



# From Ambition to Action

Embedding Long Duration Storage  
in European Energy Strategy

As Europe advances toward climate neutrality by 2050 under the European Green Deal, energy storage will play a critical enabling role, managing the variability of renewable generation, enhancing energy security, and supporting increasingly complex transmission system operations.



**HYDROSTOR**



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# Abstract

**Long Duration Energy Storage (LDES) must be a cornerstone for Europe's energy transformation, offering the flexibility, resilience, and security needed to support a renewable-powered future. As Europe advances toward climate neutrality by 2050 under the European Green Deal, energy storage must play a critical enabling role, managing the variability of renewable generation, enhancing energy security, and supporting increasingly complex transmission system operations.**

System flexibility needs are projected to grow from 11 percent of electricity demand in 2021 to 30 percent by 2050. To meet binding renewable targets, near-time, intra-day, and multi-day duration storage must scale in parallel with variable renewables. However, significant regulatory and market barriers continue to hinder deployment. With delivery timelines of 7-10 years, LDES must be embedded into energy planning today to ensure future system readiness.

Without decisive action, Europe risks filling flexibility gaps with new gas infrastructure, undermining climate goals, increasing system costs, and compromising energy security. In light of the European Commission's concerns over supply chain resilience, as highlighted in the European Critical Raw Materials Act, planners must prioritise storage technologies that leverage readily available materials and regional supply chains.

This white paper provides a working definition of the three key storage duration categories, an assessment of the risks of failing to integrate storage into long-term energy planning, and targeted policy recommendations to enable cost-effective, large-scale deployment of Long Duration Energy Storage (LDES) in Europe.

These recommendations are presented in consecutive order and build on each other to enable successful LDES deployment.

## Policy recommendations:

1. **Robust Duration-Aware System Modelling:** European grids should employ sophisticated modelling techniques to determine future system needs. These models must differentiate between short and long duration storage solutions, associated costs, asset lifetimes, and directly inform resource procurement and development.
2. **Substantive Investment Signals:** Establish LDES-specific targets (e.g., 8+ hour duration) and develop a transparent procurement schedule open to diverse technologies across multiple procurement rounds.
3. **Long-Term Revenue Certainty Contracts:** As markets don't value LDES appropriately, out-of-market contract such as a 'cap-and-floor' mechanism need to be adopted to ensure revenue adequacy for LDES projects.

# The European Context

Europe's electricity grid is undergoing rapid transformation to support energy independence, renewable integration, and climate neutrality by 2050 goals. Europe is accelerating its shift away from Russian fossil fuels to achieve full energy independence by 2027 and aims to source at least 42.5% of its energy from renewables by 2030, transforming transport, industry, and buildings.<sup>1, 2</sup>

By 2050, the EU targets full climate neutrality, with interim milestones of 55% emissions reduction by 2030 and 90% by 2040<sup>3</sup>. With Europe's electricity demand set to rise to 60% by 2050, meeting this growth requires urgent grid modernisation, significant renewable integration, and investment to overcome aging infrastructure, climate risks, and market volatility.<sup>4</sup>

The European Parliament has also flagged insufficient flexibility as a risk to the operation of the system. System flexibility is projected to rise from 11% of electricity demand in 2021 to 30% by 2050, making it a cornerstone of the EU's secure and decarbonised energy transition.<sup>5</sup>

This concern prompted new legislation under the revised Electricity Market Design that requires Member States to conduct Flexibility Needs Assessments (FNAs) by June 2026, set national flexibility objectives by January 2027 and make necessary amendments to markets in 2027 to enable flexibility solutions.<sup>6</sup>

The European Commission's 2025 guidance on flexibility and the Clean Industrial Deal explicitly identifies energy storage as an essential source of flexibility, for balancing renewables variability and enhancing grid resilience.<sup>7, 8</sup> Member States are now encouraged to incorporate storage deployment pathways into their National Energy and Climate Plan (NECP) targets and objectives.

At the same time, Europe must rapidly modernise its aging grid infrastructure and expand generation capacity to meet rising demand, partly driven by extreme weather events and electrification. According to the Commission's 2025 guidance

on anticipatory investments, an estimated €730 billion will be needed by 2040 to upgrade distribution networks and €477 billion for transmission grids.<sup>9</sup>

Flexibility: "The ability of the power system to cope with variability and uncertainty in demand, generation, and grid availability."

