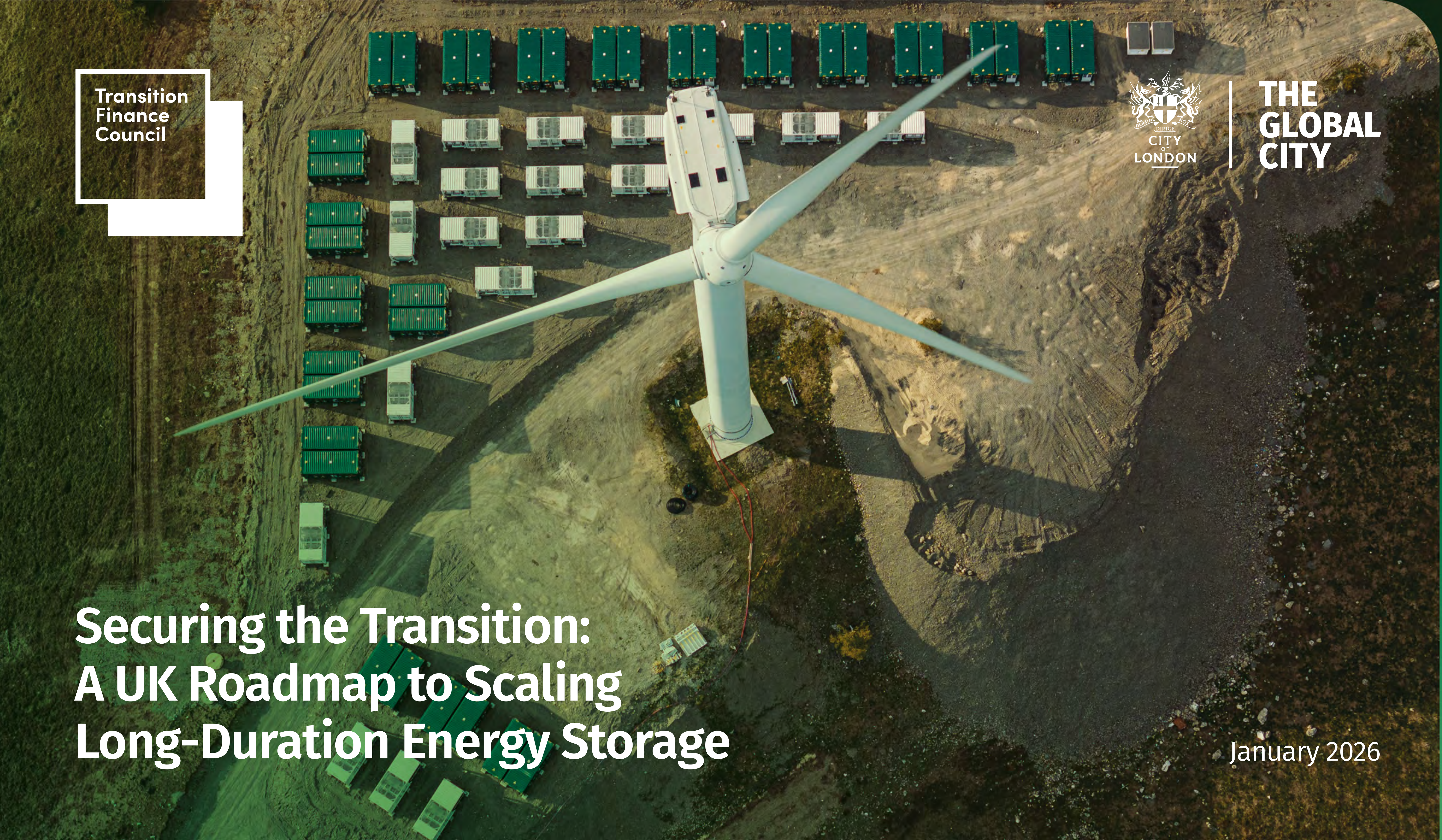

Transition Finance Council

CITY OF LONDON

THE GLOBAL CITY

Securing the Transition: A UK Roadmap to Scaling Long-Duration Energy Storage

January 2026

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Foreword

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Chair and Deputy Chair,
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The Transition Finance Council ("TFC") is taking practical steps to make the UK the best place to raise transition finance. Our three working groups – on credibility, sectoral planning, and scaling finance – bring together voices from across the economy to help build a UK transition finance market that is open, investable, and internationally aligned.

As part of our work, the TFC has published draft Transition Finance Guidelines on which we consulting domestically and internationally. The aim is to ensure that these Guidelines become the global baseline for what is and isn't considered to be credible transition finance.

Last year, the TFC also published a Finance Playbook, which is a practical guide to embedding finance into sector planning. This Finance Playbook seeks to support the creation of transition plans that will bring about a step-change in transition finance flows, through increased confidence in policy, better risk mitigation and innovative financing approaches.

The TFC has now sought in this publication to apply the principles embodied in the Finance Playbook to a specific technology sector, namely Long-Duration Energy Storage.

Currently around half the country's electricity is generated from renewable sources and the UK Government's aim is to have a fully decarbonised electricity system by 2030, subject to ensuring security of supply.

Scaling the Long-Duration Energy Storage sector will be vital in helping the UK Government meet its 2030 target, reduce the UK's reliance on fossil fuels and, ultimately, help bring down electricity bills.

This Long-Duration Energy Storage Roadmap aims to set out a practical guide to mobilising the finance required to enable the scaling-up of this sector, as well as providing a framework for future financing roadmaps for other emerging technologies.

We want to take this opportunity to thank all the TFC's members, partners, and collaborators in helping to prepare this roadmap.

1. Context

1.1 Executive summary

The UK is powering a bold industrial and digital transformation aimed at overhauling infrastructure to deliver secure, affordable, and clean electricity, tripling AI data centre capacity, and building new energy industries.

At the heart of this shift is Long Duration Energy Storage (LDES), the linchpin of a resilient, low-carbon system enabling round-the-clock renewables, unlocking clean flexibility, and underpinning the competitiveness of a digital, AI-driven economy.

Energy storage refers to technology that stores energy and then dispatches it as power, heat or cooling. Currently, LDES is assessed as an energy storage system capable of discharging at rated capacity for 8 hours or longer. Duration can be viewed on a spectrum along with capacity provided by the underlying technologies, location, integration and performance on system-level attributes, all adding to its bespoke nature.

Between the Clean Power 2030 Action Plan, the UK Infrastructure strategy, the UK Modern Industrial Strategy and the UK AI data center targets, UK energy storage capacity needs are estimated at up to 30GW by 2030 and an additional 15-20GW by 2050, across all durations. Of this, the required LDES capacity is estimated at up to 8GW by 2030 and 15-16.5GW by 2050,[1] thus necessitating a portfolio approach to LDES.

A system-led approach to LDES can provide resilience and reliability to energy systems and consumers. It can reduce net system costs, which can filter through to lower consumer bills, enable more effective deployment of renewables, reduce curtailment, grid congestion, and emissions. It can reduce the reliance on gas peakers and enable the scale of financing needed for LDES to support UK growth. The current landscape for UK LDES is evolving coherently with revenue stacking mechanisms through a combination of wholesale markets, ancillary and balancing revenues, regulatory support through the cap and floor (C&F) agreement, and capacity markets (CM). A combination of these mechanisms, along with reducing technology costs provides a strong foundation for bankability, especially for LDES with high TRLs. The report identifies a requirement of £10–15bn in committed capital through 2030, £30-60bn through 2050, and up to £100bn factoring in contingencies and refurbishments.

As a starting point, this report is a call for action to investors and insurance companies to build capacity for LDES technologies on bankability, risk and return assessment, and capital allocation across infrastructure, private debt and equity portfolios. For the insurance industry, this is an opportunity to develop products and solutions, including performance warranties to improve TRLs for technologies.

However, this is still insufficient to scale financing up to the levels required to meet UK system needs in the longer term. This report outlines the path forward, informed and iterated through stakeholder engagement between NESO, DESNZ, Ofgem, NWF, GBE, developers and investors. This report also provides strategic recommendations and an implementation plan and roadmap on systems planning, policy, market mechanisms and capital support to scale financing for UK growth needs, and beyond.

The key strategic recommendations to the UK Government are:

1. To embed LDES into the heart of the UK growth agenda through Clean Power 2030, the Infrastructure and Modern Industrial Strategy, and the UK's AI data centre targets.
2. To provide LDES revenue parity through lifecycle pricing to adequately compensate duration.
3. To broaden the risk budget and mandates for NWF and GBE with a specified percentage allocated for concessionary and catalytic capital (including LDES).
4. To encourage investor, developer and insurance company engagement with:
    a. NESO on the Strategic Spatial Energy Plan (SSEP) 2026 consultation and energy system planning.
    b. DESNZ on potential policy interventions resulting from SSEP conclusions and to enable binding LDES deployment target setting.
    c. NESO on transparency and review of capacity markets derating updates and skip rates.
    d. GBE and NWF on developing blended finance options and co-investment opportunities.
    e. DESNZ and Ofgem on grid pricing regimes and industrial decarbonisation policy.
    f. Ofgem and NESO on accuracy and transparency regarding data and assumptions across LDES technologies, along with industry-wide technical and commercial standards for project assessments.

This report is the first of a series, aimed at providing roadmaps to mobilise financing at scale, for technologies and sectors, to support the UK Government's growth, competitiveness, and decarbonisation goals.

[1] Clean Flexibility Roadmap estimates 16.5 GW for 2050. NESO estimates 15.3 GW for 2050.

1.2 Transition Finance Council (TFC) Playbook

LDES is a crucial technological lever for growth, affordability and the transition to a low carbon UK economy in sectors including utilities, infrastructure and energy.

Transition planning occurs across a layered, interconnected ecosystem spanning global, national, sectoral, and company levels where direction flows downwards from higher-level strategies whilst policies and insights flow back upwards from implementation on the ground.

The key transition planning tools include:

Technology scale-up roadmap - sets out the pathway to accelerate the deployment and commercialisation of a specific transition-enabling technology or suite of technologies, such as offshore wind, solar, or heat pumps. A sector transition plan may include several technology roadmaps which may evolve as new technologies emerge.

Sector transition plan - sets out a sector's forward-looking ambition and strategy for its transition towards a lower-carbon and climate-resilient future, including a range of technological and process-related transition levers, associated financing needs and policy support.

Finance plan - outlines how to mobilise and direct finance towards the solutions, technologies, infrastructure needs, and actions required to deliver a sector transition or scale-up a critical technology. The finance plan is a critical component of both sector transition plans and technology scale-up roadmaps.

