GIE position on Artelys study: Evaluation of the benefits brought by underground hydrogen storage

Through its flagship Green Deal[1], its comprehensive Fit for 55 Package[2] or even its newly introduced REPowerEU plan[3], the European Union (EU) has developed the basis for a regulatory framework to drive investment into clean energy. While Member States must now translate these commitments into national policies, GIE is convinced that further attention should be given to underground hydrogen storage (UHS) to kick-start the emergence of a clean hydrogen ecosystem at the lowest cost to society.

For this purpose, GIE has prepared a study with the support of Artelys to provide evidence that the benefits brought by UHS are critical to the electricity and hydrogen systems. This study is the first of its kind, providing a further in-depth understanding of the role played by UHS in the Power-to-Gas value chain. Key expected outcomes include, among other things, RES deployment, avoided renewable electricity sources (RES) curtailment, avoided CO_2 emissions, reduced investment costs and operational costs, etc.

Given the results, GIE calls for better integration of UHS into the regulatory framework and asks for financial support. Please read the paper and GIE study to see more detail on these points and the value UHS can provide.

I. Setting the scene

In recent years, business developers have faced challenges hindering the development of clean hydrogen ecosystems and, therefore, the decarbonisation of hard-to-abate sectors that account for a large share of CO_2 emissions.

A. Renewable-only electrolysis system results in high LCOH

Powering an electrolyser solely by on-site RES capacities results in high LCOH due to low facility utilisation [Figure 1]. Furthermore, intermittent hydrogen production does not ensure a steady stream of renewable hydrogen supply to industrial users. This utilisation may have led to over-dimensioned electric grids or short-term storage to avoid congestion.

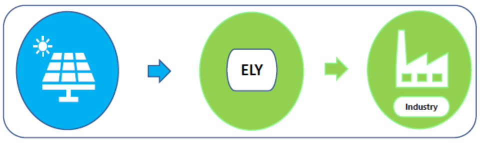

Figure 1 - Renewable-only electrolysis system

[1] European Commission (2019) *The European Green Deal*, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2019) 640 final.

[2] European Commission (2021) *'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2021) 550 final.

[3] European Commission (2022) *REPowerEU Plan,* Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2022) 230 final.

B. Renewable electrolysis system using battery/electricity grid as virtual storage is only a short-term solution to lower LCOH

To overcome this challenge, business developers have recently oversized their on-site RES plant (or electrolyser) [Figure 2]:

- Storing any excess of on-site RES production in the grid when generating more than the hydrogen demand,
- Buying power from the grid (or batteries) when the on-site RES is not generating enough to power the whole electrolysis system.

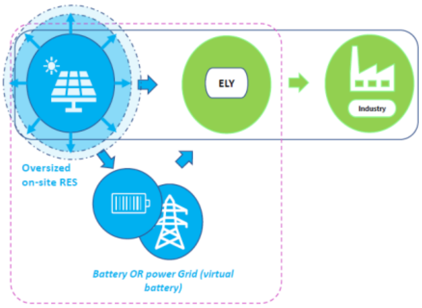

Figure 2 - Renewable electrolysis system using battery/electricity grid as virtual storage

Such short-term storage solutions for energy shifting [Figure 2] have reduced LCOH compared to a renewable-only electrolysis system [Figure 1] by increasing the utilisation of electrolysis. However, this cost advantage will erode over time as deeper penetration of RES further increases storage costs due to the lack of scalability of short-term electricity storages (other constraints related to these technologies also need to be considered, e.g. elevated comparative costs[4], limited availability of strategic raw materials and high costs for recycling used batteries).

C. Renewable electrolysis system using UHS as a long-term solution to lower LCOH

By 2030, the rise in RES will require a molecule-based system to better co-optimise the entire value chain, enabling better sectoral integration and sector coupling. This will require the transfer of the energy content of electrons to molecules, thereby enabling the storage of any RES excess via UHS to ensure bulk energy shifting [Figure 3].