ENTSO-E Vision: A Power System for a Carbon Neutral Europe  
[vision.entsoe.eu]

Europe faces a pivotal challenge: deliver on its climate and energy security ambitions, while also maintaining grid stability, resilience, and cost-efficiency for consumers. Europe must implement proactive system planning and remove investment barriers by enabling robust signals with long-term revenue visibility for investors to successfully meet these challenges.



# Energy Storage as a Key Pillar of Europe's Energy Transition

Energy storage deployment is critical to achieving Europe's energy security and long-term energy independence goals. As the EU transitions to a renewables-oriented grid, energy storage becomes indispensable for shifting electricity from the time it is generated to the time it is needed—whether within a day, intra-day or across multiple days, or even between seasons. This temporal flexibility is essential for balancing variable renewable generation and ensuring grid reliability under increasingly volatile conditions.



Three specific storage duration ranges and associated technology are outlined here:

## Short-duration storage (2 to 8 hours)

Primarily lithium-ion batteries, these resources play a vital role in daily grid operations. They manage real-time fluctuations in electricity demand, support frequency regulation, and respond to both anticipated and unexpected system needs.

## Long-duration storage (8 to 24 hours)

Technologies such as advanced compressed air energy storage (A-CAES) and pumped hydroelectric systems provide sustained energy delivery beyond the capabilities of short-duration batteries. These solutions are more cost-effective for longer discharge periods and are increasingly being integrated into national flexibility plans.

## Multiday storage (24+ hours)

Emerging technologies like iron-air batteries are designed to store energy for 24 hours or more, with some systems capable of exceeding 100 hours. These solutions are essential during multi-day system stress events, such as prolonged low-wind or low-solar periods and are being prioritized in EU innovation funding streams.

These three storage duration categories, when combined, can support the EU's climate neutrality targets, enhance resilience against extreme weather and geopolitical shocks, and reduce reliance on imported fossil fuels.



# Long Duration Energy Storage in Focus

Long Duration Energy Storage is increasingly recognised as a critical enabler of Europe's energy transition, providing the deep flexibility needed to integrate high shares of renewables and ensure year-round reliability.

While the European Commission's 2023 Recommendation on Energy Storage and the 2025 Energy Storage Inventory signal growing support for LDES, current deployment remains limited, with most investment still concentrated in short-duration lithium-ion BESS. This focus, while valuable for near-term grid flexibility and balancing, does not address the impending flexibility challenges posed by systems with high penetrations of renewables.

In contrast, jurisdictions like California, US and New South Wales, Australia are advancing dedicated LDES procurement frameworks, with California already contracting more than a gigawatt of projects and New South Wales launching long-duration storage tenders under its Electricity Infrastructure Roadmap. These efforts demonstrate how targeted policy and market design can accelerate LDES deployment.

To keep pace, the EU must urgently move beyond pilot projects and short-duration solutions by scaling dedicated LDES auctions, removing market barriers, and ensuring fair access to capacity and ancillary service markets. LDES projects have 7–10 year delivery timelines, therefore, to satisfy system needs in the 2030–40 timeframe action is required now.

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“Energy storage is a strategic imperative for Europe. ...We need to make sure that the energy from our wind and solar is not wasted. Energy storage can be our safe guarantee for that purpose... And it's not just about delivering more storage; it's about delivering the right type of storage... Long-duration technologies will become more important”

Dan Jørgensen, EU Energy and Housing Commissioner, October 2025

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## Risk of Inaction

Failing to implement a coordinated, duration-aware energy storage strategy will result in systemic inefficiencies and long-term risks across Europe's energy landscape:

### Flexibility Concerns and Reduced System Security

The EU remains 58% dependent on energy imports, with fossil fuels still accounting for nearly 60% of gross available energy. This leaves Member States vulnerable to geopolitical shocks and volatile global markets, as seen during the 2022–2023 energy crisis. The European Parliament has flagged flexibility shortfalls as a near-term reliability risk, particularly as thermal plants retire and renewable penetration increases.<sup>10, 11</sup>