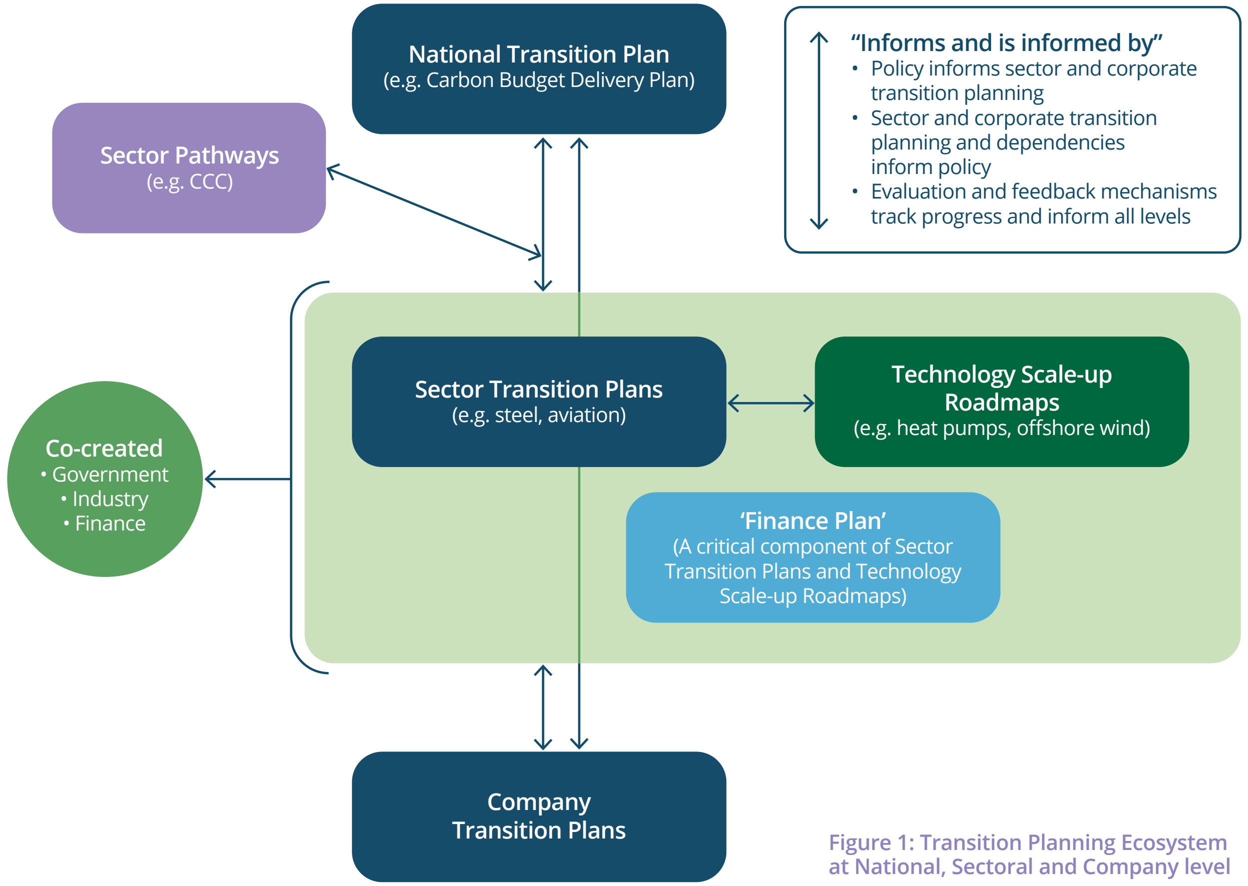


Figure 1: Transition Planning Ecosystem at National, Sectoral and Company level

Application of TFC Sector Transition plans: The Finance Playbook for LDES

LDES is in the unique position of being a set of technologies that are in the process of scaling up and offer the potential to be a sector in the future. LDES has cross-sectoral applications, namely in utilities, energy, and infrastructure, and is at the heart of the UK's ability to support the energy demand that a modern digital and industrial economy requires.

The TFC guidance from the sectoral finance playbook provides clear links between a sovereign's national transition plan, sector decarbonisation pathways, and sector transition plans. For LDES, this mainly includes the technology scale-up roadmap that sets out the pathway to accelerate the deployment and commercialisation of a portfolio of technologies, and the finance plan laying out the investment needs and financing mechanisms for the sector. Building on the finance context and dependencies, the LDES finance plan translates the broader UK ambition, system needs and technology attributes into a coordinated, costed, and time-bound programme of investments and financing milestones.

1.3 Co-creating the roadmap

The TFC playbook recommends co-creation as a structured mechanism for business, finance, and government to come together supported by civil society and academia, to share knowledge, build a shared vision, and co-develop financeable sector transition plans and roadmaps.

By coordinating these actors, co-creation helps reduce uncertainty, leverage system-wide agency, and strengthen the credibility and mobilisation of transition finance. Financial institutions consistently emphasise the importance of government-led direction and policy certainty to unlock transition finance.

The TFC process for LDES as a pilot is informed by stakeholder engagement, discussions, and feedback and is based on the nine principles of co-creation articulated in the playbook:

- The LDES deep dive is anchored by a mission to develop a decision-useful technology scale-up and finance roadmap to credibly support the UK Clean Power 2030 Plan along with the Infrastructure Strategy and the Modern Industrial Strategy and the Government's AI data centre targets.
- The LDES roadmap has been authored as a follow-up to the work done by DESNZ, NESO and Ofgem on LDES over the past few years and has been done in consultation with the respective teams from these organisations. The LDES deep dive process has been convened by the TFC alongside a team of developers, corporates, investors, academics, regulators, and policy makers, supporting inclusivity and openness to ensure standing, legitimacy and credibility among all relevant stakeholder groups. The process captures the Principles of Responsible Policy Engagement, including climate alignment, evidence-based advocacy, and transparency.
- Starting with independent academic research support on LDES from University College Dublin (UCD), alongside evidence-based research and data from across the ecosystem, the LDES deep dive process has been well resourced and dynamically run with a broader team including the TFC, utility companies, government and investors. With 1-1 stakeholder discussions, weekly group check-ins, government-industry roundtables and a detailed and iterative review of the work, this co-operative approach has been both inclusive and efficient, as well as being dynamic, adaptive, and iterative.

Effective governance is a prerequisite to scaling institutional financing. By promoting and ensuring active progress on the scaling and financing roadmap with DESNZ, NESO, OfGem, developers, and investors, the roadmap provides the tools and next steps for scaling implementation, delivery and financing, as well monitoring and evaluation systems to track progress and adapt strategies.

This report synthesises insights on systems, finance, and policy, and outlines how policymakers, government and investors can work together to support the full lifecycle of diverse LDES technologies.

2. UK LDES technology landscape

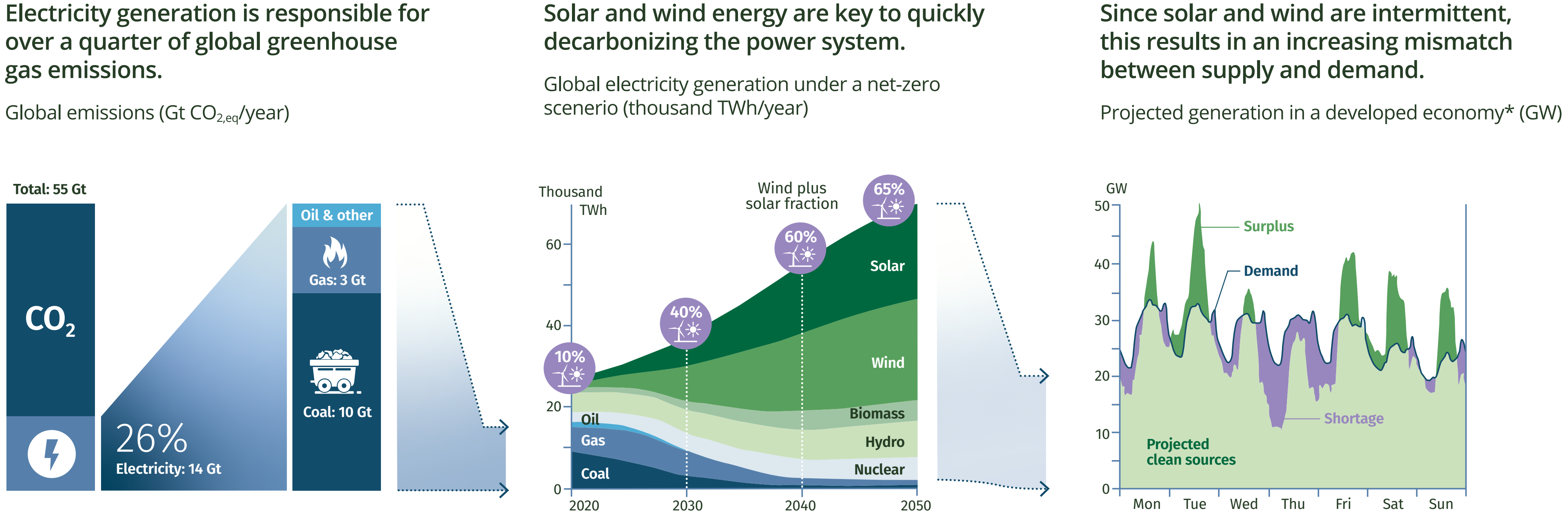
2.1 Strategic context, landscape and UK system needs

The strategic goal of the deep dive is to provide a technology scale-up and financing roadmap, to support, scale-up and mobilise financing for UK LDES.

The UK Clean Power 2030 Plan targets three goals, including the need for a secure and affordable energy supply, the creation of essential new energy industries, and the need to reduce greenhouse gas emissions with the support of a large skilled workforce. The UK Infrastructure strategy targets building, developing and innovating economic infrastructure including energy infrastructure. The Government has also unveiled an ambitious plan to triple its AI-capable data centre capacity to 6GW by 2030, recognising that current infrastructure is insufficient to meet the demands of large-scale AI applications. Clean energy sources continue to grow, especially with renewables like solar and wind now being cost competitive. The variability of these sources however demands robust storage solutions to balance supply and demand, reduce curtailment, and ensure grid reliability. As clean energy demand grows, the real gamechanger is not merely harvesting clean energy, but also effectively storing it.

Figure 2: The Clean Electricity Challenge[2]

The Clean Electricity Challenge: Solar and Wind Fluctuate



*Example of fluctuations shown over one week.
See our website for fluctuations shown over one year.

[2] https://fcarchitects.org/content/the-basic-the-gaps-ldes

This puts LDES at the heart of the UK's growth and competitiveness, serving as a foundational enabler for a clean, resilient, and flexible energy system and the linchpin of a resilient, low-carbon electricity system. LDES can enable grid flexibility, reduce curtailment, and replace fossil-based backup with round-the-clock renewable power. As the UK transitions toward a digitised, AI-driven industrial economy, storage is becoming a strategic asset supporting advanced manufacturing, digital services, and the decarbonisation of the power sector. UK policymakers and investors therefore must embed LDES into the core of energy infrastructure planning, to unlock secure, affordable power, catalyse new energy industries, and mitigate the economic and social costs of transition.

Despite the strategic importance of LDES, financing remains a critical barrier. It is also important to note that LDES technologies range from the very nascent to the well-established, therefore no single LDES technology can meet all system needs. LDES faces a disconnect between the promise of the underlying technologies and the capital required to scale them, stemming from market structures that undervalue LDES's full system benefits, regulatory gaps, and the absence of tailored financial instruments. Adding new and evolving LDES technologies to the existing mature LDES installed capacity as a core infrastructure service and sector is a unique opportunity for the UK Government and its stakeholders to target and support growth, infrastructure, system resilience and clean energy goals.

UK system needs

The UK's Clean Power 2030 Plan and analysis from NESO indicates system requirements for LDES capacity of up to 8GW by 2030 (along with 23-27GW of short duration storage). This, in addition to the 6GW target for AI-capable data centre capacity by 2030, leads to total storage capacity needs of 30GW+ by 2030. It is also important to note that current discussions all revolve around power-to-power, whilst power-to-heat is still an area for further review and application in UK industrial decarbonisation.

The above system requirements are estimates based on the broad targets set and lack granularity in terms of the specific technology type, storage duration, geographic location, integration, developer and project specifics, amongst several other relevant factors. The unique characteristics of the underlying energy storage project necessitate a bespoke approach to analysis, assessment and financing. **OfGem has published its Multi-Criteria Assessment (MCA) framework that developers and investors are urged to review and engage with as they approach the UK LDES project pipeline.**

However, before engaging with technology and project level assessments, it is important to clearly identify the system drivers for scaling LDES. A clear understanding of system needs, technology attributes, market design, and the delicate balance between supporting innovation and preserving merchant market dynamics, is crucial to ensuring an orderly transition. These drivers include management of system constraints and renewables integration, industrial decarbonisation, reduction of curtailment, security of supply and system operability, provision of real-time flexibility, and support for wider economic and social objectives (e.g. skills, supply chain, local benefits).

