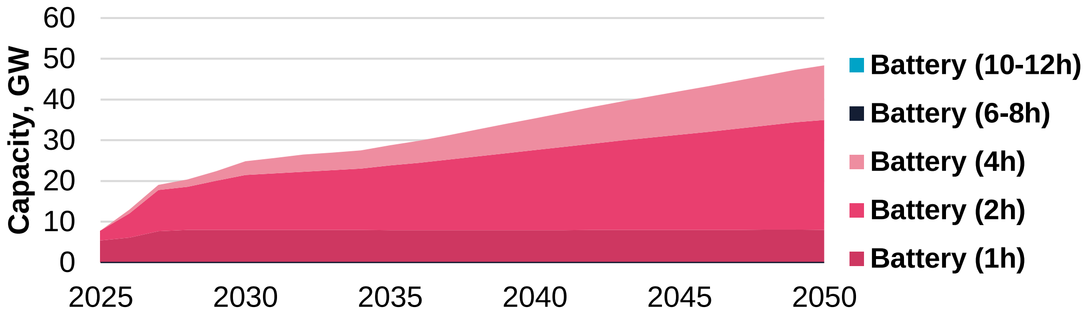
Under the No BESS in C&F scenario we see the following buildout of battery storage and LDES technologies:

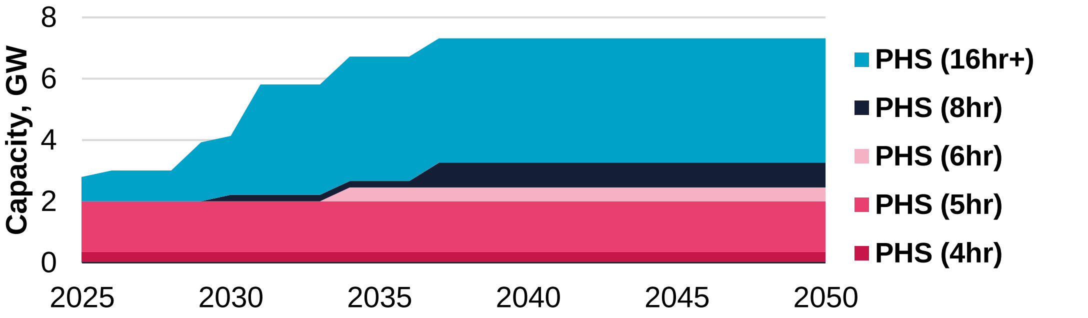
- **Battery buildout:** in this scenario we see 1hr, 2hr, and 4hr battery capacity build in line with the Clean Power 2030 ambitions. There is no buildout of long-duration BESS, instead we see a range of LDES technologies. The battery capacity reaches 25GW in 2030, increasing to 35GW in 2040, and reaching 48GW in 2050.

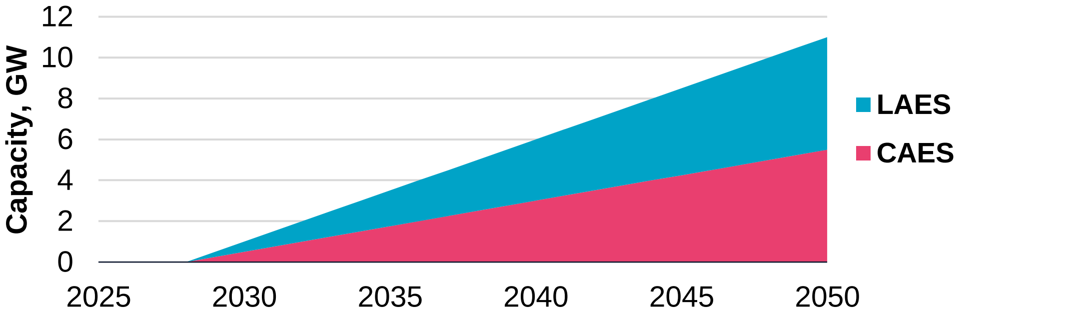
- **Pumped Hydro Storage:** in line with the Clean Power 2030 ambitions, pumped hydro storage buildout continues into the 2030s, reaching a total capacity of 7.3GW. There is some uncertainty about the exact timing of these longer duration assets, but we have worked from publicly stated online dates.
  - **Note on total potential:** based on the pipeline of projects, there is potential for a greater volume of PHS to be built. However, in this analysis we assume that some projects will not be cost competitive and will not be built. Our total volume of PHS build still exceeds all NESO's FES 2024 pathways.
  - **Note on duration:** we have grouped projects into a single 16hr+ group with an average duration of 20hrs. This maintains the same total GWh and GW of PHS as our central forecast.

- **Compressed Air and Liquid Air Energy Storage:** this scenario has CAES and LAES capacity starting to come online from 2029 with a uniform buildout to 5.5GW each in 2050 to deliver the volume of long-duration storage required by the system.