### Higher Costs from Inefficient Procurement and Infrastructure

In 2023, redispatch and curtailment management costs across the EU reached €4 billion, driven by grid bottlenecks and lack of flexibility. Without strategic investment in long-duration energy storage (LDES), these costs are projected to rise to €11–26 billion by 2030 and up to €103 billion by 2040, depending on grid expansion scenarios.<sup>12, 13</sup>

### Missed Climate Targets

Despite progress, 15 Member States fall short of their contributions to the EU's primary energy consumption target for 2030, with significant gaps also in renewables and energy efficiency. Continued reliance on fossil fuels could delay the retirement of carbon-intensive assets, undermining the EU's legally binding commitment to reduce emissions by 55% by 2030 and achieve climate neutrality by 2050.<sup>14, 15</sup>

### Stranded Assets and Renewable Curtailment

Fossil fuel power generation still makes up 45% of installed capacity in the EU, yet less than 5% will be permissible by 2050 under current climate targets. Without strategic planning, this transition could result in hundreds of gigawatts of stranded assets, representing billions in sunk costs. Additionally, between 100 and 310 TWh of renewable generation is projected to be at risk of curtailment by 2040 due to grid bottlenecks and lack of flexibility—equivalent to the annual electricity consumption of 20–60 million European households.<sup>16, 17</sup>

# Policy Recommendations

This section presents three critical policy actions to enable cost-effective, large-scale integration of Long Duration Energy Storage (LDES)

1. Robust Duration-Aware System Modelling
2. Substantive Investment Signals
3. Long-Term Revenue Certainty Contracts

These recommendations are complemented by supplemental considerations for market design enhancements to that will enable the deployment of LDES infrastructure in a least cost manner, while meeting system reliability and decarbonisation objectives in line with European Green Deal, Electricity Market Design reform, and REPowerEU priorities.



# Recommendation #1: Undertake Robust Duration-Aware System Modelling

Under Electricity Market Design (EMD) reform, all EU Member States are required to conduct Flexibility Needs Assessments (FNAs) by the end of June 2026. These assessments aim to quantify national flexibility needs over a five-to-ten-year horizon, ensuring system reliability, efficient renewable integration and reduced fossil fuel dependency. The European Commission's 2025 guidance on flexibility and the Clean Industrial Deal explicitly recognises storage as a critical enabler of the energy transition, particularly long-duration energy storage (LDES).

In undertaking the required flexibility analysis, system planners must consider a wide range of storage technologies, each with distinct cost profiles, performance characteristics, and durations. Developing least-cost portfolios to meet system goals requires tools to move analysis and planning into strategic deployment on the grid.

System planners increasingly rely on sophisticated software that leverages internal cost minimisation engines that model evolving grids and forecast flexibility needs against near and long-term cost trade-offs. These models should forecast load requirements for all 8,760 hours per year, with nodal representations of supply and demand, system emissions targets, annualized costs for existing and potential new resources, anticipated lifetimes, and changes in grid topology. Topographical changes include possible transmission enhancements, anticipated imports, and anticipated outages.

The models innately select a least cost mix of resources for optimal procurement that meet future load forecasts, providing a glide path to future anticipated resource mixes, including retirements, and inform regulators on a least cost pathway.

Critically, these software models routinely select long duration storage (8-24 hours), as they provide a mechanism to move relatively low-cost energy from renewable sources from times of excess generation to periods of outsized needs. Similar modelling exercises in the UK undertaken by LCP Delta, in California undertaken by the California Energy Commission, and in Ireland undertaken by Baringa, indicate significant potential system cost savings from deploying long duration storage.

**United Kingdom:** In 2024, the UK's Department for Energy Security and Net Zero (DESNZ) commissioned LCP Delta to inform their LDES procurement approach.<sup>18</sup> The modelling showed that deploying 20 GW of LDES by 2050 could cut system costs by up to £24 billion (NPV)—a 3.5% reduction. LDES offers strong value, especially in scenarios with limited deployment of gas CCS

and hydrogen, where it could save £12–31 billion. Technologies with longer durations proved most beneficial, prompting the UK to raise the minimum duration requirement from 6 to 8 hours in its Cap and Floor procurement. Future procurements may require even longer durations.

