Technical lessons learnt from European pilots

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1: Geostock, France

2: Storengy, France

3: RAG, Austria

4: Uniper, Germany

5: Gasunie, Netherlands

26/05/2023

Acknowledgment

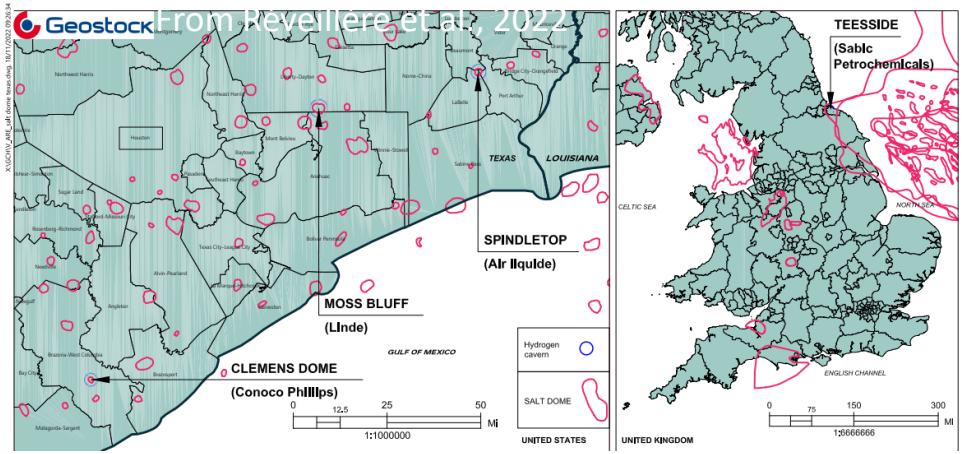
The Project is co-founded by European Union

Current status of pure H2 underground storages

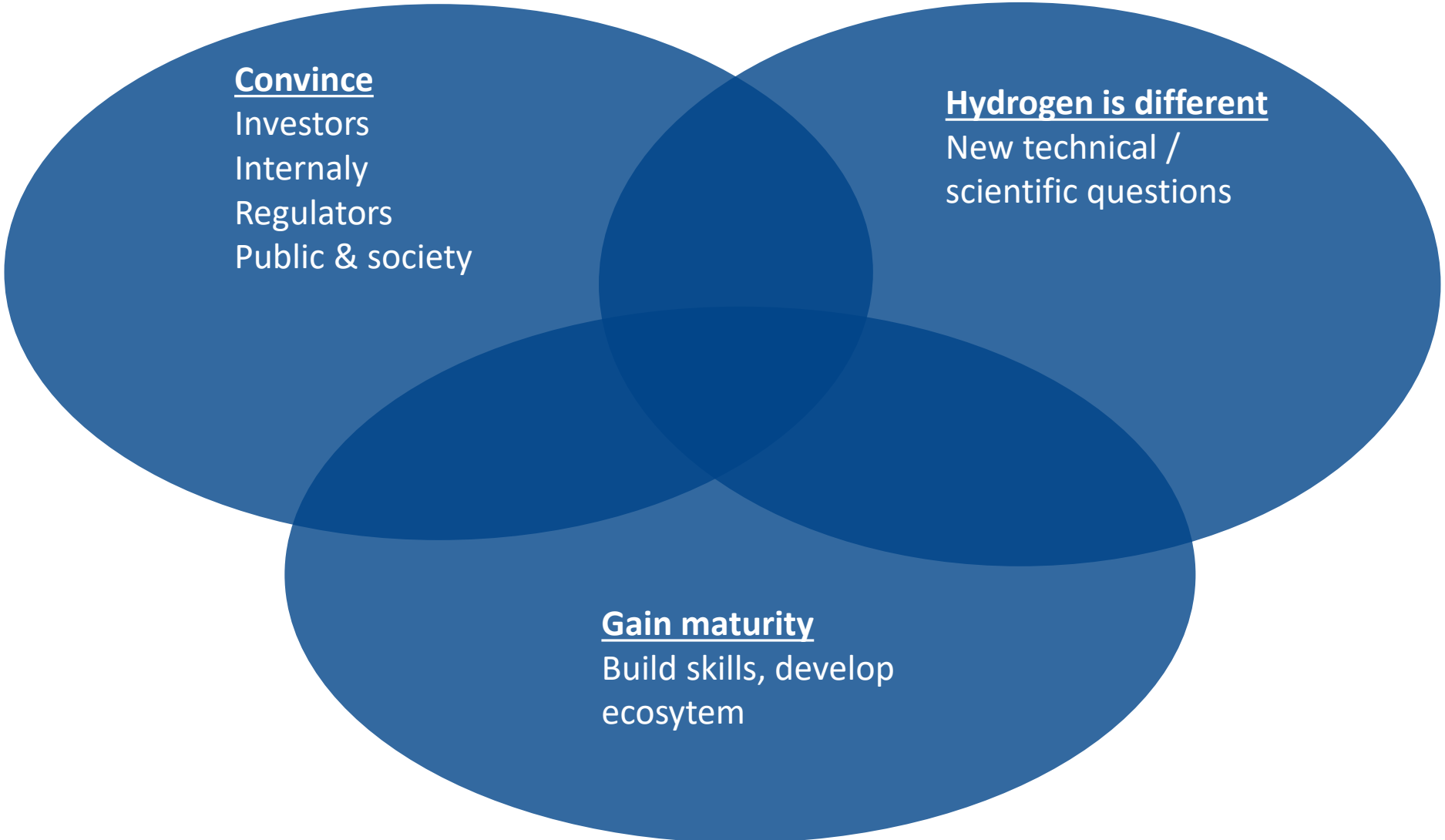
- Industrial projects built/under construction
  - 6 salt caverns have stored H_2, starting 50 years ago
  - 2 industrial caverns beeing leaching in Utah (USA). ACES project

- Pilot projects under construction/testing:
  - 5 in salt caverns (**HyStock**, **HyPSTER**, H2CAST, HyCAVMobil, **HPC Krummhörn**)
  - 1 in depleted field (**Sun Storage 2030**)
  - 1 in lined mined cavern (HyBrit)

- 4 are beeing presented today



Why these pilots ? What achievements/goals ?



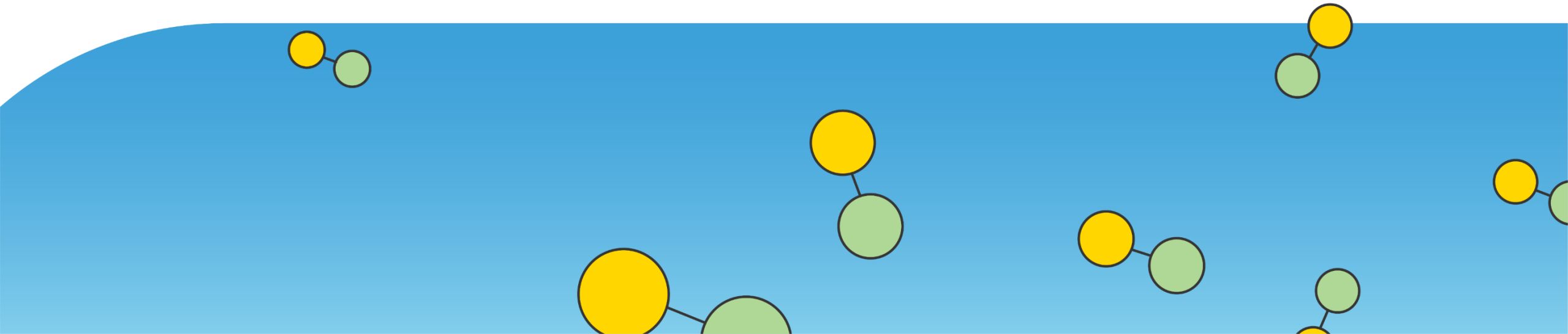
hystock

power to hydrogen

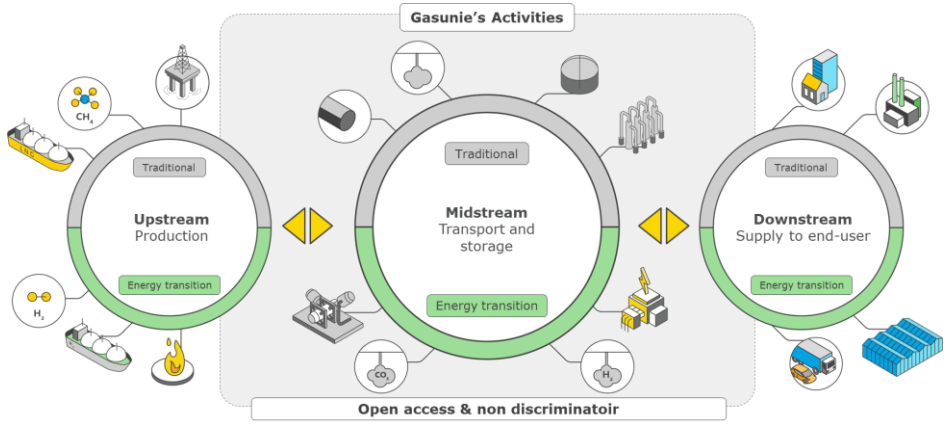
hystories
Hydrogen Storage in European Subsurface

