Underground Sun Storage

“Underground storage of Hydrogen in porous geological media”

AUSTRIA AG

RAG Austria AG

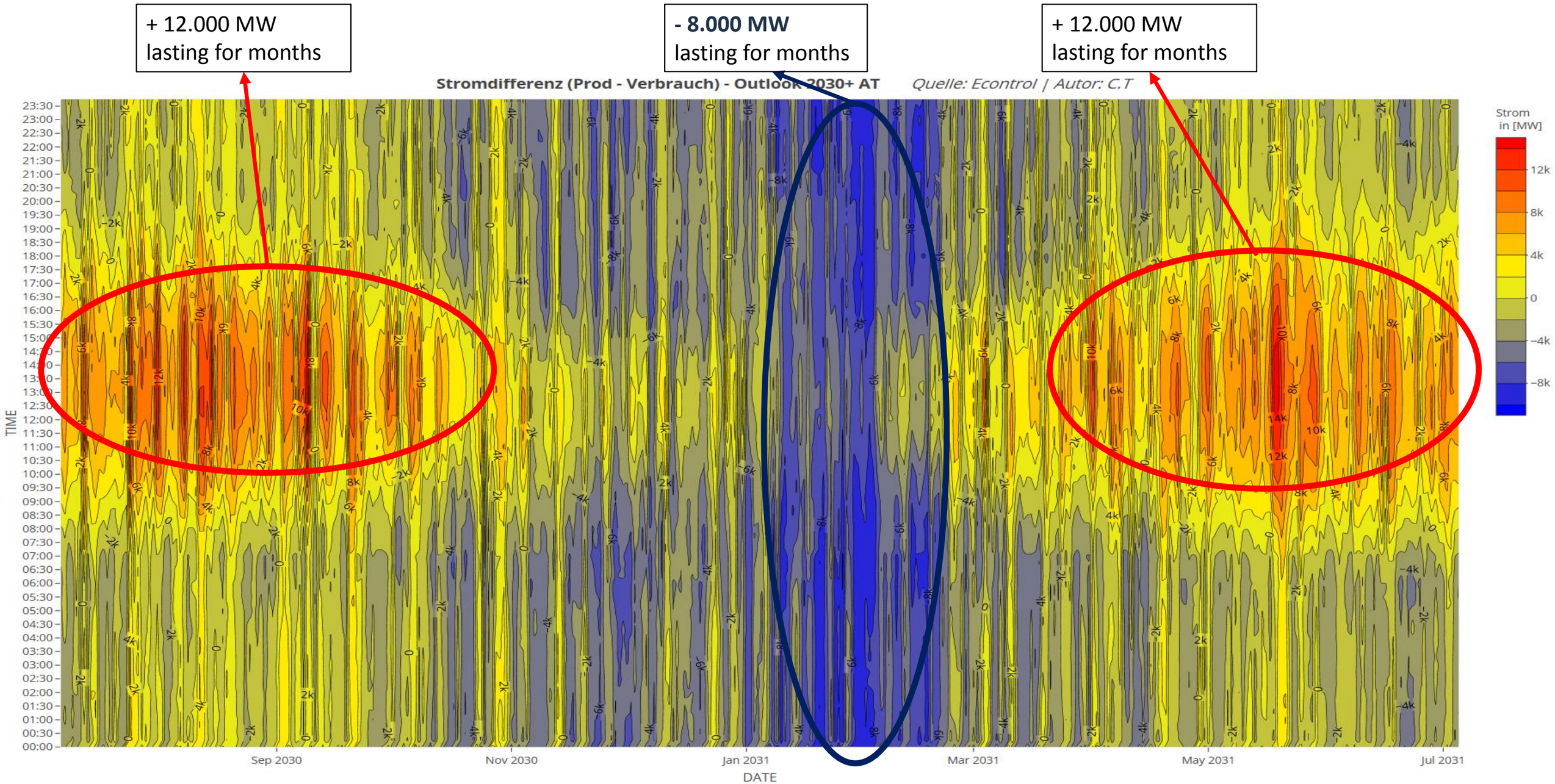
Company Profile and

Vision

- Among leading technical Underground Gas Storage Operators
- State of the art facilities
- Storage volume 66 TWh (6bcm)
- Unload capacity 30 GW

- Follow the vision to serve the renewables with our existing assets by constant improvement and innovation

