# Procuring Long Duration Energy Storage (LDES)

## A Technical Guide for Decision Makers

September 2026


Make better decisions

Maximise value for your system

Accelerate energy transition

# Procuring Long Duration Energy Storage

## A Technical Guide for Decision Makers

**Disclaimer**

This publication provides technical guidance for designing procurement processes that can fairly evaluate long duration energy storage resources across technologies, applications, and markets. It is intended to support decision makers and should be adapted to local market design, grid-code, permitting, land-use, safety, and regulatory requirements. The guidance is not legal, financial, engineering, or investment advice. Decision markers for procurements should undertake market consultation and necessary specialist considerations before issuing tender documents.

The Long Duration Energy Storage (LDES) Council is a global industry association representing long duration energy storage technology providers, customers, investors, and service providers. The LDES Council builds the case for long duration energy storage by amplifying the collective expertise of its members and partners, transforming knowledge into action and action into local and global impact.

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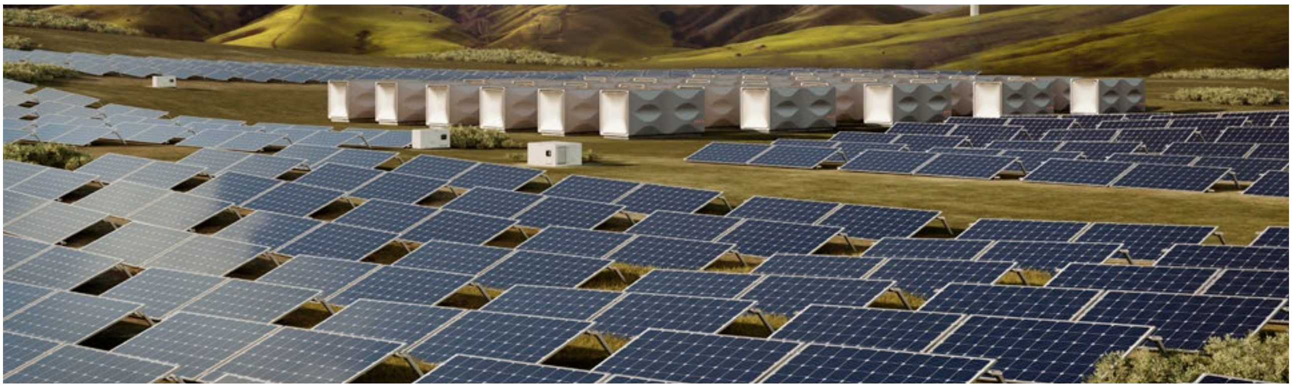


# Background: Why LDES Procurement Requires Dedicated Guidance

Long duration energy storage (LDES) is a core component for reliable, affordable, and deeply decarbonised energy systems. As power systems add higher shares of variable renewable generation, electrify industrial heat and transport, and face more frequent periods of system stress, procurement frameworks need to value storage resources that can shift energy over extended durations.

LDES procurement differs from short-duration storage procurement, often cycling less frequently over a different revenue stack and over longer assets lifetimes. LDES can provide energy shifting over multi-hour, multi-day, and seasonal periods; support capacity adequacy during prolonged stress events; reduce renewable curtailment; defer or avoid network reinforcement investment; deliver essential system services including frequency, voltage control and black start; provide resilience for critical loads; and contribute to industrial decarbonisation where 24/7 affordable clean heat or power is required.

The ability to stack these revenue streams across multiple value channels is a defining commercial characteristic of LDES, and procurement frameworks that recognise only a single technology systematically undervalue LDES solutions relative to their full system contribution.

The International Energy Agency (IEA) notes that annual battery storage additions exceeded 75 GW in 2024 but cautions that batteries alone cannot meet all future flexibility requirements, particularly where seasonal flexibility is needed1. As renewable penetration increases, power systems will require a broader portfolio of storage technologies with diverse durations to minimise curtailment and maintain reliability.

This is consistent with analysis from the International Renewable Energy Agency (IRENA), which projects that power-system flexibility needs across daily, weekly, and seasonal timescales will continue to grow as variable renewable shares rise, with long duration storage assessed alongside interconnectors and demand-side measures as one of several resources needed to meet this growing requirement2.

The global scale of the system need for storage is substantial: more than 70 governments and organisations have endorsed a collective target of 1,500 GW of installed energy storage by 20303. This underscores the urgency of procurement frameworks that can bring forward high-value storage across the full range of durations and technologies.

[1] International Energy Agency (IEA) - World Energy Outlook (2025)

[2] International Renewable Energy Agency (IRENA), Flexibility for a secure and affordable power sector transformation (January 2026)

[3] COP29 Global Energy Storage and Grids Pledge (launched November 2024, Baku)

# Purpose of this Technical Guide

This guide is presented around a single practical goal: ensuring procurement processes are fully inclusive of long duration energy storage (LDES) solutions that would deliver value to the energy and heat systems, consumers, and the community.

> LDES can be deployed as a standalone asset, integrated with generation sources, or located near electricity or heat demand centres.

LDES can enhance system reliability, flexibility, and resilience, and reduce overall system costs and enable deep decarbonisation. The criteria outlined in this Technical Guide are intended to support procurement of multiple LDES use cases including both front- and behind- the-meter solutions.

This guide encourages procuring entities to begin by defining the underlying system need before determining the procurement approach. This includes asking key questions such as: What duration or durations are required? Is the need local or system-wide? Is the primary objective reliability, congestion relief, renewable energy integration, heat decarbonisation, resilience, seasonal balancing, or a combination of these? What delivery timeline is required? Can procurement be structured through separate streams or delivery windows to maximise participation from technologies with different deployment timelines and levels of market maturity?

Technology-neutral, inclusive, needs-led procurement produces better outcomes for systems, consumers and the climate. Whereas, tenders that prescribe a single technology, require narrow technical specifications based on inputs rather than outcomes, focus on costs over value, or impose short commissioning deadlines can unintentionally exclude viable resources that deliver greater system value.

This document provides practical considerations to help address these questions and support technology-neutral procurement that is aligned with system needs and long-term market objectives.

This guide draws on assessments from the International Energy Agency, the International Renewable Energy Agency, National and Federal Energy Departments (Worldwide), the Electric Power Research Institute., Lazard, the World Bank and LDES Council reports existing reports and research.

# Who Is This Technical Guide For

This guide supports procurement decision makers preparing Requests for Information, Requests for Proposals, tenders, auctions, long-term contracts, regulated asset mechanisms, or bilateral procurement processes for long duration energy storage. It is designed to help procurers define their system need clearly, be inclusive of a range of technologies, and evaluate bids on the basis of lifecycle system value rather than narrow cost metrics alone.

It is intended for a broad range of decision makers, including:

- System, transmission and distribution operators
- Utilities and energy producers
- Industrial customers, including for heat, cooling and power
- Government, regulators and energy planners, and
- Investors in LDES technologies.

## Decision makers are encouraged to:

- Use this document as a foundation for drafting new, or updating existing, LDES-inclusive tendering processes.
- Integrate this technical guidance into energy storage information and procurement requests, including Requests for Proposal.
- Adapt the criteria checklists to align with their respective regulatory, system, and policy requirements for energy storage.