The UK system constraints and opportunities are covered under NESO's system modelling and account for supply and demand side assessments, including seasonal and daily variability in renewable generation, grid stability requirements (e.g. inertia, reactive power, black start), and capacity and duration curves that reflect actual system mismatches.

In basic terms, the fundamental system need can effectively be summarised as a single outcome of dispatchable capacity (GW) replacement through curtailment reduction (TWh). This then defines the capacity (GW) and duration (GWh) needed to achieve the desired outcome. There are, however, various factors that drive cost optimisation of LDES across use cases, which can serve as key attributes to guide and scale LDES deployment, all ultimately driving a portfolio approach and diversification across technologies. These include:

- **Storage duration and efficiency** for system operability, flexibility and market revenues.
- **Co-location with generation and demand** enhancing system benefits and providing 24/7 reliable clean heat and power to industry and data centres.
- **Scalability and expansion potential** for future capacity increases.
- **Ability to provide ancillary services** including inertia, frequency response, restoration, short circuit, voltage support.
- **Integration with other energy vectors** including thermal energy networks, synthetic fuels, LNG terminals, district heating, industrial processes.

NESO's work on the upcoming Strategic Spatial Energy Plan (SSEP) is intended to incorporate system modelling updated annually or biennially. This should provide the granular detail to developers and investors needed to inform procurement volumes and assess the system level suitability of certain technology types over others. For policymakers, this should help steer any policy discussions and interventions needed on the above, as well as potential long-term risks and opportunities for investors in existing and new technologies, especially post-2030. **The SSEP is expected to be out for consultation in 2026 and we recommend that developers and investors actively engage, in order to achieve a robust output, as well as integrating the plan into their LDES financing and investment decisions.**

> **LDES, by definition, implies long duration, which is assessed as 8 hours or above of continuous dispatch. However, duration needs to be viewed on a spectrum based upon the capacity it provides, as well as its performance on a combination of the attributes described above, in the context of affordable, resilient and secure energy supply across the system.**

Current landscape review

The current UK LDES landscape is supported by frameworks including Ofgem's Cap-and-Floor and Capacity Markets and other essential elements of power market design, grid charging regimes, carbon pricing and industrial decarbonisation policy. Ofgem's Cap-and-Floor (C&F) scheme, launched in 2025, aims to unlock investment in power-to-power LDES and mirrors the interconnector model, offering a revenue cap and floor. The C&F agreement is technology-neutral by design as each technology brings different benefits. The C&F is not intended to give preferential treatment to any LDES technologies, with the only requirement being the capacity to store and discharge electricity from and back to the grid. There are discussions to be had on the minimum sizes by MW and the exclusion of operational projects that disadvantage some LDES assets. The floor payments are structured to support solvency and provide a solid foundation for development of the LDES business model.

Following the first application window in June 2025, Ofgem approved 77 projects, totalling 28.7GW of discharge capacity to proceed to detailed project assessment. Of the 77 eligible projects, 48 are lithium-ion battery systems, representing over 20GW of capacity. This dominance stems from several factors, including the fast pace of deployment, high TRLs, global manufacturing capacity and emphasis on near-term deliverability and cost-effectiveness. The eligible pool is dominated by:

- Li-ion batteries (20.2GW), followed by;
- Pumped Storage Hydro (PSH) including Coire Glas (1.45GW) and Earba (1.8GW), and;
- Flow Batteries including vanadium and zinc chemistries (~2.6GW).
- Currently smaller technologies like LAES and CAES are also part of the mix.

Green hydrogen is still in the pre-commercial stage but may provide benefits for seasonal balancing.

It is receiving substantial government support through a separate business model in development, including one for hydrogen-to-power and hydrogen storage through the Net Zero Hydrogen Fund, as well as indirectly through CCUS investments.

2.2 Technology overview and comparative assessment

LDES technology types

LDES technologies, including mechanical, thermal, chemical, and electrochemical systems, can store electricity for hours, days, or even weeks at a time, all at a competitive cost. This flexibility enables electricity to be produced and consumed at different times, thereby reducing system stress and preventing the costly overbuilding of renewable capacity.

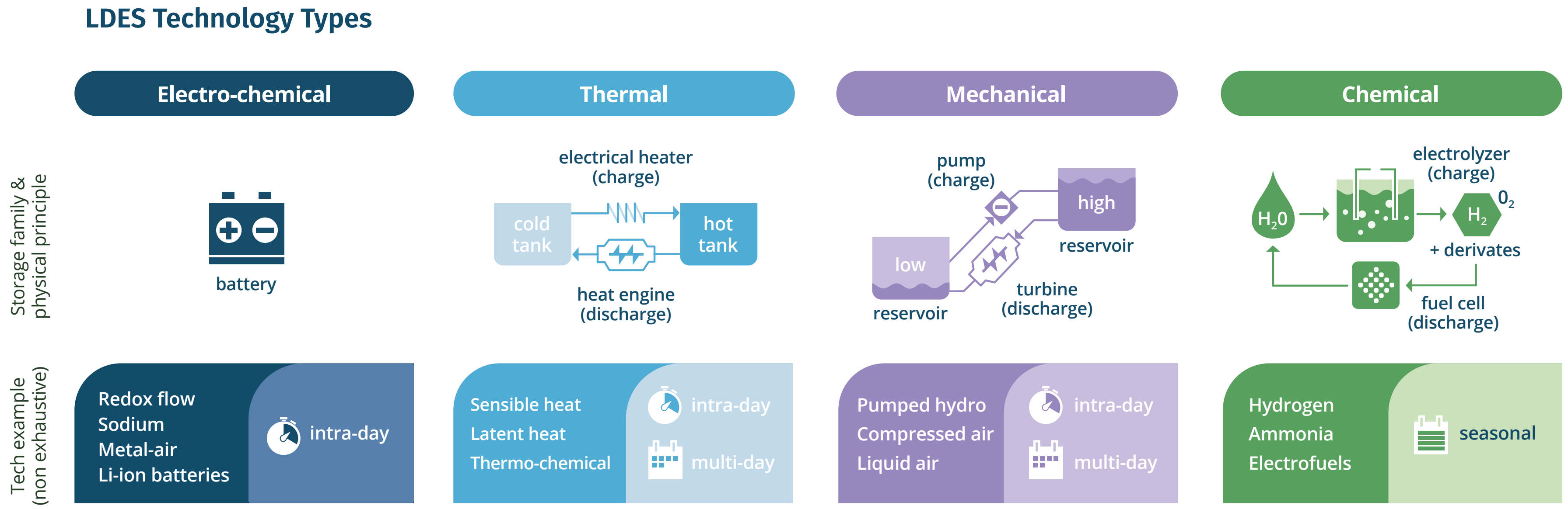


Figure 3: LDES Technology Types

LDES encompasses a diverse portfolio of technologies, including Li-ion Batteries, Flow Batteries, CAES, LAES, Pumped Hydro, and Hydrogen. Each offers distinct advantages in terms of duration, scalability, cost trajectories, and co-benefits for system resilience and grid stability. On the diagram above, thermal storage can also have heat discharge directly for end-use heating. A comparative analysis of LDES technologies highlights clear trade-offs between technical maturity, performance characteristics, and cost trajectories.

Duration is a spectrum determined not just by chemistry alone but system configuration as well. Therefore, by increasing energy capacity (kWh) relative to power (kW), storage systems can deliver sustained output over longer periods. One could argue that cost and performance improvements in technologies like Li-ion and their inclusion in the C&F have made these configurations viable for long-duration use cases. Li-ion is now used for multi-hour load shifting and renewable firming, when paired with renewables or other assets. In the portfolio approach to LDES, Li-ion has an important role to play along with other technologies.

Technology Readiness Levels (TRLs) are structured frameworks used to assess the maturity of a technology, ranging from basic research and concept stage to full-scale deployment in operational environments. They provide a common language for R&D, investment, and commercialization decisions. There are three main standard providers:

- **NASA** - Originator of the TRL concept in the 1970s for aerospace and space systems. Focuses on rigorous testing in relevant and operational environments for mission-critical technologies.
- **EU Horizon 2020** - Adapted TRLs for industrial and commercial innovation projects in Europe. Emphasizes readiness for market deployment and integration into industrial environments.
- **ISO 16290** - International standard formalizing TRL definitions for aerospace and defence sectors. Provides globally harmonized terminology and criteria for technology maturity assessment.

Below is a consolidated view of the most common TRL definitions (based on NASA, EU Horizon 2020, and ISO 16290 definitions):

Figure 4: Comparison of TRL Definitions

TRL	NASA Definition	EU Horizon 2020 Definition	ISO 16290 Definition
TRL 1	Basic principles observed		
TRL 2	Technology concept formulated		
TRL 3	Experimental proof of concept		Analytical and experimental critical function proof
TRL 4	Technology validated in lab		Component/subsystem validation in lab
TRL 5	Technology validated in relevant environment		Component/subsystem validation in relevant environment
TRL 6	Technology demonstrated in relevant environment		System/subsystem model or prototype demonstration in relevant environment
TRL 7	System prototype demonstrated in operational environment		
TRL 8	System completed and qualified		Actual system completed and qualified through test and demonstration
TRL 9	Actual system proven in operational environment		

- NASA focuses on **space/aerospace applications**
- EU Horizon emphasizes **industrial and commercial deployment**
- ISO 16290 formalizes definitions for **aerospace and defense sectors**

The TRLs of different LDES technologies, but even more importantly that of their underlying components, are very diverse. In many cases, investors can over-index on the technical and commercial maturity of the underlying LDES devices yet underappreciate the more prosaic but still significant risks associated with construction and operating risk.

Figure 5: Comparative Performance Snapshot across LDES Technologies

Type		Discharge duration	Cycle efficiency	Market readiness	Expected lifetime
Electrochemical	**Li-ion batteries**	Short: 0.25-4 hours Extended: 6-8 hours	90-95%	TRL 7	10-15 years
	Flow batteries	4-8 hours	50-80%	TRL* 6-8	>20 years
	Zinc-ion batteries	Up to 6 hours	80-90%	TRL 6	20 years
	Sodium sulphur	Up to 6 hours	85-90%	TRL 7	15-20 years
	Iron-air battery	Up to 100 hours	50-70%	TRL 5	20 years
Chemical	**Hydrogen**	Intraseasonal	40-50%	TRL 8	5-30 years
Mechanical	**Gravity energy storage**	8-10 hours	70-90%	TRL 6-8	30-40 years
	Pumped storage	8-32 hours	50-80%	TRL 9	>40 years
	Compressed air	4-8 hours	40-70%	TRL 7	25-30 years
	Liquid air	6-24 hours	70-80%	TRL 8	>30 years
Thermal	**Sensible heat**	Up to 120 hours	55-90%	TRL 8-9	>20 years
	Latent heat	Up to 120 hours	70-90%	Large range - mostly TRL 4-6	15 years
	Thermochemical storage	Hours to months	60-80%	TRL 4-6	15 years

Sources: ERM WBCSD Report.

Pumped hydro is a mature option, with proven efficiency and multi-gigawatt deployments, Li-ion has rapidly improved in duration, economics and reliability, while CAES/LAES represent rapidly growing areas where the UK has developed global research leadership.

Thermal Energy Storage (TES) is an LDES technology that stores energy in the form of heat, typically using materials such as molten salts, ceramics, or phase-change substances. TES systems absorb excess electricity, often from renewable sources, by heating these materials and later releasing the stored energy as heat or converting it back to electricity through steam turbines or other heat-to-power processes. This approach offers energy density, scalability, and cost-effectiveness for applications like industrial heat supply and grid balancing. TES can also serve as an enabler for decarbonising sectors with high thermal energy demand and supporting renewable integration into power systems.

