Breakthrough Energy | Cleantech for Europe | With analyses led by SYSTEMIQ

CLEANTECH REALITY CHECK

LONG DURATION ENERGY STORAGE

Storing hopes for the energy transition

What is LDES ?

Long Duration Energy Storage (LDES) technologies store energy for long time periods (> 8 hours), to be used at a deferred time through reconversion or as a different carrier. LDES provide profile smoothening and curtailment avoidance for renewables. LDES solutions consist of :

- Electrochemical (power-to-power): e.g., flow battery, metal air.
- Mechanical (power-to-power): Pumped-Hydro Storage or other less traditional technologies such as compressed or liquid air.
- Thermal (power-to-heat): heat storage e.g., molten salt or heat storage bricks.
- Chemical (power-to-x): Storage of e.g., hydrogen or ammonia before they are used as fuel or chemical feedstock.

Currently, Pumped-Hydro Storage, the most mature LDES technology, faces limitations due to geographic needs such as water proximity and elevation. Other LDES solutions are therefore needed. Specifically, thermal LDES solutions have an advantage of simplicity of technology for installation. Thermal LDES can also displace fossil thermal power plants in district heating, as well as near-term cost competitiveness vs. fossil-based heat source especially in regions with lower renewables cost or curtailed renewable energy.

Key take-aways

- The EU needs ~200 GW of non-fossil fuel storage to reach 55% decarbonisation by 2030, of which ~130 GW is LDES. Of the 130 GW, 65 GW will be served by Pumped-Hydro Storage (PHS), and 55-65 GW by novel LDES technologies. To achieve this objective, the EU is required to install 10 GW/year in the next five years.

- LDES recently gained momentum due to a power market reform, mandates for country-level flexibility assessments, and the initiation of storage auctions in several countries. However, barriers to LDES deployment remain and include the lack of specific goals and action plans, resulting in uncertainty in permitting processes and an unleveled playing field with other (shorter duration) storage technologies such as Li-ion batteries.

- Moving forward, the EU must start laying the foundation for LDES scale-up. This starts with setting targets and action plans, introducing incentives and de-risking mechanism to increase business case viability, as well as adjusting grid regulation to support LDES integration into the power system.

LONG DURATION ENERGY STORAGE

STORING HOPES FOR THE ENERGY TRANSITION

STRATEGIC OBJECTIVES FOR EUROPE

- **Provide flexibility and enable renewables growth** in power market, as the EU's 42.5% renewables target by 2030 cannot be achieved with a stable energy system without storage and penetration of variable renewable power is exceeding 40% in six Member States.[1]
- **Reduce curtailment of renewable electricity by 5-10%[2] in 2030**, saving significant administrative costs (at around €10-20 billion)[2]
- Provide **clean dispatchable power and grid balancing mechanism** that can be produced domestically, reducing **dependency on imported fossil fuel for grid balancing** supply
- Support retrofitting of fossil assets that conserve existing skillset during operation and provide **additional jobs with new skillsets**

CURRENT PROGRESS OF LONG DURATION ENERGY STORAGE IN THE EU

OFF-TRACK — ON-TRACK

STATUS : NOT ENOUGH PROGRESS In order for the EU to reach their renewable energy goal in 2030, the yearly deployment rate of LDES - especially novel LDES technologies - needs to expand in the next five years.

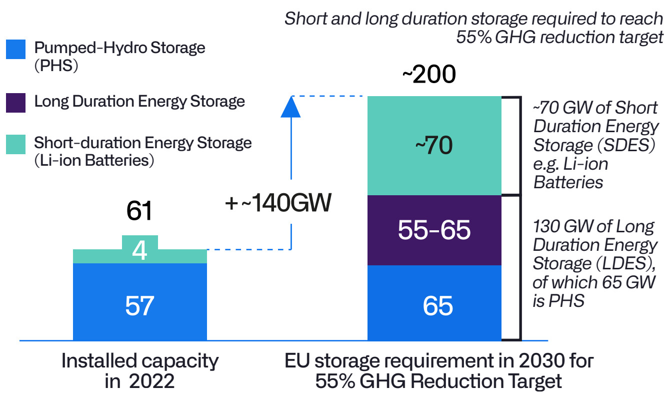
0.8 GW of novel LDES technology is operational[11] and **3.7** under development[11] out of additional **65 GW** required by 2030.