Gasunie: Crossing borders in energy

HyStock: large scale underground hydrogen storage in salt caverns



Gasunie: a European energy infrastructure company

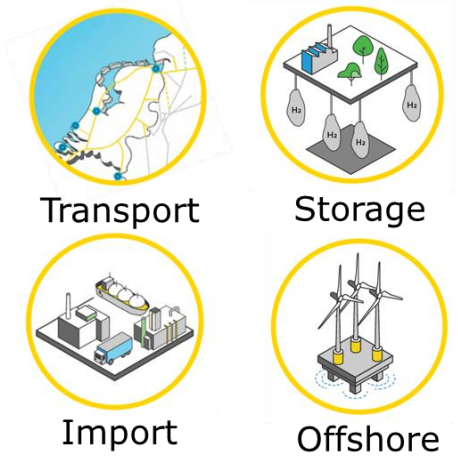


We are a connecting factor in the energy value chain

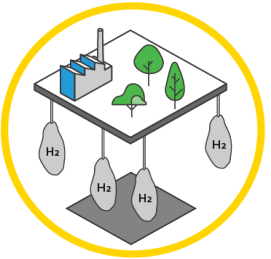
Hydrogen is an essential component to achieve a CO_2-neutral energy supply

- Gasunie ambition is to be driver of the hydrogen market in The Netherlands and Germany.
- Our system is based on principles of open access and non-discriminatoir
- Our role is to develop and to manage the required hydrogen infrastructure fully owned or in partnerships.
- Four focus themes onshore and offshore pipeline transport, underground storage and import terminals.

4 Themes



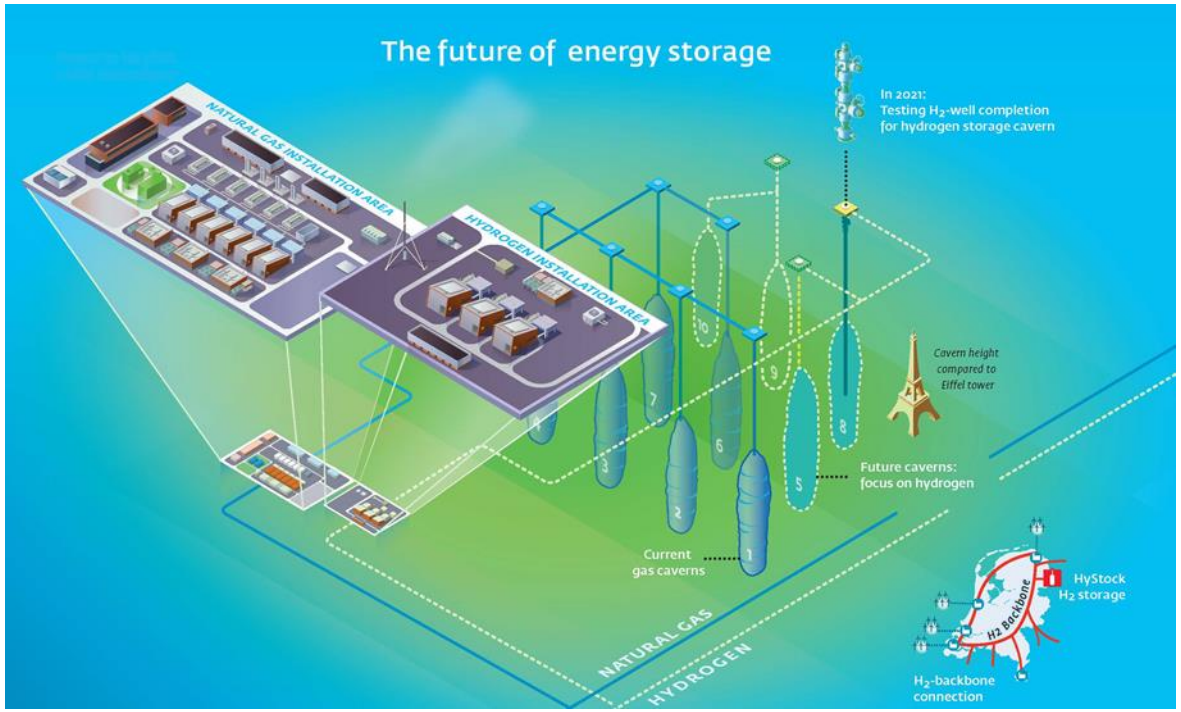
Underground Hydrogen Storage



Storage

Ambition
Develop and manage large-scale modular Underground Hydrogen Storage facilities in The Netherlands and Germany that are connected to the hydrogen networks.

- **HyStock project (The Netherlands)**
  - First salt cavern storage facility (≈ 200 GWh) operational in 2028.
  - Development of (at least) four salt caverns in Zuidwending (NL) for large-scale storage of hydrogen soon after 2030.
- **H2Cast pilot project (Germany)**



website www.hystock.nl

Hystock project – Demonstration project A8 (1/2)

Demonstration project A8

to demonstrate safety, integrity and operational procedures of hydrogen storage making use of an existing borehole.

Started in Q1 2021 and completed in Q4 2022.

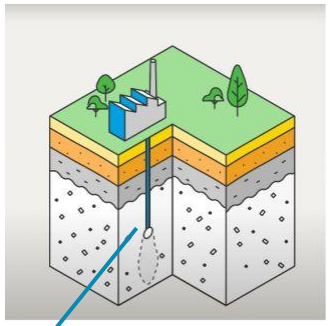
Work package 1

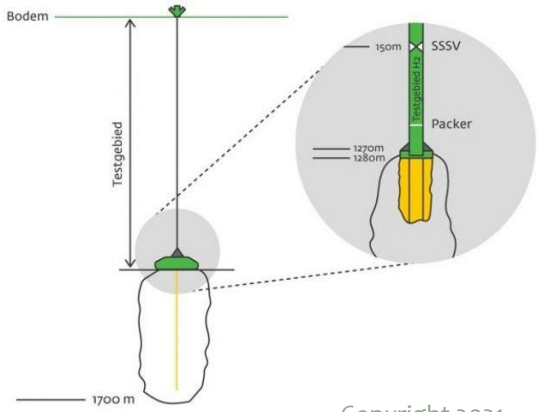
- Development of a generic risk identification methodology for hydrogen storage in salt caverns
- Development of a generic workflow to quantify risks associated with hydrogen leakage from salt cavern storage well

Hystock project – Demonstration project A8 (2/2)

Work package 2

- Design and execute an integrity test to assess integrity of last cemented casing, casing shoe, wellhead and Xmas-tree.
- Verify suitability and technical tightness of the hydrogen storage system under operational hydrogen storage conditions, including:
  - Materials (steel, cement)
  - Components (casing, tubing, wellhead, SSSV)
  - Well intervention equipment (wireline, snubbing)
  - Operational procedures
- Collect samples to support further research and gain insights on the effect and impact of stored hydrogen, including:
  - Geochemical and bacterial
  - Impact on materials





