Uniper Energy Storage -
H2 Readiness of surface installations on natural gas storages

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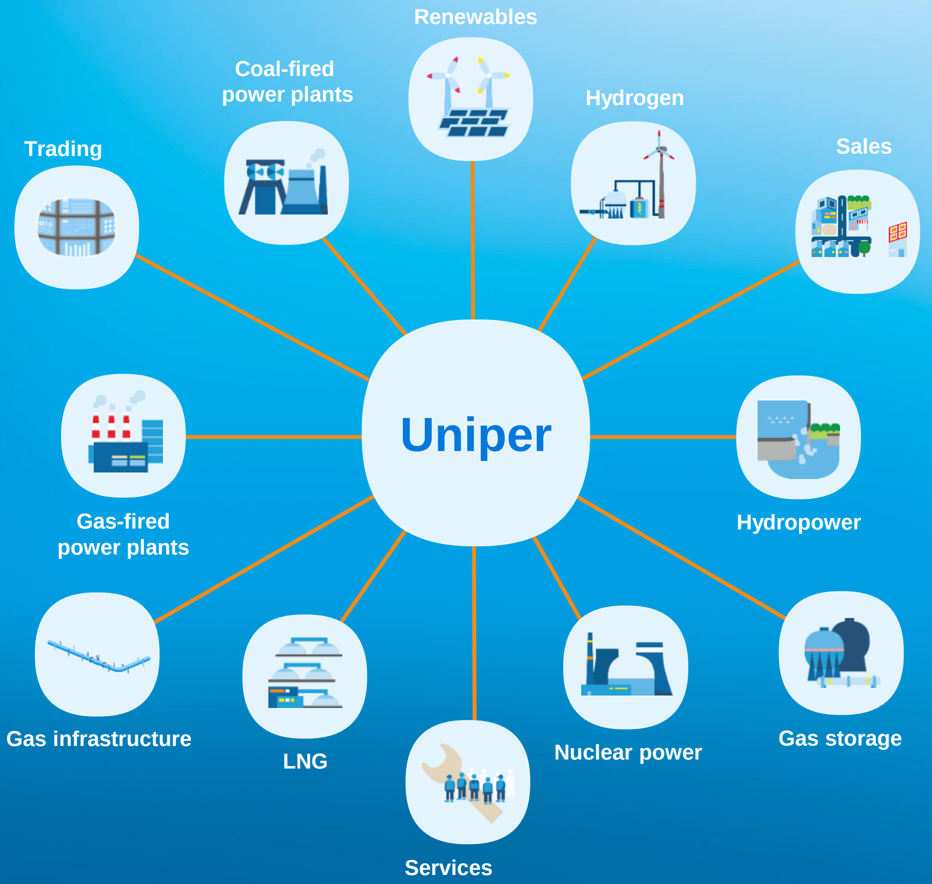
At a glance

7,000 employees ensure security of supply in Europe

Active in more than **40** countries

~ 22.5 GW generation capacity



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Uniper Energy Storage GmbH

- Unbundled gas storage system operator (SSO) in accordance with German and European regulatory law.
- Largest SSO in Germany, 4th largest SSO in Europe with 8.2 bn m3 WGV.
- Construction and operation of underground gas storage facilities.
- Development of new energy storage technologies;

  2013 H_2 electrolysis Falkenhagen in operation

  2016 H_2 electrolysis Reitbrook in operation

  2018 Methanation Falkenhagen in operation

  2024 Commissioning of first H_2 cavern in Krummhörn planned.

Decades of experience in gas storage

1926	2003	2008	2016
ruhrgas	e·on Ruhrgas	e·on Gas Storage	uniper

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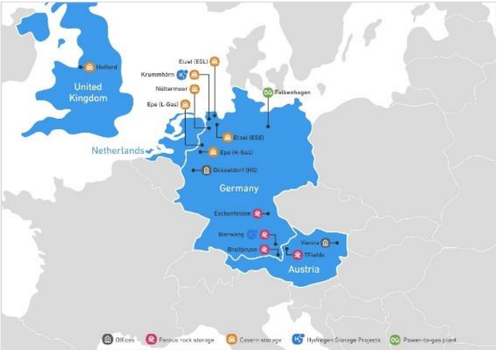