# LDES Technology Families and Applications

Long duration energy storage (LDES) is defined as any technology that stores energy and then dispatches it as power, heat, or cooling for extended periods, ranging from eight hours to days, weeks, or seasons. It takes various forms; chemical, thermal, mechanical, and electrochemical storage, and with power-to-power, power-to-heat and power-to-X applications.

The LDES Council organises LDES solutions into four technology families, defined by the form in which energy is stored and the applications they serve:

- **Electrochemical storage:** includes flow, metal-air and other long duration battery chemistries that store energy in chemical form and discharge as electricity over extended periods.
- **Mechanical storage:** includes pumped hydro, compressed air, liquid air and gravity-based storage systems. These technologies store energy in physical or pressure form and are typically suited to large-scale, long duration power applications.
- **Thermal storage:** stores energy as heat or cold, enabling discharge as industrial process heat, space heating and cooling, or conversion back to electricity. Particularly relevant for industrial decarbonisation, district energy, and behind-the-meter applications.
- **Chemical storage:** includes hydrogen, ammonia, and other energy carriers produced through electrolysis or synthesis. Suited to seasonal storage, industrial fuel-switching, and long-distance energy transport applications.

These technology families can be deployed across a wide range of use cases, including:

- Grid-scale solutions supporting system operators and utilities to balance and secure the grid over extended periods.
- Storage co-located with renewable generation, optimising output and enabling firm power purchase agreements.
- Power-to-heat solutions providing industrial and commercial users with 24/7 clean, affordable process heat and cooling, avoiding peak pricing periods and replacing backup fossil generation.
- Behind-the-meter power-to-power solutions giving large energy consumers (including data centres) 24/7 secure, clean, and affordable energy, and faster grid connections.
- Microgrids, where generation, demand, and storage are co-optimised for affordability, reliability and resilience.

# FIGURE 1

The four families of LDES technologies across applications

| | Description | | Charge-Discharge Period |
|---|---|---|---|
| Electrochemical (power-to-power) | Battery systems that can store electricity through chemical reactions<br>• Flow battery<br>• Metal anode (e.g. iron, zinc, lithium-ion battery)<br>• Metal air | Charge → Disharge | Hours to days |
| Mechanical (power-to-power) | Systems that use heat, water or air with compressors, turbines, & other machinery<br>• Pumped hydro<br>• Compressed air<br>• Liquid air/ CO2<br>• Gravity | Charge → Reserve → Turbine (discharge) | Hours to days |
| Thermal (Power-to-Power) | Systems that convert electricity to thermal energy, store in inexpensive materials & output as electricity<br>• Sensible heat<br>• Latent heat<br>• Thermo-chemical | Charge → Option to output power | Hours to days |
| Thermal (Power-to-Heat) | Systems that convert electricity to thermal energy, store in inexpensive materials & output as heat<br>• Sensible heat<br>• Latent heat<br>• Thermo-chemical | Charge → Heat delivery (hot water, steam or air) | Hours to days |
| Chemical (power-to-power) | High density energy carrying chemicals produced from energy sources, which can be converted back to electricity<br>• Hydrogen<br>• Ammonia<br>• Electrofuels | Electrolyzer (charge) + derivates → Option to convert back to electricity | Seasonal |
| Chemical (power-to-x) | High density energy carrying chemicals produced from energy sources, which can be stored, used as fuels or as chemicals feedstock<br>• Hydrogen<br>• Ammonia<br>• Hydrocarbons/Alcohol<br>• Carbons | Electrolyzer (charge) + derivates → Option to use in industry | Seasonal |

Source: LDES – The Basics & the gaps, (FCArchitects, 2023) ; Annual Report LDES Council (2024)

# 1. Ensuring Eligibility for Diverse LDES Technologies and Durations

Ensuring eligibility for a broad range of energy storage technologies is important for building resilient and future-ready energy systems. Multiple forms of LDES solutions are already being deployed commercially today, delivering a range of services and revenue streams across diverse durations and applications. Enabling these technologies to compete on a level playing field – based on system or customer needs rather than technology type – promotes competition and cost savings and supports deployment of the most system-suitable and cost-effective solutions.

## Storage Technology Neutral Language

To achieve this, procurement processes, including Requests for Information (RFIs) and Requests for Proposal (RFPs), should adopt storage technology-neutral language from the earliest stages (in particular, referring to energy storage rather than "battery storage"). This is necessary to ensure a broad range of LDES technologies can participate and that evaluation criteria assess proposals against performance requirements, system needs, and market readiness rather than technology type.

## Duration Bands and System Needs

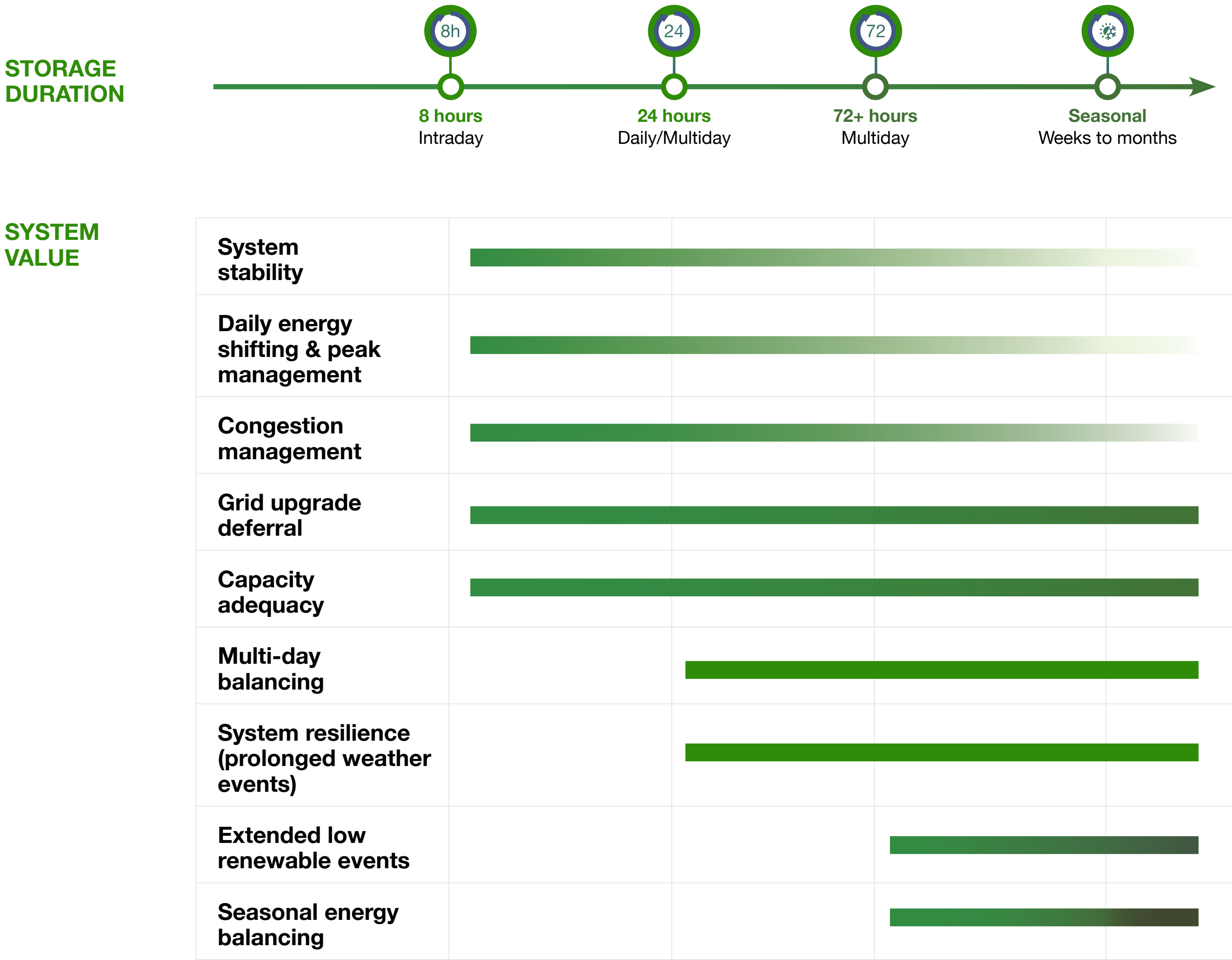
The duration requirements specified within procurement frameworks should reflect the system need being procured rather than technology characteristics. While the figures shown below are illustrative, they demonstrate how increasing storage duration enables different value streams and why procurement and market design may need to evolve as system needs shift from daily flexibility towards multi-day reliability and seasonal adequacy.