UNDERGROUND SUN.STORAGE

hystories
Hydrogen Storage in European Subsurface

RAG Austria AG

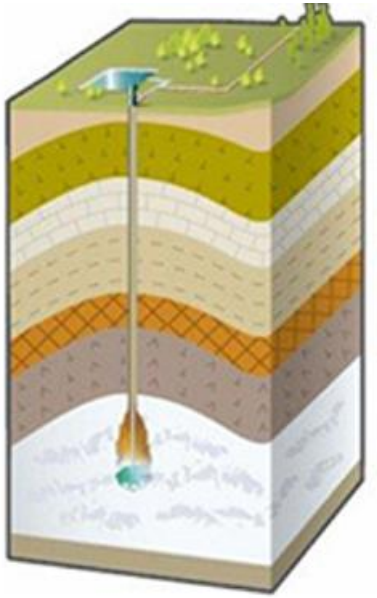
Company Profile and Vision

- Among leading technical Underground Gas Storage operators
- State of the art facilities
- Innovation in energy storage
- Storage volume 66 TWh (6 bcm)
- Unload capacity 30 GW

- Follow the vision to serve the renewables with our existing assets

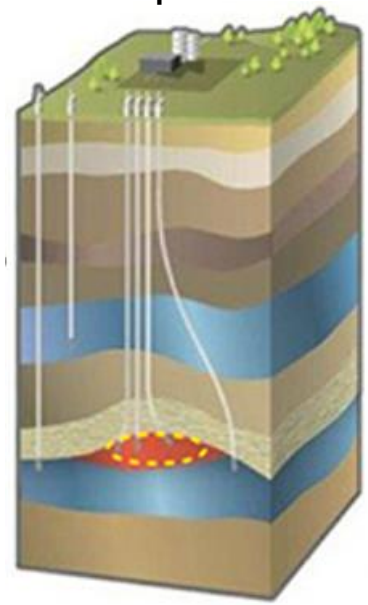
Storage options for Hydrogen

Salt caverns



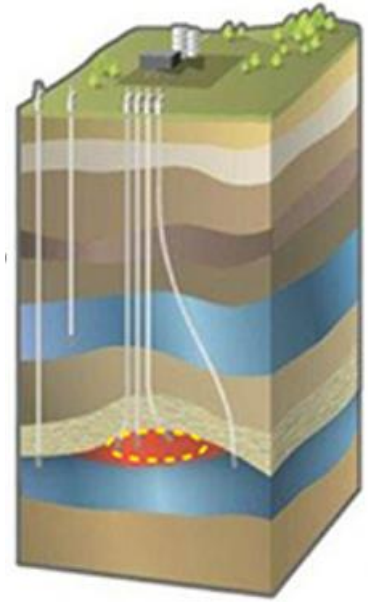
19%

Aquifers



6%

Hydrocarbon reservoirs



75%

Share at EU total volume of existing UGS

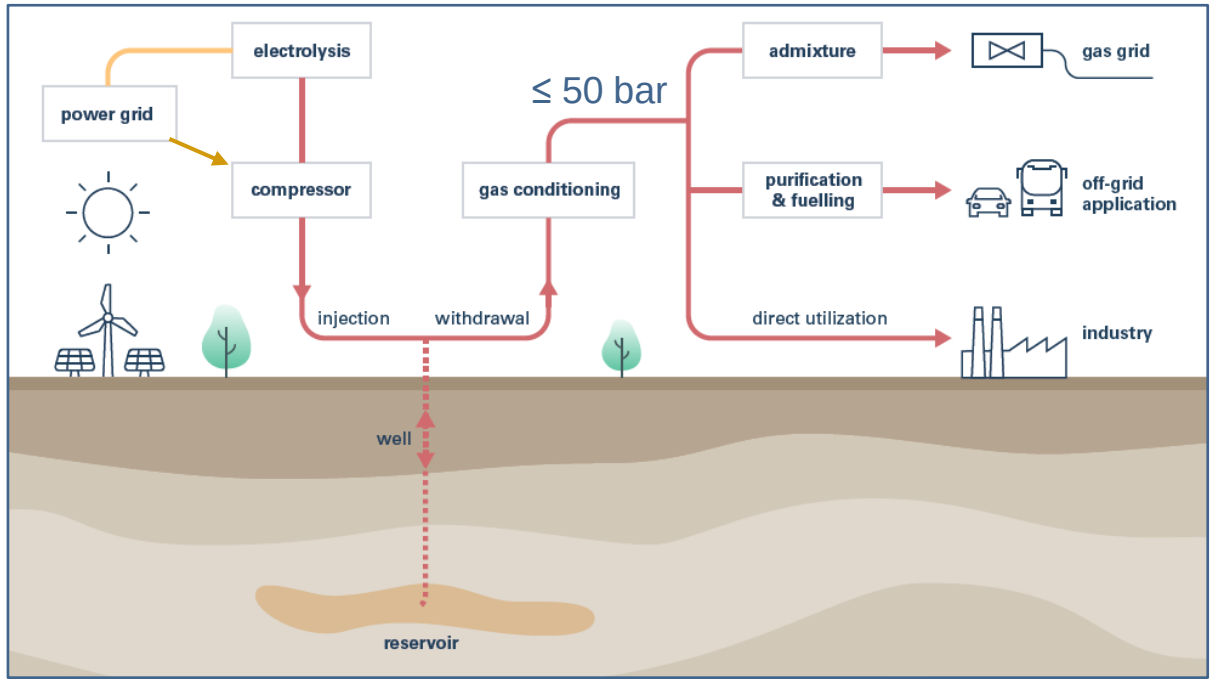
RAG – Hydrogen Storage Project overview

Abb.	Full titel	timeframe
USS	Underground Sun Storage	07/2013 – 06/2017
USS2030	Underground Sun Storage 2030	03/2021 – 02/2025
USC	Underground Sun Conversion	03/2017 – 02/2021
USC-FlexStore	Underground Sun Conversion – Flexible Storage	12/2020 – 05/2023
C-CED	Carbon – Cycle Economy Demonstration	07/2021 – 06/2025
HyStorIES	Hydrogen Storage in European Subsurface	01/2021 – 12/2022
HyUsPRe	Hydrogen Underground Storage in Porous Reservoirs	10/2021 – 01/2023
SERVARE	Seasonal storage in an optimal regulatory framework by assessing various opportunities	10/2022 – 09/2023

UNDERGROUND SUN.STORAGE

Demonstration Project

RAG AUSTRIA AG



- Depleted natural gas reservoir
  - TOV: 1.2 Mio Nm³
  - ~1000 m depth, sandstone
  - 75 bar hydrogen pressure
- 2 MW water-electrolysis (PEM)
- Integration into RAG plants in 2023
  - newly built 8 km Hydrogen Pipeline

    (PN70 operating pressure ≤ 50 bar)
  - Hydrogen CHP
  - Green Heat & Power for RAG winter demand

Partner: axiom, BOKU Universität für Bodenkultur Wien, ENERGIE AG Oberösterreich, ENERGIE INSTITUT an der Johannes Kepler Universität Linz, EVN, HyCentA Hydrogen Center Austria, K1 MET metallurgical competence center, TU WIEN Technische Universität Wien Vienna University of Technology, Verbund, voestalpine EINEN SCHRITT VORAUS., WIVA P&G Energy Model Region