Battery Breakdown under the No BESS in C&F scenario







In the All BESS in C&F scenario, long-duration BESS displaces other LDES post-2030, maintaining system security and emissions levels

Under the All BESS in C&F scenario we see the following buildout of battery storage and LDES technologies:

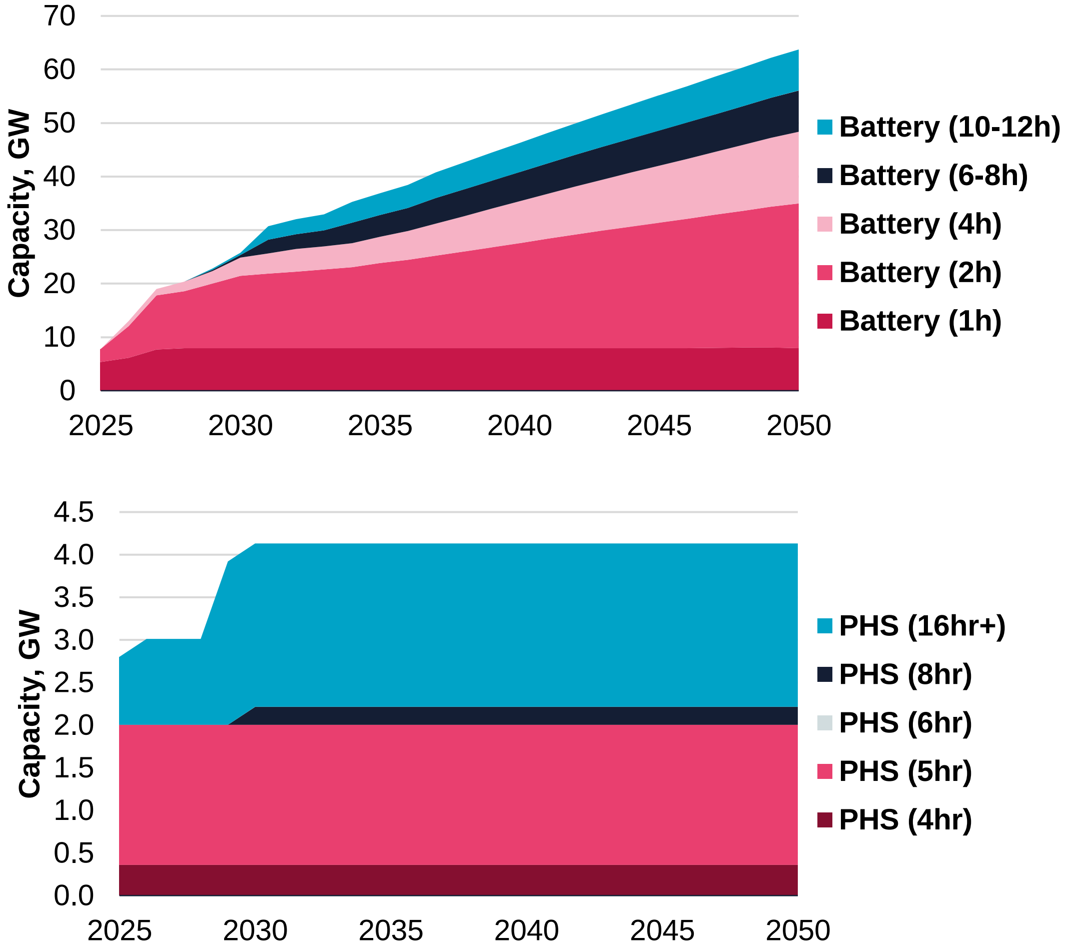
In this scenario we assume that all BESS is included in Cap and Floor, resulting in the ability to meet system requirements for long duration energy storage through battery-enabled LDES.

- **Battery buildout:** **i**n this scenario, we see 1hr, 2hr, and 4hr battery capacity build in line with the No BESS in C&F scenario. On top of this we start to see 6-8hr and 10-12hr long-duration BESS coming online instead of increased pumped storage capacity, and CAES/LAES capacity. The total amount of long-duration BESS that comes online by 2050 is 17GW, split evenly between the two duration types.

- **Pumped Hydro Storage:** in line with the Clean Power 2030 ambitions, pumped hydro buildout reaches 4.1GW by 2030 as the most economically advantage PHS projects build. However, following this, the scenario considers no further buildout as LDES is provided by long-duration BESS.

- **Compressed Air and Liquid Air Energy Storage:** CAES and LAES are replaced by long-duration BESS in this scenario.

Storage breakdown under the All BESS in C&F scenario



In the All BESS in C&F scenario, long-duration BESS displaces other LDES post-2030, maintaining system security and emissions levels

The graph on the right shows the overall change in capacity mix over time between the No BESS in C&F and All BESS in C&F scenarios.

When the capacity mix changes, we ensure that the following two features of the market are maintained:

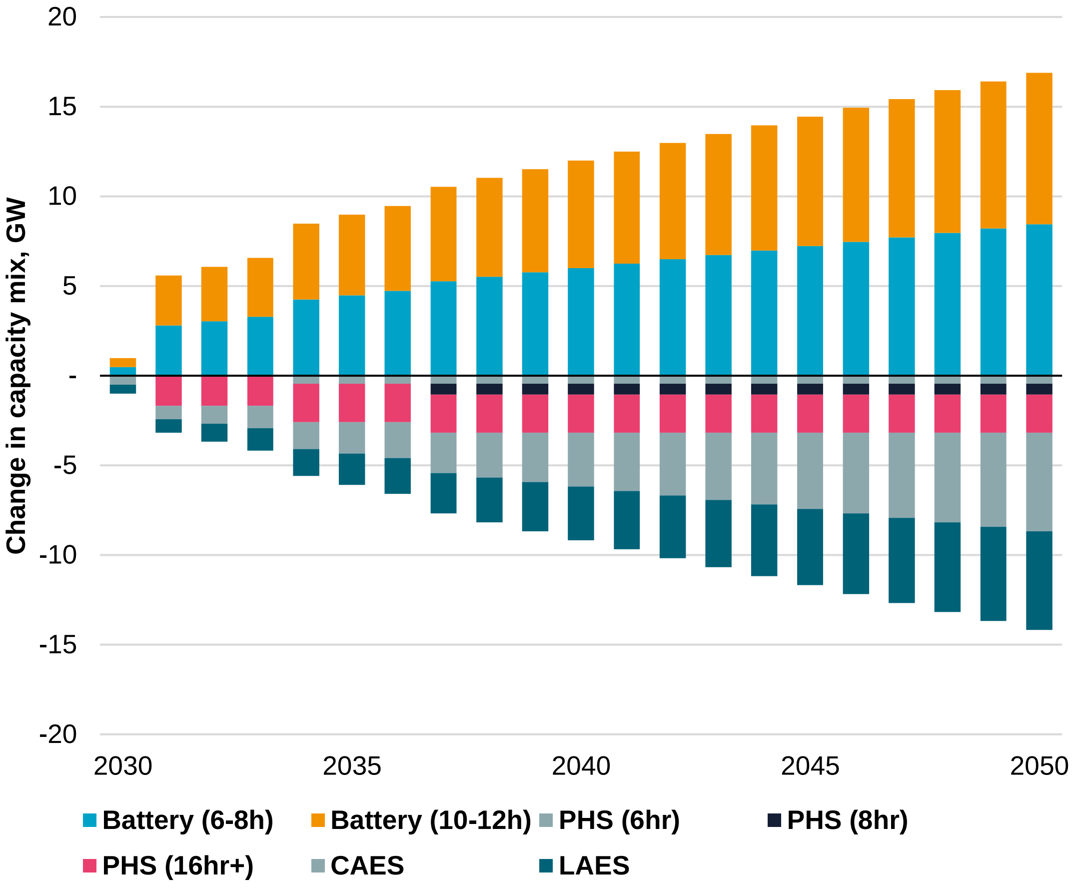
- **System security:** the overall level of derated capacity is constant
- **Carbon emissions:** emissions from power generation are consistent between scenarios.

To ensure that these features are consistent across the scenarios, we need a higher capacity of 6-8hr and 10-12hr BESS to replace the capacity of the pumped hydro storage, compressed air and liquid air that comes off the system.

Note: maintaining these two system properties between the two scenario will reduce the impact on the system costs of generation. The system cost impact will mostly be realised through changes in CapEx costs.

Reducing pumped hydro storage capacity raises concerns about losing the associated job creation benefits in low-income communities. However, BESS can also create employment opportunities, including for locally based contractors. One possible advantage of BESS is their flexibility, as they can be deployed in a wider range of locations and placed closer to areas with grid constraints. This flexibility could help circumvent some of the geographical limitations of pumped hydro storage (particularly in urban and industrial regions) offering potential for more widespread job creation across the country.

Change in capacity mix between the No BESS in C&F and All BESS in C&F scenarios



Annex B – CapEx assumptions

We have updated CapEx assumptions for each technology based on expected learning rates and updated costs

CapEx costs are a main driver of system costs. Due to technological advancements, economies of scale, and improved efficiencies CapEx costs for all technologies decrease over time.

CAES/LAES

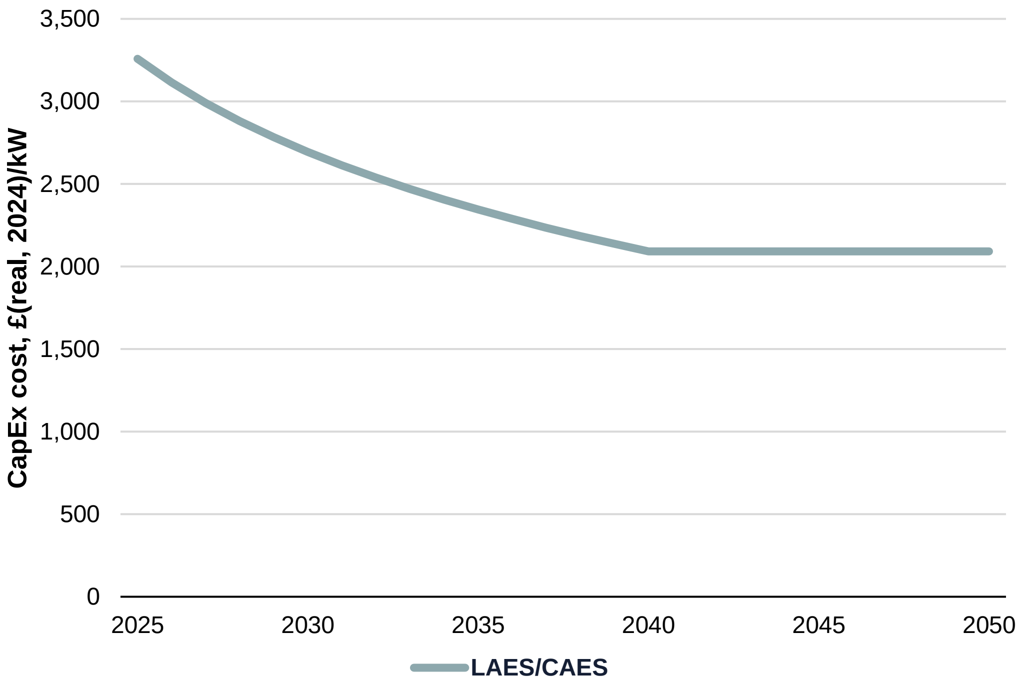
Current cost assumptions

- Our starting assumption for LAES/CAES in 2020 comes from the DESNZ LDES report[1] which started at £4,000/kW in 2020 (£2020). This is roughly in line with cost estimates in a separate report for NESO in 2022[2].
- However, this is well below costs for known large scale LAES projects[4] which place these technologies at £6,000/kW (£2024).