> **Understanding this distinction enables more informed decision making and builds confidence in deploying a diverse portfolio of technologies and durations.**
>
> **Different LDES technology solutions across duration bands can provide complementary system benefits, enhance overall system value, and create opportunities for revenue stacking where multiple value streams are captured simultaneously.**

In order to procure solutions across different duration bands aligned to system need, decision makers can utilise multi-track procurements, duration-specific assessment criteria and/or minimum capacity thresholds.

## FIGURE 2

Power to Power: Illustrative Mapping of system value and procurement route to storage duration




**ILLUSTRATIVE PROCUREMENT & COMMERCIAL FRAMEWORKS**

**Competitive markets with long-term revenue certainty**
LDES typically requires long-term contracts or revenue floors to be financeable.

**Longer duration requirements**
Procurements increasingly specify minimum duration, availability and performance to deliver greater system value.

**Dedicated LDES or capacity procurements**
Where conventional markets do not sufficiently value multi-day services, dedicated mechanisms may be required.

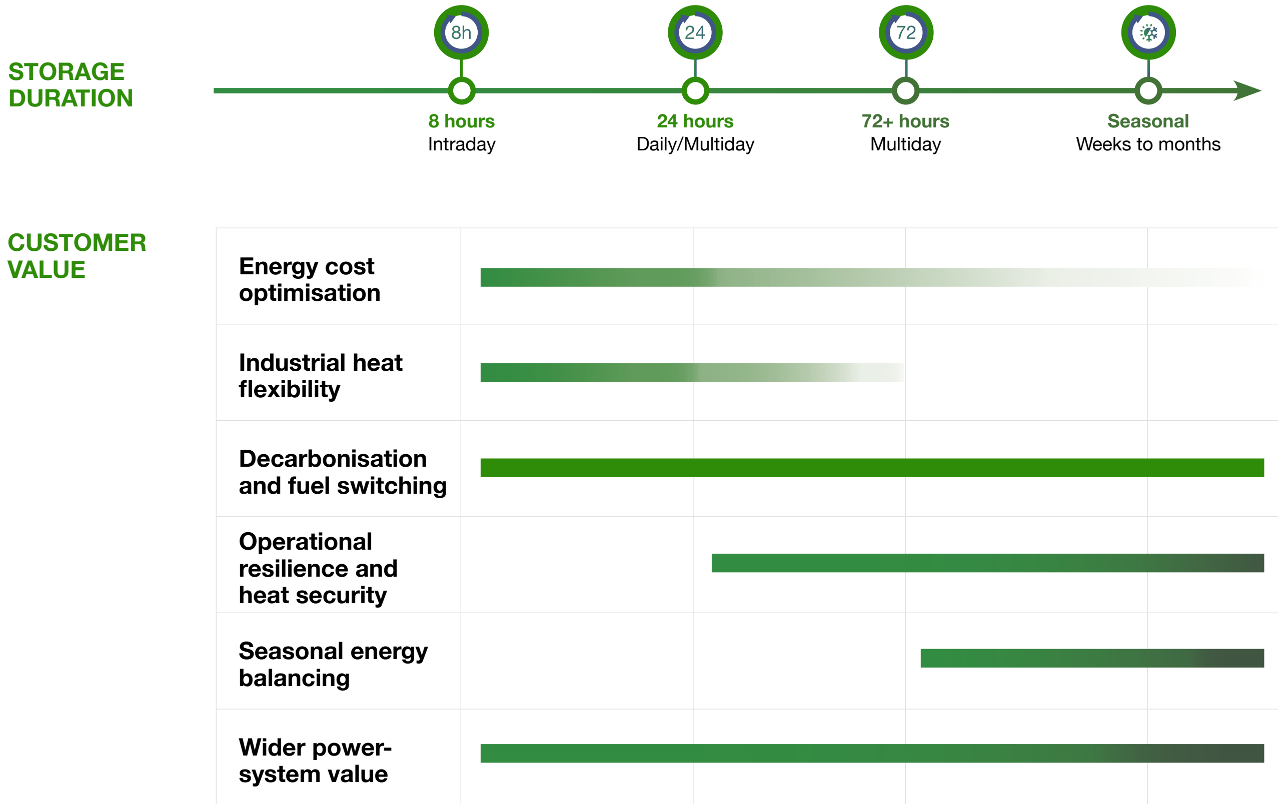
**Long-term availability contracts**
Greater emphasis on availability and reliability during infrequent periods of prolonged system stress.

**Strategic, hybrid or regulated frameworks**
Long-term contracted, hybrid or regulated models may be appropriate for seasonal and strategic system value.

**Note:** The durations shown are indicative points along a continuum rather than fixed thresholds. Appropriate duration and performance requirements should be based on system-specific modelling and the use case being pursued. Many value streams provide co-benefits across multiple timeframes.

## FIGURE 3

Power to Heat: Illustrative Mapping of Customer and system value and procurement route to storage duration




| ILLUSTRATIVE PROCUREMENT & COMMERCIAL FRAMEWORKS | | | | |
|---|---|---|---|---|
| | **Behind-the-meter investment**<br>Industrial or commercial investment driven by energy cost savings, resilience or decarbonisation. | **Long-term industrial energy contracts**<br>Bilateral agreements with industrial users for reliable, low-carbon heat supply. | **District Heating Procurement**<br>Municipal or utility-led contracts to ensure reliable heat supply for consumers. | **Strategic heat security programs**<br>Public mechanisms to secure critical heat supply during extreme or prolonged events. |

**Note:** The durations shown are indicative points along a continuum rather than fixed thresholds. Appropriate duration and performance requirements should be based on system-specific modelling and the use case being pursued. Many value streams provide co-benefits across multiple timeframes.

## Technology Readiness and Market Readiness

While Technology Readiness Levels (TRLs) are widely used to assess the maturity of technologies, procurement frameworks should avoid relying solely on high TRL requirements where the objective is to accelerate innovation alongside deployment for energy storage procurement.

Restricting participation exclusively to technologies at TRL 8–9 may reduce delivery risk in the short term, but it also unintentionally limits technology diversity, reduce competition, and slow the commercialisation of emerging long duration energy storage solutions. Many LDES technologies are progressing rapidly through demonstration and early commercial deployment, with technologies at TRL 5–7 increasingly supported by operational pilots, first-of-a-kind commercial projects and industrial-scale demonstrations.