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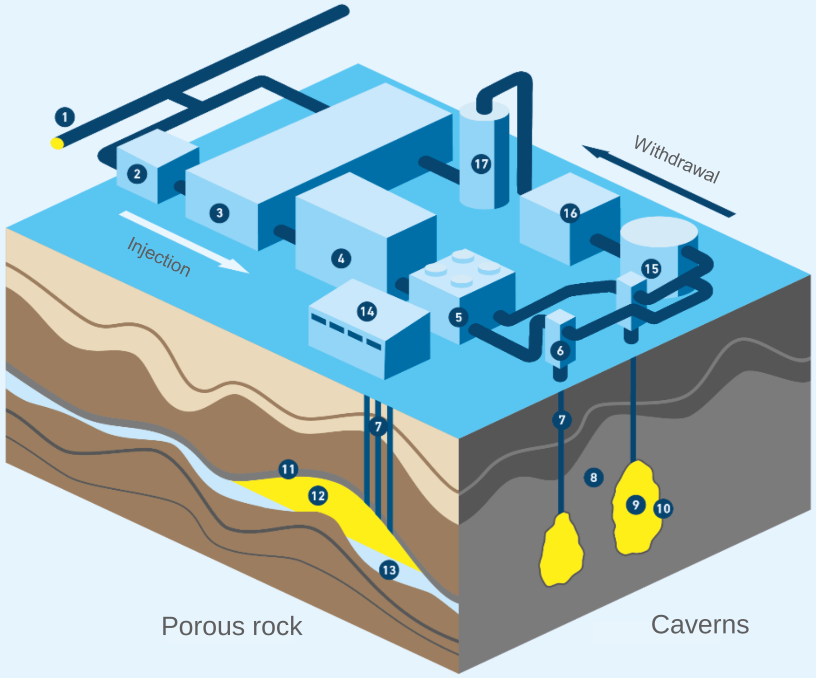
How natural gas is stored



1. Gas transmission system
2. Filters
3. Metering station
4. Compressor station
5. Cooler
6. Well head (on each well)
7. Well
8. Salt formation
9. Caverns
10. Cavern wall
11. Gas-tight caprock
12. Gas-bearing section
13. Water-bearing section
14. Control room
15. Preheating system
16. Pressure let-down system
17. Dehydration unit

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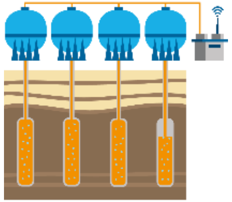
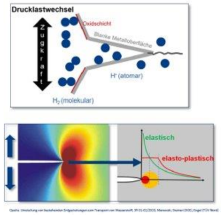
General aspects
- Storage is not transportation -



High pressure (> 200bar) essential for energy storage application
→ Maximization of storage capacities due to limited volumes

vs.

Hydrogen partial pressure as the key driver for integrity issues



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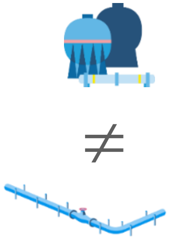
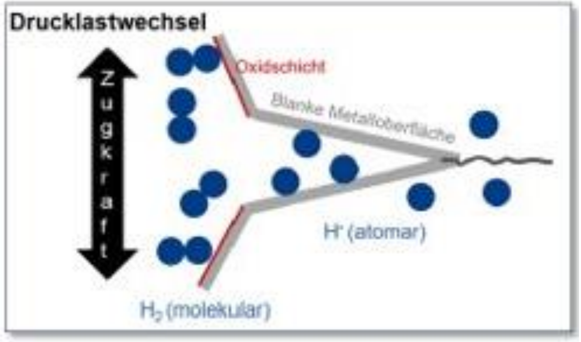
existing regulation insufficient for storage process conditions
→ focus on gas transport applications

vs.

Gas storage process conditions not comparable to transportation grid



Hydrogen diffusion
- understand the capabilities of your equipment -

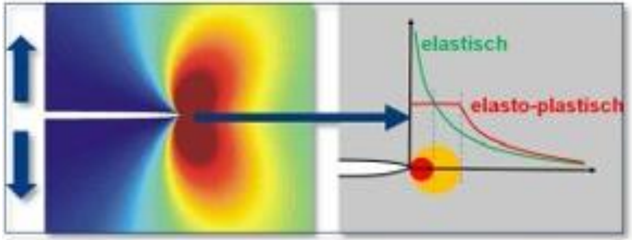


- Hydrogen smallest molecule known

  → Diffusions can not be avoided, only slowed down
- Diffusion into material possibly resulting in change of mechanical properties
- Tightness to atmosphere as well as component internals in focus
- Integrity important for detachable connections and process control e.g.
  - Flanges
  - Valves
  - Process Equipment e.g., vessels, heat exchangers
  - Instrumentation e.g., pressure sensors
- Hydrogen with major influence on process safety and process integrity.