Future costs reductions

- The DESNZ assumption is that LAES/CAES achieve a similar £/kW cost as pumped storage by 2030, which is highly optimistic given the maturity of PHS.
- Instead, we have applied a learning curve for lithium-ion batteries to the initial 2020 figure to come to a forecast of cost reduction over time, taken from a report for DESNZ[3].
- This assumes these technologies will replicate the fast cost reduction seen for BESS. In practice, this is optimistic because of the widespread deployment of Li-Ion batteries across power, transport and other applications, all of which drive cost reduction.
- This is not as fast as the DESNZ assumption of ~65% reduction in cost between 2020 and 2030 but still represents a ~45% reduction in the same period.
- Consistent with other CapEx assumptions, we've assumed no learning beyond 2040.

CapEx costs across technologies and durations



[1] Scenario Deployment Analysis for Long-Duration Electricity Storage
[2] Energy Storage Technical Feasibility Assessment, NGESO
[3] Storage cost and technical assumptions for DESNZ report, Mott MacDonald
[4] UK Infrastructure Bank, Centrica & Partners Invest £300M in Highview Power
[5] Building materials and components statistics: February 2025 - GOV.UK
[6] Cost Estimating Guidance - GOV.UK
[7] Global Cost of Renewables to Continue Falling in 2025 as China Extends Manufacturing Lead: BloombergNEF | BloombergNEF

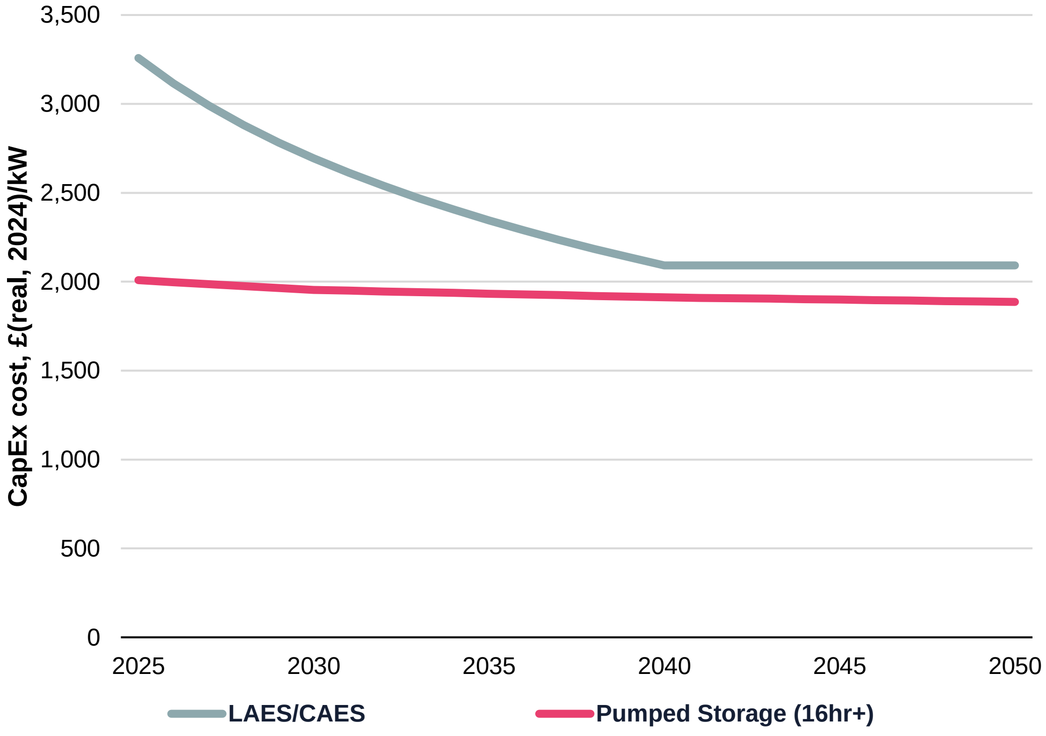
We have updated CapEx assumptions for each technology based on expected learning rates and updated costs

CapEx costs are a main driver of system costs. Due to technological advancements, economies of scale, and improved efficiencies CapEx costs for all technologies decrease over time.