Procurement authorities should therefore consider adopting tiered procurement pathways that align technology maturity with project objectives. For example:

| Technology maturity | Illustrative procurement approaches by technology maturity |
|---|---|
| **TRL 5–6** | Innovation competitions, demonstration programmes, pilot procurements, innovation funding and first-commercial deployment opportunities. |
| **TRL 7** | Early commercial deployment, phased commercial procurements, strategic demonstrations, first-of-a-kind projects and targeted revenue support. |
| **TRL 8–9** | Technology-neutral competitive procurement, long-term contracts, capacity mechanisms, flexibility markets and system-scale deployment. |

Procurement designers may reserve portions of a procurement, or establish dedicated innovation lots, for smaller projects or emerging technologies where doing so supports innovation, competition and technology diversity while maintaining overall procurement objectives.

Recognising that technology maturity is dynamic is equally important. Emerging technologies can progress from demonstration to commercial deployment within relatively short timeframes as manufacturing scales, operational experience grows and financing conditions improve. Procurement frameworks should therefore remain sufficiently flexible to accommodate technologies as they mature, rather than embedding static eligibility criteria that require periodic regulatory revision.

Ultimately, procurement should seek to balance deployment certainty with market development, creating opportunities for both established commercial technologies and emerging solutions that are approaching commercial readiness.

The LDES Council 2025 Technical Report on Cost Benchmarking for Long Duration Energy Storage Solutions captures the Technology Readiness Level assessments across a wide range of technologies[4]. The LDES Council's 2024 Annual Report set out the inaugural Market Readiness Levels for a range of LDES technologies. These Market Readiness Levels are periodically updated to reflect evolving technologies and market conditions[5].

[4] The LDES Council's 2025 Cost Benchmarking for Long Duration Energy Storage Solutions provides transparent, real-world cost benchmarks for long duration energy storage technologies and shows that costs are expected to decline significantly by 2030.

[5] The LDES Council's 2024 Annual Report included a mapping of member technologies against market readiness to illustrate the diversity and maturity of the current LDES landscape. This assessment is being updated to reflect the evolving commercial status of technologies and will be incorporated into the Council's forthcoming updated LDES Council market readiness assessment. As the sector continues to mature, technology readiness should be viewed as dynamic rather than static, with procurement frameworks adapting accordingly.

Procurement frameworks should draw on these assessments when setting eligibility criteria, to ensure that emerging technologies with strong system-value potential are not excluded by requirements calibrated to the most commercially mature solutions. Considering MRLs alongside TRLs enables procurement to support both commercially proven and rapidly emerging technologies as markets evolve.

## FIGURE 4A

LDES Council Market Readiness Levels for LDES Technologies

| Category | Technology | Market readiness | Storage duration (hours) | Round-trip efficiency (%) | Geographical footprint (kWh/m²) |
|---|---|---|---|---|---|
| Electrochemical (power-to-power) | Vanadium Flow batteries | Early commercial | 4-24+ | 60-80% | 20-50 |
| | Lithium-Ion (LFP, NMC) | commercial | 2-10 | 85-96% | 90-95 |
| | Sodium-Ion | Early commercial | 4-20 | 60-85% | 2-43 |
| | Zinc Air | Early commercial | 10-100 | 40-45% | 2-43 |
| | Zinc Bromine Flow | Early commercial | 4-12 | 60-70% | 2-43 |
| | Iron Air | Early commercial | 100 | 40-45% | 2-100 |
| | Non-Metal chemical storage | Emerging | 0-200 | 40-50% | 300-1500 |
| | Static (non-flow) Zinc Halide* | early commercial | 4-16+ | 75-92% | 25-65 |
| | Iron-chromium flow batteries* | early commercial | 4-12+ | 55% | 6.9 |

*Updated technology types included to reflect the evolving diversity in LDES technologies.

| Category | Technology | Market readiness | Storage duration (hours) | Round-trip efficiency (%) | Geographical footprint (kWh/m²) |
|---|---|---|---|---|---|
| Mechanical (power-to-power) | Compressed-air energy storage | Early commercial | 6-100 | 40-70% | 12.5 |
| | Liquid Air | Commercial | 10-72 | 60-75% | 59-74 |
| | Liquid $CO_2$ | Emerging[1] | 4-24 | 70-80% | 4-5 |
| | Gravity-based | Emerging | 0-15 | 70-90% | 7 |
| | Pumped Hydro Storage (PHS) | Commercial | 0-10 | 70-85% | 5-12 |
| | Closed loop PHS and run of river | Commercial | 0-15 | 50-80% | 4-5 |

Source: Long Duration Energy Storage Council. Data collected from members.

# FIGURE 4B

## LDES Council Market Readiness Levels for LDES Technologies

| Category | Technology | Market readiness | Storage duration (hours) | Round-trip efficiency (%) | Geographical footprint (kWh/m²) |
|---|---|---|---|---|---|
| Thermal (power-to-power) | Sensible heat | Early commercial | 200 | 55-90% | 30-800 |
| | Latent heat | Emerging to commercial | 25-100 | 20-50% | 30-450 |
| | Thermo-chemical | R&D/Emerging | Not available | Not available | Not available |
| Thermal (power-to-heat) | Sensible heat | Early commercial | 200 | 55-97% | 30-800 |
| | Latent heat | Emerging to commercial | 25-100 | 20-93% | 350-1644 |
| | Thermo-chemical | R&D/Emerging | Not available | Not available | Not available |

| Category | Technology | Market readiness | Storage duration (hours) | Round-trip efficiency (%) | Geographical footprint (kWh/m²) |
|---|---|---|---|---|---|
| Chemical (power-to-power) | Hydrogen | Emerging | 24-1000* | 28-40% | 5-80** |
| | Ammonia | Emerging | 170-350 | 35-40% | 98 |
| | Methanol | Emerging | 170-350 | Not available | Not available |
| Chemical (power-to-x) | Hydrogen | Early commercial | 24-1000* | 40-70% | 5-80** |
| | Ammonia | Early commercial | 170-350 | 35-40% | 98 |
| | Methanol | Early commercial | 170-350 | Not available | Not available |

Source: Long Duration Energy Storage Council. Data collected from members.

* Revised storage duration to reflect the evolving market.

** Revised geographic footprint (kWh/m²) to reflect the evolving market.

## Valuing Diversity in Procurement

Decision makers should consider the value of diversity in procurement across several dimensions:

- Duration diversity supports long-term system needs. Procuring solutions of a single duration or limited to a single technology pathway may provide lower long-term value to the buyer, system, and consumers. Comprehensive long-term system planning should underpin these decisions.

- Technology diversity drives innovation and reduces costs for future consumers. Emerging LDES solutions may carry substantial cost reduction potential over time; procuring a diverse range of solutions can lock in low costs for current consumers while realising cost reduction opportunities for future consumers.

- Supply chain diversity reduces risk. Decision makers may see value in avoiding overreliance on a single supply chain and in supporting the development of local manufacturing and installation capacity.

Rather than excluding or mandating technologies to meet these goals, decision makers should seek to identify and quantify the value of diversity and embed this transparently within the procurement methodology. This enables decision makers to weigh the respective merits of, for example, short-term cost reductions against long-term diversity value, and enables industry to focus investment and optimise bids based on the desired outcomes of the buyer.