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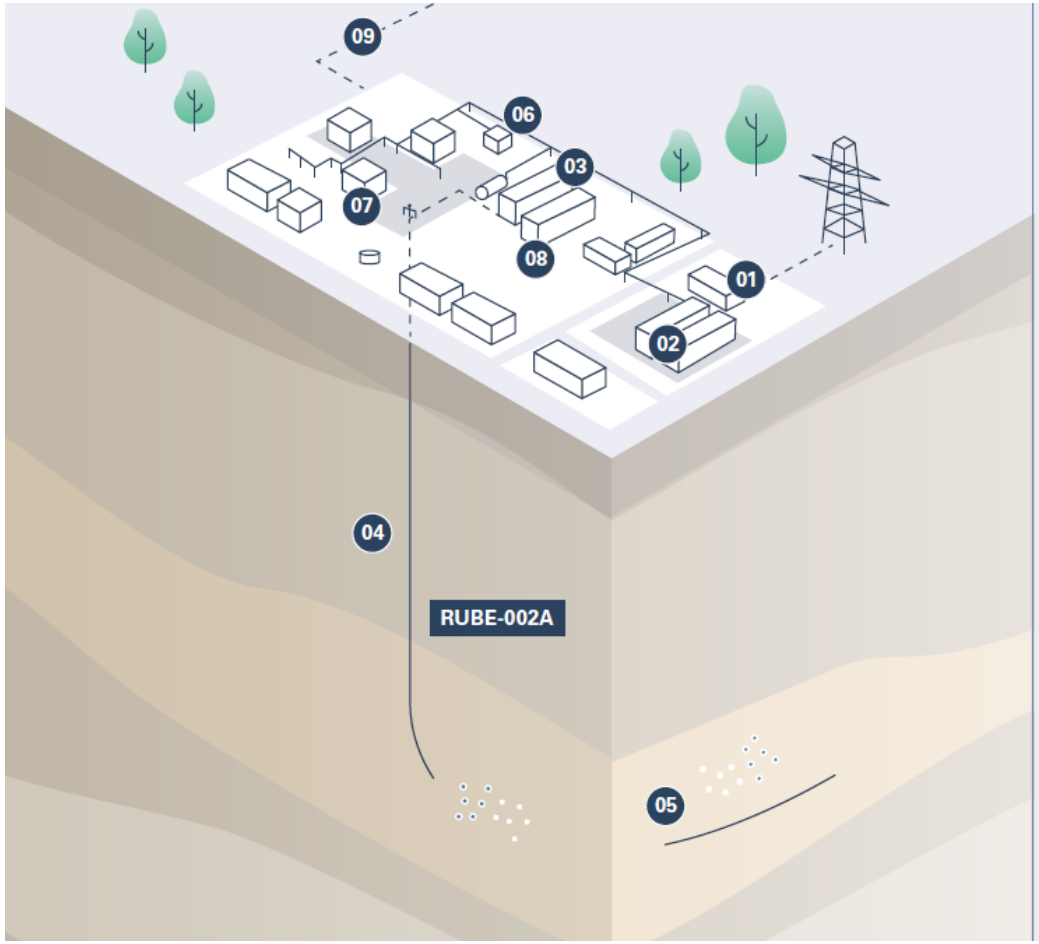
Underground Sun Storage - Impressions

UNDERGROUND
SUN.STORAGE

Plant Overview



01 Trafostation
Transformer station

02 Elektrolyseanlage
Electrolysis

03 Verdichteranlage
Compressor unit

04 Sonde
Well

05 Sandstein-Poren-Lagerstätte
Sandstone-Gas-Reservoir

06 Gastrocknung
Drying unit

07 Gasqualitätsmessung
Gas quality measuring

08 Wasserstoffaufreinigung **11/2023**
Hydrogen Purification

09 Wasserstoffleitung
Hydrogen pipline

Objectives

- Interseasonal energy storage solution
- Proof of technical feasibility
- Alignment between results from lab experiments and field test
- Development and demonstration of hydrogen purification
- Modelling of the Austrian energy system – storage demand
- Use case consideration and development of associated services

RAG Austria AG

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hypster

Hydrogen Storage

hystories

Hydrogen Storage in European Subsurface

HyPSTER stands for Hydrogen Pilot STorage for large Ecosystem Replication

- Project start date: January 2021
- Location : Etrez (Ain 01) | France
- H_2 Production: Electrolyzer (1 MW)
- Storing capacity: 3 tons H_2 (exp. phase)
- Total budget: 13 M€ (5M€ funding)
- End of the Pilot Phase: 2024
- Perspective Phase II: 44 tons H2 (2025)

Description: Test industrial-scale renewable hydrogen production and storage in salt caverns supported by technical and economic reproducibility of the process to other sites throughout Europe.

9 partners, 4 countries

Consortium Partners

H2 & Subsurface expertise

storengy, ARMINES, BROUARD CONSULTING, ESK

Regulation & Safety

INERIS

Storage replication potential

inovyn, storengy

Technical and economic assessments

elementenergy

Bacteriology Purification

equinor

Communication

axelera

Coordination

storengy, elementenergy

2 Strategic partnerships

Schneider Electric, TechnipFMC

Hypster is a project co-funded by the European Union's Horizon 2020 Programme through the Fuel Cells Hydrogen Joint Undertaking (FCH-JU), now Clean Hydrogen Partnership, under grant agrement number 101006751

HyPSTER project is divided into two parts

Renewable Hydrogen Production

- Electrolyzer 1MW
- Water
- Electricity
- Hydrogen transportation by tubes trailers

Pilot of Hydrogen Storage in salt cavern

- Use of an existing cavern
- Tightness tests
- Pressure variation cycles

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Situation map: Etrez UGS

Etrez NG Storage facilities

Planned H_2 Production Platform

EZ53 Cavern Platform

Hypster is a project funded by the European Commission - Project Number : 101006751

Detailed Design – 3D layout

Electrical substation (including General PLC)