Pumped storage

- For our pumped storage assumptions, we have taken the mid-point of the medium and high scenarios from the DESNZ LDES report[1], the reason we have chosen this level of CapEx is twofold:
  - We do not replace the entire PHS pipeline with long duration BESS in the BESS in C&F scenario. Instead, we assume that the less cost-competitive projects are replaced and some lower-cost projects build. This assumption means that it is likely that the projects we are replacing have a higher-than-average PHS CapEx cost.
  - The price of materials associated with construction of PHS plants have risen dramatically since the DESNZ report[5]. In particular, the cost of concrete has increased by 34% since 2020. Pumped storage is an established technology and therefore cost reductions in future from learning are likely to be minimal, in fact, it is more likely that CapEx costs increase over time given the inclusion of embodied carbon costs, which will likely rise over time[6].
- The CapEx assumptions are assumed to be constant for different durations of pumped storage between 8hrs and 32hrs in DESNZ's report.

CapEx costs across technologies and durations



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We have updated CapEx assumptions for each technology based on expected learning rates and updated costs

CapEx costs are a main driver of system costs. Due to technological advancements, economies of scale, and improved efficiencies CapEx costs for all technologies decrease over time.

Li-Ion batteries

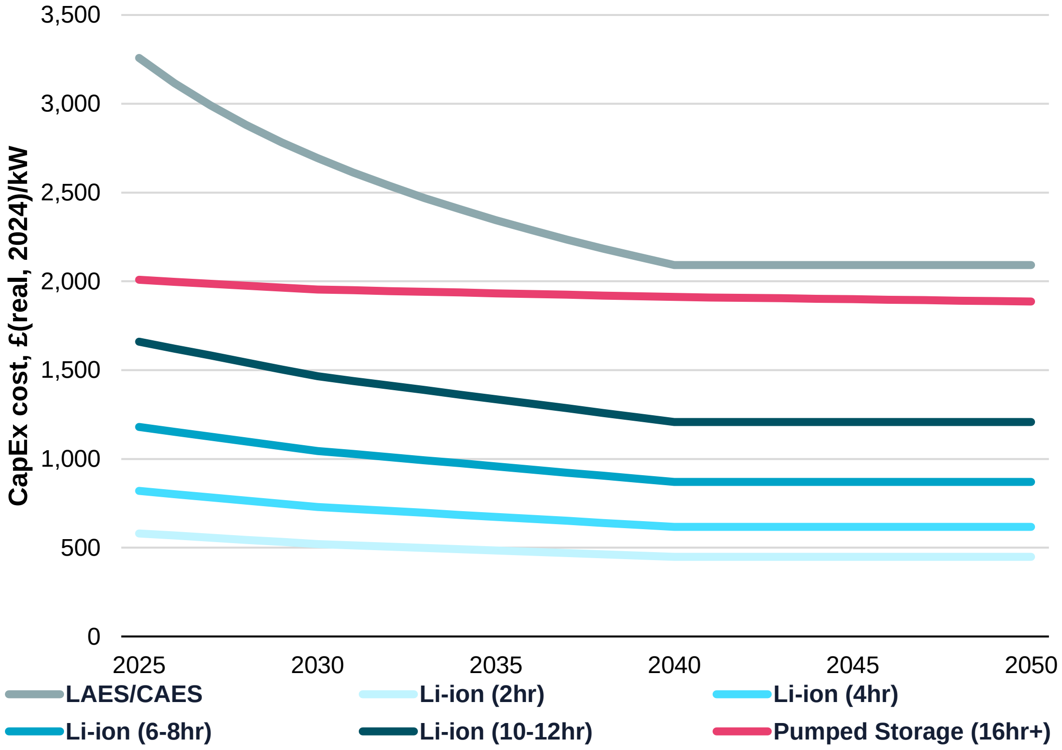
- The CapEx assumptions for all lithium-ion battery storage come from our own internal storage assumptions (Q4 2024).

- This reflects our latest in-house views on the costs associated with building this technology which are more in line with industry expectations than DESNZ assumptions, which were ~10% higher in 2030 for 6-8hr BESS.

- Note that we have not assumed any economies of scale with building longer-duration batteries. That is, the cost of adding 2hrs of duration is constant as duration increase, rather than costs falling. If we were to assume economies of scale, the benefits of long-duration BESS in this report would increase.

- However, these cost estimates are still above where investors in BESS are seeing current equipment prices and are therefore conservative when evaluating the benefits of long-duration BESS. In fact, according to a report by BNEF, BESS prices have fallen by a third in 2024 alone[7], this would place current projects well below the cost curves modelled. BESS CapEx costs are expected to fall by as much as 11% this year. If this rapid decrease in CapEx costs continues, the system benefits of BESS are likely to be even larger than our modelling suggests.

CapEx costs across technologies and durations



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[7] Global Cost of Renewables to Continue Falling in 2025 as China Extends Manufacturing Lead: BloombergNEF | BloombergNEF

We also updated assumptions to reflect more up-to-date CapEx and provide other more realistic project assumptions

The assumptions that have been used for the modelling of batteries have been taken from our latest in-house view:

- For consistency with the DESNZ study on the benefits of LDES we have kept most of the core storage assumptions unchanged.
- We have refined the assumption of lifetime for BESS to reflect reduced cycling of longer duration BESS and based on experience of warranties available for planned BESS projects (e.g. 2hr BESS projects are quoted 20-year warranties).
- Hurdle rates for all technologies have been updated to reflect a realistic cost of capital for investment in LDES. We have also updated assumptions on cost of capital for other technologies required in this analysis (peaking thermal: 12%, offshore wind: 9%).
- Note that hurdle rates would be lower if projects were developed under Cap and Floor. However, we have considered all assets at a comparable hurdle rate across scenarios. Lower hurdle rates would reduce the benefits of reducing CapEx spend by displacing other LDES with BESS shown on slide 12, though the benefit would remain similar in magnitude. Lower hurdle rates would also increase the system benefit of BESS at all durations and raise the expected margin per kW as a lifetime NPV, shown on slide 16.