## Thermal storage inclusion

Thermal storage can deliver power, heat, cooling and combinations of these as an output. Decision makers should avoid precluding thermal storage solutions through procurement criteria designed primarily around electricity-based metrics. Procurement processes should recognise thermal energy services alongside electrical solutions and evaluate technologies based on the specific system need being procured.

## Deployment track record

Decision makers should seek to avoid implementing requirements based on significant deployment track records or local deployment history, as this can disproportionately disadvantage many emerging LDES technologies, limit competition and reduce the opportunity to secure the most cost-effective long-term outcomes. Evidence from pilots, comparable international deployments, certified technology performance data, parent-company experience, or independent engineering assessments are additional data points that are appropriate to consider and should be taken into account.

# Technical Checklist: Ensuring Eligibility for Diverse LDES Technologies

| Criterion | Recommended approach |
|---|---|
| **Storage technology inclusion language** | Design procurement frameworks to be technology inclusive, allowing all storage solutions that satisfy the identified system need to compete.<br>RFPs and tenders should use storage technology-neutral language unless there is a clear technical reason to specify a technology. Replace “battery energy storage system” with “energy storage system” or “long duration energy storage resource” throughout tender documents. |
| **Duration bands and system needs** | Implement evaluation criteria that recognise the distinct value propositions of technologies and procure solutions across different duration ranges |
| **Technology readiness and market readiness** | Where appropriate, contracting authorities should consider establishing dedicated innovation or emerging technology procurement pathways alongside mainstream commercial procurement to encourage technology diversity and support the continued evolution of the LDES market. |
| **Valuing diversity in procurement** | The procurement framework should seek to identify, value and appropriately reward diversity, whether based on system need, innovation or supply chain diversity benefits. |
| **Thermal storage inclusion** | Ensure thermal storage technologies are not excluded through use of electricity metrics, where the thermal storage solution can meet system requirements. |
| **Deployment track record** | Avoid unnecessarily onerus requirements relating to previous deployment track records and/or deployment in the same region. |

# 2. Physical and Operational Considerations

Physical and operational constraints embedded in procurement requirements can limit participation by LDES technologies, affecting project feasibility and the quality of responses received. Procurement authorities should review each of the following areas carefully.

## Power and Energy Capacity

Procurement requests should distinguish clearly between power capacity in megawatts and energy capacity in megawatt hours, to reflect the different capabilities and value streams provided by energy storage technologies. A 100 MW project with 400 MWh of delivered energy capacity provides four hours of discharge at rated output; a 100 MW project with 10,000 MWh provides 100 hours. Eligibility criteria should be aligned with the underlying system need rather than relying on unnecessarily restrictive minimum power or energy capacity thresholds.

Where distinct system needs exist across different duration ranges, procurement frameworks should establish separate streams or evaluation windows aligned to the required durations, services, or operational characteristics, rather than applying a single set of thresholds across all storage technologies.

Where minimum capacity thresholds are implemented in order to minimise administrative burden or grid connection applications, decision makers should consider enabling a limited quantity of applications below that threshold to support innovation and competition and/or not restricting smaller projects where they utilise existing grid connections.

Similarly, where procurements are disaggregated across multiple durations, timeframes and utilities, decision makers should seek to ensure that larger assets can still participate.

## Geographic Accessibility and Land Use

Procurement design should account for the range of geographic requirements across LDES technology families. Some technologies require significant land area or specific siting conditions. When location rules are too restrictive – through zoning/planning limits, land-use constraints, or preserved-area designations – they can eliminate otherwise high-value solutions before they are assessed against performance criteria.

Ensuring sufficient geographic flexibility allows a broader range of technologies to compete and better aligns project siting with the system value being procured. A clear exception is where a project must be located within defined parameters for grid connectivity or adequate proximity to industrial demand. Energy density, expressed in kilowatt hours per square metre, is a useful metric for evaluating land-use efficiency across different technology types and is captured in the LDES Council Market Readiness Level framework in Figure 4: LDES Council Market Readiness Levels for LDES Technologies.[6]

The LDES Council encourages procurement frameworks to recognise and incentivise the redevelopment of brownfield and legacy energy sites for LDES deployment. Repurposing former industrial assets – including coal mines, coal-fired power stations, and other retired energy infrastructure – reduces development barriers, leverages existing grid connections, and can accelerate project delivery. Integrating LDES technologies into former fossil-fuel-dependent regions can transform legacy energy sites into long-term clean energy assets while supporting local economic continuity, including job retention where appropriate.

[6] Ibid. The LDES Council's 2024 Annual Report included a mapping of member technologies against market readiness, illustrating the diversity and maturity of the current LDES

## Project Timelines and Commissioning

Procurement designs that impose narrowly defined commissioning timelines can unintentionally favour technologies with shorter deployment cycles while excluding viable and potentially higher value LDES solutions. LDES projects will often require longer development and commissioning periods than shorter-duration storage, although timelines vary considerably by technology and project. As LDES technologies mature, supply chains develop and deployment experience grows, timelines are likely to shorten; however, some technologies will continue to require longer lead times due to their infrastructure, siting, permitting or construction requirements. Eligibility criteria should incorporate sufficient flexibility, including the use of estimated or indicative delivery schedules where consistent with the underlying system need.

Aligning project timelines with the system need, rather than applying rigid commissioning deadlines, broadens competition, supports technology diversity, and enables the participation of LDES technologies capable of delivering substantial system value.

Where there is an urgent deployment need, decision makers should consider introducing a separate procurement track for longer lead-time resources, allowing immediate needs to be met without excluding technologies that can provide value over the longer term.

## Asset Life and Long-Term Contracts

Procurement frameworks should evaluate storage resources on the basis of lifecycle system value rather than short-term performance or upfront capital cost alone. Many LDES technologies offer operational lifetimes that are expected to exceed those of other typical energy assets, enabling delivery of capacity, reliability, resilience, and flexibility services over multiple decades.

Recognising these long asset lives within procurement evaluation criteria improves investment efficiency and supports the deployment of storage resources that provide enduring value to the power system. Procurement design should reflect longer contract tenors where appropriate. Long-term contracts of 15 or more years can improve investment certainty, reduce financing costs, and enhance project bankability by providing predictable revenue streams over a meaningful portion of the asset operational life.

## Round-Trip Efficiency and Dispatch Cycles

Round-trip efficiency will often be an unsuitable metric when used in isolation. A system with lower round-trip efficiency may compensate through substantially lower running costs, longer duration value, and an extended asset life. Procurement frameworks should allow a range of round-trip efficiency values to accommodate diverse LDES technologies and should avoid overly prescriptive duty-cycle requirements.

Dispatch cycle requirements should reflect the duty-cycle characteristics of LDES technologies and enable multi-day or seasonal storage operation, rather than implicitly limiting projects to a single daily charge-discharge cycle. Prescriptive cycling assumptions undervalue long duration flexibility and exclude solutions designed to provide energy over extended periods during prolonged system stress. Procurement tendering pathways should allow variable and lower-frequency dispatch profiles that align with the system services and resilience value LDES technologies are designed to deliver.