**California:** In 2023, the California Energy Commission (CEC) completed a modelling exercise for the California grid.<sup>19</sup> This work indicated that under certain scenarios significant quantities and durations of storage were necessary. Further, this work shows that long duration storage could reduce the amount of capacity that would be necessary to build by roughly 100 GW and overall system costs by roughly \$6 billion per year by 2045, in certain scenarios.

**Ireland:** Baringa completed modelling for the role of storage to the Irish grid through 2040. This study showed that strategic deployment of LDES could deliver up to €85 million per year in net savings to Irish electricity consumers by 2030. The study cited that lower wholesale costs, less curtailment, and reduced reliance on import capacity drove these savings. LDES can reduce renewable oversupply by up to 60%, constraint volumes by 90%, and curtailment by 100%.<sup>20</sup>



## RECOMMENDATION

Hydrostor recommends that European grid planners urgently employ sophisticated modelling techniques to determine future system needs. These models must differentiate between short and long duration storage, include a diverse range of technologies, associated costs and asset lifetimes, and they should closely inform resource procurement.

# Recommendation #2: Provide Substantive Investment Signals

Providing stakeholders, such as investors, developers, and technology providers, with a procurement target is essential to mobilise investment efficiently. Procurement schedules, capacities, and qualification criteria well in advance of desired procurement dates provide clear market signals, allowing at risk investment in early development activities. Targets are especially important for long-lead time, cost-effective LDES resources.

## Specific LDES Targets

Once the Flexibility Needs Assessments are completed, Member States then must set indicative national targets for non-fossil flexibility informed by their respective assessments by January 2027. It will be important that duration-specific storage targets are set as part of this process. These targets are a critical first step towards building a substantive investment signal for LDES developers.

## Specific Long Duration (8+hr) Mandate

The UK's Clean Power 2030 Plan sets distinct targets for short-duration (29-35 GW) and long-duration (4-6 GW) storage by 2030, recognising their different roles in grid flexibility and reliability. Without clear, differentiated targets, long-duration storage risks under-deployment, leaving future security of supply gaps and increasing curtailment and infrastructure costs. Establishing separate targets ensures fit-for-purpose investment signals, enabling both types of storage to deliver their full value to the energy system and consumers.

## Procurement Process Visibility

Following on from the previous steps, several organised markets have developed specific procurement processes for long duration energy storage, with procurement targets specified in traditional power capacity (GW) with a minimum duration requirement of 8+hrs. The responsible body is then mandated to set up a procurement process for applications from relevant projects on a technology agnostic basis.

One of the earliest markets to adopt procurement targets for long duration storage was California, which completed an assessment in 2021 that required utilities to contract for 1 GW of 8-hour duration storage by 2025. Further, California authorised procurement for up to an additional 1 GW of 12-hour duration and 1 GW of multi-day duration storage that must be contracted by 2028.<sup>21</sup> The state utilities overseeing the process saw large quantities of long duration storage bids from a variety of technologies, delivering competition. These bids resulted in

**Without clear, differentiated targets, long-duration storage risks under-deployment, leaving future security of supply gaps and increasing curtailment and infrastructure costs.**

secured contracting for the required capacity. Utilities structure their contracts incorporating anticipated merchant revenues including day-ahead energy, real-time energy, and ancillary services.

New South Wales also set a clear investment signal for LDES through a committed procurement target and structured schedule. The Electricity Infrastructure Roadmap called for procurement of up to 1 GW (with at least 13.79 GWh of charging capacity) of at least 8-hour duration storage via competitive bid tenders. The government increased this target to require that at least 28 GWh be procured by 2034. Tenders will be issued on a regular, transparent schedule, backed by long-term energy service agreements (LTESAs).