2030+ residual scenario for electricity in AT

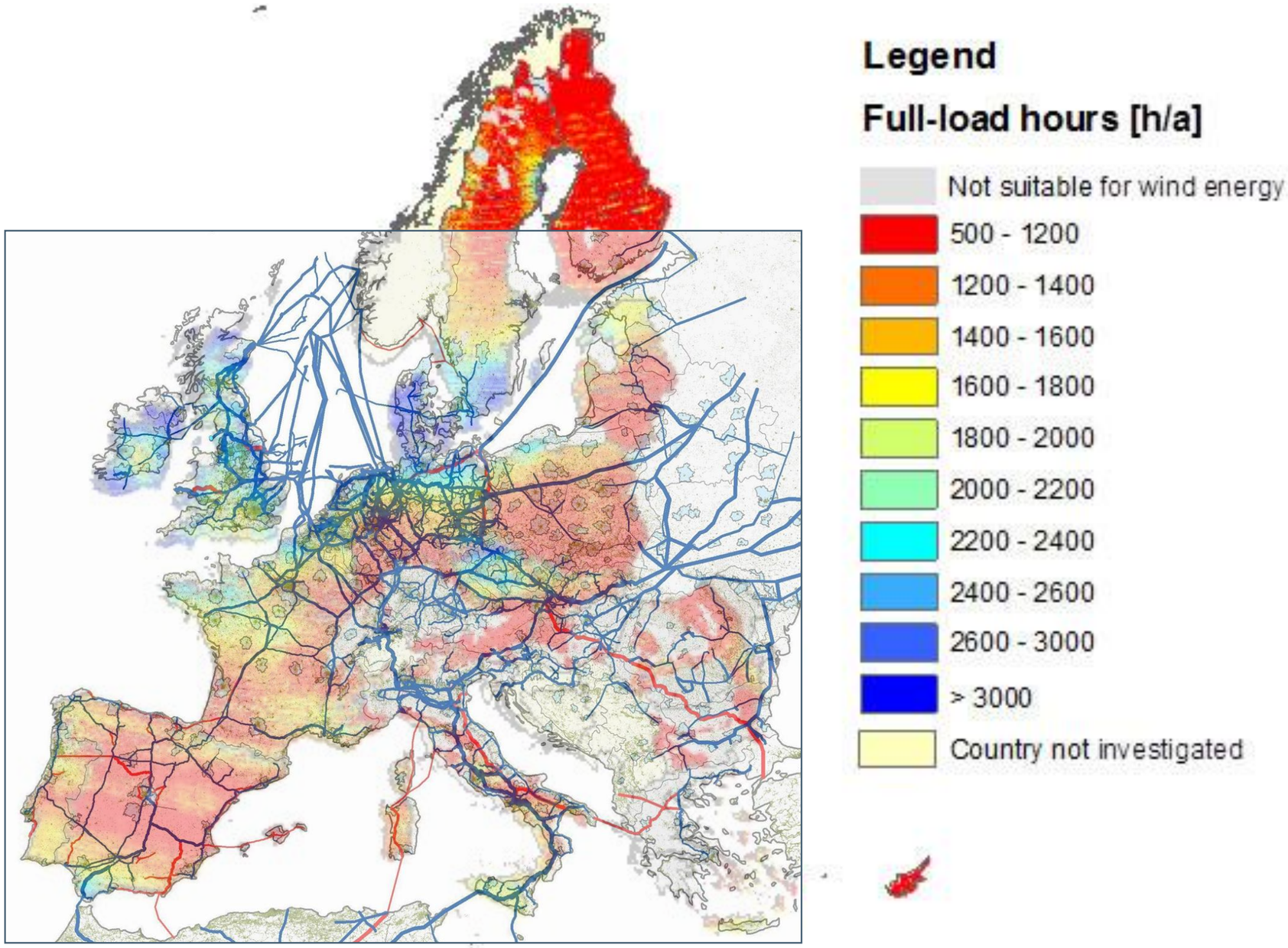


INPUT data: 2030+ vs. 2017 @15 minute intervals:

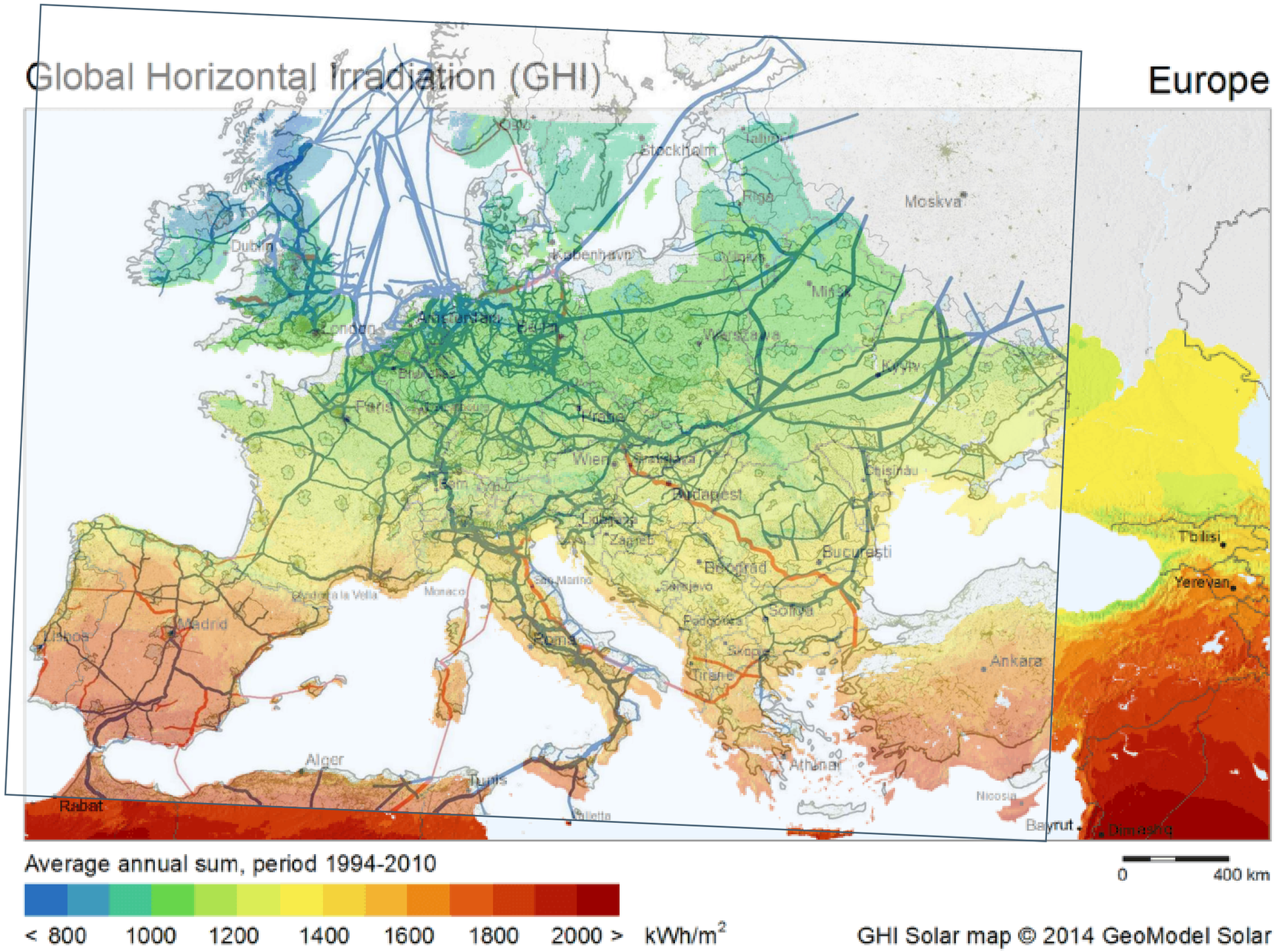
- Demand: +30% (~63 to 81 TWh/a)
- RES generation : Wind x3, Solar x20, Hydro x1 (~ 41 auf 80 TWh/a)

