

# HUG WP2: TECHNICAL RISKS OF UHS

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Research event on January 22<sup>nd</sup>, 2026

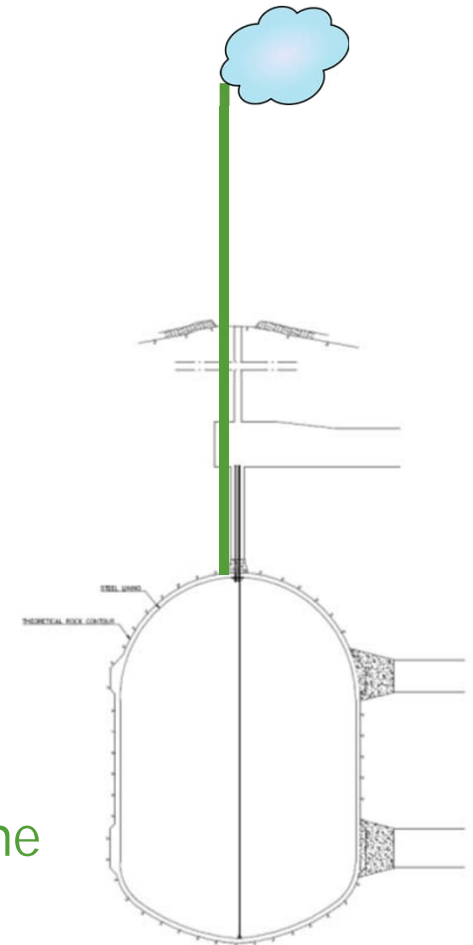
Tero Välisalo, research scientist

# Main safety concerns of Underground Hydrogen Storage (UHS)

1. Leakage, i.e. loss of containment (LOC)
  - Probability is difficult to estimate, lots of uncertainties.
  - Consequences depend on the release rate and how the released hydrogen can be conducted to a safe location.
2. Contamination of hydrogen
  - The most safety critical contaminant is air/oxygen, because it causes flammable mixture inside UHS -> storage explosion?
  - Decrease of purity level due to other contaminants creates an economical risk.
  - The contaminants must be identified before the gas is injected into UHS
  - What is the realistic target for UHS hydrogen purity in UHS / grid?

# In case of a leakage

- If there are several storages at the site or the storage is connected to a network, the preferred action is to transport most of the hydrogen from the leaking storage to other storages.
  - Massive leakage is not probable, if the structure does not fail completely.
- The UHS structure must be designed to catch the leaked hydrogen and conduct it to a safe location
  - Drainage pipelines can be utilized to create an easy pathway for leaked hydrogen.
- Complete emptying of storage with water (pushes H<sub>2</sub> out of the storage)



Skallen CNG storage.

# Technical causes of a leakage

- All leakages are caused by faults in the gastight liner or in pipeline connections with liner.
- Gastight liner does not bear load without the structure behind it, so the integrity of the liner depends fully on the supporting structure.
- Liner construction quality is essential, non-destructive testing (NDT) of weldings is a must.
- Structural causes of liner leakage e.g.:
  - Rock mass failure, managed with reinforcement (rock bolts) and location of the UHS
  - Concrete failure; managed with concrete casting quality monitoring and temperature management during the curing process.
- As the pressure in UHS varies, the volume of the UHS will slightly vary
  - What kind of movement is normal/acceptable and what is not – must be defined and monitored during the operation.