The hydrogen business model underpins the UK Government's Clean Power Plan and broader industrial and infrastructure strategies by creating a framework for scaling low-carbon hydrogen production, transport, and storage. It supports the twin-track approach of electrolytic and CCUS-enabled hydrogen to decarbonise power generation, heavy industry, and transport. Closed-loop Hydrogen-based long-duration energy storage (H_2-LDES) systems, particularly those using salt caverns, can provide multi-day to seasonal storage with high energy density, help reduce curtailment, enhance grid reliability, and replace fossil-based backup, albeit still with low levels of round-trip efficiency (RTE). Hydrogen storage in solution-mined salt caverns is now recognized as the only viable pathway to deliver tens of terawatt-hours of seasonal balancing at national scale, making it indispensable to long-term system design. Recent policy updates include Hydrogen Allocation Rounds (HAR1 and HAR2) and dedicated business models for production, power, and infrastructure, complemented by funding for regional hydrogen networks and the core hydrogen pipeline (Project Union). Further support is needed such as recognising H_2-LDES in planning tools and adapting market mechanisms like C&F and the CM. H_2 LDES can potentially further improve price signals and enable additional efficient monetisation of surplus renewable energy, boosting the UK's growth and competitiveness.

These complementarities underline that no single LDES technology can meet all system needs. A portfolio approach is important to meet the system requirements of duration, efficiency for system operability, flexibility and market revenues, co-location with generation, scalability and expansion potential, and ability to provide ancillary services.

Overall, LDES should be understood not merely as a supplementary flexibility option, but as a systemic requirement for balancing renewable variability across hours, days, and seasons.

2.3 Consumer needs, cost reduction and benefits

Investing in LDES is increasingly recognised as a critical strategy for reducing the overall cost of decarbonisation and stabilising electricity bills. UK and international studies consistently show that well-integrated storage can deliver multi-bn-pound annual savings while enhancing system reliability and resilience. For instance, modelling by the Carbon Trust and Imperial College London suggests that optimal deployment of storage by 2030 could save the UK energy system up to £7bn annually, with £2bn directly from storage and £5bn from improved use of renewables and infrastructure efficiency.

Further analysis by DESNZ, NESO, and LCP Delta reinforces the growing value of LDES as renewable penetration increases, projecting potential savings of up to £13bn between 2030 and 2040. In addition, there is significant potential value of LDES to behind the meter (BTM) assets such as industrial heat and data centres. The overall benefits arising from it include reduced constraint and balancing costs, enhanced grid reliability, and lower carbon emissions. International research, such as the US NREL Storage Futures Study, echoes these findings. Policy mechanisms like Ofgem's cap-and-floor regime are now in place to help translate these system-wide savings into tangible consumer benefits, making LDES the cornerstone of a cost-effective and resilient net-zero energy system. Finally, the Ofgem LDES C&F provides the policy mechanism to turn these savings into investable reality, by sharing upside and downside between consumers and developers. The C&F structure acts as a form of government-backed revenue protection, reducing downside risk, stabilising returns, improving bankability and financing costs, ultimately creating system savings that can reflect in consumer bills.

> **In conclusion, the combined evidence from modelling, system operators, regulators, and global studies shows that LDES significantly reduces system costs per year, stabilises bills, and enhances grid reliability and stability. When supported by sound policy and pass-through design, LDES can cut total system costs by several billion pounds per year, lower average consumer bills, and enhance reliability, establishing it as a central pillar of a low-cost transition to clean power.**

2.4 Social benefits

The wider social benefits of scaling-up Britain's LDES infrastructure extend beyond price reductions for consumers. LDES projects also represent an opportunity to kick-start economic growth in previously left-behind areas of the country, whilst simultaneously bringing skilled and well-paid jobs to these areas. Current projects, such as the Earba project in North-West Scotland and the Dorothea project in North-West Wales, stand to bring significant investment to their respective regions, with Dorothea alone projected to sustain 600 skilled jobs, alongside hundreds more in the supply chain, as well as generating private investment in local infrastructure. A fully scaled up and diversified LDES sector would multiply the above projected benefits. In this way, LDES can play a key role not only in supporting the government's clean energy mission, but also its economic growth mission and the attendant rebalancing of the country's economy away from the South-East thereby envisioned.[3]

[3] Pumped Storage Hydro - British Hydropower Association

3.
UK LDES finance context

3.1 Mapping finance to the technology scale-up and sector transition

The LDES finance context is driven by the fact that it is a technology in the process of scaling up to a sector.

The overarching TFC sector transition plan framework maps the principles of credible transition finance and sets a clear vision, establishing the necessary foundations, strategies, and review mechanisms to enable progress from ambition to reality.

For LDES, as a crucial technology in the process of scaling, the ambition and foundation also link closely to the commercialisation, adoption readiness and bankability of the various technologies.

The components therefore embedded within the technology scale-up and financing plan include:

- The **UK LDES revenue landscape and bankability** based on TRLs, current and potential revenue mechanisms, regulatory support and other considerations for financing.
- The **system need** for LDES aligned with national commitments, in this case Clean Power 2030, the Modern Industrial strategy, Infrastructure strategy, and AI data centre strategy and targets, levers, and dependencies.
- The **finance plan** builds on the system need through a detailed analysis of the investment need through a broadly coordinated, costed and time-bounded strategy, which identifies technological, infrastructural, insuring, policy and financing milestones. The plan details system and investment needs, outlines risk profiles across the technology lifecycle, the needs and roles of capital providers, case studies and practical application of financing mechanisms, catalytic capital and other levers.

3.2 UK LDES revenue landscape and bankability

The revenue environment for UK LDES is evolving. A UK LDES asset can earn money by shifting electricity through time and by standing ready to stabilise the system. Revenue stacking is an important construct for bankability of LDES and refers to the ability of LDES assets to participate in multiple energy markets and services. Revenue stacking provides the foundation for the technology market fit and the business model, ultimately improving bankability, financing terms and credit worthiness.

In addition, for any LDES technology, the depth is a function of efficiency, duration, maturity, site characteristics, and where the system is on its decarbonisation path. It is important to note the location of where a project is developed in the grid. An LDES asset at the right node can provide value to the grid operator and earn revenues through the provision of reactive power, short circuit and inertia. Conversely, an LDES asset in the wrong location may not be as valuable, despite the revenue stack relying extensively on the CM, C&F and arbitrage. In practice, the main revenue sources that dominate are as below:

Figure 6: Revenue Sources and Mechanisms

Revenue Mechanism	Description
Wholesale Arbitrage	Charging when prices are low (often when wind is abundant and curtailment risk is high) and discharging when energy process increase
Ancillary and Balancing Services	These include frequency response, reserve, inertia and black-start support, plus redispatch in the Balancing Mechanism (BM)
Capacity Market (CM)	This pays for dependable availability during stress events. The CM matters for LDES because it provides a multi-year baseline that is relatively immune to daily price noise
24/7 Renewable Energy Guarantees of Origin (REGO) / Energy Attribute Certificates (EACs)	A potential revenue stream is through PPAs and 24/7 REGO / EACs to corporates who want to decarbonise on a 24/7 basis. REGOs are certificates issued in the UK to verify that a given amount of electricity has been generated from renewable sources
Other	Other revenue streams for storage include through managing network costs at both transmission and distribution level (both in front of meter and behind the meter) and managing connection costs (behind the meter). For example, a data centre co-located with LDES could have a smaller grid connection and lower annual transmission costs, as peak demand is lower than it would be otherwise. The REMA discussions and development of a reformed national pricing model could have ramifications for all system users and could result in very different ways of passing through network costs

On the revenue mechanisms themselves, there are important nuances and considerations for bankability assessment that are outlined below:

- **The UK Cap-and-Floor (C&F) Regime is a primary revenue stabiliser for LDES.** The design borrows from a decade of interconnector regulation where on an annual basis, total eligible revenue from wholesale arbitrage, ancillary services and the CM are added and reconciled against a pre-set band. If the sum falls below the floor, the scheme tops it up to that minimum, and if it exceeds the cap, the surplus is shared back with consumers. In short, LDES assets still chase spreads and services keeping the market signal intact, however the downside and upside are bounded to convert volatile merchant earnings into stable cashflow streams for investors. Investors can think about the C&F as an insurance scheme to reduce uncertainty. The "depth" of support needed by an asset can be:
    - Low depth – Arbitrage and CM cover most revenue and the floor behaves like insurance.
    - Medium depth – Routine top-ups in average years, though upside still exists.
    - High depth – The floor shoulders a substantial share of the economics and the cap becomes important for consumer value-sharing in scarcity years.

  It is important to note that the floor only provides returns in line with debt financing, so in medium and high depth situations, equity investors may not get the level of returns required and therefore will not invest.

- **Capacity Markets (CM):** The CM uses a concept called "derating" to translate nameplate megawatts into the firmer capacity that can genuinely be relied upon at peak stress. A storage plant with longer duration and strong performance data will, all other things being equal, receive a higher derating factor and therefore more CM income per installed MW. **For investors, derating anchors the baseline of revenue that debt lenders underwrite.** This is a critical construct as rightsizing LDES duration for its capacity and merit order between BESS and other storage and dispatching it in an optimal manner within the portfolio can displace peaking capacity with 5-10 hours and baseload with the longer duration. Effectively, a portfolio of LDES has the potential to fully displace the equivalent capacity of other flexible supply, such as CCGT/OCGT.

The relevant metric for new investment in this space is the CM derating in the four-year ahead auction process. In the last four-year ahead auction, c.80% of batteries winning CM contracts had a fifteen-year agreement (with a constant derating factor). This currently consists entirely of short duration batteries (<8 hours). However, NESO expects long duration batteries to have a similar pattern (if not higher given the higher capex required) which should support modelling for new investment.

Examples from other jurisdictions, including California's Resource Adequacy (RA) framework and South Australia's Firm Energy Reliability Mechanism (FERM), provide a useful analogue to the situation in the UK. All three mechanisms, the UK's CM, California's RA, and South Australia's FERM, share the common goal of ensuring system reliability during peak demand by securing firm capacity through obligations or contracts, complementing energy-only markets and supporting diverse technologies to manage renewable intermittency. **However, the UK CM stands out for its competitive, transparent auctions, long-term contracts, technology neutrality, and clear reliability standards, as well as for being more investor-friendly and scalable, especially for long-term infrastructure investors.**

- **Renewable Energy Guarantees of Origin (REGOs) and Energy Attribute Certificates (EACs)**: Each REGO represents 1MWh of renewable electricity. They provide transparency for consumers and businesses regarding the renewable origin of their electricity supply and are often used by energy suppliers to demonstrate compliance with green tariffs or sustainability commitments. Traditionally, REGOs in the UK have been matched on an annual basis, since 24/7 renewables supply do not necessarily reflect the real-time availability of renewable generation. The move to 24/7 (hourly or sub-hourly) matching using granular carbon-free EACs allows consumers and suppliers to verify that their electricity consumption is matched with carbon-free generation in real time.

  Under the current annual REGO system, storage assets cannot effectively participate, as the economics do not incentivise storing and shifting renewable energy to periods of scarcity. With 24/7 EACs, storage operators can buy certificates when renewable supply (and certificate prices) is abundant and cheap, store the energy, and then sell certificates when supply is scarce and prices are higher. This creates a new, time-based revenue stream for storage, rewarding their flexibility and ability to balance supply and demand. NESO's modelling suggests that revenues from 24/7 EACs could account for a significant portion of battery storage income, especially as demand for granular matching grows. NESO notes that price volatility and unpredictability may limit the effectiveness of certificates alone in supporting investment, so careful market design and rule-setting will be important.