# Technical Guide: Physical and Operational Considerations

| Criterion | Recommended approach |
|---|---|
| **Power and energy capacity** | Design procurement frameworks to enable participation across a range of project sizes and durations, with separate streams or windows established where distinct system needs exist at different duration ranges. |
| **Geographic accessibility and land use** | Design procurement to maximise LDES participation through geographic flexibility. Encourage use of brownfield sites and existing grid connections. |
| **Project timelines and commissioning** | Allow flexible eligibility requirements and indicative timetables to account for supply chain delivery, construction, connection, permitting, planning, and environmental approvals for LDES technologies.<br><br>Maximise participation by enabling long lead-time resources to participate in procurement, in a separate track where necessary. |
| **Asset life and long-term contracts** | Award longer-term purchase agreements of 15 or more years to increase the bankability of LDES projects and reduce financing costs where applicable. |
| **Round-trip efficiency and dispatch cycles** | Allow for a range of round-trip efficiency values in procurement frameworks, and avoid using this metric as an exclusion criterion.<br><br>Enable dispatch cycle flexibility to support multi-day, intraday, and seasonal storage, rather than restricting projects to daily cycling assumptions. |

# 3. Commercial and Financial Evaluation

LDES technologies can provide system-wide benefits that are often overlooked in conventional assessment criteria. These benefits are reflected in the range of services anLDES asset can provide, including energy arbitrage, capacity adequacy, ancillary services, avoided curtailment, congestion relief, seasonal balancing and multi-day capacity shifting.

## Levelised Cost of Storage

Levelised Cost of Storage (LCOS) is a useful metric for comparing storage technologies that deliver large volumes of energy through frequent, predictable cycling. However, it should not be used as the sole basis for evaluating LDES. Many LDES applications are designed to provide system capacity, resilience and reliability during infrequent but high-impact events, rather than maximise annual energy throughput. Because LCOS divides lifetime costs by the total energy discharged, assets that cycle only occasionally by design can appear artificially expensive despite delivering significant system value.

For example, a 100 MW, 40-hour LDES asset may operate only a handful of times each year during prolonged periods of low renewable output, transmission outages or extreme weather. While this results in a relatively high LCOS, the asset may avoid costly loss-of-load events, reduce reliance on peaking generation, defer transmission and distribution reinforcement, enable greater renewable integration, and provide firm capacity over multiple days. These are examples of how LDES provides additional resources that could not be captured in a “charge and discharge” scenario.

Procurement frameworks should therefore treat LCOS as one input rather than a standalone decision metric, complementing it with assessments of capital cost (or Total Plant Cost as used in the LDES Council’s cost benchmarking study[7]), asset lifetime, operational performance and the broader system value delivered through flexibility, reliability, resilience and avoided network and generation investment.

## Revenue Stacking and Market Participation

A defining commercial characteristic of LDES is the ability to access multiple complementary revenue streams simultaneously. Procurement and assessment criteria should recognise this capability and design evaluation frameworks accordingly.

The principal revenue streams available to LDES assets include:

- Energy arbitrage: buying electricity when prices are low and discharging when prices are high, capturing intraday, multi-day, and seasonal price spreads depending on duration.
- Capacity and adequacy payments: compensation for providing firm capacity that can meet peak demand during prolonged stress events, including multi-day periods of low renewable output.
- Frequency regulation and response: rapid response to frequency deviations provides a revenue stream available to eligible LDES technologies in most electricity markets.
- Voltage support: reactive power services that improve local grid stability and qualify for ancillary service payments in many jurisdictions.
- Black start capability: the ability to restart grid sections following a system outage, which commands premium ancillary service payments in markets where this service is procured.
- Congestion relief and grid deferral: LDES assets can relieve transmission and distribution congestion, generate network use-of-system revenues or avoid constraint costs, and be rewarded for deferring the need to upgrade grid infrastructure.

landscape.

[7] The Cost Benchmarking for Long Duration Energy Storage Solutions report by the LDES Council and EPRI provides transparent, real-world cost benchmarks for long duration energy

- Avoided curtailment: capturing renewable energy that would otherwise be curtailed and discharging it during periods of higher system value.
- Resilience and critical load contracts: long-term contracted payments for providing backup energy to critical infrastructure, industrial facilities, or communities during extended outages.
- Decarbonising industries: providing firm, 24/7 affordable clean power to energy consumers, directly substituting fossil-fuel process heat or grid power and reducing exposure to volatility.

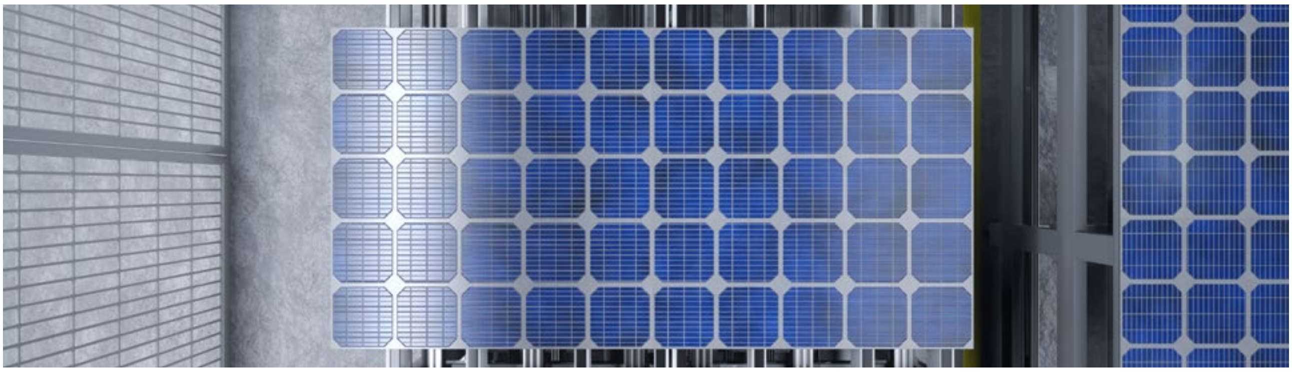
> **Procurement frameworks should be designed to allow LDES projects to access and demonstrate the full range of applicable revenue streams. Evaluation criteria that recognise only a single service type will systematically undervalue LDES solutions and reduce the quality of market responses.**

Longer duration storage assets may also access hybrid or regulated compensation mechanisms, such as cap and floor schemes or regulated asset participation models, which provide revenue certainty over the asset lifetime. Procurement design should accommodate these structures, particularly for technologies with infrequent but high-value dispatch profiles.

## Bankability and Project Finance

Procurement frameworks have a direct bearing on the ability of LDES developers to secure project financing. Long-term contracts, clear revenue stacking pathways, and technology-neutral eligibility criteria collectively reduce the risk perceived by lenders and equity investors, lowering the cost of capital and accelerating deployment.

For a more detailed analysis of LDES bankability, including revenue contract structures, lender requirements, risk allocation frameworks, and case studies of bankable project structures, see the LDES Council publication: Accelerating LDES Bankability: A Practical Framework for Overcoming Obstacles to Investment in Long Duration Energy Storage[8].



storage technologies and shows that costs are expected to decline significantly by 2030.

[8] The LDES Council's 2025 Accelerating LDES Bankability: A Practical Framework for Overcoming Obstacles to Investment in Long Duration Energy Storage report identifies nine factors that shape investment in long duration energy storage and outlines the actions needed to unlock capital at scale.