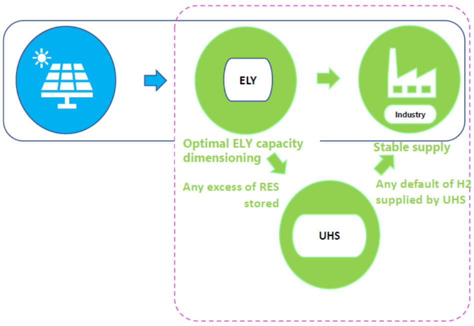

Figure 3 - Renewable electrolysis system using UHS as renewable hydrogen storage

The electricity system will not be congested and allow higher scalability of on-site RES:

[4] Cole, Wesley, A. Will Frazier, and Chad Augustine (2021) *Cost Projections for Utility-Scale Battery Storage: 2021 Update*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-79236.

- Any excess of RES production that would not be consumed will be stored (i.e. injected into UHS) instead of curtailed (thus limiting congestion or any over-dimensioning of the electricity system).
- Any default of renewable hydrogen will be supplied (i.e. withdrawn from UHS that could be along hydrogen pipelines) to the industrial user when the power grid is not generating electricity from RES.

This will result in reduced LCOH while allowing better use of RES and reduction of grid withdrawals.

II. Artelys study

In 2021, in anticipation of the Hydrogen and Decarbonised Gas Market Package, GIE members decided to launch a new study with the support of Artelys with a double objective:

- The identification of the different values of UHS in a nascent hydrogen ecosystem,
- A first evaluation of UHS benefits by assessing the impact of adding UHS capacities progressively into a set of territorial use cases.

A. Identification of the values of UHS

In continuity with the previous study on underground gas storage (UGS)[5], Artelys has re-defined the values that UHS brings to the energy system [Table 1]. The first three values have already been identified for UGS and reviewed from a hydrogen perspective. On top of that, two additional values have been considered (kick-start and environmental ones).

UHS values	Value Description	Associated KPI
System value	UHS enables to better use cheaper hydrogen sources and decreases the full cost of hydrogen production	Levelized cost of hydrogen
Arbitrage value	UHS fosters renewable hydrogen production by allowing better use of local RES resources	Share of hydrogen supply routes and electrolyser load factor
Insurance value	UHS decreases the capacity needs of a backup hydrogen supplier and potentially of alternative electricity production capacities.	Hydrogen production capacities
Kick-start value	UHS allows for a system-level optimisation of electrolysis and RES sources, facilitating the emergence of a hydrogen economy	Investment in on-site renewable and electrolysers
Environmental value	UHS allows the system to withdraw decarbonised electricity for hydrogen production, thereby reducing carbon emissions	Carbon footprint of hydrogen and avoided RES curtailment

Table 1 - Values identified for UHS and KPIs used to measure these values (Artelys-GIE, 2022)

B. Quantitative evaluation of the benefits brought by UHS in a series of four territorial use-cases

Compared to the gas system, the role of underground storage is even pronounced in a Power-to-Gas value chain as it enables the power system to deal with the intermittency of RES at a large scale [Table 1].

[5] Artelys (2019) *Value of the gas storage infrastructure for the electricity system*. Study for GIE. Available here.

Timeframes	Consumption UGS/UHS	Production	
		UGS	UHS (for electrolytic H2)
Hourly	Daytime vs nighttime activities (residential, tertiary)	Constant over these timescales (methane production and imports)	RES production variability - Hourly (solar PV in particular) - Weekly (wind power in particular) - Seasonal (hydro, wind and solar PV) Network congestions
Weekly	Weekday vs weekend activities (residential, tertiary)		
Seasonally	Thermosensitivity (mostly residential)		

Table 2 – Comparison of UGS and UHS over different timeframes (Artelys-GIE, 2022)

C. Main outcomes

As part of integrated infrastructure, UHS is a pivotal resource to facilitate the emergence of a hydrogen ecosystem by providing the essential bridge between variable electricity supply options (RES and low grid tariffs) and stable hydrogen demand profiles. By allowing better use of RES resources and better and more efficient utilisation of grids, UHS reduces both the electricity system and hydrogen costs as well as the average carbon emissions. This competitive advantage provided by UHS can lead to a reduction in the need for alternative supplies.