=> Big scale seasonal storage needed

European Potential for Wind Energy Generation



European Potential for Solar Energy Generation



Development of the Underground Sun Storage Project

Motivation

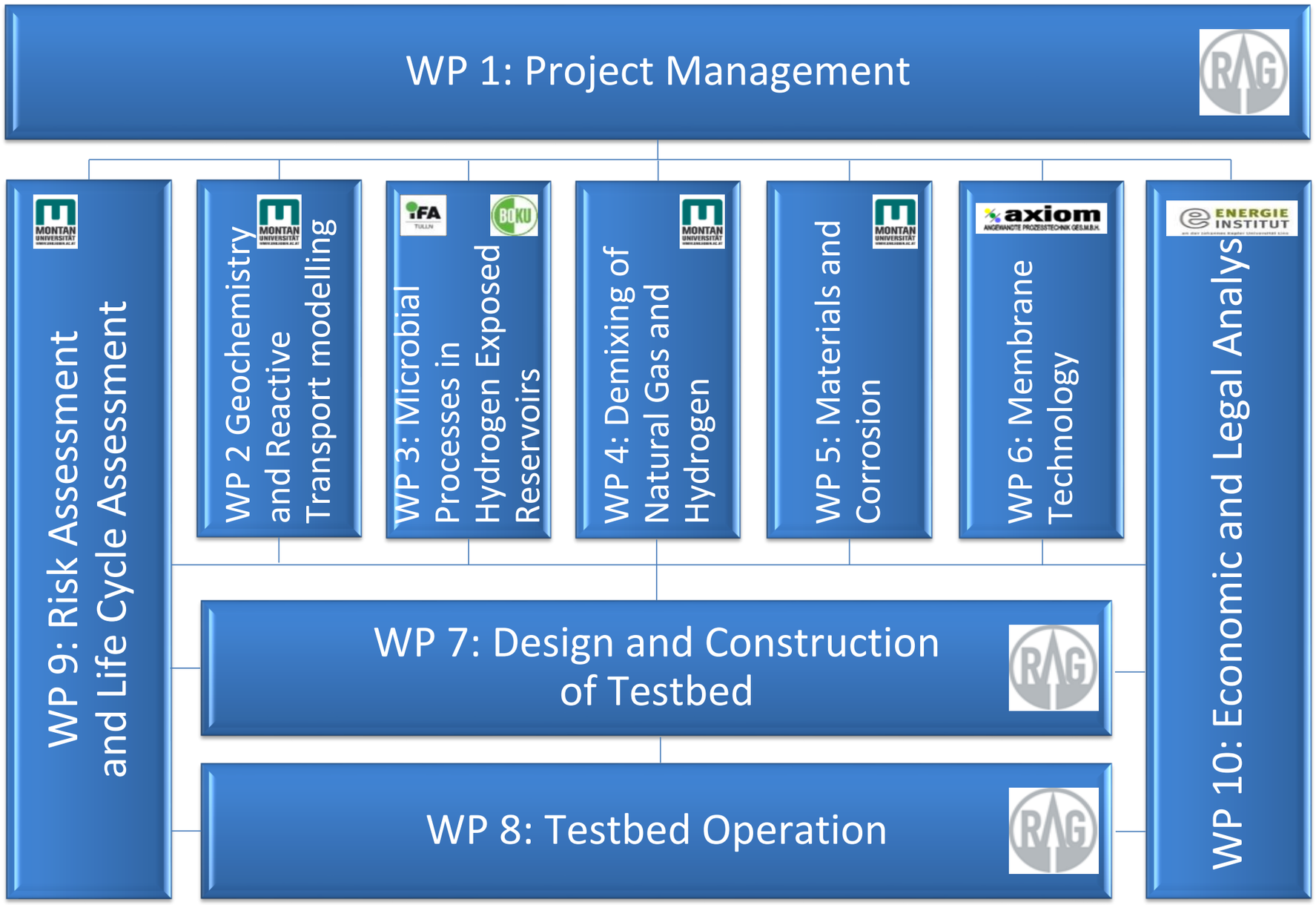
- Gas Storage is Energy Storage
- Gas Storage is ‘invisible‘ and ‘available on demand‘-Energy
- Gas has an existing infrastructure in many regions of the world
- Gas can be greened from 0-100% without changing the system

Goals of the Project

- Demonstration of Storability of renewable gases in Gas Storage facilities
- Research on effects of 10% hydrogen admixtures in existing Gas Storage Facilities

Partners

Project


WP 1: Project Management
WP 9: Risk Assessment and Life Cycle Assessment
WP 2 Geochemistry and Reactive Transport modelling
WP 3: Microbial Processes in Hydrogen Exposed Reservoirs
WP 4: Demixing of Natural Gas and Hydrogen
WP 5: Materials and Corrosion
WP 6: Membrane Technology
WP 10: Economic and Legal Analys
WP 7: Design and Construction of Testbed
WP 8: Testbed Operation