  Overall, the 24/7 REGOs and granular EACs can unlock new value for storage assets by allowing them to participate in certificate trading, rewarding assets that help match renewable supply to demand in real time, providing sharper price signals during periods of renewable scarcity, and creating financial incentives for both innovation and investment in storage and demand-side response. It can increase transparency and credibility, address greenwashing concerns and align with evolving carbon reporting standards (the GHG protocol is currently working on guidance).

- **Behind-the-Meter (BTM) assets**: While the overall approach works reasonably for revenue stacking across most LDES technologies, it may disadvantage some BTM assets. BTM assets are storage systems located on the consumer side of the electricity meter (e.g. in homes, businesses, or industrial sites) and is primarily used to manage on-site energy use, reduce bills, and/or provide grid services. While BTM assets allow users to avoid network charges when combined with generation assets such as solar, they can often appear as a demand side response (DSR) rather than standalone storage, limiting their access to full revenue stacks (e.g. capacity markets, frequency response).

> **The UK has a market orientated approach to LDES that includes participation in wholesale and balancing markets, ancillary services plus capacity markets, wrapped inside the C&F agreement, along with potential 24/7 REGO/EACs along with other revenue streams. A clear view of system needs and attributes of technology types, an understanding of revenue stacking across markets combined with the C&F, and inclusion of multi-year duration benefits, can provide the building blocks for bankability across LDES.**

3.3 Scale-up roadmap to a sector – financing the lift-off

After the significant breakthroughs in LDES technology, improving TRLs, policy focus and regulatory developments in the past few years, LDES is now entering a phase where financing is key to scaling and lift-off. Financing the UK LDES system is linked to two key systemic goals:

- The UK Clean Power 2030 derived capacity targets of up to 8GW through 2030.
- The longer-term capacity needs to reach Net Zero 2050, informed by the DESNZ LDES deployment scenario analysis and potentially by the upcoming SSEP from NESO.

The TFC Finance Playbook can provide clear pathways and steps to mapping UK LDES system needs and technology attributes, as well as the needs of capital providers in the system, to highlight current financing opportunities, and scale future financing opportunities for LDES to deliver clean, affordable, and resilient power through to 2050.

4.
Finance plan for UK LDES

4.1 Total investment need

Based on studies from DESNZ and NESO, as well as the UK Clean Power 2030 plan and other sources, the current installed LDES capacity stands at 2.8GW, versus the estimated capacity requirement of up to 8GW by 2030 and up to 16.5GW by 2050. The total investment needs for UK LDES can therefore be classified into two stages:

Current investment need based on the Clean Power 2030 horizon:
The UK's Clean Power 2030 Plan and Ofgem's LDES Cap-and-Floor Window 1 together define the near-term scale of investment required to integrate renewables and achieve system flexibility this decade. Ofgem's current shortlisted capacity is different from the Clean Power 2030 Action Plan and may see only a portion of the shortlisted capacity approved. Hence, we have elected to use the capacity requirements as outlined by Clean Power 2030 to size the investment need.[4]

The Clean Power 2030 Action Plan targets 4–6GW of LDES (alongside 23–27GW of short-duration batteries) as the system flexibility requirement to achieve a zero-carbon grid by 2030. Translating that system target into a financial envelope requires technology-specific capital intensity assumptions, expressed in £/kW.

DESNZ's Scenario Deployment Analysis and Ofgem's Technical Decision Document identify the following cost bands (in 2020 £):

- Li-ion (6–8 h): £1,500–£3,200 / kW
- Pumped Hydro (8–32 h): £1,200–£1,900 / kW
- Lower-efficiency LDES (LAES / CAES 6–12 h): £880–£6,000 / kW

Taking the previous figures and (through our own calculations) applying these intensities to the 4–6GW LDES capacity required under Clean Power 2030 gives a range of approximately £6–14 bn (mid-point ≈ £10–12bn).

Based on rough estimates and approximate calculations, total investment (£) = installed GW × 1,000,000 × £/kW, plus allowances added for development, EPC, grid connection, and owner costs consistent with the "building block" methodology under the LDES cap-and-floor regime, at an illustrative mid-point of £2,500 / kW, each 1 GW of new LDES capacity represents ~£2.5bn of investment. **While Ofgem's Track 1 pipeline is at 24.5GW, the targeted deployment in window 1 is at 2.7-7.7GW, equating to an approximate overall capital requirement of up to £15bn through 2030, depending on the projects approved, final technology mix, site characteristics, and maturity.**

This near-term capital will finance the UK's first fleet of long-duration assets, mainly Li-ion systems, new pumped-hydro expansions, and a handful of first-of-a-kind thermal or flow projects. Construction timelines vary from 1–2 years for modular batteries to 5–8 years for civil heavy PSH, implying staggered investment flows but a comparable cumulative spend by 2030.

Long-Term Investment Need – 2050 System Transformation:
Beyond 2030, the *DESNZ Scenario Deployment Analysis* shows a steady rise in required flexibility, which is expected to be reflected in the NESO SSEP as well. While flexibility can be achieved using multiple technologies including storage, demand response and so on, modelled scenarios project up to 15.3 – 16.5GW of LDES need by 2050, to underpin a fully decarbonised and resilient electricity system.

Extending the above cost logic directly by using the same £/kW archetypes and adding a rough assumption that technology costs reduce on average by c.15–25% over two decades, each GW of new LDES capacity in 2050 corresponds to £2.0–2.5bn of installed capital. Multiplying this by the 10–20GW system requirement implies a total investment need of roughly £30–60bn through 2050, excluding reinvestment for mid-life refurbishment. Adding in development and inflation contingencies can bring the cumulative long-run envelope to £60–100bn, consistent with Ofgem's Window-1 aggregate (£79bn base, £62–101bn range).

The UK's clean-energy system need directly converts into quantifiable investment needs:

- **Delivering up to 8GW of LDES by 2030 requires roughly up to £15bn in committed capital.**
- **Achieving up to 16.5GW by 2050 raises the cumulative envelope to £30–60bn, or up to £100bn including contingencies and refurbishments.**

The systems cost savings is a complex quantification. Studies by AFRY and Carbon Trust & Imperial College find that LDES could reduce total system expenditure by £7–13bn by 2040–2050, primarily via avoided renewable curtailment, deferred transmission build, and lower balancing costs. Based on a simple assessment, the capital required for LDES broadly equates to the system savings of £30–60bn over 25 years, meaning that it will repay itself several times over. Additional considerations including time value of money and various other factors can lead to significantly higher systems savings from a cost perspective.

Roughly speaking, each incremental gigawatt of long-duration flexibility represents c.£2–2.5bn of infrastructure investment but yields annual system savings of £0.5–1bn once operational.

This is the essence of the LDES value proposition. It is capital-intensive but can be deflationary for the system and consumers, turning investment into enduring reductions in system costs, consumer bills, and emissions.

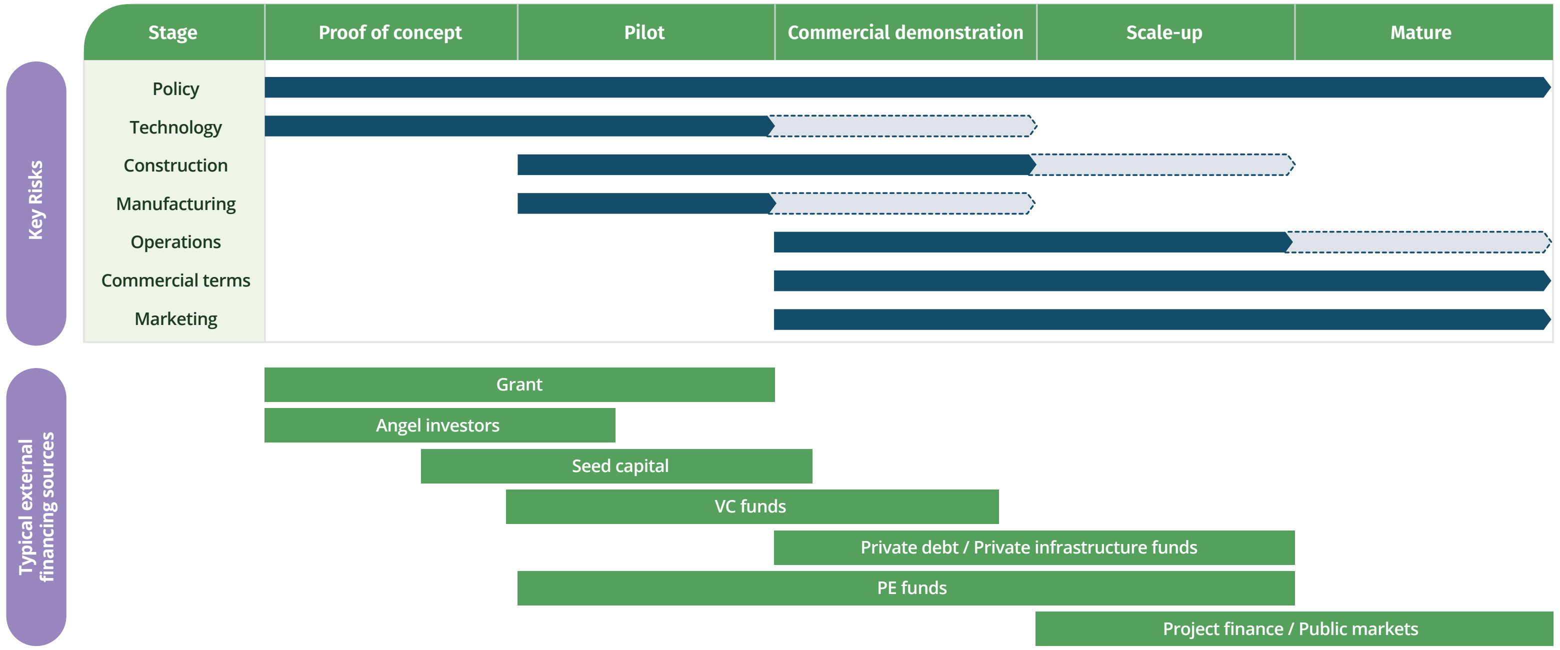
[4] It is important to note that the scientific merits of specific modelling studies are beyond the scope of this document but in general most modelling studies currently have assumptions and flaws in the methodologies used to represent LDES technologies, which represent an area for improvement going forward.

4.2 Key risks across technology stage of development and lifecycles

The technology lifecycle roadmap typically starts with the proof-of-concept (PoC) and pilot, moving towards commercial demonstration, scale-up and maturity. The TRLs broadly capture the stage of the lifecycle albeit with more detail and nuance needed around the specific technology, its underlying components and sector and jurisdiction specific considerations.

The funding lifecycle typically follows the technology lifecycle and TRLs as well, with the early stages dominated by angel investment, seed capital and grants, before progressing further to private equity and VC funds, then to private debt and infrastructure funds, followed ultimately by project finance and public markets financing.