→ Clear picture about the capabilities of installed equipment essential

Hydrogen embrittlement
- understand your material problems -



Hydrogen Embrittlement

Main damaging mechanism

- Result of diffusion of hydrogen into the material
- Saturation of the microstructure with hydrogen cannot be prevented (Concentration gradient).

Degree of embrittlement influenced by

- Amount of hydrogen absorbed
- High strength (high hardness level), grain boundary particles or inclusions can result in increased susceptibility to embrittlement.

Sufficient stress on embrittlement object or area leads to material cracking and failure

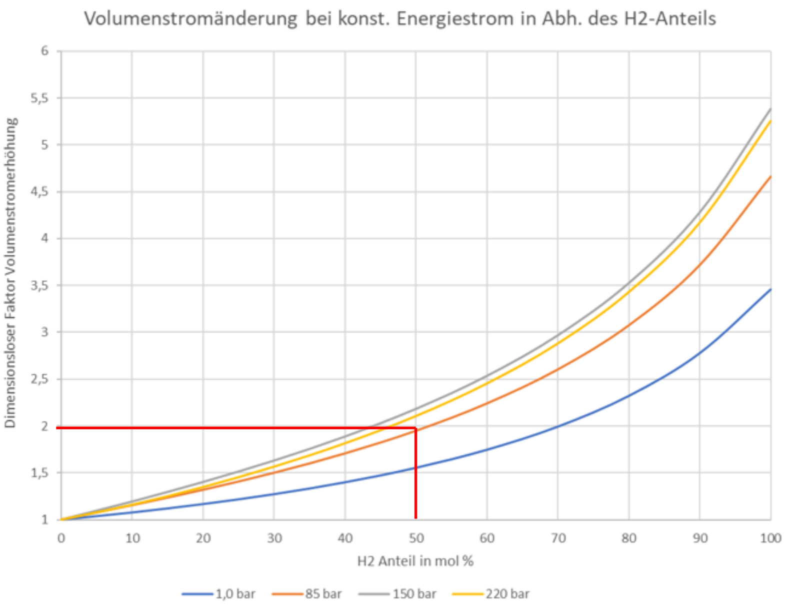
EIGA* standard IGC Doc 121/14 “Hydrogen Pipeline Systems” sets material requirements for equipment used in H2 atmosphere.

→ **Detailed information about installed material properties essential.**

*European Industrial Gases Association

Influence of gas parameters on plant technology
- understand your process -

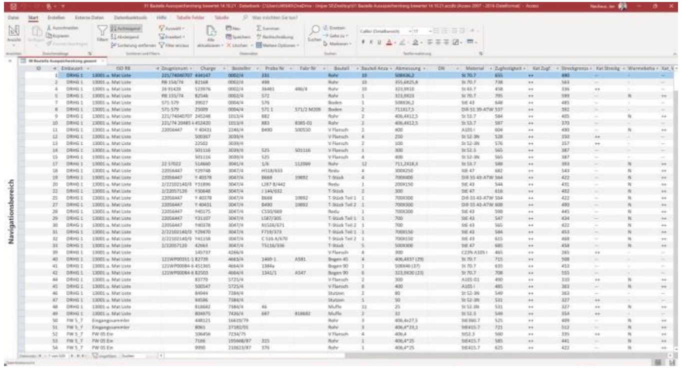
Gas quality	Decrease in molar mass, density, heating and calorific values with increasing H2 contents.
Amount of energy	In order to keep the energy quantity constant with increasing H2 fractions, larger volume flows are required.
Geometry	Due to existing pipeline and equipment cross-sections, flow velocities increase.
Machines and equipment	Influences the performance of turbines, compressors and plant technology.



→ Evaluation of influence on injection and withdrawal process necessary.

Investigation concept

collect – limit – analyze – test – certify



Step #1

→ Summarizing all available data about detailed properties of installed equipment in a material data base

→ Overviewing the complete process and identifying all critical aspects regarding

→ security

→ integrity

→ functionality

→ contractual effects like quality, quantity & energy content

Step #2

→ Setting tolerable limits regarding

→ security,

→ integrity, e.g., EIGA*

→ process functionality

where suitable regulations are available (and appropriate).