**Several other governments have either set or are setting longer-duration procurement targets, including:**

1. **Ofgem**, the UK's Energy Regulator, was requested by the Department for Energy Security & Net Zero (DESNZ) to open a process to award Cap & Floor contracts to between 2.7 and 7.7 GW of LDES assets with a minimum duration of 8+ hrs and with target delivery dates of 2030 and 2033. The signal for a second window is expected in Q1 2026.<sup>22</sup>
2. **New York's State Energy Research and Development Authority (NYSERDA)** is procuring 600 MW of 8-hour storage by 2030, using a capacity market mechanism-like support scheme.<sup>23</sup>
3. In Canada, Ontario's **Independent Electricity System Operator (IESO)** plans to procure 600-800 MW of storage capacity during its Long-Lead Time (LTT) Request for Proposal (RFP) in 2026. LTT contracts will offer 40-year terms.<sup>24</sup>
4. In Italy, **Terna's** Centralised Allocation Mechanism for Energy Sustainability (MACSE, translated) scheme is targeting 50 GWh of energy storage by 2030, starting with 2.5 GW of 4-hour batteries in the first round, while noting its intention to increase to 8-hour or LDES in subsequent rounds.<sup>25</sup>
5. Ireland's Transmission System Operator, **EirGrid** is currently consulting on plans for procurement of an initial 500 MW of LDES by 2030, with Department Climate, Energy and Environment (DCEE) poised to undertake 2030 to 2040 quantification of need analysis in 2026.<sup>26, 27</sup>



**RECOMMENDATION**

Hydrostor recommends that investment signals start with an LDES specific target by setting a minimum duration of 8+hours, then build a clear and transparent timing and capacity procurement schedule open to a diverse range of technologies, over multiple procurements window to achieve delivery target dates.



# Recommendation #3: Provide Long-Term Revenue Certainty Contracts

What is clear from evidence submitted to the UK Government's 2024 LDES consultation, is that there is a gap between the revenues required for long-term LDES investment and those available through existing market mechanisms. This is not unique to the UK market.

Once Flexibility objectives and targets are set by January 2027, the Electricity Market Reform Act mandates Member States to enable market reforms that support flexibility assets. Market reforms will enable revenue stacking across capacity, balancing, and ancillary services, improving investment signals for flexible assets.

Revenue certainty mechanisms coupled with market reform can bridge the gap. Power Purchase Agreement (PPAs) and Cap-and-Floor contracts are examples of contract styles that if designed appropriately would allow developers to underwrite long duration storage projects.

## Power Purchase Agreements

Project financing and the provision of long-term capital are crucial for project development. Bilateral agreements, such as power purchase agreements between developers and utilities or government entities, offer a pathway for this provision. Project financing is generally not possible without these long-term agreements from credit-worthy parties.

The utilities, which are subject to scrutiny over ratepayer costs, also benefit from this arrangement, as regulators overseeing these contracts are the same regulators implementing rules mandating the procurement through open processes.

For example, California's load serving entities procured 1 GW of LDES through power purchase agreements. Several other US-based utilities are following California's lead, contracting LDES through power purchase agreements following open competitive processes.

## Cap-and-Floor

Cap-and-Floor programs are mechanisms that ensure specific projects earn revenues between a predetermined floor and a predetermined ceiling or cap. This guaranteed minimum revenue stream is often necessary for financing new resources. This ability to obtain investment then enables development. Without these guaranteed floors, financing and development would not be feasible for many of the long duration storage technologies.

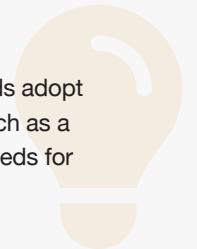
Cap-and-Floor programs can also ensure that resources participating under the regime cannot earn unfettered positive returns while participating in the market. While returns below the floor are trued up, returns above the specified cap are returned to ratepayers.

The UK announced its LDES Cap-and-Floor scheme in 2024. The first round opened in June 2025, with 77 projects, representing 28 GW of 8+ hour storage, deemed eligible for further review. Ultimately, the government will select between about 3 and 8 GW of successful projects that should be operational between 2030 and 2033. The UK's system operator is expected to confirm timelines for further procurement soon.



## RECOMMENDATION

Hydrostor recommends that European grids adopt a vehicle to ensure revenue sufficiency, such as a cap-and-floor program, after identifying needs for long duration storage.