The analysis of the territorial use cases considered in Artelys study allows us to showcase the different services that UHS will provide. All quantitative results are detailed in the study for each territorial use case, each value and an incremental amount of UHS capacities (in the form of sensitivity analyses).

III. Next steps

In this study, the values generated by UHS are related to territorial use cases. They consist in potential future business models that will be developed to generate system-wide benefits for both electricity and hydrogen systems. Further studies are now required to go a step further.

A. Delivering on REPower EU Plan: UHS capacity needs by 2030

In order to deliver on REPowerEU's ambitious targets by 2030, it will be relevant to quantify the required UHS capacity needs based on country granularity. The different national amounts will then be aggregated at the EU level while adopting a holistic approach. Additional factors will be analysed, such as the role of imports and exports (intra and extra-EU), the deployment of other storage options, the evolution of the power infrastructure and market, etc.

Besides quantifying the UHS capacity needs, different archetypes of UHS will be identified in relation to their business models and role within the energy system. On top of Artelys use cases, as an illustration, UHS will also allow to store potential hydrogen imports produced in other geographical locations (e.g. other countries or other areas not close to consumption centres).

B. UHS targets should be determined for the transition path until 2030

Evaluating the UHS capacities required for 2030 and defining much-needed targets at a national level would enable Storage System Operators (SSOs) to prepare their transition pathways. This exercise is especially challenging in the current energy crisis as UGS is heavily strained and will not be available by 2030. Indeed, minimum storage filling levels that entered into force in July 2022 as part of the new gas storage Regulation[6], demonstrate that most existing UGS capacities are required for security of supply and diversification purposes in the coming years when the conversion of these sites for hydrogen or newly built capacities is already expected.

Europe is facing its first winter in 50 years without ample Russian energy supplies. The last months of Russian flows and the supply from third countries were used to fill European UGS nearly[7]. Mild weather during the 2022-2023 winter might obviate the need for rolling power outages, whereas a cold winter could overwhelm supplies. Challenges may also arise post-winter, during spring 2023, to ensure the minimum filling storage obligations. Additional efforts and cooperation with third countries will be required to ensure that minimum filling levels of storage can be secured. Competition with Asian markets and booming LNG imports into the EU need to be further evaluated to ensure high storage minimum levels, knowing that they may start from a shallow base at the end of March 2023.

This focus on the energy crisis explains that existing UGS plays an essential role in securing today's European gas market. Nevertheless, the transition to renewable and low-carbon energy and the deployment of hydrogen in end-use sectors increasingly require UHS to be ready by 2030, either by repurposing existing storage facilities or building new hydrogen storage sites (salt caverns, depleted fields and aquifers, onshore and offshore). To avoid conflicting targets, developing a transition path for UHS is now required to ensure a real transition path from methane to hydrogen storage, as well as a regulatory and financial framework triggering the necessary investments.

Furthermore, the creation of UHS cannot be left to 'at risk' companies taking uncertain investment decisions. Instead, long-term financial certainty is required, including funding mechanisms, an adequate permitting regime and a clear framework for converting UGS or building new ones. Given the long lead times[8], it will be essential to take decisions now on UHS development to ensure there is adequate storage for a future hydrogen economy.

C. Towards 2040 and 2050: Long-term vision and pathways for UHS

The long-term perspective (2040-2050), with the consolidation of a mature European hydrogen infrastructure, would also require a cross-sectorial assessment to quantify the potential benefits that UHS would deliver for the whole energy system and their contribution to achieving the EU's 2050 energy and climate targets.

[6] Regulation (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022 amending Regulations (EU) 2017/1938 and (EC) No 715/2009 with regard to gas storage

[7] On 1st November 2022, EU gas storage reached 95% of filling level according to GIE's AGSI platform. For more information about the storage transparency platform: https://agsi.gie.eu/

[8] Guidehouse (2021) *Picturing the value of underground gas storage to the European hydrogen system*. Study for GIE, available at: https://www.gie.eu/wp-content/uploads/filr/3517/Picturing%20the%20value%20of%20gas%20storage%20to%20the%20European%20hydrogen%20system_FINAL_140621.pdf