EIGA

*EIGA standard IGC Doc 121/14 "Hydrogen Pipeline Systems" sets material requirements for equipment used in H2 atmosphere

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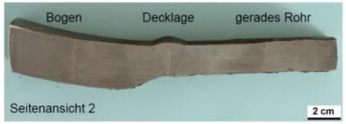
Investigation concept

collect – limit – analyze – test – certify



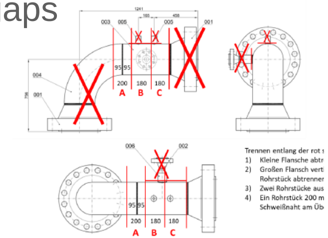
Step #3

→ <u>Analyzing material data</u> base in comparison to limits set;

→ Identifying *theoretical* general sustainability in hydrogen environment

→ <u>Analyzing process data</u> set with regards to limits set

→ Identifying *theoretical* functional & integrity process gaps



Step #4

→ Developing a <u>material testing</u> concept for *existing equipment;*

→ *re-check* of theoretical integrity approach for material

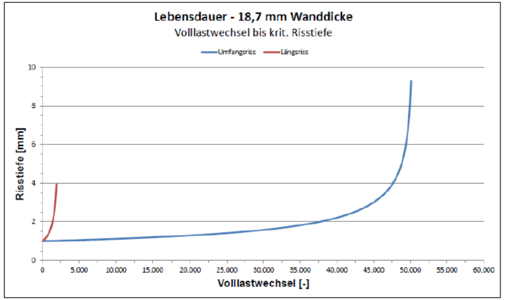
→ adjustment of theoretical approach.

Step #5

→ Developing a <u>certified standard</u> approach for *energy storage* conditions, regarding;

→ integrity

→ remaining service life of existing equipment.



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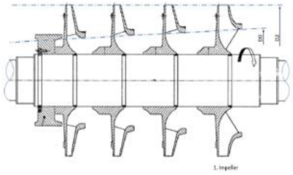
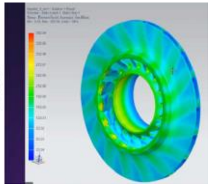
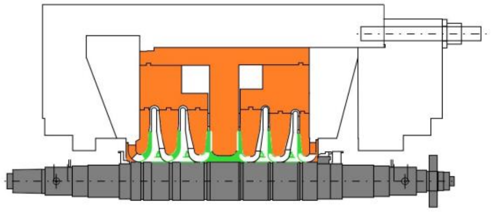
Status quo
Evaluation - injection process

Gas turbine driven turbo compressor	Electric motor driven turbo compressor
< 2% H2 • Installation of additional temperature sensors.	**< 2% H2** • No modification necessary.
2 – 10% H2 • Combustion chamber adjustment. • Additional exhaust gas treatmen.t • Exchange of compressor rotor. • Exchange of process gas cooler.	**2 – 10% H2** • Exchange of compressor rotor & stator parts.
10 – 20% • Gas turbine modifications analogue to “2 – 10% H2”. • New compressor necessary.	**10 – 20%** • Compressor modifications analogue to “2 – 10% H2”.







→ **Major exchange of equipment already at 2% H2 blend.**

Status quo
Evaluation - withdrawal process

Piping and valves

- Overall components: 615
- H2 compatibility
  - Up to 2%: 461 (75%)
  - Up to 10%: 267 (43%)
  - Up to 20% 236 (36%).
- Phosphorus and sulphur content limit hydrogen compatibility of materials (EIGA*).
- No binding statements from manufacturers on the hydrogen compatibility of valves.

Equipment

- Overall equipment: 6
  - 3 x Tanks
  - 1 x Filter
  - 1 x Heat exchanger
  - 1 x Absorber column.
- limited hydrogen suitability of the existing equipment materials.
- Replacement of the installed equipment necessary if hydrogen content exceeds 2%.

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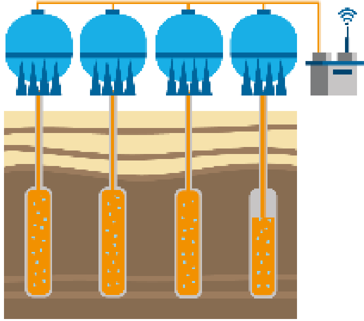
- Replacement of the installed PGC necessary if hydrogen content exceeds 2%.
- Maintenance concept for existing pressure sensors.
- Temperature and level indicators are suitable for 100% hydrogen service.
- Manufacturer's declarations limit the suitability of flow transmitters at 10% hydrogen.



