The role of underground hydrogen storage (UHS) in strengthening EU energy security and resilience

A Position Paper by H2eart for Europe

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A shifting paradigm in energy security

Europe's energy system is increasingly defined by variability and interdependence. The transition towards a more sustainable energy supply is fundamentally changing how energy systems operate.

At the same time, new system risks have become more pronounced. Climate-driven volatility, including periods of extreme weather, geopolitical uncertainty and infrastructure constraints are becoming central risks of the system. These risks can manifest in both physical and economic terms – through supply disruptions, reduced availabilities and sustained periods of high market prices. These developments jointly increase the need for a more resilient energy system, embedding sustained, structural flexibility across energy vectors. In this context, resilience becomes a critical enabler of energy security, strengthening Europe's agency over its energy supply.

Underground Hydrogen Storage (UHS) can play a crucial role for Europe's future energy security by providing long-duration, large-scale flexibility, enabling energy to be stored over weeks or seasons and deployed when needed. This allows the future low-carbon system to manage prolonged stress events, not just short-term variability.

As H2eart for Europe, an alliance of European UHS operators, we identify the following priorities to unlock the critical contribution of UHS to energy security:

- embed UHS in European security of supply frameworks;
- establish frameworks that unlock investment in UHS; and
- enable coordinated system planning, recognising UHS benefits for energy vector integration.

Why needs for flexibility and resilience are changing

Flexibility in the power sector has traditionally focused on short-term balancing, but this is no longer sufficient. As renewable penetration increases alongside electrification of new sectors, flexibility needs are expected to rise significantly, both in scale and duration due to shifts on the supply and demand sides.

Prolonged stress events, such as cold *Dunkelflaute*, highlight this challenge. These require multi-day or even seasonal responses, in addition to real-time and hourly balancing. As a result, the system must evolve to deliver additional structural flexibility – the ability to manage sustained periods of imbalance.

EUROPEAN FLEXIBILITY NEEDS IN THE POWER SECTOR (REL. TO 2021)

77% increase in **weekly** flexibility needs by 2030

27% increase in **seasonal** flexibility needs by 2030

EEA/ACER (2023)[1]

Flexibility will also be crucial in the emerging hydrogen market. Early demand will likely develop in the industry sector, where offtakers require stable baseload supply with little to no flexibility on the demand side. At the same time, hydrogen supply will be inherently variable, driven by renewable generation profiles, import patterns and potential unanticipated supply disruptions. This creates a structural mismatch between variable supply and inflexible demand, increasing the need for both flexibility and resilience.

Resilience goes beyond pure flexibility. While flexibility enables the system to respond to variability, resilience determines whether it can withstand and recover from sustained shocks. This requires an energy system that is not only adaptable, but also robust – with sufficient redundancy, diversity of supply and the ability to operate under stress without compromising security of supply. Strengthening resilience therefore ensures the system can absorb volatility while preserving affordability and reliability.

[1] EEA/ACER (2023): Flexibility solutions to support a decarbonised and secure EU electricity system, available here. Indications are relative to 2021 flexibility requirements.

The risks of inaction come at a high price

Without a long-term framework to strengthen energy security throughout the energy transition, the European energy system faces material and persistent risks:

- **Higher system costs**, driven by continued reliance on inefficient back-up at volatile prices
- **Inefficient investment**, as the system overbuilds generation capacity to compensate for missing flexibility
- **Greater exposure to supply disruptions**, particularly during prolonged or unexpected stress events

As exposure to variability increases and stress events become more frequent and unpredictable, gaps in reliable and long-duration flexibility translate directly into higher prices, lower reliability and reduced control over energy supply. Over time, this weakens affordability, sustainability and security, undermining the objectives of the energy transition.

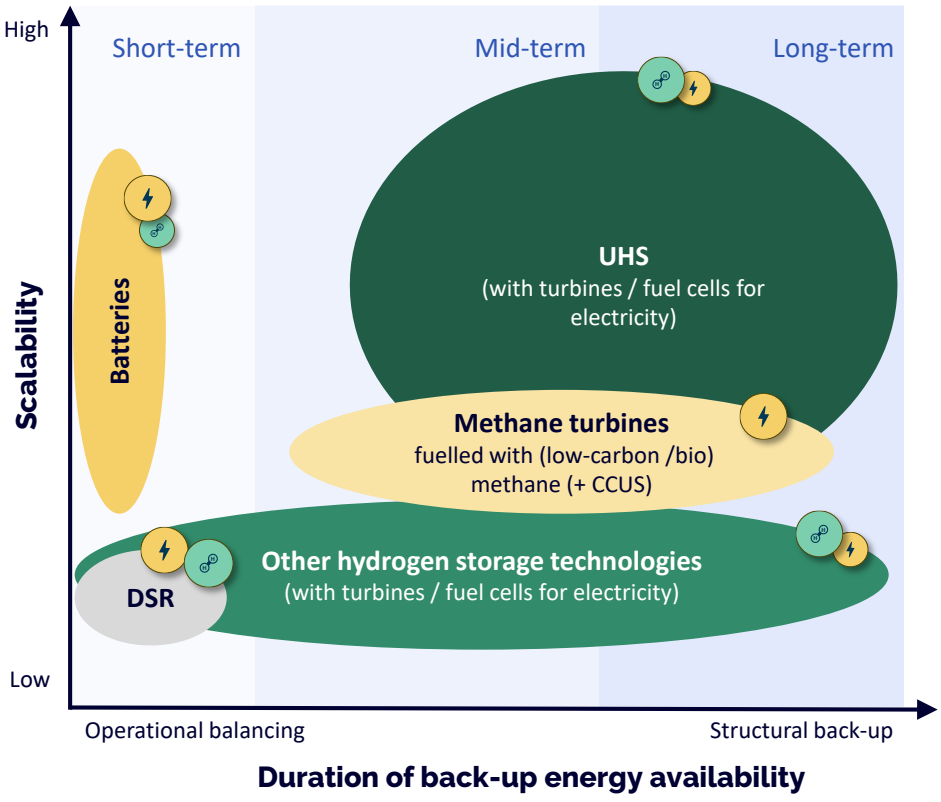
A structural response includes UHS at its core

Delivering a resilient, low-cost energy system requires flexibility across timescales – from short-term balancing to multi-day and seasonal back-up.