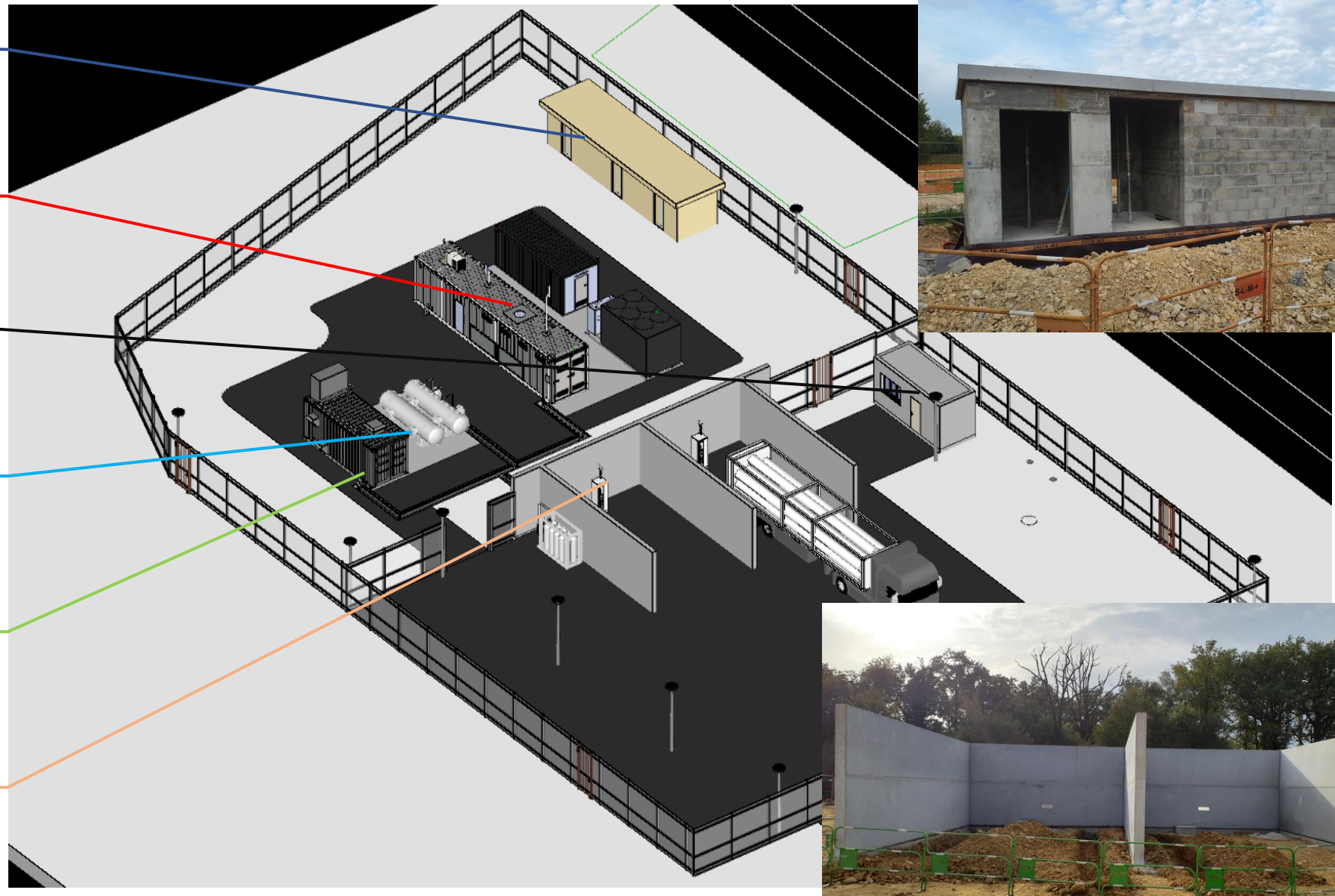
Electrolyzer package

Supervision

Buffer tank

Compressor

Tube trailer Filling station



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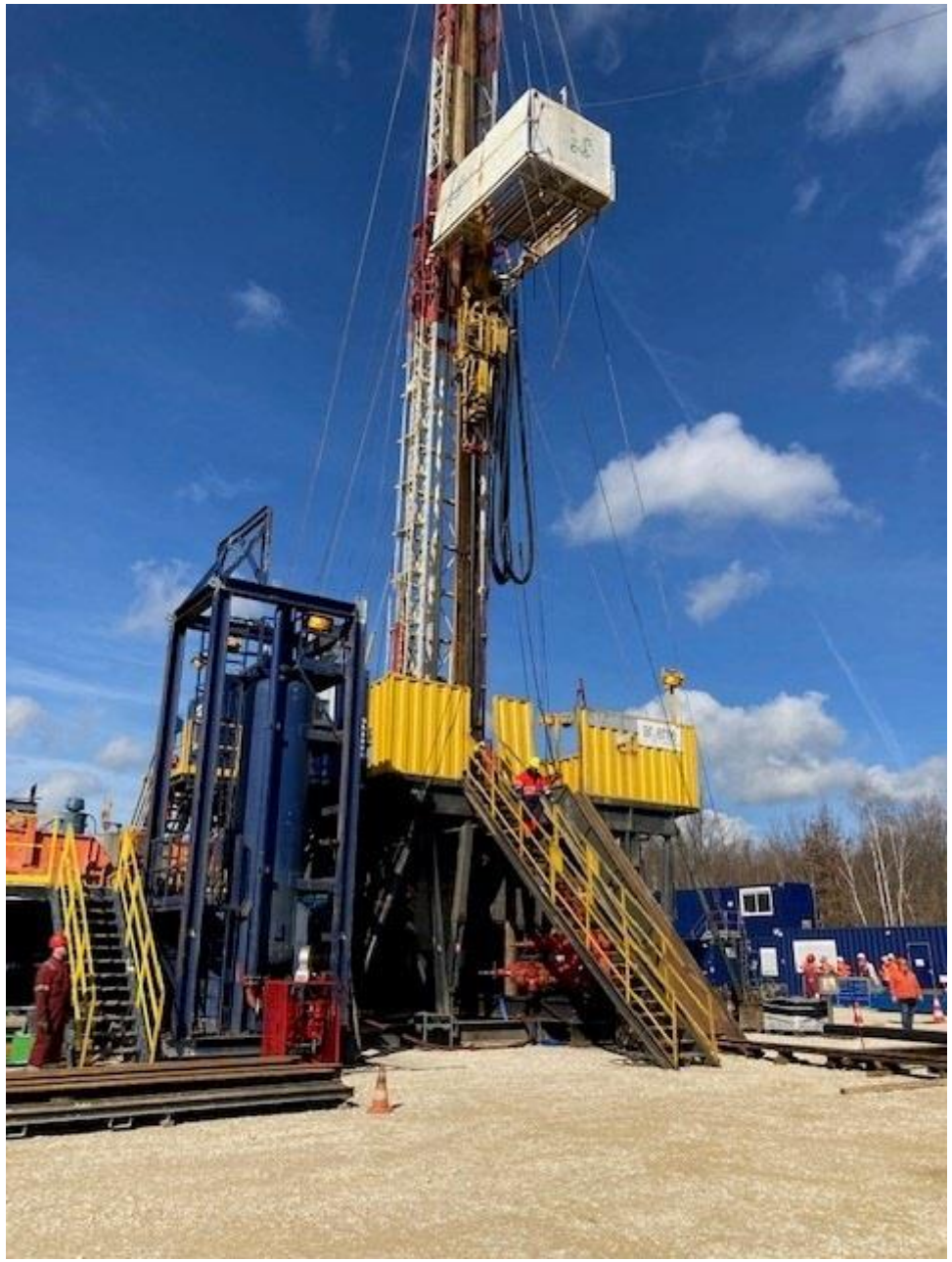

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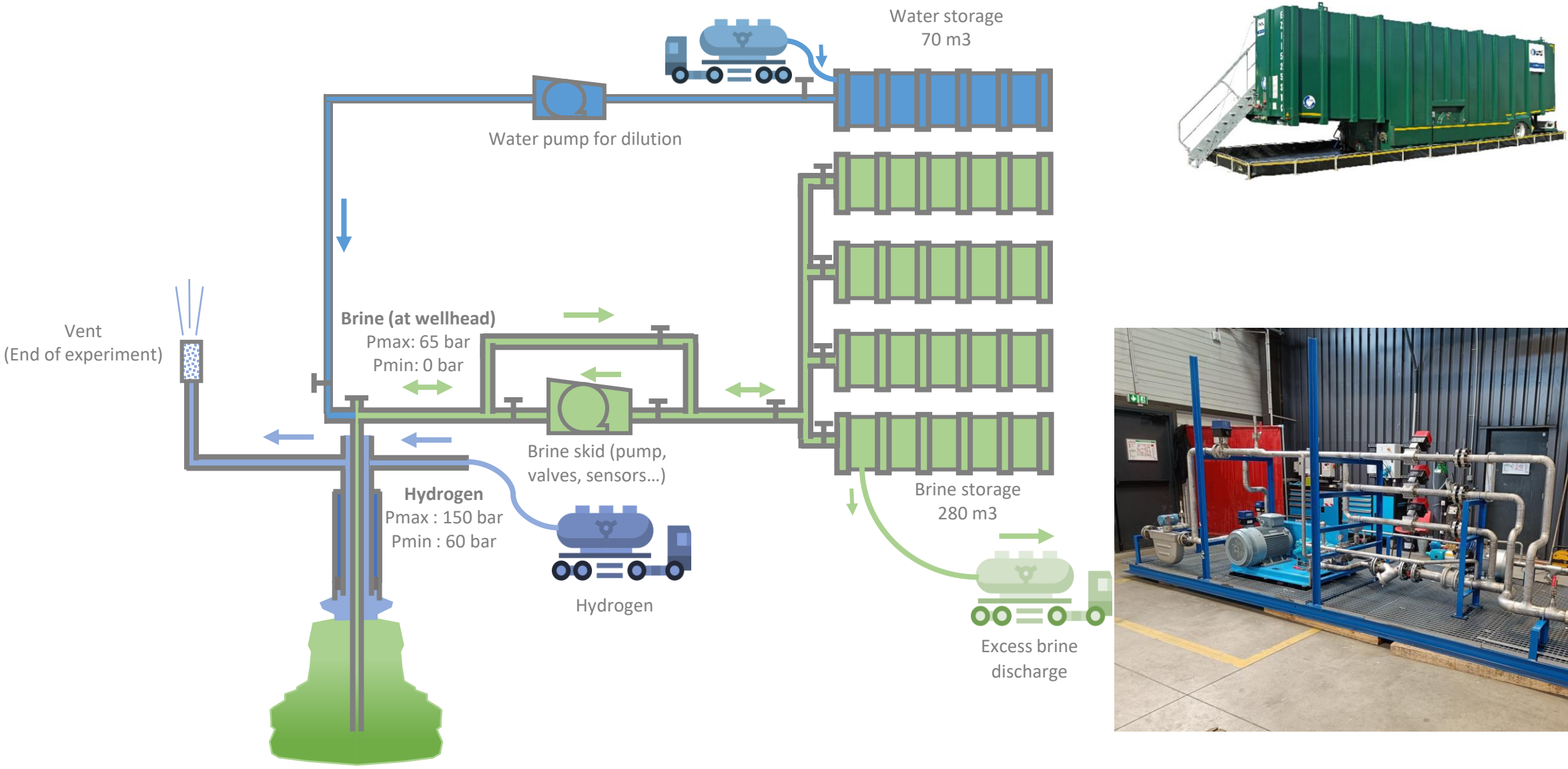
EZ53 platform: principle diagram