# Technical Checklist: Commercial and Financial Evaluation

| Criterion | Recommended approach |
|---|---|
| **Lifecycle cost analysis and levelised cost of storage** | Assess costs based on the specific use case and in relation to delivered system benefits and services over project lifetime.<br>Use LCOS as one input among several, not as the primary or sole evaluation metric. |
| **Revenue stacking and market participation** | Procurement and assessment criteria should recognise the ability of longer duration storage assets to deliver value across multiple complementary revenue streams and to participate in those markets, including capacity markets, ancillary services, grid deferral and mechanisms such as cap and floor schemes. |
| **Bankability and project finance** | Ensure the procurement process is purposefully designed to improve project bankability, including through contract structures that reduce cost of capital and provide revenue certainty over a meaningful portion of the asset operational life. |

# Technical Checklist for Procuring Long Duration Energy Storage

Use this consolidated checklist to review any energy storage procurement document for LDES-readiness. Each item corresponds to detailed guidance in the relevant section of this guide. A procurement process that satisfies all items below will ensure that long duration energy storage technologies can participate on a fair and competitive basis.

| 1. Ensuring Eligibility for Diverse LDES Technologies and Durations | | |
|---|---|---|
| | **Criterion** | **Recommended approach** |
| ☐ | **Storage technology neutral language** | Design procurement frameworks to be technology inclusive, allowing all storage solutions that satisfy the identified system need to compete.<br>RFPs and tenders should use storage technology-neutral language unless there is a clear technical reason to specify a technology. Replace “battery energy storage system” with “energy storage system” or “long duration energy storage resource” throughout tender documents. |
| ☐ | **Duration bands and system needs** | Implement evaluation criteria that recognise the distinct value propositions of technologies and procure solutions across different duration ranges |
| ☐ | **Technology readiness and market readiness** | Where appropriate, contracting authorities should consider establishing dedicated innovation or emerging technology procurement pathways alongside mainstream commercial procurement to encourage technology diversity and support the continued evolution of the LDES market. |
| ☐ | **Valuing diversity in procurement** | The procurement framework should seek to identify, value and appropriately reward diversity, whether based on system need, innovation or supply chain diversity benefits. |
| ☐ | **Thermal storage inclusion** | Ensure thermal storage technologies are not excluded through use of electricity metrics, where the thermal storage solution can meet system requirements. |
| ☐ | **Deployment track record** | Avoid requirements relating to significant deployment track records and/or deployment in the same region unless absolutely essential. |

| 2. Physical and Operational Considerations | | |
|---|---|---|
| | **Criterion** | **Recommended approach** |
| ☐ | **Power and energy capacity** | Design procurement frameworks to enable participation across a range of project sizes and durations, with separate streams or windows established where distinct system needs exist at different duration ranges. |
| ☐ | **Geographic accessibility and land use** | Design procurement to maximise LDES participation through geographic flexibility. Encourage use of brownfield sites and existing grid connections. |
| ☐ | **Project timelines and commissioning** | Allow flexible eligibility requirements and indicative timetables to account for supply chain delivery, construction, connection, permitting, planning, and environmental approvals for LDES technologies.<br><br>Maximise participation by enabling long lead-time resources to participate in procurement, in a separate track where necessary |
| ☐ | **Asset life and long-term contracts** | Award longer-term purchase agreements of 15 or more years to increase the bankability of LDES projects and reduce financing costs where applicable. |
| ☐ | **Round-trip efficiency and dispatch cycles** | Allow for a range of round-trip efficiency values in procurement frameworks, and avoid using this metric as an exclusion criterion. |

| 3. Commercial and Financial Evaluation | | |
|---|---|---|
| | **Criterion** | **Recommended approach** |
| ☐ | **Lifecycle cost of storage** | Assess costs based on the specific use case and in relation to delivered system benefits and services over project lifetime.<br><br>Use LCOS as one input among several, not as the primary or sole evaluation metric. |
| ☐ | **Revenue stacking and market participation** | Procurement and assessment criteria should recognise the ability of longer duration storage assets to deliver value across multiple complementary revenue streams and to participate in those markets, including capacity markets, ancillary services, grid deferral and mechanisms such as cap and floor schemes. |
| ☐ | **Bankability and Project Finance** | Ensure the procurement process is purposefully designed to improve project bankability, including through contract structures that reduce cost of capital and provide revenue certainty over a meaningful portion of the asset operational life. |

# Annex A: Terminology

The terminology in this glossary has been developed by the LDES Council to provide a consistent, technology-neutral vocabulary for long duration energy storage procurement across electricity, thermal and other storage applications. These definitions are intended as guidance and do not supersede market, regulatory or legal definitions adopted by individual jurisdictions or procurement authorities.

| Term | Definition |
|---|---|
| **Capacity adequacy** | The ability of the electricity system to reliably meet forecast demand under normal and stressed conditions by ensuring sufficient dependable capacity is available when required. |
| **Congestion management** | Reducing transmission or distribution network constraints by shifting energy across time or location, improving utilisation of existing network infrastructure. |
| **Decarbonisation and fuel switching** | Replacing fossil fuel-based heat with electricity, renewable heat or other low-carbon energy sources to reduce greenhouse gas emissions. |
| **Energy cost optimisation** | Reducing energy costs by shifting consumption to lower-cost periods, increasing self-consumption of renewable energy and reducing peak demand charges where applicable. |
| **Grid upgrade deferral** | Reducing or delaying investment in transmission or distribution infrastructure by using storage or flexibility resources to manage local constraints. |
| **Industrial process flexibility** | Providing operational flexibility by decoupling energy consumption from heat demand, enabling optimisation of industrial processes while maintaining production requirements. |
| **Intraday storage** | Storage primarily used to balance supply and demand within the same day, typically supporting energy shifting, peak management, renewable integration and ancillary services over durations ranging from several hours to approximately 24 hours. |
| **Land-use efficiency** | A measure of how efficiently a technology uses land, commonly expressed as installed power (MW/ha) or energy capacity (MWh/ha), depending on the application. |
| **Levelised cost of storage (LCOS)** | A metric estimating the lifetime cost of storing and delivering energy, expressed as cost per unit of discharged energy under defined technical and financial assumptions. |
| **Multi-day storage** | Storage capable of providing energy or system services across multiple consecutive days to support reliability during extended periods of low renewable generation, sustained high demand, fuel supply disruptions or network constraints. |
| **Operational resilience and heat security** | Maintaining reliable heat supply during electricity interruptions, fuel supply disruptions or network constraints to support business continuity. |
| **Revenue stacking** | Combining multiple value streams or revenue sources - such as energy arbitrage, capacity payments, ancillary services, congestion relief, resilience services or avoided network costs - to improve project economics. |

| Term | Definition |
|---|---|
| **Round-trip efficiency (RTE)** | The ratio of energy delivered from storage to the energy used to charge it over a complete charge-discharge cycle, expressed as a percentage. |
| **Seasonal balancing** | The storage and delivery of energy over weeks or months to address seasonal variations in renewable generation, electricity demand or heat demand. |
| **Storage duration (hours)** | The length of time a storage resource can continuously discharge at its rated power. Storage duration is determined by the relationship between usable energy capacity (MWh) and power capacity (MW): Duration (hours) = Usable Energy Capacity (MWh) ÷ Power Capacity (MW). For example, an 800 MWh asset with a 100 MW power rating has an 8-hour duration. |
| **System need** | The underlying operational or planning challenge that a procurement seeks to address, such as resource adequacy, congestion, renewable integration, resilience, flexibility or network investment deferral. Procurement should define the system need before specifying performance requirements. i.e. “What the system Needs” |
| **System resilience** | The ability of an energy system or asset to anticipate, withstand, respond to and recover from high-impact or prolonged disruptions while maintaining critical services. |
| **System stability** | Maintaining secure and stable power system operation by supporting frequency, voltage, inertia and other essential system services required for reliable operation. |
| **System value** | The overall benefit a resource provides to the energy system through one or more services, including reliability, flexibility, renewable integration, congestion management, resilience and reduced system costs. i.e. “What benefit LDES provides the system” |
| **Technology-neutral procurement** | A procurement approach that defines the required service or performance outcome without prescribing a specific technology, allowing all eligible resources capable of meeting the requirements to compete on equal terms. |

# Annex B: Example Procurement Clauses Developed by the LDES Council

The example clauses in this annex have been developed by the LDES Council to illustrate technology-neutral procurement language. They are not taken from any individual procurement document and should be adapted to local legal, regulatory and market requirements.