UHS plays a central role by providing long-duration, large-scale and dispatchable flexibility in the future energy system. As a low-carbon technology enabling energy to be stored over extended periods and deployed when needed, UHS can ensure security of supply during prolonged stress events.

This long-duration capability is critical. As illustrated in **Figure 1**, most low-carbon back-up technologies operate within limited windows of the flexibility spectrum. Batteries and demand-side response are effective for short-term balancing, but their contribution declines rapidly as duration increases. Other back-up technologies can provide mid-term flexibility, but face constraints in scale, duration or long-term sustainability.

Figure 1 Low-carbon back-up technologies by scalability and duration of energy availability



Source: *Frontier Economics for H2eart for Europe*
Note: *A green circle denotes hydrogen in end-use, and a yellow circle denotes electricity in end-use.*

UHS is uniquely positioned within this landscape. Its combination of scale and long-duration storage enables energy to be stored over weeks or seasons and promptly dispatched when needed. This allows it to provide structural back-up capacity – not just balancing day-to-day variability, but also maintaining supply through prolonged system stress.

Without UHS, this gap would remain unaddressed in Europe's future energy system. The system would lack a credible source of long-duration flexibility, increasing exposure to supply disruptions and sustained periods of high prices. UHS is therefore not simply part of the flexibility mix – it is also a foundational component of system security in a decarbonised energy system.

How to unlock system security

Unlocking system security requires coordinated action across policy, planning and markets. UHS can deliver system-wide benefits, but only if frameworks evolve to recognise its role, integrate it effectively and de-risk investment.

As H2eart for Europe, an alliance of European UHS operators, we identify the following priorities for unlocking the contribution of UHS to energy security:

- embed UHS in European security of supply frameworks;
- establish frameworks that unlock investment in UHS; and
- enable coordinated system planning, recognising UHS benefits for energy vector integration.

Embedding UHS in security of supply

UHS strengthens energy security across all its core dimensions:

- **adequacy** – ensuring sufficient storage capacity to maintain supply during extended periods of low energy supply;
- **resilience** – improving the system's ability to absorb and recover from shocks quickly; and
- **preparedness** – enabling credible responses to extreme/unexpected but plausible stress events in a transforming energy system.

It is therefore vital that UHS is embedded within Europe's security of supply architecture. As risks become more structural and prolonged, adequacy and preparedness frameworks need to evolve to also reflect the role of UHS as long-duration storage. Without explicit recognition, the value of UHS remains underrepresented – leading to underinvestment and exposing Europe's energy system to systemic risks. While UHS may not immediately mitigate current shortages, it provides critical insurance for the future. This requires anticipatory investments today, ahead of materialised shortages, to ensure the system remains secure and functional in the future.

In practice, this means integrating UHS into adequacy assessments, resilience planning, system modelling and stress testing. It should also play a defined role in risk preparedness and crisis response.

Establish frameworks that unlock investments in UHS

Despite its system-wide value, UHS faces structural investment barriers due to capital intensiveness of asset development, uncertainty regarding prices and volumes, and regulatory

barriers. Its benefits extend beyond energy markets, while revenues remain uncertain and long term with lead times of up to ten years.

Unlocking investment in UHS requires clear regulatory recognition of UHS as core system infrastructure well-designed de-risking mechanisms and long-term contracting frameworks.

This ensures investment decisions reflect full system value, rather than short-term market signals. Without this alignment, the system risks under-delivering the infrastructure needed to support long-term resilience.

H2eart for Europe stands ready to support policymakers in embedding UHS at the core of Europe's future energy system.

Enabling coordinated system planning

Security must be planned at a system level. Electricity, gas and future hydrogen systems are increasingly interdependent, and decisions in one directly affect the others.

Planning these systems in isolation creates inefficiencies and weakens resilience. A coordinated approach between energy vectors is needed, aligning storage, transport and generation with overall system needs and interdependencies.

Security in a low-carbon energy system is not delivered by individual assets alone. It depends on how infrastructure is planned, connected and operated as a whole. Given the long lead times of infrastructure such as UHS, anticipatory decisions are required today to ensure system-wide robustness under future uncertainty.

About H2eart for Europe

H2eart for Europe is an EU-wide, CEO-led alliance committed to accelerating the decarbonisation of the European energy system at lowest cost to society by scaling up underground hydrogen storage (UHS). Launched in Brussels on 23 January 2024, the alliance provides fact-based analysis to support policymakers and draws on the expertise of its members, leading companies shaping the future of hydrogen storage across Europe. We are committed to investing in UHS infrastructure to meet the flexibility needs of a decarbonised energy system.

The organisations listed below are the members of H2eart for Europe.

For media inquiries, please contact info@h2eart.eu.