Test Field Key Data

Physical Parameters

- HP3A is very small and isolated
- Field experiments at reasonable costs and risks
- Conditions comparable to commercial RAG storage facilities
  - High Permeability (up to 600 MD) Average Porosity (25%)
  - Water Saturation (~30 %) No active Aquifer

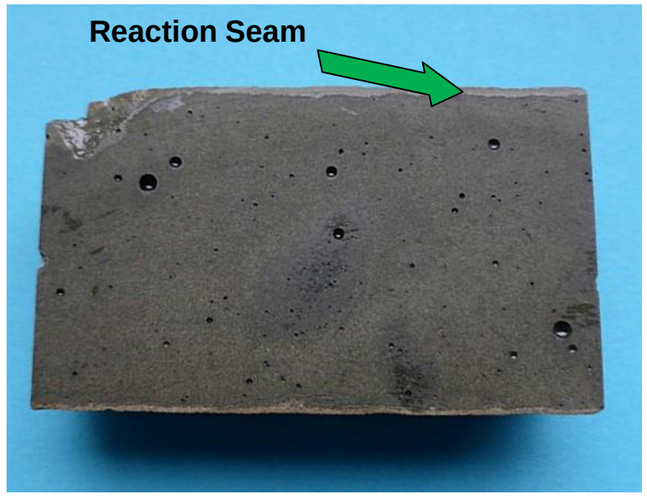
Volumetrics

- GIIP ~6,15 MMNm³ net. Production ~4,45 MMNm³
- 1,22 MMNm³ Gas Mixture 115.444 Nm³ Hydrogen
- Pressure Range Reservoir (34 – 78 Bar(a))