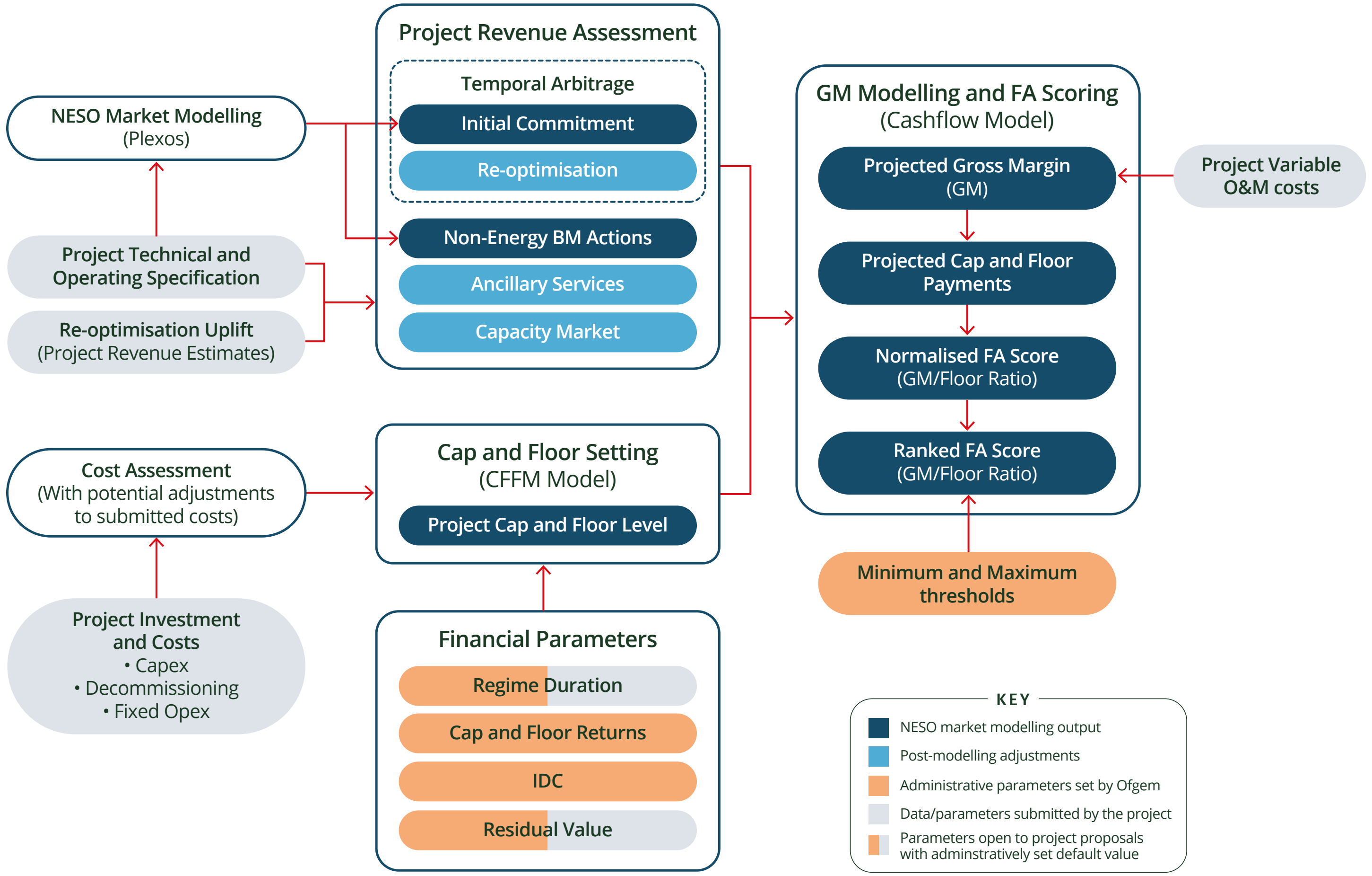
Figure 7: Technology Funding Lifecycle



Additionally, insurance products can also be developed and utilised during the various stages of the technology lifecycle to actively manage and transfer risks.

The Ofgem approval process is structured around a Multi-Criteria Assessment (MCA), evaluating projects across economic value (via NESO modelling), strategic contribution (technology diversity, deliverability, resilience), and financial viability (floor dependency and consumer impact).

Figure 8: Ofgem Multi-Criteria Assessment Framework



The chart below provides a basic snapshot of current bankability across LDES technologies.

Figure 9: Current Bankability Snapshot for LDES Technologies

Technology	Revenue certainty	Upfront capex and build timeline	Ongoing capex / O&M	Current Bankability Snapshot
PSH (~10h+)	High once operational with strong CM baseline plus spreads	Very high capex; 5–8+ yrs build	Low–Medium with periodic refurbishment cycles	Core infrastructure with IG profile post construction and suitable for long-tenor refinancing
Li-ion (8h)	Medium–High reliant on merchant and services plus CM (insufficient alone at current spreads)	Medium capex; 1–2 yrs build; sensitive to spreads & degradation	Medium (augmentation managed by OEM plan)	IG profile for core-plus infrastructure power portfolios;
Flow batteries (8–12h)	Medium reliant on merchant and services followed by CM (insufficient alone at current spreads)	Medium capex; 1.5–3 yrs build; cycle life & electrolyte cost	Medium (chemistry-specific)	Bankable with C&F and performance guarantees
LAES / CAES (10–14h)	Medium reliant on merchant plus CM (insufficient alone at current spreads)	Medium–High capex; 2–4 yrs build → sensitive to efficiency & achieved cycles	Medium (mechanical O&M)	Moderate bankability with C&F and milestone based tests
Hydrogen P2G2P (24h+)	Medium–Low from markets. Can increase with deeper floor and cap limits windfalls	High capex; 2–5+ yrs build → floor depth, efficiency & stack replacements	Medium–High (stacks, compression, fuel handling)	Needs equity and catalytic capital; suited to strategics / DFIs and patient capital

Given the bespoke nature of individual LDES technologies, the LDES lifecycle can be divided into three broad categories: 1) pre-operation, 2) during operation and 3) post-operation. There are a varied set of risks by technology type.

The costs and value-for-money category, which includes capex, O&M expenditure, lifecycle costs, repowering, and component replacement, is also a factor and can vary by technology specifics, developer, and project location. This factor is not indicated above but is part of the assessment frameworks from OfGem and investors.

The table outlines the major risks across each LDES technology type (pre-, during and post-operation), mapped to Ofgem's MCA framework.

Figure 10: LDES Technology Risks Prior to, During and Post Operation

	Technical Feasibility and Maturity			Deliverability (Siting, Permitting, Supply Chain)			System Value (Flexibility, Duration, Services)			Environmental and Social Impact			Operational Risk and Safety			Market and Revenue Risk			Regulatory and Policy Risk		
	FOAK, technology readiness, engineering risk, repowering			Siting, supply chain, permitting, construction, geological, environmental (pre)			Duration, flexibility, ancillary services, operational flexibility			Siting, environmental, recycling, end-of-life, social acceptance			Safety, mechanical/ material risk, cybersecurity, insurance			Revenue stack, market volatility, merchant risk, financial alignment			Policy uncertainty, regulatory compliance, permitting, standards		
LDES Type	Pre	During	Post	Pre	During	Post	Pre	During	Post	Pre	During	Post	Pre	During	Post	Pre	During	Post	Pre	During	Post
Li-ion Batteries	■			■				■						■		■					
PSH				■	■			■		■		■		■		■					
Flow Batteries (VRFB)	■			■				■				■		■		■					
CAES	■			■		■		■						■		■					
LAES	■			■		■		■						■		■					
Thermal Energy Storage	■			■				■				■		■		■			■		■
Hydrogen-based Storage	■			■				■						■		■			■		■
Gravity-based Storage	■			■				■						■	■	■					

Overall, for all stakeholders, NESO's system level modelling provides crucial systems level guidance to build their own capabilities around bankability assessment on a project specific basis. Developers and investors are encouraged to engage with NESO, OfGem and DESNZ to obtain the transparency needed on ongoing costs, skip rates, and the overall assessment process. The feedback mechanism is crucial to align and calibrate views on the project's level feasibility and improve bankability over rime. The recommendations are outlined in more detail in the **Strategic Recommendations and Roadmap** section.

4.3 Needs and roles of capital providers

Financing LDES requires tailoring capital sources to the technology type, developer, development phase and project specifics which determine the overall risk and funding profile. Figure 4 on the Technology Funding Lifecycle provides an overview of the links between capital providers and the stage of the LDES technologies.

The needs and roles of capital providers and the links to capital flows and development phases are best illustrated through examples of financings seen to date globally. A summary and detail of the financing examples highlights the involvement of private debt and infrastructure investors in high TRL LDES, namely Li-Ion BESS and Pumped Hydro with a combination of private equity, concessional capital and grants being common for other technologies.

Figure 11: Financing Examples Summary

Technology Type	Private Debt	Infrastructure	Private Equity	Concessional Debt (Loans/Bonds)	Concessional Equity (Grants/Subsidies)	Notable Amounts / Notes
Pumped Hydro	Genex (AUS)	Genex (AUS)	Genex (AUS)	KfW (DE), CEFC (AUS)	ARENA (AUS), EU RRF (ES/IT)	A$610m (CEFC, AUS), €500k/project (DE), €6bn (ES), €3.6bn (IT)
Li-ion BESS	Octopus/ Nexta (IT)	Octopus/ Nexta (IT)	Emeren/Matrix (IT), Form Energy (US)	CEFC (AUS), NEDO (JP)	CEC (US), NEDO (JP), EU MACSE (IT)	$30m (Form, US), €17.7bn (IT, MACSE), 17bn yen (JP)
Flow Batteries	-	-	Sumitomo (JP), Vattenfall (DE)	NEDO (JP), KfW (DE)	NEDO (JP), SINTEG (DE)	2 MW/20 MWh (DE), 5 GWh (JP, NGK)
Iron-Air Battery	-	-	Form Energy (US)	-	CEC (US)	$30m (Form, US)
CO_2 Battery	-	-	Energy Dome (IT)	EIB (EU)	EU-Catalyst (EU), MACSE (IT)	€17.7bn (IT, MACSE)
Hydrogen Storage	-	-	RWE, Uniper (DE)	KfW (DE)	Innovation Auctions (DE)	400+ MW (DE)
Sodium-Sulphur BESS	-	-	NGK (JP)	NEDO (JP)	NEDO (JP)	5 GWh (global, JP)

Italy – Energy Dome CO_2 Battery (Ottana, Sardinia)

- Energy Dome is pioneering a first-of-a-kind commercial demonstration of its CO_2-based thermodynamic LDES technology in Ottana, Sardinia.
- The project is designed for a 10-hour discharge duration and is part of Italy's ambitious target to deploy 70 GWh of storage by 2033.
- The project is supported by the EU-Catalyst programme, a public-private innovation fund, and has secured an offtake agreement with ENGIE under an Energy Storage as a Service model.
- While the specific project funding amount is not disclosed, it sits within the broader MACSE programme, which has €17.7bn allocated for utility-scale storage in Italy.
- The main investors include the European Commission, the European Investment Bank, Breakthrough Energy Catalyst (Bill Gates-backed), and ENGIE as the corporate off-taker.
- The project benefits from concessional capital through EU-Catalyst and state aid. Pricing details are not public, but under the MACSE framework, operators retain 20% of ancillary and balancing market margins.

United States – Form Energy Iron-Air Battery (Mendocino County, California)

- Form Energy is deploying its first commercial-scale iron-air battery project in Mendocino County, California.
- The system will provide 5 MW of power and 500 MWh of storage, enabling 100-hour continuous discharge archetype of LDES. The project is scheduled for commissioning in 2025.
- Funding includes a $30mm grant from the California Energy Commission (CEC), supplemented by private equity and venture capital from investors, such as Breakthrough Energy Ventures and ArcelorMittal.
- While the CEC grant for this project is $30mm, Form Energy has raised over $800mm in total equity for its broader portfolio. The project is supported by the state government and private venture capital, with concessional capital provided via the CEC grant.