Summary of updated assumptions

Attribute	BESS	Compressed air energy storage	Liquid air energy storage	Pumped hydro storage
Duration (hrs)	Up to 12hrs	8hrs	8hrs	20hrs
Hurdle Rate	12% (with 14% sensitivity)	12%	12%	12%
Lifetime (Years)	15-30yrs, depending on duration	*40yrs (with 20yrs sensitivity)*	*40yrs (with 20yrs sensitivity)*	*50*

Assumptions not listed or in grey are in line with values used in DESNZ's report
Source: DESNZ LDES benefits report by LCP Delta and Regen

Annex C - Analytical framework

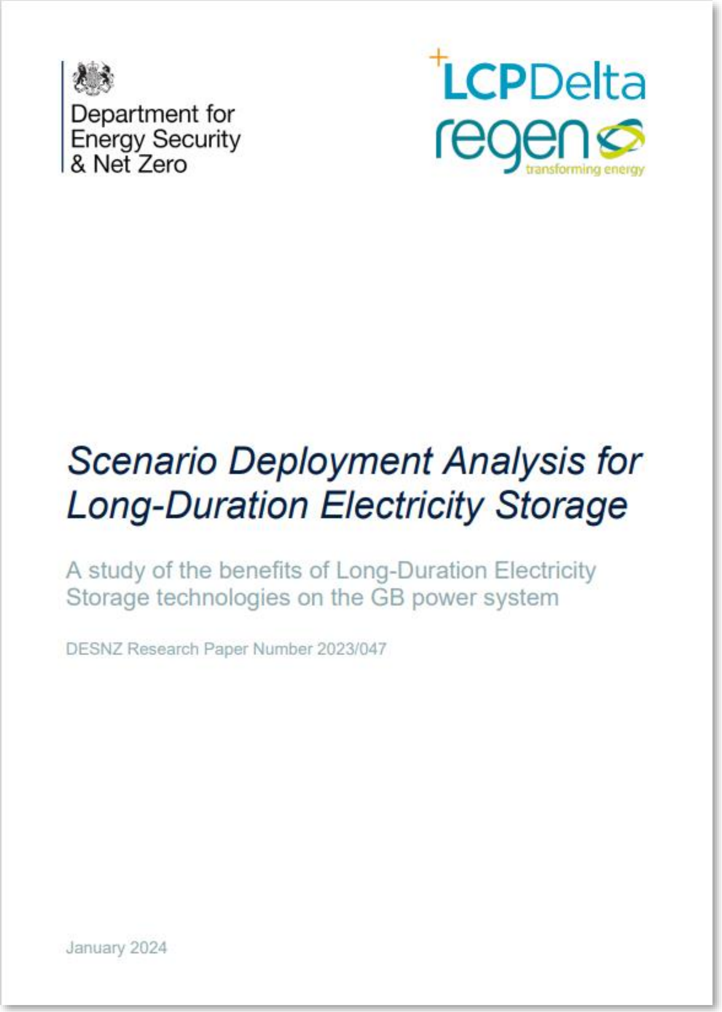
Our approach aligns with the analysis undertaken by LCP Delta for DESNZ on the value of LDES

Key findings from previous DESNZ report

- *“The modelling shows that adding LDES to the system can have a positive impact on both emissions and system costs, with the duration of deployed LDES being the biggest factor in the size of that impact.”*
- *“The capital costs of LDES technologies are critical in determining the net benefits of these technologies. Reducing the capital costs of these technologies increases system benefits.”*
- *“Overall, Long-Duration Electricity Storage technologies could have a significant impact on providing the flexibility the future GB power system will need, driving reduction of both emissions and system costs.”*

Limitations addressed by this analysis

- The background capacity mix was based on DESNZ’s scenario from 2021, which is **not consistent with Clean Power 2030** targets.
- The DESNZ study used **outdated cost assumptions** ([Generation Costs 2020]) for LDES and other technologies. This will have a significant impact for technologies such as BESS which have seen significant CapEx reductions.
- Other assumptions used for BESS should be updated when considering LDES projects, such as lifetime.


Department for Energy Security & Net Zero

LCPDelta

regen transforming energy

Scenario Deployment Analysis for Long-Duration Electricity Storage

A study of the benefits of Long-Duration Electricity Storage technologies on the GB power system

DESNZ Research Paper Number 2023/047

January 2024

Source: *DESNZ LDES benefits report by LCP Delta and Regen*

The key metric when assessing the value of a technology to the GB system is the impact on whole system costs