- Temperature 39,5°C

Subsurface Aspects

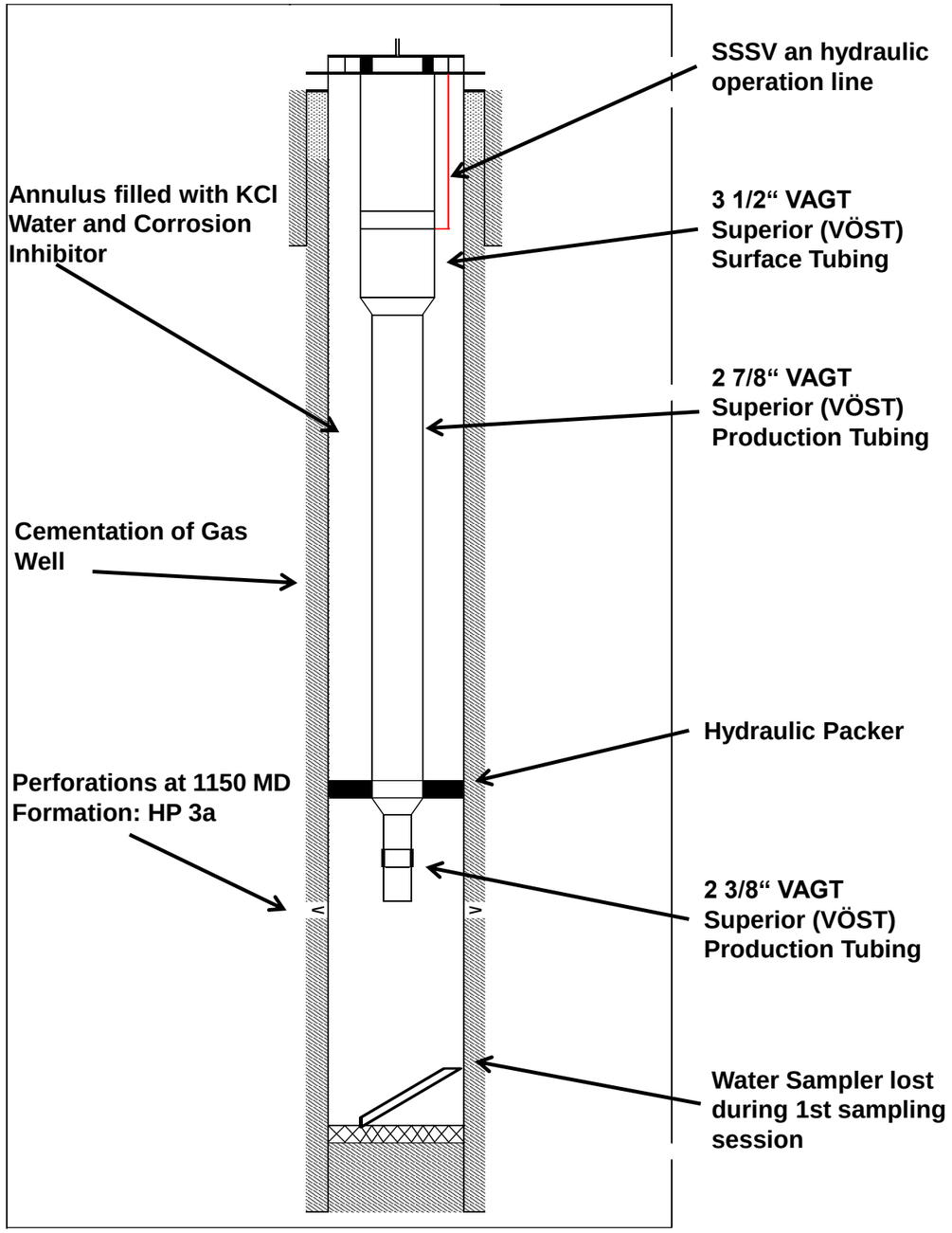
- **Open Questions from the Literature**
  - Are the different materials in a gas storage facility resistant against hydrogen?
  - Is the tightness of the subsurface reservoir also given for hydrogen?
  - How does the hydrogen move in the subsurface?
  - Does the hydrogen change the chemical equilibrium of the reservoir?
  - Does hydrogen react with microbes in the reservoir?