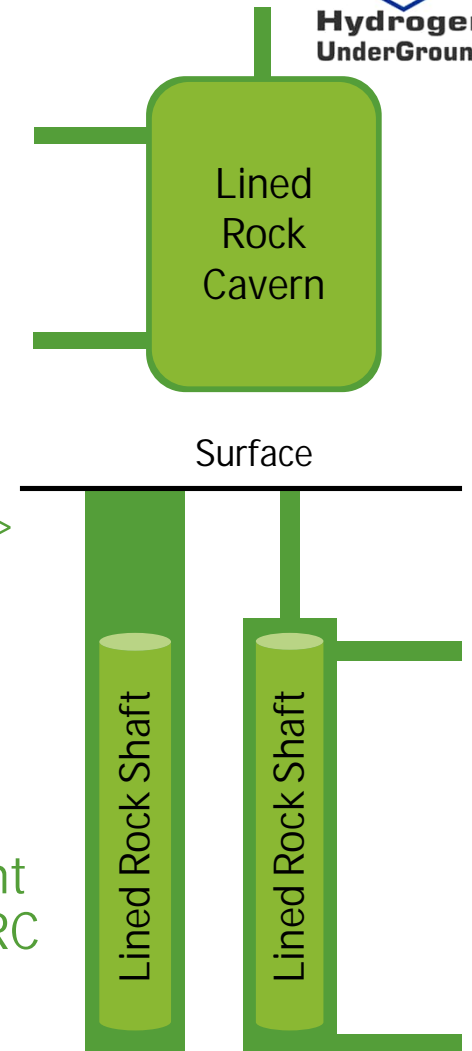
# Consequences of a leakage

- The leaking hydrogen creates a cloud with air which is flammable.
- The flammable volume size depends mainly on the mass flow of the leakage, but also environmental conditions (especially wind) and the height of the leakage affect the cloud size and the energy content of it.
  - In consequence analysis softwares it is typically assumed that 10% of the total mass of hydrogen reacts in case of an explosion.
- In open air conditions detonation-type of hydrogen cloud explosion is not probable, but still possible
- In studied "10% area" leakage cases (pipeline size: 25/50/100/125/150 mm and pressure 100/150/200/250/300 bar) the hazardous areas for explosion pressures and heat radiation were a couple of tens of meters.



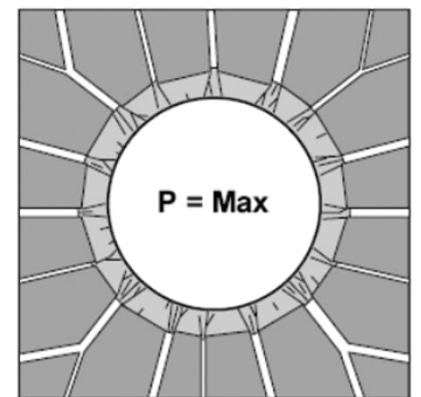
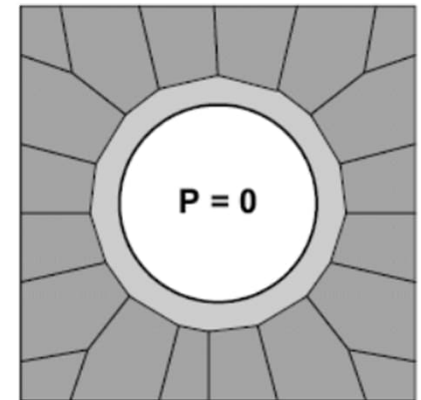
# LRC vs. LRS

- There are no significant differences in the safety of different UHS types.
- The wall structure will be basically the same in both solutions.
- LRS's rock wall surface is smoother because of the drilling method -> concrete structures are lighter and easier to construct.
- In LRS drilled from the surface, the capacity is limited due to limitations in the drilling technology.
  - In this type of LRS the sealing plug in the surface is a critical point.
- In LRS drilled with raise boring technology, access to the lowest point of shaft is required, but the capacity can be in the same level as in LRC



# Monitoring of storage condition

- The UHS condition must be monitored to anticipate problems in early stage.
  - Leakage monitoring reacts too late.
- Liner condition is difficult to assess, but it should be done somehow
  - Acoustic emission; setting up an acoustic fingerprint for the liner which can be compared against the following studies?
- As the pressure fluctuates in the storage, also the volume / shape of the cavern changes.
  - Is it possible to monitor the shape of a cavern?



Source: Johansson, J. 2003. High pressure storage of gas in lined rock caverns – cavern wall design principles. Licenciate thesis. Stockholm: KTH Royal Institute of Technology.

# Operational values that affect safety

- Pressure, pressure change rate
  - acceptable values TBD
- Temperature, temperature change rate
  - acceptable values TBD
- Shape/size of the UHS
  - Acceptable deformations (crack opening) and deformation speed TBD
- Hydrogen leakage detection
  - H<sub>2</sub> content in the drainage pipelines.

# Latest activities & next steps

- Consequence analysis report is available at HUG Teams.
- A research report on preliminary risks is under way.
  - More precise picture of LRC/LRS construction challenges and possible hazardous scenarios
- Risks of different actors connected to a common UHS & sociotechnical perspective to risk - meetings with HUG companies during springtime.