A RAPID DEPLOYMENT OF LDES IS NEEDED TO REACH THE EU'S RE GOALS IN 2030

- The EU needs ~200 GW of non-fossil fuel storage to reach 55% decarbonisation by 2030, of which ~130 GW is LDES[3] (incl. Pumped-Hydro Storage (PHS)).
- Only ~57 GW of LDES storage is currently deployed. All 57 GW is PHS, a technology that is projected to max out at 65 GW by 2030. In the next five years, 55-65 GW of novel LDES technology outside of PHS is required, equal to installing 10 GW/year.
- 118 TWh of renewables is projected to be curtailed in 2030. Deploying 55-65 GW of additional LDES can help reduce 5-10% of curtailment, assuming each 10 GW LDES helps avoid 2-4 TWh reneawbles[5] curtailment.

Installed and required storage capacity in the EU[3]

GW

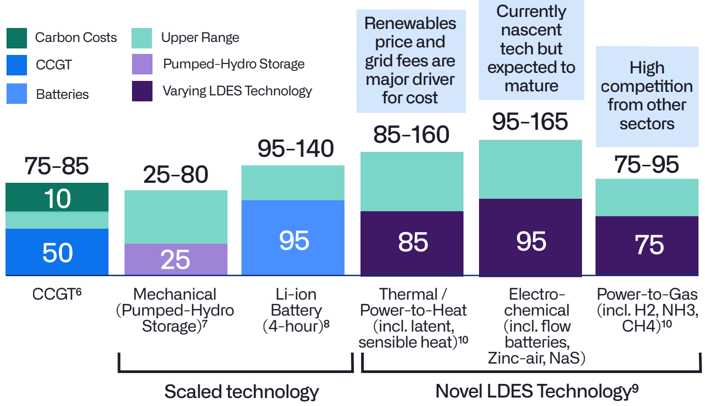


LDES TECHNOLOGIES ARE TRAILING IN COST COMPETITIVENESS WHEN COMPARED TO FOSSIL-FUEL-BASED BALANCING

- The cost comparison is differentiated by technology maturity: 1) scaled storage technology, and 2) novel LDES technologies.
- Natural gas-based flexibility assets (e.g., Combined Cycle Gas Turbines) still show lowest cost on normal fuel prices. The gap between CCGTs and low-carbon storage technology could be bridged by a carbon tax.
- Other LDES not analysed include borehole energy storage (geography-specific), chemical storage (see the hydrogen derivatives Reality Check), and mechanical LDES with low technology readiness level (e.g., Liquid CO²).

Levelised Cost of Storage (LCOS) in 2030

€/MWh



Notes: 1. European Environment Agency – Share of VRE in each country | 2. ACER 2024 Market Monitoring Report – assuming €4B per 10 TWh curtailed (in Germany) | 3. Study on energy storage: Contribution to the security of the electricity supply in Europe: EU Directorate General of Energy (2020), using METIS-Baseline 2030 Scenario, aligned with 55% GHG Reduction targets and 37% VRE penetration compared | 4.Making Clean Power Flexy (EMBER, 2023) | 5. Scenario Deployment Analysis for Long-Duration Electricity Storage: A study of the benefits of Long-Duration Electricity Storage technologies on the GB power system (LCP Delta, 2023) | 6. Systemiq calculation using NREL LCOE model and project-specific assumptions (Carbon price assumed to be 95 €/ton) | 7. Novel Thermal Energy in the European Union (Clean Energy Technology Observatory – EU JRC, 2023) | 8. Systemiq calculation using Cost Projections for Utility-Scale Battery Storage: 2023 Update (NREL) and 0.04 – 0.05 $/kWh LCOE | 9. LCOS of LDES technologies are derived from Real-time Modeling and Optimisation of Molten Salt Storage with Supercritical Steam Cycle for Sustainable Power Generation and Grid Support (H.R. Rahbari et al., 2024) | 10. Power-to-Heat technologies are calculated based on reconversion from heat/gas to power. 11. 2024 LDES Annual Report (LDES Council, 2024)