Material Behaviour



- Steel and cement samples tested under lab and field conditions
  - Cement samples show signs of calcification in blind and hydrogen samples
  - Steel samples show no signs of embrittlement or significant reduction of strain to rupture
- Elastomers where tested only in the field
  - Visual observation shows no significant changes
  - Changes in mass and volume comparable to gas industry standards
  - Further investigation in follow up project (USC)

Well and Reservoir Tightness

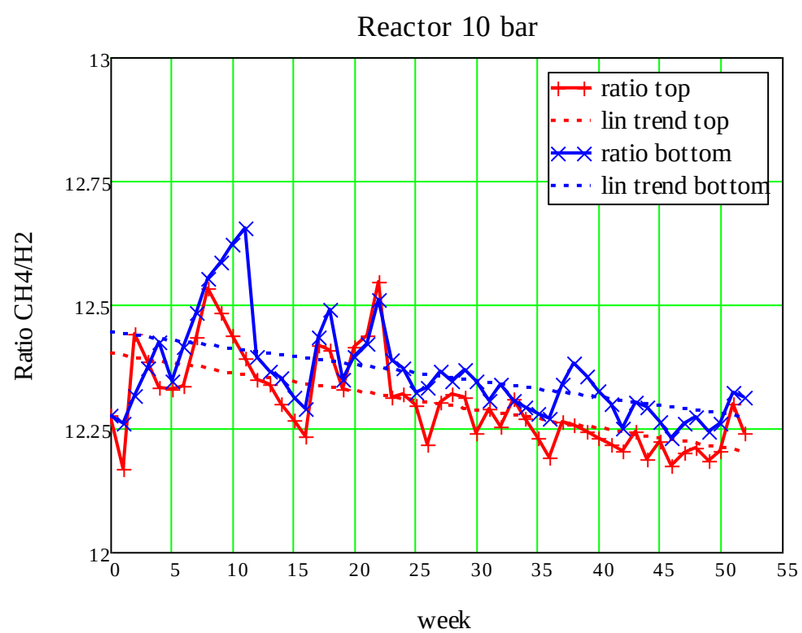


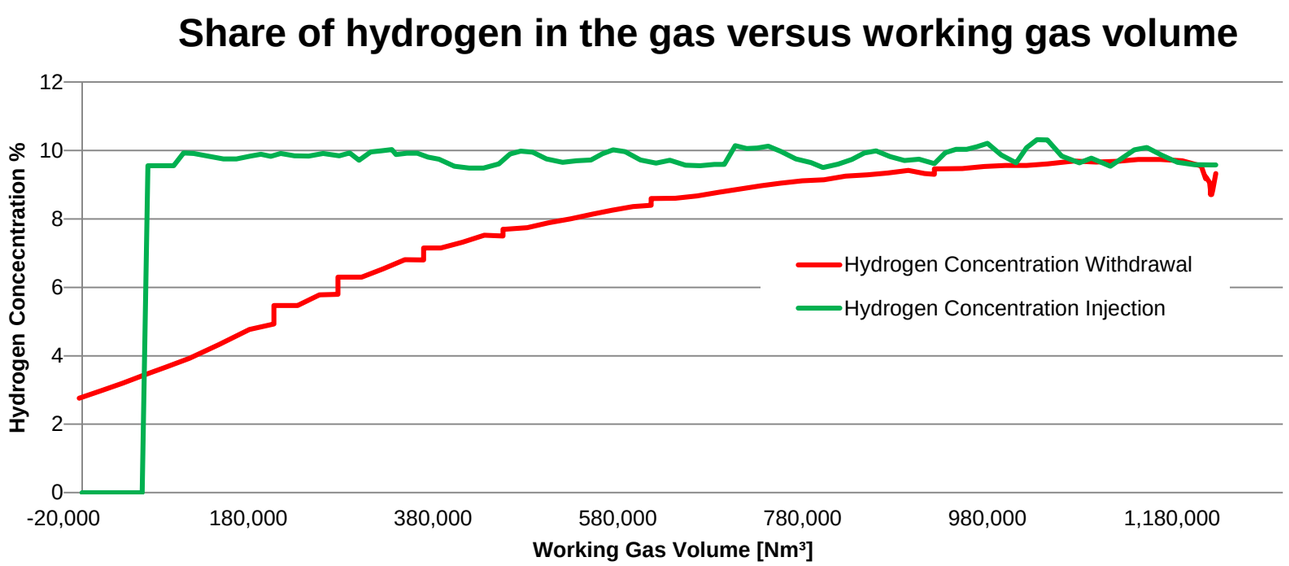
- **Well**
  - No observation of hydrogen in the annulus
  - No degradation of tubing or casing (USIT)
  - No detection of gas migration in the well cementation (CBL)
  - Rubber elements of packers where unchanged

- **Reservoir**
  - Permeability of hydrogen and methane in the cap rock are in the same order of magnitude

		Permeability [m²] Cap Rock	
Formation	**Core**	Methane	Hydrogen
A	**2**	$2.1\ 10^{-18}$	$2.3\ 10^{-18}$
	3	$2.5\ 10^{-18}$	$2.7\ 10^{-18}$
B	**1**	$8.5\ 10^{-19}$	$8.2\ 10^{-19}$
	3	$3.2\ 10^{-18}$	$1.9\ 10^{-18}$