# Supplemental Recommendations

In addition to the three critical recommendations made above, Hydrostor also recommends that European authorities implement the following market design enhancements to ensure accurate price signals and efficient integration of LDES in line with European Green Deal, Electricity Market Design reform, and REPowerEU priorities:

|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Resource Adequacy<br/>Markets Capture Resource<br/>Specific Differences:</b>  | As resource mixes evolve, traditional ‘capacity’ stacking techniques are no longer sufficient. Careful consideration is needed to determine capacity accreditation for different types of resources, to ensure a portfolio of different resources are included. The capacity from a four-hour storage resource should be valued differently than an 8-hour or a 24+hour duration resource, just as solar resources provide a different capacity value than wind resources. The European Resource Adequacy Assessment (ERAA) provides a framework for assessing adequacy across technologies and timeframes. Consideration should be applied as these markets impacts revenue streams, procurement and financing. |
| <b>Temporally Granular Real-Time<br/>Energy Markets:</b>                         | Energy markets operated in real-time should be granular in the timeframes to capture events that can potentially disrupt supply and demand. Allowing sufficient granularity (likely 5-minute or 15-minute intervals) can signal to resources when there are supply challenges on the system and allow economics to coordinate least-cost responses. The EU is transitioning to 15-minute trading intervals under the Single Day-Ahead Coupling (SDAC), effective October 2025. This granularity enables better integration of intermittent renewables and more precise system balancing, aligning with the EU’s flexibility and reliability goals.                                                               |
| <b>Carefully Set Energy Market Price<br/>Caps (and Floors):</b>                  | Energy Price caps can drive pricing during extreme intervals for the energy markets, these in turn can have outsized impacts on average monthly or annual prices, which have impacts on ratepayers and generation. Ensuring that prices are significant enough to reflect scarcity and the value of lost load, but not so high to overstate these values is important for any energy market.                                                                                                                                                                                                                                                                                                                     |
| <b>Accommodate Procurement<br/>of Resources with Long<br/>Development Times:</b> | Some specific resource types take longer for permitting or development than others. Under the REPowerEU Plan and the revised Renewable Energy Directive (EU/2023/2413), Member States are urged to streamline permitting and procurement for infrastructure-heavy resources like LDES, which may require 5–10 years for development/construction. The EU Grid Action Plan and DSO Entity guidance emphasize the need for permitting reform to accelerate deployment. Regulators should pay careful attention to these timelines, while allowing these resources into solicitation and modelling processes when selecting and procuring specific resources as grids evolve.                                       |
| <b>Develop Robust Ancillary<br/>Service Markets:</b>                             | The EU is reforming ancillary services markets to support frequency response, inertia, voltage control, and black start capabilities. ENTSO-E’s Market Report highlights the need for harmonized balancing platforms (e.g., MARI, PICASSO) and expanded remuneration mechanisms for flexibility services.                                                                                                                                                                                                                                                                                                                                                                                                        |



## Conclusion

To meet rising demand and ensure system resilience, the European Commission estimates that €730 billion will be needed to upgrade distribution networks and €477 billion for transmission grids by 2040. Achieving these goals requires proactive system planning, removal of investment barriers, and the creation of robust market signals that offer long-term revenue visibility to attract private investment.

A key component of this transition is system flexibility, which is projected to grow from 11% of electricity demand in 2021 to 30% by 2050. Recognizing the risks of insufficient flexibility, the European Parliament has mandated that Member States conduct Flexibility Needs Assessments (FNAs), aligned with their National Energy and Climate Plans (NECPs), to quantify and plan for the flexible resources needed to maintain grid stability.

Energy storage has been identified as essential for balancing the variability of renewables and enhancing grid resilience, and Member States are encouraged to urgently include storage deployment pathways in their FNAs and NECPs.

**In this context, Hydrostor recommends three strategic actions to support the deployment of long-duration energy storage (LDES) and ensure grid reliability:**

1. Undertake robust, duration-aware system modelling to accurately assess flexibility needs across different time horizons;
2. Establish LDES-specific targets and develop a transparent, multi-year procurement schedule that supports a diverse range of technologies through a cadence-based approach; and
3. Implement mechanisms to ensure revenue sufficiency, such as cap-and-floor programs, once long-duration storage needs are identified.

These actions are a strategic imperative and essential for enabling Europe to deliver on its climate and energy ambitions while maintaining a stable, resilient, and cost-efficient electricity system for consumers.

By acting decisively, Europe can avoid stranded assets, reduce curtailment, and maintain its global leadership in clean energy, while delivering reliable, affordable power to millions of homes and creating thousands of jobs.