Australia – Kidston Pumped Hydro Project (Queensland)

- The Kidston Pumped Hydro Project, developed by Genex Power in Queensland, is a landmark example of repurposing disused gold mine pits for LDES.
- The project will deliver 250 MW of power and 2 GWh of storage and is currently under construction.
- The total project cost is A$777mn, with a significant A$610mn debt facility provided by the Clean Energy Finance Corporation (CEFC) and a A$47mn grant from the Australian Renewable Energy Agency (ARENA).
- The funding structure combines project finance (debt and equity), government green bank support, and federal grants. Investors include CEFC, ARENA, and private equity. Both CEFC and ARENA provide concessional terms. Pricing is not disclosed, but revenue will be generated through a long-term offtake agreement with EnergyAustralia and participation in the merchant market.

Japan – National LDES Financing and Deployment

- Japan's LDES landscape is anchored by mature pumped hydro (27 GW), large-scale sodium-sulphur batteries (NGK, 5 GWh globally), vanadium flow batteries (Sumitomo, pilot scale), and lithium-ion and emerging chemistries.
- In 2023, 1.669 GW of stand-alone storage was awarded through national auctions. Key developers include NGK Insulators (sodium-sulphur), Sumitomo Electric (VRFB), and various independent power producers and trading houses.
- Funding is provided through the NEDO BESS Installation Subsidy Scheme (¥17bn, or ~$115mn in 2023), the Battery Production and Supply Subsidy (for domestic manufacturing), and the GX Promotion Act, which will raise ¥20tn over 10 years via public green bonds.
- Projects also benefit from 20-year availability-based payments through the Long-Term Decarbonisation Auction (LTDA). Investment sectors include public equity (NEDO, METI, OCCTO), concessional capital (subsidies, green bonds), private equity, and public debt.
- Concessional capital is a major feature, and pricing under the LTDA is set by 20-year contracts, with the average balancing market price at 172 yen/kW/30min in FY2025 H1.

Germany – LDES Financing and Policy

- Germany's LDES sector is dominated by mature pumped hydro (6.5 GW) and features innovative pilots such as Vattenfall's 2 MW/20 MWh vanadium redox flow battery.
- The country has mandated 500 MW of LDES procurement for 2025–2026, with durations up to 72 hours. While the change of government has not resulted in any changes in storage strategy, the implementation timeline and technical specifications may be revised as part of the ongoing reform and consultation process.
- Developers include Vattenfall (VRFB), RWE, Uniper, and various hydrogen and Power-to-Gas (P2G) developers.
- Funding mechanisms include concessional loans from KfW (up to €500,000 per project at 4.75% interest), innovation concept auctions (400+ MW by 2023, scaling to 1,000 MW by 2028), and exemptions from double grid fees, EEG surcharges, and electricity taxes.
- Investors span public debt (KfW loans), concessional capital (tax/fee exemptions, innovation grants), private equity (utilities, project sponsors), and public equity (federal/state R&D).
- Concessional capital is central to the German model. KfW loans are priced at 4.75%, while auction pricing for LDES is not yet public but is expected to be capacity-based with cost recovery.

United Kingdom – Battery Storage and Grid Flexibility

- In 2025, the UK's NWF has notable investments in the LDES space:

  • The NWF committed up to £200mm in equity to Fidra Energy, alongside EIG, as part of a £445mm equity raise for the Thorpe Marsh Battery Energy Storage System (BESS) in South Yorkshire. This project will be the largest standalone battery storage facility in the UK and Europe, with a capacity of 1,400 MW / 3,100 MWh, expected to start operations in mid-2027. The financing package also includes £594mm in debt from international lenders, bringing total capital to c.£1bn. NWF's role is catalytic, closing an equity gap in the BESS market and accelerating delivery of grid-scale storage that might otherwise be delayed.

  • The NWF partnered with Equitix and Aware Super, an Australian pension fund, to launch a £500mm investment platform called Eelpower Energy. NWF is committing up to £200mm in equity, acting as a cornerstone investor to attract private capital. The platform will build, own, and operate grid-scale battery energy storage systems (BESS) across the UK, targeting over 1GW of new capacity to support renewable integration and grid stability. Initial projects include seed assets in Coventry, Perth and Kinross, and Angus, with construction starting immediately. This initiative addresses a critical equity gap in the BESS market and aligns with the UK's Clean Power 2030 mission.

- The NWF has also invested £50mm in AMP Clean Energy to support the deployment of battery storage solutions across the UK, specifically targeting local energy networks and grid flexibility. This investment is part of NWF's broader clean energy portfolio and is intended to catalyse further private capital and scale up both long- and short-duration battery energy storage system (BESS) assets.[5] The company have now refinanced and we were able to step away from this transactions, having helped to successfully crowd in private capital in the initial deal and subsequently.[6]
- In 2023, NWF committed £62.5mm to Pulse Clean Energy, a move that successfully "crowded in" £220mm in private debt from a consortium of lenders (Santander, NatWest, ABN Amro, Nord/LB, Investec, CIBC) for the construction of six new BESS projects (over 700 MWh) in Scotland, Devon, Greater Manchester, and Wales. These projects are expected to be operational by the end of 2027.[7]

In addition, NWF has notable investments in Highview Power (LAES) and Invinity Energy (Vanadium Flow Battery) as well.

Deal information	
Deal announced	June 2024
Sector	Energy storage
Location	Trafford, Greater Manchester
Counterparty	Highview Power
Total financing	£325m
UKIB finance	£165m
Product	Debt and equity

Highview is constructing its first commercial-scale Liquid Air Energy Storage (LAES) asset in the UK (50MW discharge and 300MWh of storage) at Carrington in Greater Manchester. The project will also include stability island, which will provide stability services such as; reactive power, inertia and short-circuit level to the grid at all times. This is critical to allow for the long-term replacement of fossil fuel-based power plants for system support and help reduce curtailment costs.

Deal information	
Deal closed	May 2024
Sector	Energy storage
Location	North Lanarkshire and West Lothian
Counterparty	Invinity
Total financing	£56m
UKIB finance	£25m
Product	Equity

Invinity are increasing the company's existing manufacturing capacity in Scotland by expanding its current operation in Bathgate and expanding to a second site in Motherwell. UKIB will cornerstone £25m of a £56m public fundraise and crowd-in other investors. The investment will help Invinity scale up their new Vanadium Flow Battery (VFB) model (Mistral) and improve the automation of the manufacturing process, which will enable Invinity to reduce costs and compete with Lithium-ion batteries in the 4+ hour duration space.

[5] (source: impact-investor.com)
[6] (source: netzeroinvestor.net)
[7] https://www.nationalwealthfund.org.uk/news-and-publications/blogs/boosting-battery-storage/

Overall, pumped hydro, Li-ion and grid scale BESS, with their high TRLs and revenue stacking, allow for the participation of private debt and infrastructure investors, alongside LAES and flow batteries being funded through the support of catalytic debt and equity capital from the NWF, MDBs, and DFIs. While there has been notable commendable support to the LDES space from NWF, including through catalytic capital investments, specifying and increasing concessional capital to this space along with private capital mobilisation would be recommended as well. In addition, clear allocation and investment targets on LDES from GBE would also be encouraged.

Insurance Markets for LDES
The insurance market offers significant opportunities to support the growth, bankability, and commercialisation of LDES projects, hence the early participation of insurance companies in technology development and capital stack design for LDES bankability and improve investor confidence to scale transition finance. Insurance products can be tailored to cover both performance guarantees, such as system-level commitments on availability, output, or efficiency, and performance warranties, which are typically manufacturer-backed promises on equipment durability or degradation. In addition, insurance products can cover a range of risks from construction, operational, business continuity and disruption, liability, catastrophe, cyber and data risks amongst others, all of which can serve to derisk credit and improve bankability.

For performance guarantees, insurers can provide performance guarantee insurance or surety bonds that backstop the financial obligations of EPC contractors or service providers, ensuring that liquidated damages or penalties are paid if contractual metrics are not met. This helps de-risk revenue streams and makes projects more financeable. For performance warranties, warranty insurance can protect project owners against the risk of manufacturer insolvency or large-scale product failures, ensuring that repair or replacement costs are covered even if the OEM cannot fulfil its obligations. Beyond these, insurance markets can also offer solutions for construction risks, business interruption, cyber risk, and merchant revenue volatility, providing risk solutions for LDES.

Importantly, insurance solutions can also help accelerate the advancement of LDES technologies through the TRL scale by de-risking demonstration and early commercial projects. At lower TRLs, where technology and operational risks are higher, insurance products such as performance guarantee insurance, construction all-risk, delay-in-startup, and warranty insurance can transfer risk away from project sponsors and financiers. This makes it more feasible for developers to secure financing and for investors to commit capital to first-of-a-kind or early-stage projects.[8] As more projects are insured and successfully operated, data collected by insurers and project owners can be used to refine risk models, reduce premiums, and further lower the cost of capital, creating a virtuous cycle that accelerates the commercialisation and scaling of LDES technologies. As the sector matures, insurance products are expected to become increasingly sophisticated, enabling greater capital flows and accelerating LDES deployment globally.

Catalytic Capital and Blended Finance for LDES
High TRLs, the C&F mechanism, revenue stacking and the potential for insurance products can all serve to enhance LDES bankability. However, there is still a need for concessional capital to add to the breadth and diversification of financing sources and risk-sharing offerings seen in other jurisdictions.

Catalytic capital and blended finance are increasingly central to unlocking investment in LDES, especially for technologies and business models that are not yet fully de-risked or commercially mature. Catalytic capital refers to investment, often from public, philanthropic, or development finance sources, designed to absorb higher risk or accept lower returns to mobilise additional private capital and accelerate market development.

In the LDES sector, catalytic capital has been deployed through mechanisms such as grants, concessional loans, first-loss tranches, and public guarantees. Notable global examples include:

- In Australia, CEFC and ARENA have provided concessional debt and grants for projects like the Kidston Pumped Hydro and the Broken Hill project by Hydrostor, de-risking early-stage investment and enabling commercial lenders to participate.
- In the United States, the Department of Energy's LDES Demonstrations Program and CEC grants have provided catalytic, non-dilutive funding for first-of-a-kind projects (such as Form Energy's iron-air battery), resulting in significant system benefits and enabling large follow-on private capital raises.
- Despite the focus on Li-ion technologies, the €17.7bn MACSE programme for utility-scale storage in Italy is a good example of combining state aid, EU innovation funding, and offtake contracts to crowd in private investment and rapidly scale up grid-connected LDES.

In the UK, the NWF has notable investments in Highview Power and Invinity, both at the company and the project level including the Carrington LAES project. Both companies had previously received grants from DESNZ to get them to the point at which they were looking to deploy at grid scale and NWF could consider investment. Those grant schemes no longer exist, but the C&F will help to bring projects through to commercialisation. The policy priority is on those technologies and companies that are ready to deploy at scale.

Additional direct investments from the NWF are in AMP Clean Energy and Pulse Clean Energy specifically targeting local energy networks and grid flexibility. This investment is part of NWF's broader clean energy portfolio and is intended to catalyse further private capital and scale up both long- and short-duration battery energy storage system (BESS) assets. GBE's strategic priorities include supporting the development and deployment of LDES technologies, with a focus on PSH, LAES, and CAES, as well as on grid-scale batteries.

Further concessional support is nevertheless needed to expand access to broader, diversified financing sources and risk-sharing offerings as seen in Europe and Australia. As seen in best practice globally, well-designed concessional, catalytic and blended finance solutions can deliver system benefits, accelerate cost reductions, and help establish robust markets for LDES technologies.

[8] Electrical Energy Storage Systems Insurance | Munich RE

5. Enabling environment for finance

5.1 Strategic recommendations and roadmap

To unlock the full potential of LDES and deliver a resilient, decarbonised, and affordable power system, the UK must pursue a coordinated, multi-stakeholder roadmap. The TFC LDES group has engaged with public sector stakeholders including DESNZ, NESO, Ofgem and the NWF, alongside the LDES Council, investors and industry collaborators from the UK, Europe, Australia and the US. The strategic recommendations and roadmap for LDES outlined below are informed by these stakeholder discussions. The recommendations range from engagement on system needs, policy support, refinements to market mechanisms, provision of catalytic capital, to significant capacity building and capital allocation across investor portfolios.