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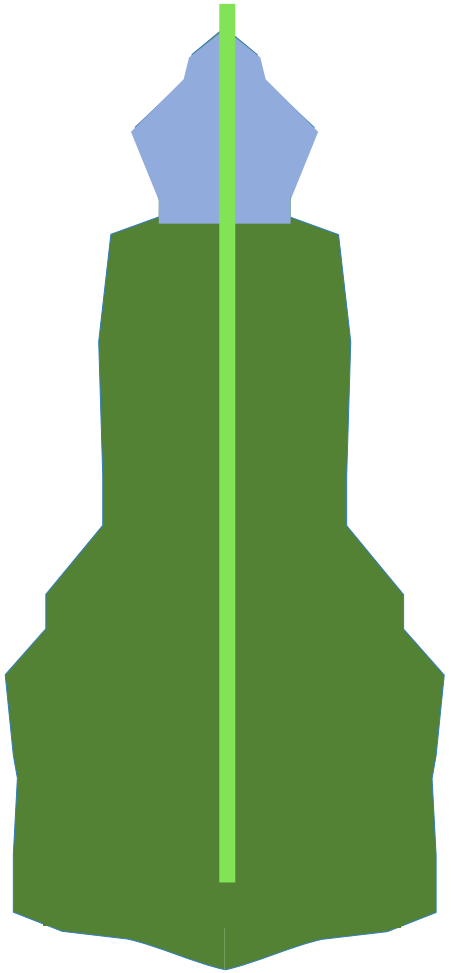
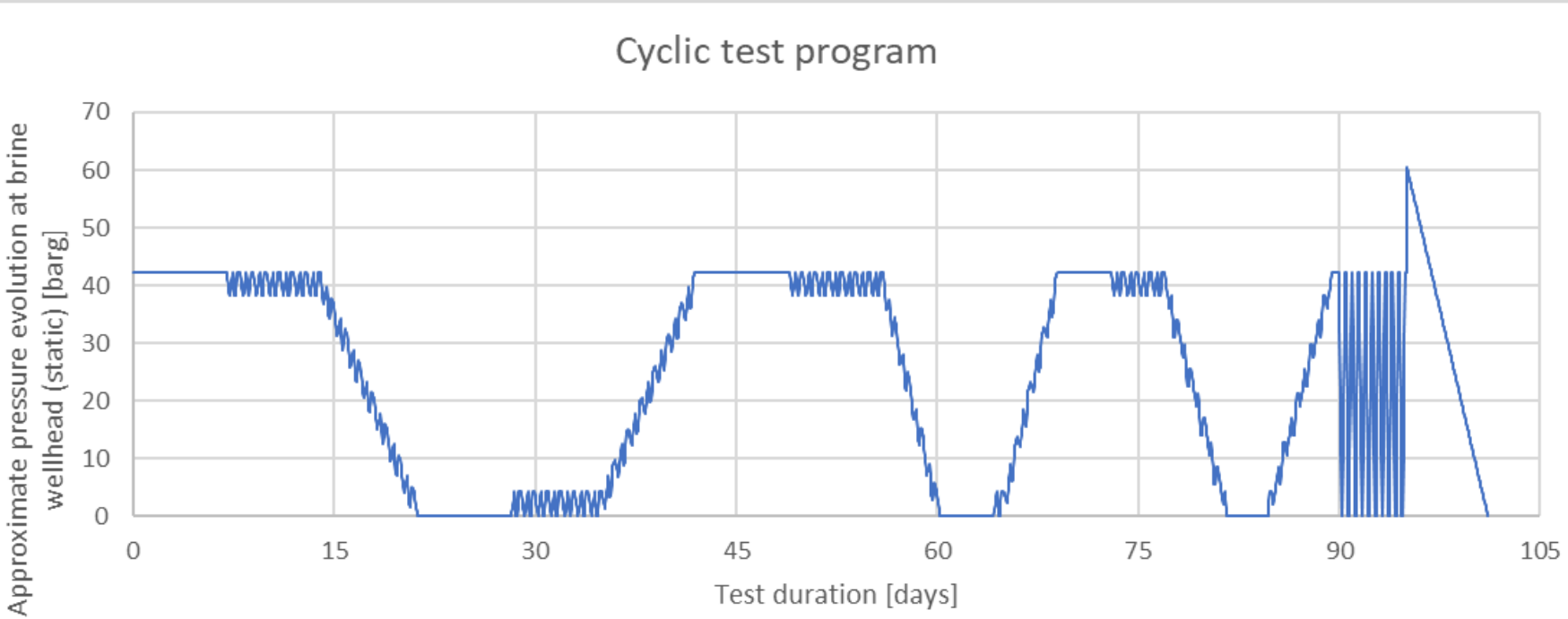
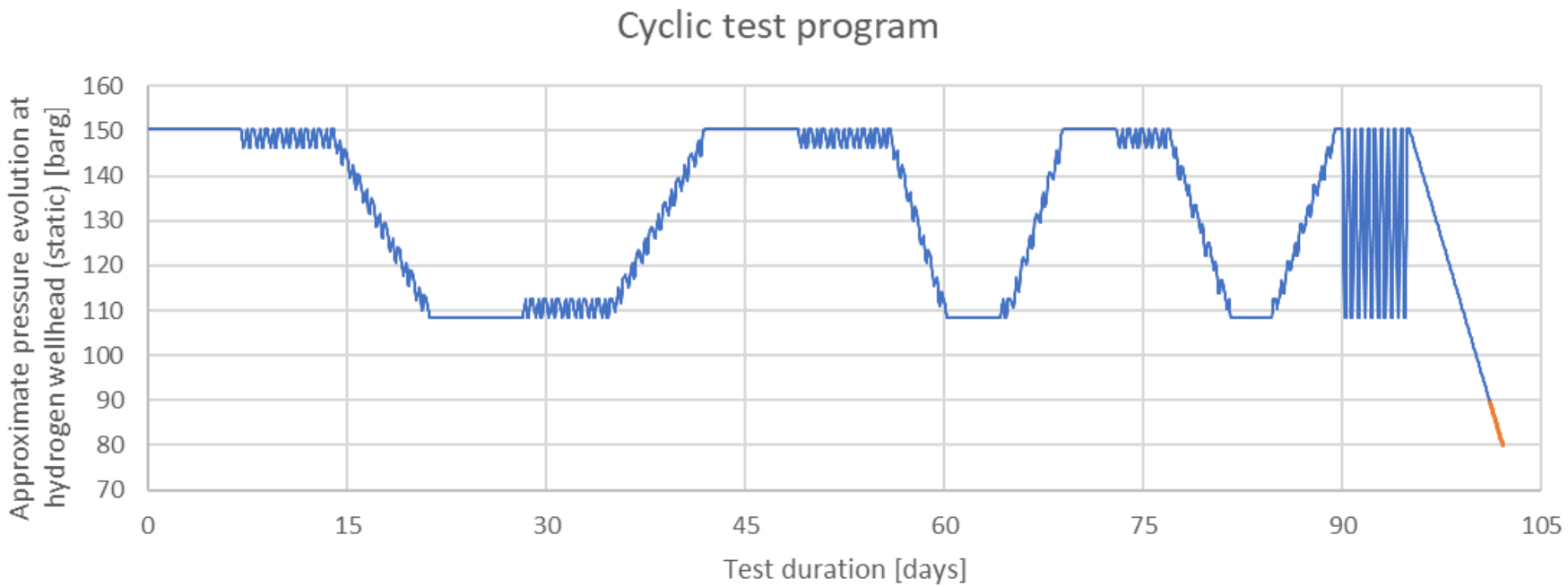
Cycling tests



Brine

H_2





Hypster is a project co-funded by the Europe
agrement number 101006751

HPC Krummhörn

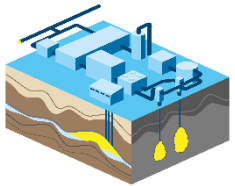
hystories
Hydrogen Storage in European Subsurface

HPC- Hydrogen Pilot Cavern (Krummhörn, GER)

Myriam Panofen & Annette Lenze

Hystories – final conference,
Paris, 25th May 2023

Uniper Energy Storage – at a glance

= 9 x  4 x  > 80 TWh 

Energy Storage

Gas Storage facilities in GER, UK & AUT

Connected Market areas

Total gas storage capacity

Market leader:

We are the **largest gas storage operator in Germany** and one of the most efficient in Europe.

Energy transition:

We are essential for the energy transition because we **guarantee the necessary flexibility** for the renewable energy system.

Hydrogen:

Uniper Energy Storage has a **great potential** for storing hydrogen in Europe.