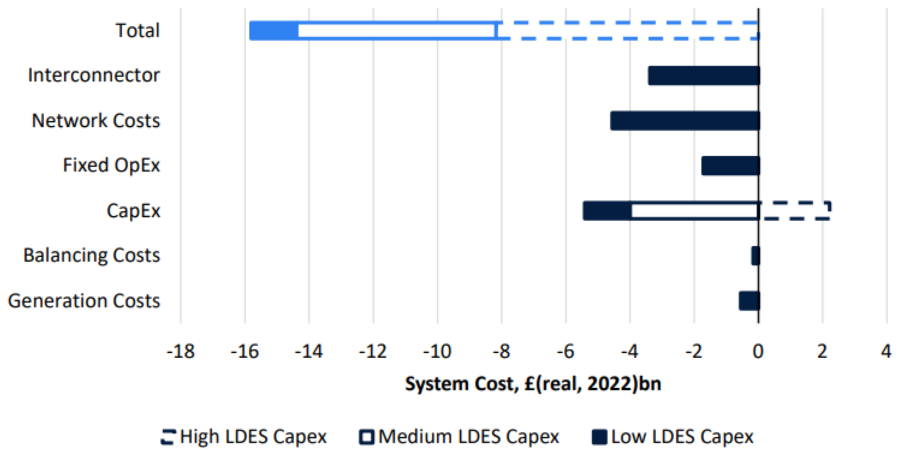
System costs

The underlying costs of building, maintaining and operating infrastructure to provide energy and services

- **Generation costs:** the fuel and variable operating and maintenance (VOM) costs of plants associated with meeting electricity demand hour to hour, i.e. wholesale market dispatch
- **Carbon costs:** the carbon costs based on carbon emissions priced at social cost of carbon (i.e. DESNZ central appraisal price).
- **CapEx costs:** the capital costs including pre-development, construction and infrastructure costs (all £/kW) for building plants, as well as financing costs.
- **Fixed OpEx costs:** the fixed operating costs of plants, any operating costs that do not vary with output, and represented in £/kW terms.
- **Network costs:** the cost of maintaining, reinforcing and extending the transmission network. Distribution network costs are not directly included in our modelling.
- **Interconnector costs**: the costs associated with building, maintain and operating interconnectors. Costs are calculated based on a 50:50 split between net imports priced at the domestic market price and at the foreign market price.

Example output from LCP Delta's analysis for DESNZ, showing system cost impacts of one LDES scenario

Figure 43: *Example Scenario 4 – System Cost Comparison for factual with 10GW of Established LDES Long and counterfactual (DESNZ Net Zero higher demand) with no LDES at differing LDES CapEx levels*



Source: *DESNZ LDES benefits report by LCP Delta and Regen*

The analysis presented in this report uses a **consistent framework for calculating system cost impacts** of different long-duration storage technologies.

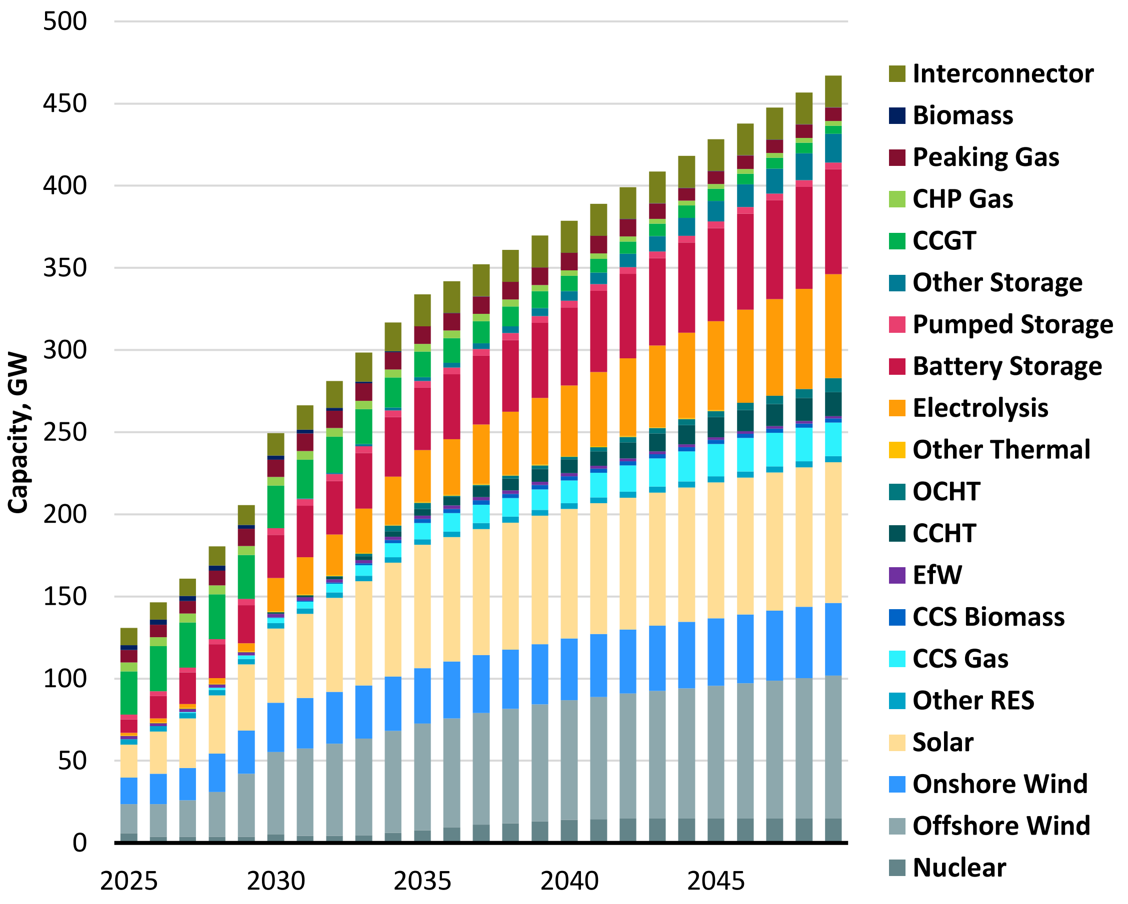
We have updated assumptions from the DESNZ analysis to reflect Clean Power 2030 targets

For the purposes of this analysis, we have used a Clean Power 2030 consistent scenario developed by LCP Delta.