→ **Analog to injection process, H2 sustainability limits set @ 2% H2 blend.**

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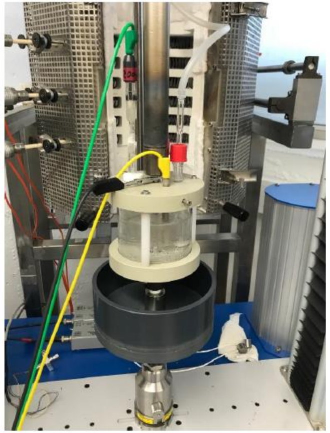
Status quo
Verification process - material testing

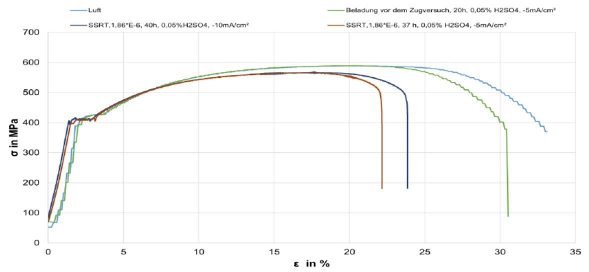
UST and R&D partners have developed a material testing concept which is already being applied in a test phase.

- Microstructural and electrochemical investigations (microstructure, hardness measurement).
- Mechanical tests (tensile test, KSBV, SSRT cathodic/high pressure).

Challenges

- Only little knowledge & capacities in the area of high-pressure hydrogen material testing on the market.
- No clear picture about necessary tests for clear integrity picture.
- Unstandardized approach for hydrogen loading of material .
- Heat-effected zones of weldings vs. Base material.





→ **High pressure H2 testing opens new chapter of R&D challenges**

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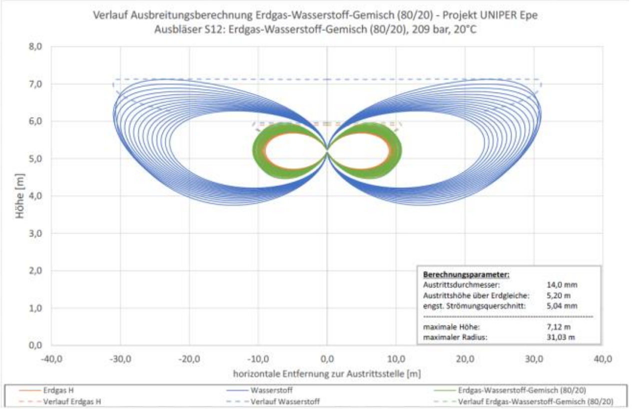
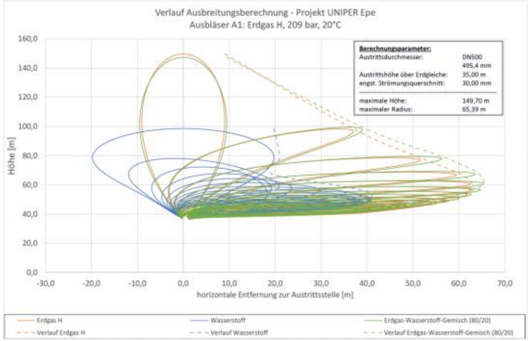
Status quo
Regulatory and safety

- Different classification regarding ATEX 2014/34/EU
  - Hydrogen IIC
  - Natural gas IIA

  effecting approval of safety installations
- Wider range of explosion limits for hydrogen (4 – 75% H2 vs. 4 – 16% CH4)
- Influence of hydrogen on EX zones and heat radiation to be evaluated

→ **New general requirements setting a new set of safety requirements**





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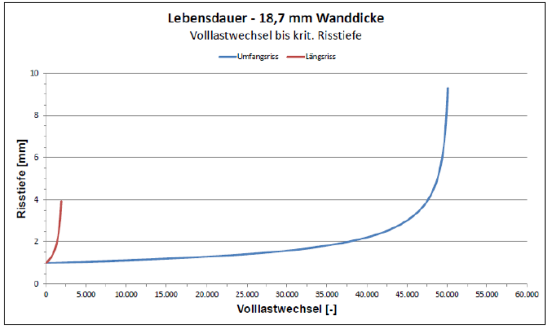
Next steps

- Rules and standards is key -

- Integration of material testing results
  - Re-check of theoretical approach for existing material
  - Adjustment of theoretical approach
- AI based material evaluation
- Intensifying cooperation with notified bodies and working groups in developing a certified standard approach for hydrogen storage conditions regarding
  - integrity
  - Remaining service life of existing equipment
- Developing a project roadmap based on results of remaining service life investigations of existing equipment.



→ **Remaining service life of existing natural storage equipment as key enabler for large scale hydrogen/ hydrogen blend storage due to invest cost reduction**

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Thank you very much for your attention!

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