# Hydrostor Overview

## Re-inventing Compressed Air Energy Storage

Hydrostor's Advanced Compressed Air Energy Storage (A-CAES) technology offers a breakthrough in long-duration energy storage by transforming how compressed air systems operate. A-CAES stores excess renewable energy by compressing air and storing it in purpose-built rock caverns deep underground. When electricity is needed, the stored air is released through turbines to generate power and return it to the grid.



Unlike traditional compressed air systems, Hydrostor’s design eliminates the need for fossil fuels and increases siting options beyond salt caverns. It achieves this by:

- Capturing and storing heat from the compression process using a proprietary thermal management system.
- Maintaining constant pressure with a water compensation system, enabling efficient and emission-free operation.

This innovation builds on over four decades of global CAES operations, including facilities in Germany and Alabama, while delivering a zero-emission, utility-scale solution for modern grid needs.

A-CAES facilities offer the same benefits as pumped hydro storage (long lifetime, inertia, reliability, and dispatchability) but with greater siting flexibility, smaller land and water requirements. A typical 500 MW / 4 GWh A-CAES plant requires ~100 acres and can deliver eight or more hours of dispatchable energy, supporting approximately 400,000 homes.

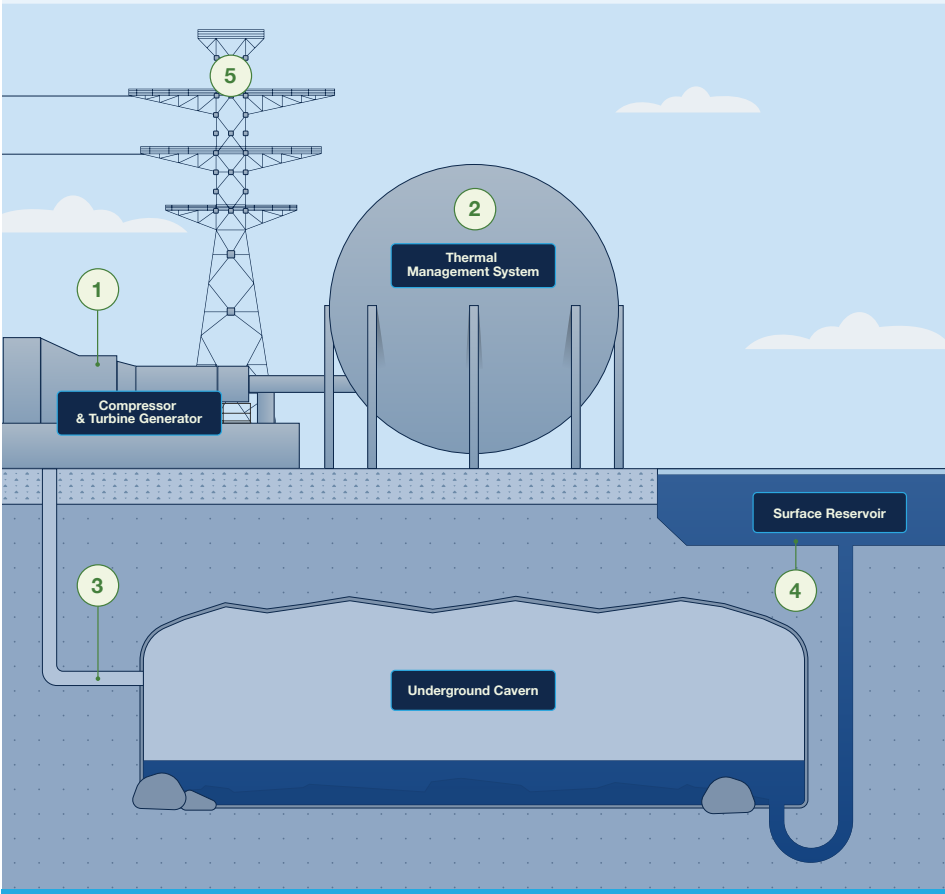
With proven components, established supply chains, and a 50+ year lifespan, A-CAES delivers the same grid-stabilizing services as gas plants, without the emissions.

A-CAES represents an evolutionary leap in energy storage, combining flexibility, scalability, and sustainability.