Figure 12: Recommendations and Roadmap

1 System and Policy Needs	2 Market Mechanisms	3 Scaling Financing for Deployment of LDES
Embed LDES into Clean Power, Infrastructure Modern Industrial Strategy, AI DC for UK growth	**Revenue parity for long-duration assets** including lifecycle pricing	**Build investor capacity and expand private sector capital allocations** across infrastructure, private debt and equity portfolios
Use SSEP to set up **binding LDES deployment targets**	**Enable business models and bankability** with revenue stability	**Review opportunities for insurance** to develop products to improve TRLs
Embed a portfolio approach, with system level attributes as drivers of a diverse technology mix	**Clarify market signals and revenues** to de-risk investment	**Expand catalytic finance** through a broader mandate for NWF
Strategic infrastructure status - PSH, CAES, LAES	**Continue engagement on skip rates**, planned technology and process updates	**Expand public finance** through GBE grants, FOAK support and blended finance structures and innovation
Streamline planning and permitting		
Align future UK policy for dynamic pricing by co-locating storage with industrial demand		
As part of industrial strategy, **secure supply chains and launch workforce skills development**		

5.2 Policy and regulatory interventions

A list of recommendations and broad sequencing of actions over the next few years by stakeholder group is provided below:

For investors over the course of 2026-27

- There is a clear call for action to build capacity for LDES technologies on bankability, risk and return assessment, and the allocation of capital across infrastructure, private debt, and equity portfolios.
- Investors are also encouraged to actively engage with NESO on the development of the SSEP and the consultation expected to emerge through the course of 2026.
- Depending on the findings of the SSEP and its implications, investors can engage with DESNZ on any emerging policy actions from arising from the former to further guide system improvements, as well as SSEP development and implications.
- As OfGem continues their project assessments and publishes the first set of assessments (expected in Mar-26), investors are encouraged to review and engage on the outputs both from a system and a bankability perspective.
- Ongoing engagement with NESO and OfGem on robust transparency and standardised metrics across the LDES lifecycle, is encouraged as it is key to informed capital allocation and portfolio management.

For the insurance industry, over the course of 2026-27

- There is an opportunity to develop products and solutions, including performance warranties, that can help improve TRLs for technologies.

Capacity Building	Investors / Developers	Build LDES expertise through educational sessions for technology awareness and risk assessments
	TFC	Promote educational sessions on bankability assessments from Ofgem and TFC

Financing	Investors (Infrastructure, Private Debt, Private Equity)	Line up allocations of upto £15bn for the pipeline of investment opportunities depending on the projects approved, final technology mix, site characteristics, and maturity. Active involvement to improve quality and success of financing
	Insurance Markets	Actively develop insurance products – such as performance guarantee insurance, construction risk, delay-in-startup, and warranty insurance – for risk transfer away from projcet sponsors and financiers and improve feasibility for developers accelerating advancement of LDES technologies through the TRL scale, to secure financing and for investors to commit capital to first-of-a-kind or early-stage projects. As the sector matures, insurance products are expected to become increasingly sophisticated, enabling greater capital flows
	NWF / GBE on Catalytic Capital	Consider First-of-a-kind (FOAK) financing tools for systemically important LDES with high upfront capex and technology risk (vanadium for flow batteries, thermal integration for CAES, liquefaction equipment for LAES, electrolyser cost for hydrogen)

For policy makers and systems operators, over the course of 2026 and beyond

- From NESO, the SSEP consultation outputs, engagement and response is a crucial step through the course of 2026-27. The asks mainly relate to additional clarity around system needs and attributes, which can then drive the portfolio approach to LDES. In addition, maintaining and improving the transparency on performance and skip rates, alongside progress on planned technology updates, will be essential to build investor confidence.
- From DESNZ and Ofgem, the asks include enabling lifecycle pricing, revenue stacking and bankability support, while ensuring system wide savings are transparently passed through to consumers.

Policy	**DESNZ / OfGem**	Ensure revenue adequacy and parity for long-duration assets , starting with extending the C&F for multi-GW long duration assets including PSH, LAES, CAES
	DESNZ / OfGem	Introduce lifecycle pricing to reflect long asset lives in floor design. Promote long-duration system services in future market design
	OfGem	Keep *all* market and CM revenues inside the C&F band with simple, annual reconciliation. This avoids double-support, preserves dispatch incentives and provides a clean, auditable settlement line
	OfGem	Consumer Oriented Design to ensure system savings are passed through via price controls
	DESNZ	Engagement with investors on SSEP views and associated policy support for the landscape based on system needs

Transparency	**NESO / OfGem**	Transparency on technology cost and performance and their use in cost-benefit evaluation, MCA and skip rates
	NESO	Transparency in system level needs and planning and locational modelling through the SSEP
	OfGem	Build on the MCA framework further to provide quantitative metrics to capture unit costs, capacity, duration and revenue stacking, to improve standardisation and bankability

For local authorities, over the course of 2026 and beyond

- The ask remains on accelerating planning permisssion processes.

For the industry, including DESNZ, local authorities, and developers

- The ask is more support for domestic supply chains, including for UK-based manufacturing.

System and Industry	**Local Authorities**	Planning and permitting barriers. Large-footprint technologies (PSH, CAES, flow batteries with large tanks) face land-use conflicts and slow approval processes
	DESNZ / Developers	Support domestic supply chains. From vanadium electrolyte (VRFBs) to cryogenic equipment (LAES) and hydrogen electrolysers, most LDES supply chains remain nascent in the UK, relying heavily on imports. Build UK-based manufacturing and engineering supply chains

By aligning policy, market design, and finance, the UK can bridge the investment gap, mobilise institutional capital, and scale LDES to meet its Clean Power 2030 and Net Zero ambitions.

Figure 13: Potential Bankability Effects with Change in Market Mechanisms

Technology	Current Bankability Snapshot	Changes in C&F / market mechanisms needed	Potential Bankability Effects
PSH (10h+)	Core infrastructure with IG profile post construction and suitable for long-tenor refinancing	Extend C&F access and tenor for long-life assets; Streamlined strategiuc-infrastructure status and planning	Reduce construction risk, Improve leverage and terms
Li-ion (8h)	IG profile for core-plus infrastructure power portfolios;	Maintain and improve duration-sensitive CM derating; Keep all revenues in-band for simple C&F settlement	Reduce volatility profile
Flow batteries (8–12h)	Bankable with C&F and performance guarantees	Longer ancillary contract tenors	Improve leverage and terms
LAES / CAES (10–14h)	Moderate bankability with C&F and milestone based tests	Moderate floor depth; Duration-weighted CM multipliers; Clear performance metrics	Improve leverage and terms
Hydrogen P2G2P (24h+)	Needs equity and catalytic capital; suited to strategics / DFIs and patient capital	Potential explicit resilience valuation inside C&F; Availability of time-limited public backstop; Coordination with H_2 business models	Improve leverage and refinancing potential

6. Next steps and finance plan governance

6.1 Governance - metrics and targets for review

Tracking governance and progress on LDES deployment, along with efficient implementation, are essential for the effective long-term scaling of LDES across the UK economy.

To support this, there are metrics and key performance indicators (KPIs) from a variety of sources that can be monitored to gauge the advancement of LDES technologies to successful market scale-up by 2030 and beyond.

These include:

- System level metrics in terms of overall technology mix and diversification.
- Technology and adoption readiness levels (TRLs/ARLs) and commercialisation progress.
- Leading indicators should indicate relative readiness of technologies and markets for at-scale adoption (e.g. early signs that LDES is "on-track" for its role in the grid).
- Lagging indicators representative of successful scaling and adoption of LDES, in addition to readiness for 2030 and beyond for deployment of the technology (e.g. supply readiness).
- Outcomes showing the relative impact of LDES on broader targets (e.g. job creation, lower electricity costs, consumer savings, emissions reduction). These topline demand signals should be segmented into part-specific demand signals, and broadcast widely so sub-tier suppliers also have clarity on what to expect.

Figure 14: KPIs, Metrics and Targets

Leading Indicators	Lagging Indicators	Outcomes
For each demonstrated technology - Capex (£/KW, £/Kwh) - Round Trip Efficiency - Ramp Time - Operational Costs	TwH Deployed	Avoided Curtailment Capital Mobilised Consumer Savings Emissions Reductions

6.2 Successful implementation and progress

The UK is at a pivotal stage in deploying and scaling LDES from a technology to a sector, to power clean growth in the modern industrial economy. It is crucial that investors, developers, utilities, the public sector, and other stakeholders work together to pursue a constructive and coordinated journey to implementation.

The strategic recommendations and roadmap, alongside a supportive, highly engaged policy, technology and investment environment, are crucial to further progress.

- Investor capacity building and capital allocation to the attractive investment opportunities in the current LDES pipeline represent a starting point.
- To scale LDES in the coming years, the stakeholder group should continue to prioritise engagement with NESO and DESNZ through the SSEP development and consultation to support and enhance system level planning.
- The stakeholder group should advocate for market designs and policy mandates that reward LDES' flexibility and long-duration capabilities.
- As an industry, it is crucial to accelerate the development and dissemination of technical and commercial standards to reduce risk and improve investor confidence.
- To foster early and ongoing collaboration between developers, investors, insurers, and policymakers to align incentives and streamline project development.
- Finally, the mandates for NWF and GBE should be expanded and tailored to support construction and rigorous testing of first-of-a-kind projects through concessional capital while generating empirical performance data. Investors need to work with NWF, GBE and banks to expand and tailor public and private financing instruments, including grants, quasi-equity, and guarantees, to match the capital intensity and risk profile of LDES.

By taking these steps, the sector can unlock the capital flows needed to achieve the required scale-up and deliver the full system value of LDES.

Figure 15: Enablement Actions and Sequencing

<table>
<tr><th></th><th>HMG</th><th>NESO</th><th>DESNZ</th><th>OfGem</th><th>NWF / GBE</th><th>Insurance</th><th>Investors</th><th>LDES Council</th></tr>
<tr><td>Systemwide LDES deployment targets</td><td>2026</td><td></td><td>2026</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Investor capacity building</td><td></td><td colspan="3">2026</td><td></td><td></td><td colspan="2">2026</td></tr>
<tr><td>Capital allocation to bankable investment opportunities in current LDES pipeline</td><td></td><td></td><td></td><td></td><td></td><td></td><td>2026 - 2027</td><td></td></tr>
<tr><td>SSEP development and consultation to support and enhance system level planning</td><td></td><td colspan="2">2026 - 2027</td><td></td><td></td><td></td><td>2026 - 2027</td><td></td></tr>
<tr><td>LDES project assessments window 1 outputs</td><td></td><td></td><td></td><td>1Q 2026</td><td></td><td></td><td>1Q 2026</td><td></td></tr>
<tr><td>LDES revenue parity through market design and policy mandate to support long-duration capabilities</td><td></td><td></td><td colspan="2">2026 - 2027</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Development and dissemination of technical and commercial standards</td><td></td><td></td><td></td><td></td><td></td><td>2026</td><td></td><td>2026</td></tr>
<tr><td>Development of insurance products including performance warranties, and business continuity etc</td><td></td><td></td><td></td><td></td><td></td><td>Ongoing</td><td></td><td></td></tr>
<tr><td>Expand mandates for NWF and GBE to ringfence FOAK financing support while generating empirical performance data</td><td>Ongoing</td><td></td><td></td><td></td><td>Ongoing</td><td></td><td></td><td></td></tr>
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Acknowledgements and References

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