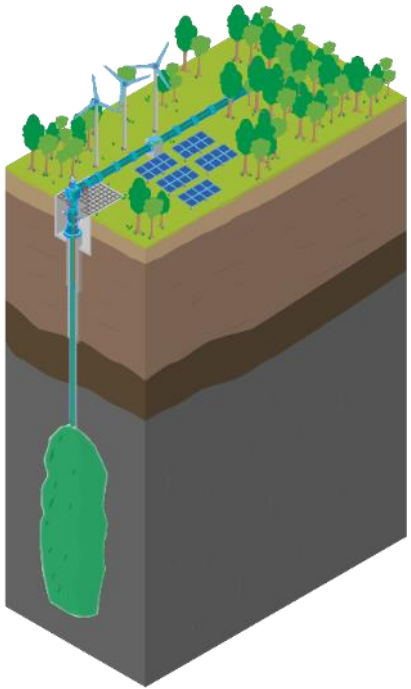
Security of supply:

Natural gas storage facilities are an **indispensable component** for security of supply - today and in the future.

Climate neutrality:

We are **proactively developing** our operations, our systems and our products towards climate neutrality.

HPC- Hydrogen Pilot Cavern



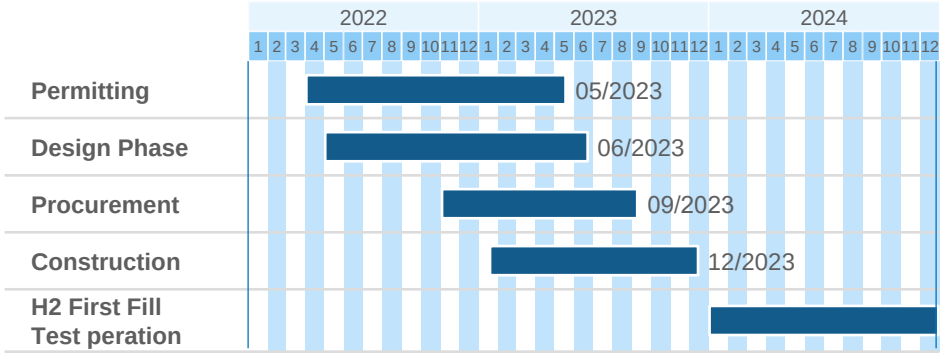
Hydrogen

Uniper Energy Storage GmbH will build an H2 pilot cavern at its site Krummhörn until 2024 to demonstrate and investigate hydrogen storage in a salt cavern.

Motivation for Uniper Energy Storage GmbH

- **Testing of H2 storage** operation and technology in a **real environment** at a demonstration plant
- Understanding of **permitting process** and requirements
- **Investigation of materials**, subsurface and surface installations and the functionality of individual components in H2 storage operation
- **Development** of a storage solution for green **hydrogen** on a **commercial scale**.

H2 pilot cavern – project key data

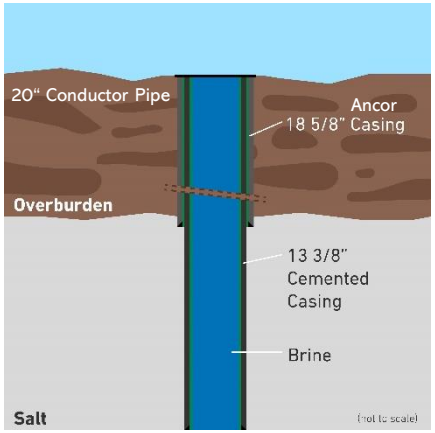


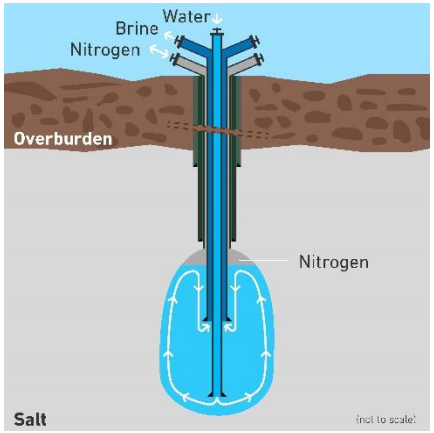
Project Key Data

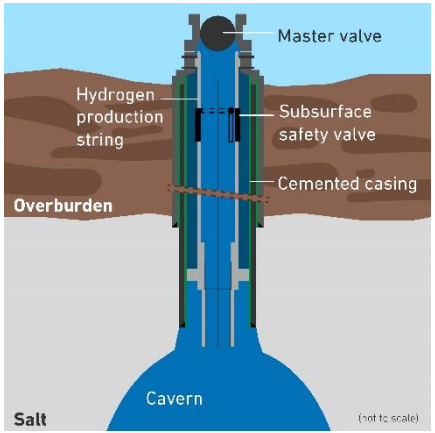
- Geom. Cavern Volume: 1 000 m³
- Pressure Regime: 70 – 270 bar
- H2 Capacity: 200 000 nm³ = 700 MWh
- H2 Working Gas Capacity: 150 000 nm³ = 500 MWh
- Max. Flow Rate: 1 200 nm³/h

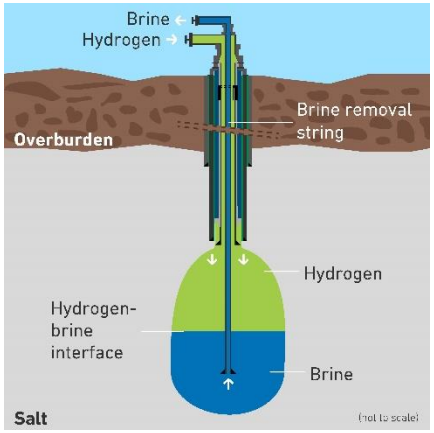
Technical project phases

Existing Borewell	Leaching Phase	Cavern H2 Completion	H2 First Fill









Investigation of existing well – cased hole

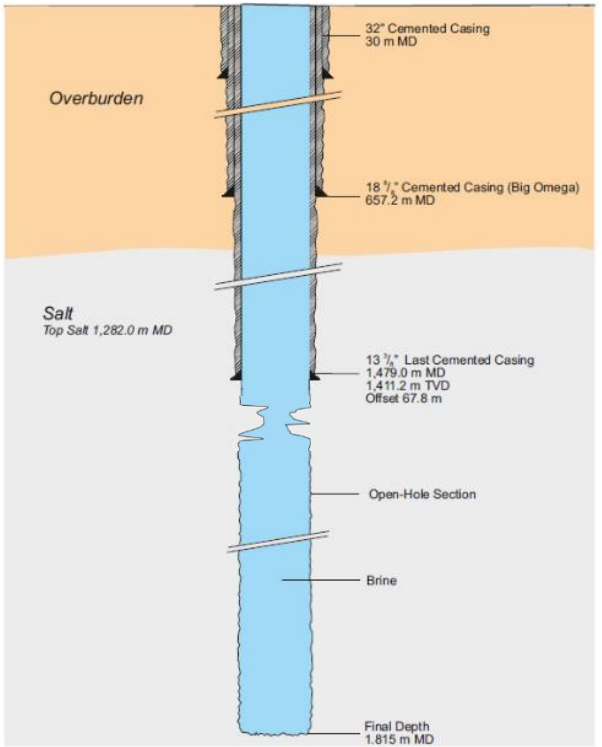
Cased hole section

- Inspection / exchange of wellhead components ☑
- Caliper Log: investigate casing geometry ☑
- USIT Log: investigate casing / cement quality ☑
- Laboratory investigation*: H2 readiness of cement ongoing
- Laboratory investigation*: H2 readiness of casing ongoing

*** Procedure and test performance verified by third party**

DNV

Investigation of the suitability of the last cemented casing as second barrier.



Investigation of existing well – open hole

Open hole section

- Re-drilling of open hole section to:
  - Re-access of the borehole
  - Obtain a uniform borehole width.
- Borehole survey.
- Install test* / leaching wellhead.
- Install test* / leaching tubings.

*** H2 readiness of test equipment proven.**

Two-stage gas tightness test

Gas tightness test

- Tightness test with In-situ-Balance method with test medium nitrogen to;
  - Verify integrity of second barrier
  - Verify integrity of casing shoe area
  - Provide basic requirements for leaching phase.