How Hydrostor re-invented compressed air:

- Traditional CAES relied on salt caverns and fossil fuels.
- Hydrostor’s A-CAES uses hard rock caverns, water compensation, and stored heat—no fuel required.
- The result: A long-life, flexible, utility-scale solution for grid stability and decarbonization.

| Feature              | 500 MW/4 GWh A-CAES Plant                                                    |
|----------------------|------------------------------------------------------------------------------|
| Storage Capacity     | ~4 GWh (8 hours @ 500 MW) → supports ~400,000 homes                          |
| Efficiency           | >60% round-trip energy efficiency                                            |
| Operational Lifespan | 50+ years                                                                    |
| Land & Water Use     | Up to 10× less land, 20× less water vs pumped hydro                          |
| Grid Services        | Inertia, reliability, peaking, load shifting, firming, transmission deferral |



The Closed Loop A-CAES Process

- 1 Compression**  
Energy powers an air compressor, generating heat in the process.
- 2 Heat exchange**  
Heat is extracted from the compression process and captured by a thermal management system for reuse.
- 3 Air storage**  
Compressed air is pumped down and stored in a purpose-built, water-filled cavern.
- 4 Water displacement**  
Compressed air displaces water, forcing it up the shaft to the surface reservoir.
- 5 Discharge**  
When energy is needed, the process is reversed to generate electricity.

## Hydrostor's Advanced Project Profiles:



**WILLOW ROCK**  
ENERGY STORAGE

Location: Rosamond, California, USA  
Technology: Advanced Compressed Air Energy Storage (A-CAES)  
Capacity: 500 MW / 4,000 MWh  
Duration: 8+ hours  
Status: Late-stage development

**Key Highlights:**

- Supports California's 100% clean energy goals by 2045
- \$1.76B conditional loan commitment from U.S. DOE
- Serves Los Angeles Basin with dispatchable, zero-emission storage
- Creates ~700 construction jobs and 25–40 permanent roles
- Enhances transmission efficiency and grid reliability



**SILVER CITY**  
ENERGY STORAGE

Location: Broken Hill, New South Wales, AUS  
Technology: Advanced Compressed Air Energy Storage (A-CAES)  
Capacity: 200 MW / 1,600 MWh  
Duration: 8+ hours  
Status: Late-stage development

**Key Highlights:**

- Enables Broken Hill to operate as a renewable-powered microgrid
- Replaces aging diesel backup and avoids costly transmission upgrades
- Backed by Transgrid, AEMO Services, and ARENA funding
- Injects AUD\$550M into NSW economy; ~750 job-years
- Supports Australia's emissions and energy security goals

## Carbon Abatement Potential of A-CAES in Europe<sup>28</sup>:

Hydrostor's Advanced Compressed Air Energy Storage (A-CAES) offers a powerful pathway for carbon abatement in Europe's energy transition. A single 500 MW A-CAES facility, discharging 4,000 MWh per cycle and operating at 95% availability, can complete approximately 248 full cycles annually. If charged from 100% renewable sources and displacing natural gas generation, this results in over 901,000 metric tons of CO<sub>2</sub> abated per year. Over a 50-year lifespan, the same facility would eliminate more than 45 million metric tons of CO<sub>2</sub>, equivalent to removing 9.8 million passenger vehicles from the road.

### Beyond emissions reduction, a 500 MW/4,000 MWh facility can:

- Power up to 1.18 million households during discharge.
- Create 700 construction jobs and 1,500 operational job-years over its lifetime.

### Scaling the Impact - Deploying ten 500 MW (8-hour) A-CAES plants would:

- Abate over 9 million metric tons of CO<sub>2</sub> annually.
- Eliminate emissions equivalent to 2 million cars per year.
- Power 11.8 million homes during peak discharge.
- Create 7,000 construction jobs and 15,000 operational job-years.

Over five decades, this fleet could eliminate more than 450 million metric tons of CO<sub>2</sub>, equivalent to removing 98 million passenger vehicles from European roads.

A-CAES provides Europe with a scalable, zero-emission solution to decarbonise its grid, enhance energy security, and meet climate targets—while creating thousands of jobs and powering millions of homes with clean, dispatchable energy.

## Endnotes

- 1 <https://energy.ec.europa.eu/>
- 2 [https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive\\_en](https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en)
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