LONG DURATION ENERGY STORAGE

STORING HOPES FOR THE ENERGY TRANSITION

ENABLERS – WHAT IS GOING WELL

POWER MARKET REFORM GIVES SIGNALS FOR ENERGY STORAGE DEVELOPMENT

The 2022 EU power market reform has kickstarted several supportive policies such as grid fee reductions (e.g., Germany) and incentives for off-peak demand (e.g., Denmark), or public financing (e.g., Spain).

FLEXIBILITY ASSESSMENTS METHODOLOGY FINALISATION

Transmission System Operators (TSOs) of EU countries are starting to submit flexibility assessments that includes non-fossil fuel technology, where LDES is expected to play a role in providing system flexibility as renewables penetration continues to grow.

COUNTRIES STARTING LONG-DURATION ENERGY STORAGE AUCTIONS

LDES auctions have started in several countries (e.g., Italy, Germany, Ireland), giving momentum to the deployment of LDES technologies in the power system.

BARRIERS – WHAT IS NOT GOING WELL

LACK OF CLEAR REVENUE MODEL FOR LDES

Lack of revenue mechanisms for LDES hinders the development of strong business cases for new projects. Storage technologies also experience double-charging of fees and go through two different permitting and solicitation processes as both consumers and producers/generators of electricity.

LACK OF TARGETS AND ACTION PLAN ON FLEXIBILITY AND STORAGE

Unlike for renewable energy and grids, countries do not have to commit to action plans and targets for storage, including LDES. This leaves LDES technology out of electricity system planning and analysis, and limits awareness of the technology.

LACK OF LEVEL PLAYING FIELD WITH OTHER TECHNOLOGIES

Novel LDES often gets less acknowledgement and awareness than other more stablished storage technologies like PHS and Li-ion. This results in an unleveled playing field, from access to public mechanisms (innovation funds), or revenue schemes (capacity payments) that are key to support their deployment.

ACTION AGENDA – WHAT NEEDS TO BE DONE

1. **Develop storage action plan and target:** The EU can accelerate this by regulating member states to develop storage, flexibility targets and action plans that include assessments of storage needs and are tied to Nationally Determined Contribution (NDCs) and National Energy & Climate Plans (NECPs), as well as commission national-level studies on LDES technology to mainstream the cause. These should include LDES use for all relevant sectors (electricity, heat, industry and transport).

2. **Provide supportive ecosystem to build compelling business cases for novel technologies:** Fiscal incentives must be adjusted to accommodate novel LDES technologies that bring positive externalities to the energy system such as flexibility, balancing or fossil fuel displacement. Supportive incentives such as revenue mechanisms (e.g., capacity payments) can accelerate deployment that is critical for technology and cost improvements.

3. **Offer novel de-risking mechanisms:** De-risking instruments, such as blended finance and public guarantees (e.g., USA Department of Energy's Loan Guarantees or the EU-Catalyst Partnership) can help scale novel LDES technologies. The EU should introduce or facilitate public guarantees to reduce project and counterparty risks and incentivise private investment in novel storage technologies.

4. **Develop a fit for purpose power grid regulation:** Review grid regulation related to storage technologies, starting from storage asset classification, adjusting grid costs (fees, taxes and levies), and a faster and more unified storage grid access solicitation process as generator and consumer, to streamline deployment of LDES technologies.

"Developing clear energy storage and system flexibility targets that are both technology-inclusive and directly tied to Nationally Determined Contributions would enable the accelerated deployment of long duration energy storage technologies that provide a range of powerful grid, economic, and social benefits to the EU energy system."

Julia Souder, Chief Executive Officer - **LDES Council**