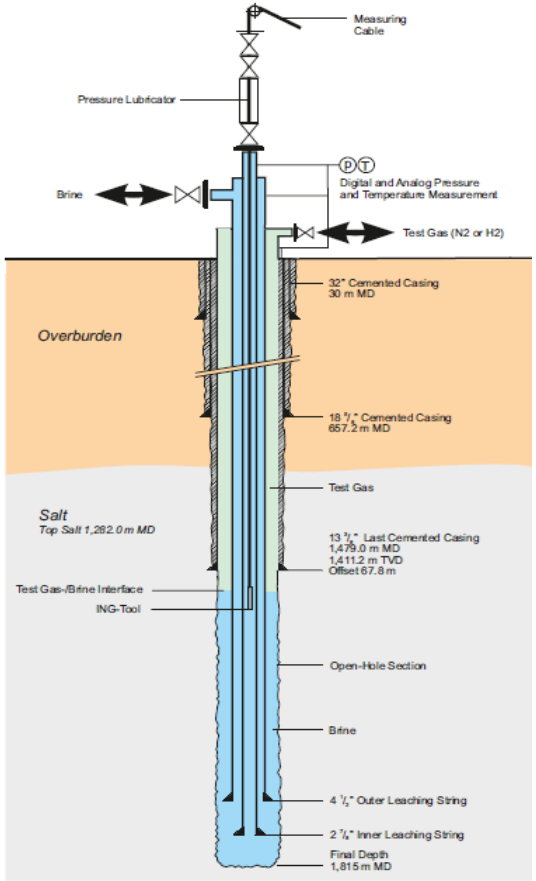
- Analog tightness test with test medium hydrogen* to;
  - Verify H2 readiness of second barrier
  - Verify H2 integrity of casing shoe area
  - Provide first indication for cavern´s suitability for hydrogen storage.

ongoing

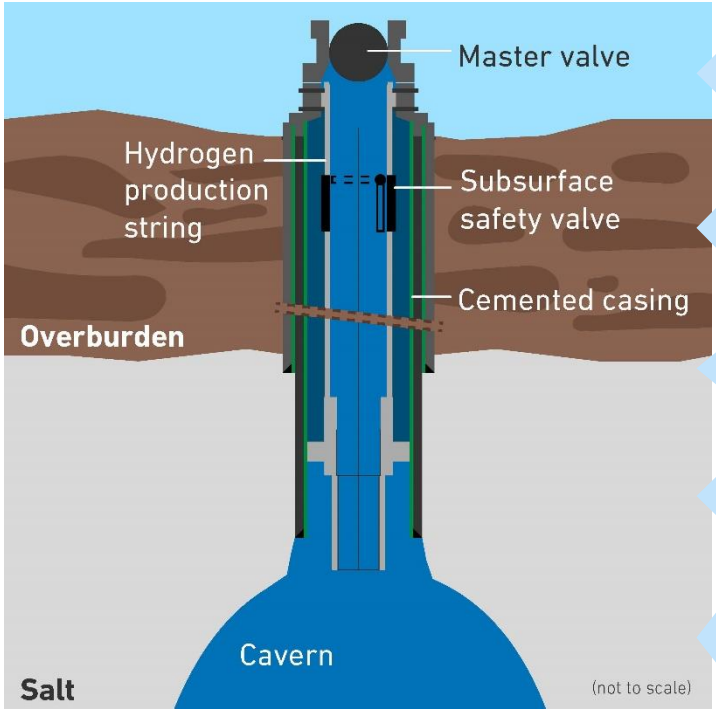
*** Test Procedure and criteria verified by third party.**

DNV

- Previous HAZOP / operational training for handling hydrogen.



H2 test operation, investigation program



Material tests for hydrogen readiness
- Investigation of subsurface installations.
- Investigation of casings / tubings, plastics, polymers (laboratory tests, tests in situ).
- Investigation of special subsurface components (Packer, SCSSSV, etc.).

Services
- Application of typical E&P Services under hydrogen-atmosphere.
- Investigation of feasibility to perform services like surveys, snubbing-works, integrity tests, etc. in hydrogen caverns.

Quality of withdrawn hydrogen
- Determination of H2 quality during injection / after withdrawal.
- Investigation of chemical / microbial alternating effects of the hydrogen.

Thermodynamics, simulation of process parameters
- Determination of the cavern temperature behavior in different operating scenarios.
- Checking / calibrating the operating simulation software.

Rock Mechanics
- Testing of different pressure regimes and injection -/ withdrawal cycles.
- Cavern contour control by sonar survey.

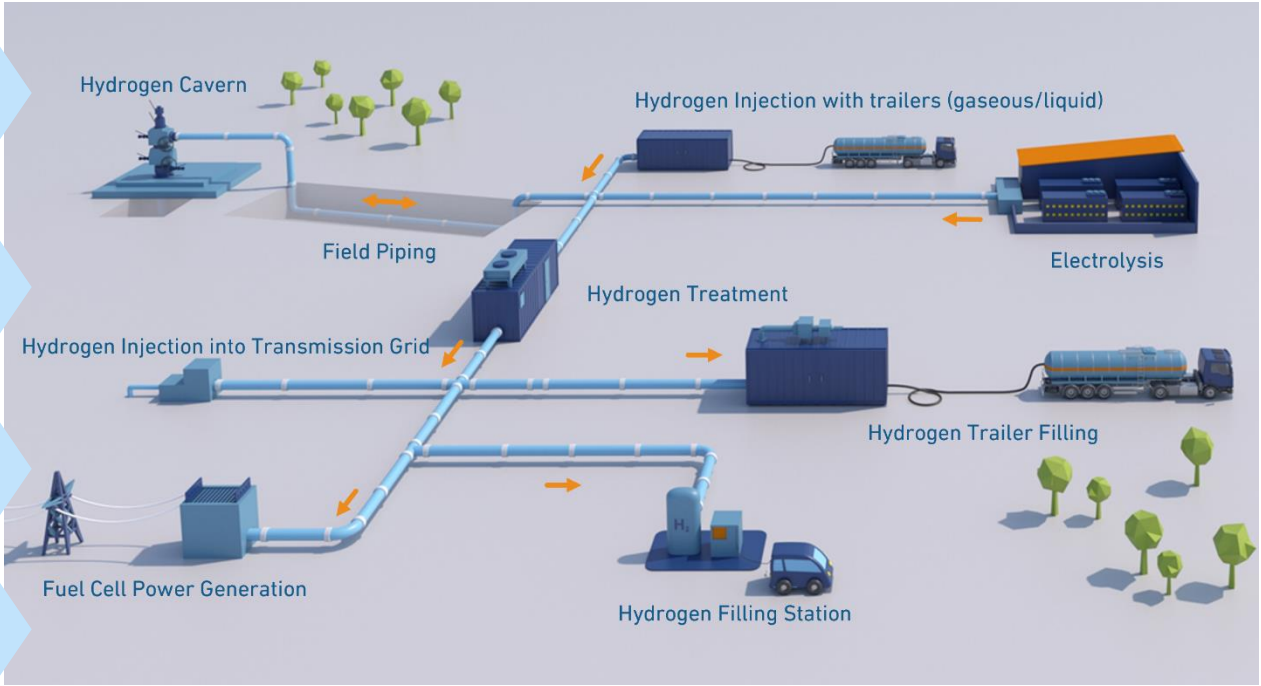
Surface installations

Hydrogen injection
- Supply of liquid hydrogen via truck, evaporation on site.
- Supply of gaseous hydrogen by electrolyzer (partnership), compression on site.

Hydrogen treatment
- On site hydrogen treatment to supply various end users.
- Test and comparison of different hydrogen drying technologies (partnership).

Hydrogen use cases
- Injection into transmission grid, liquefaction and filling, fuel cell power generation and hydrogen filling station (partnership).

Field piping
- Existing field pipeline must be qualified for the use of hydrogen.



Thank you!

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https://www.uniper.energy/energy-storage-uniper

Technical lessons learnt from pilot projects

Panel discussion

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Hydrogen Storage in European Subsurface

Hystories project consortium

Geostock

ludwig bölkow systemtechnik

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FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

Mineral and Energy Economy Research Institute
Polish Academy of Sciences

Acknowledgment

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007176. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

The Project is co-founded by European Union

Clean Hydrogen Partnership