- **Storage technology-neutral eligibility**

  Example clause: "The procurement is open to all energy storage technologies, including electrochemical, mechanical, thermal, chemical, and hybrid systems, capable of meeting the defined system service and all applicable safety, grid-code, permitting, and performance requirements."

- **Power and energy disclosure**

  Example clause: "Bidders shall separately state power capacity in MW, usable energy capacity in MWh or equivalent thermal or chemical energy units, discharge duration at rated output, charge duration, minimum state-of-charge requirements, auxiliary load, and expected availability."

- **System-value evaluation**

  Example clause: "Bids will be evaluated on the basis of lifecycle cost, deliverability, technology maturity, safety, financeability, and system value, including [as appropriate] reliability, resilience, capacity adequacy, avoided curtailment, network optimisation and deferral, ancillary services contribution, and renewable integration."

- **Round-trip efficiency**

  Example clause: "Round-trip efficiency will be evaluated in the context of the proposed service, operating profile, charging source, energy capacity cost, asset life, and system value. It will not be used as a standalone exclusion criterion unless justified by the service requirement."

- **Delivery timeline**

  Example clause: "Bidders shall provide a proposed development and commissioning schedule with key milestones for site control, permitting, grid connection, financing, procurement, construction, testing, and commercial operation. Indicative schedules may be accepted where consistent with the system need."

- **Brownfield and grid reuse**

  Example clause: "Bidders are encouraged to identify opportunities to reuse brownfield sites, retired energy infrastructure, existing grid connections, industrial land, or other legacy assets where this reduces delivery risk, land-use impacts, or system costs. Proposals demonstrating credible brownfield reuse plans will receive positive evaluation weight under the strategic and local benefits criterion."

- **Ancillary services eligibility**

  Example clause: "The procurement framework recognises eligibility for ancillary service revenue streams including frequency response, voltage support, black start capability, and spinning reserve, consistent with applicable market rules. Bidders shall describe which ancillary service streams they propose to access and how these are reflected in their revenue model."

- **Performance-based procurement**

  Example clause: "Technical specifications will define the required system outcome and performance requirements rather than prescribe a specific storage technology. Equivalent solutions capable of delivering the required service shall be considered."

- **Technology maturity**

  Example clause: "Bidders shall demonstrate that the proposed technology has reached an appropriate stage of commercial readiness consistent with the delivery timetable and project risk allocation."

# Annex C: Referenced LDES Council Reports

Download full reports ldescouncil.com/reports

- Long Duration Energy Storage Council 2024 Annual Report (2025); LDES Council Annual Report (latest edition): Market Readiness Level (MRL) assessments, deployment trends, technology landscape, cost trajectories and market developments across the four LDES technology families.

- Cost Benchmarking for Long Duration Energy Storage Solutions (LDES Council and EPRI) (2026): Comparative capital and operating cost benchmarks, cost drivers, and projected cost reductions across LDES technologies.

- Deploying LDES: Implementation Best Practices (2025): Practical guidance on project development, site selection, permitting, engineering, construction, grid integration and operational commissioning.

- Accelerating LDES Bankability (2026): Guidance on revenue models, financing structures, contractual arrangements, risk allocation and considerations for improving project bankability.

# References

The findings and recommendations in this guide are informed by, and consistent with, a growing body of independent analysis from international agencies, national laboratories, regulators, and financial institutions. The sources below are provided for decision makers who wish to consult primary, non-LDES Council material when briefing colleagues or substantiating procurement design choices.


- International Energy Agency, World Energy Outlook 2025 — sets out why battery storage alone cannot meet rising seasonal flexibility needs as renewables shares grow, underpinning the case for duration-diverse procurement.
- IRENA, Flexibility for a Secure and Affordable Power Sector Transformation (2026) — assesses global flexibility needs across daily, weekly, and monthly timescales and identifies long duration energy storage as a core flexibility resource alongside interconnectors and demand-side measures.
- National Renewable Energy Laboratory, The Challenge of Defining Long-Duration Energy Storage (2021) and the Storage Futures Study — explain why duration thresholds should be application-led rather than fixed, and chart the progression from short-duration to seasonal storage needs as renewable penetration rises.
- U.S. Department of Energy, Long Duration Storage Shot — a technology-inclusive national target to cut the cost of 10-hour-plus storage by 90 percent within the decade, treating electrochemical, mechanical, thermal, and chemical-carrier technologies on equal terms.
- Lazard, Levelised Cost of Storage Analysis — the financial sector benchmark cost study, which states directly that LCOS does not capture the situation-, market-, and owner-specific value of storage, supporting this guide caution against cost-only evaluation.
- North American Electric Reliability Corporation, Evaluating Resource Contributions for Reliability — sets out Effective Load Carrying Capability methods used by system operators to assess the reliability contribution of energy-limited resources, reinforcing why round-trip efficiency should not be used as a standalone exclusion criterion.
- World Bank, Komati Just Energy Transition Project (2022) — a real-world example of a retired coal plant in South Africa repurposed for renewables and battery storage, demonstrating the brownfield reuse principle at national scale.
- Ofgem (United Kingdom), Long Duration Electricity Storage Cap and Floor Regime — a live, technology-neutral regulated revenue mechanism for storage of eight hours or more, illustrating the long-term contract and revenue-certainty principles set out in this guide at the scale of a national regulator.
- COP29 Presidency, Global Energy Storage and Grids Pledge (2024) — the multilateral commitment, endorsed by more than 70 governments and organisations, to deploy 1,500 GW of energy storage by 2030.
- Sepulveda et al., "The Value of Long-Duration Energy Storage Under Various Grid Conditions in a Zero-Emissions Future," Nature Communications (2024) — peer-reviewed capacity-expansion modelling showing that higher LDES deployment extends storage dispatch into seasonal arbitrage, supporting evaluation frameworks that reward infrequent, high-value dispatch.

The LDES Council unites global industry leaders, customers and policymakers to accelerate the innovation, commercialisation, and deployment of long duration energy storage technologies. By advancing real projects already in motion and sharing data-driven insights, we help scale LDES solutions today - educating utilities and industrial customers on how long duration energy storage supports their goals, informing policymakers to enable adoption and advocating for flexible and secure energy systems that meet the growing demands of electrification, serving communities and industries worldwide.

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