- This scenario incorporates the most recent government ambitions with the following capacity build by 2030;
  - 50GW offshore wind capacity
  - 30GW onshore wind capacity
  - 45GW solar capacity
  - 5.4GW of nuclear capacity
  - BESS build-out of capacity at lower durations continues to grow in line with clean power 2030 ambitions, with 1hr, 2hr and 4hr BESS reaching a combined capacity of 25GW in 2030 and growing to 48GW by 2050.
  - Within the factual and counterfactual scenarios, we see a mix of LDES technologies (long-duration BESS, pumped storage, CAES, LAES) building to meet DESNZ's aim of ~20GW by 2050, as was identified in the LDES report. Slides 10 and 11 show the specific buildout in more detail.

- **Note:** this scenario is a more optimistic view of renewable deployment than LCP Delta's Central market scenario but has been designed to comply with stated Government targets.

Total System capacity under the BESS in C&F scenario



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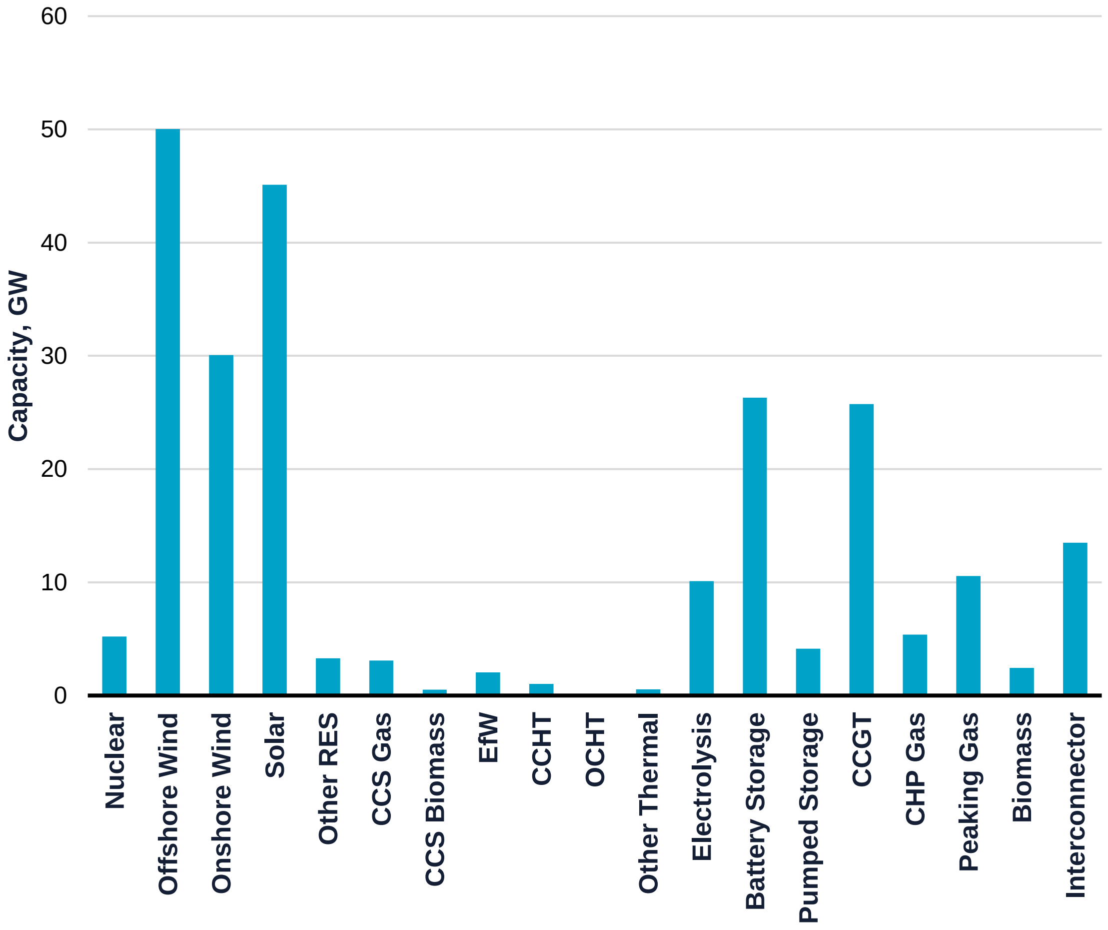
  - Within the factual and counterfactual scenarios, we see a mix of LDES technologies (long-duration BESS, pumped storage, CAES, LAES) building to meet DESNZ's aim of ~20GW by 2050, as was identified in the LDES report. Slides 10 and 11 show the specific buildout in more detail.
- **Note:** this scenario is a more optimistic view of renewable deployment than LCP Delta's Central market scenario but has been designed to comply with stated Government targets.

2030 System capacity under the BESS in C&F scenario



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