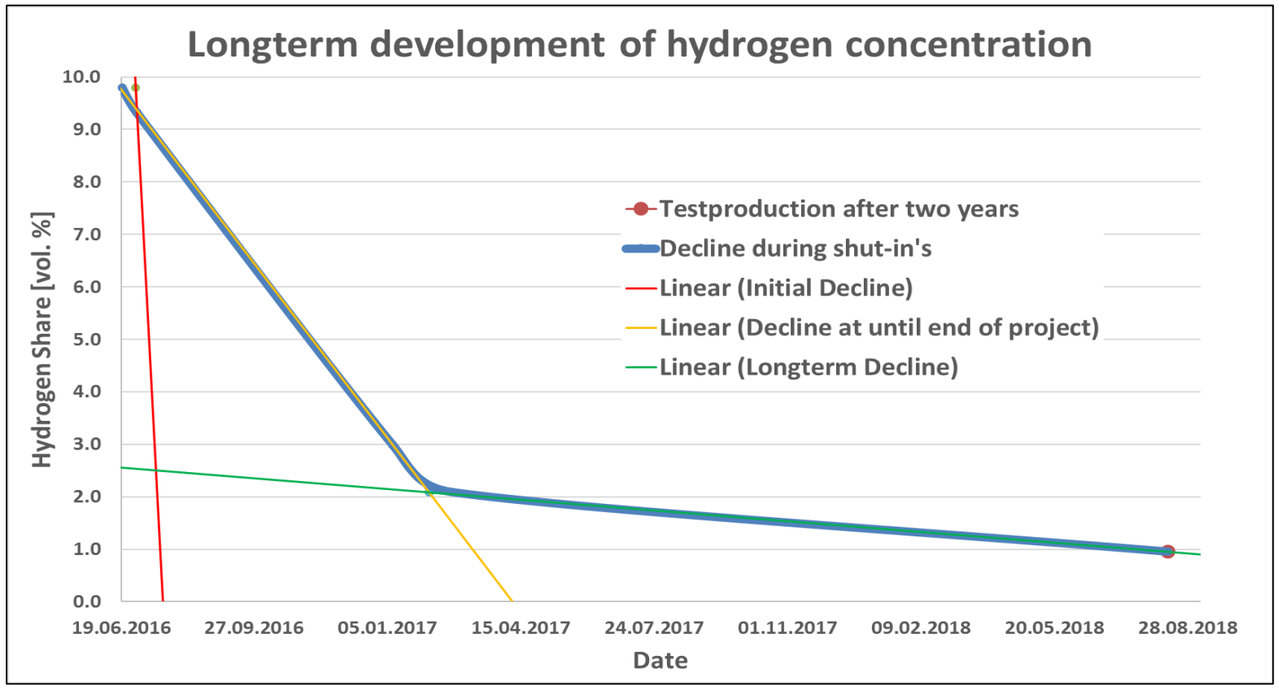
Diffusion





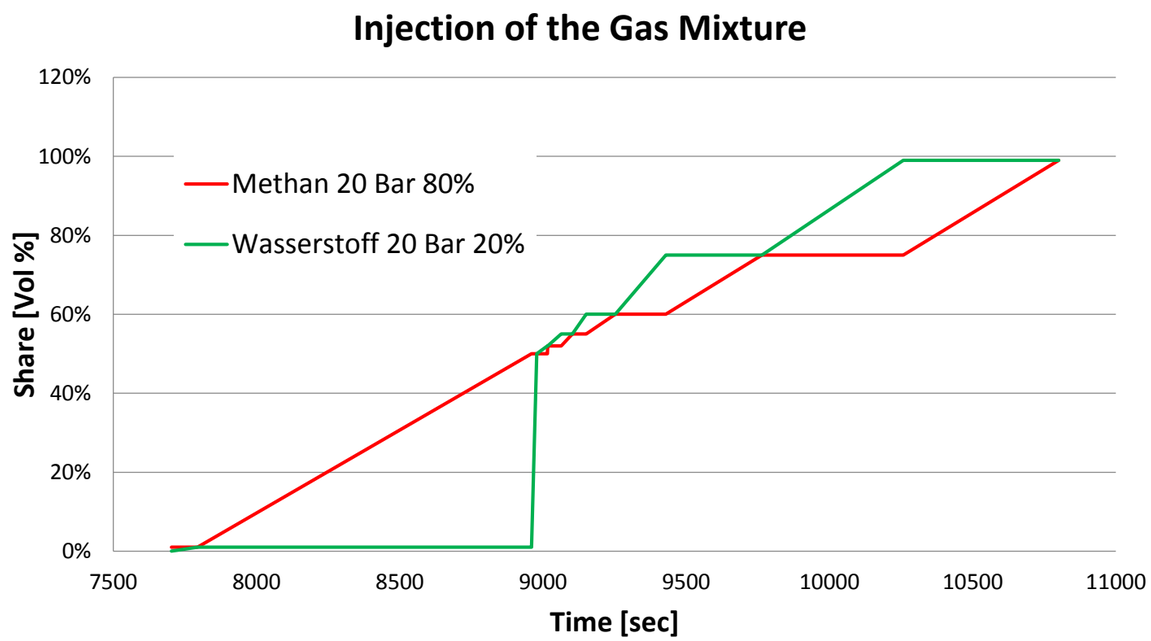
- Only relevant for gas phase
  - Hydrogen diffusion in water saturated porous media 10^{-4} – 10^{-5} m²/a
- No De- Mixing of gas during Shut In (Diffusion forces stronger then gravimetric effects)
- Changes in withdrawn gas due to
  - Diffusion?
  - Dispersion?
  - Dissolution?
  - Chemical Reactions?
  - Conversion?

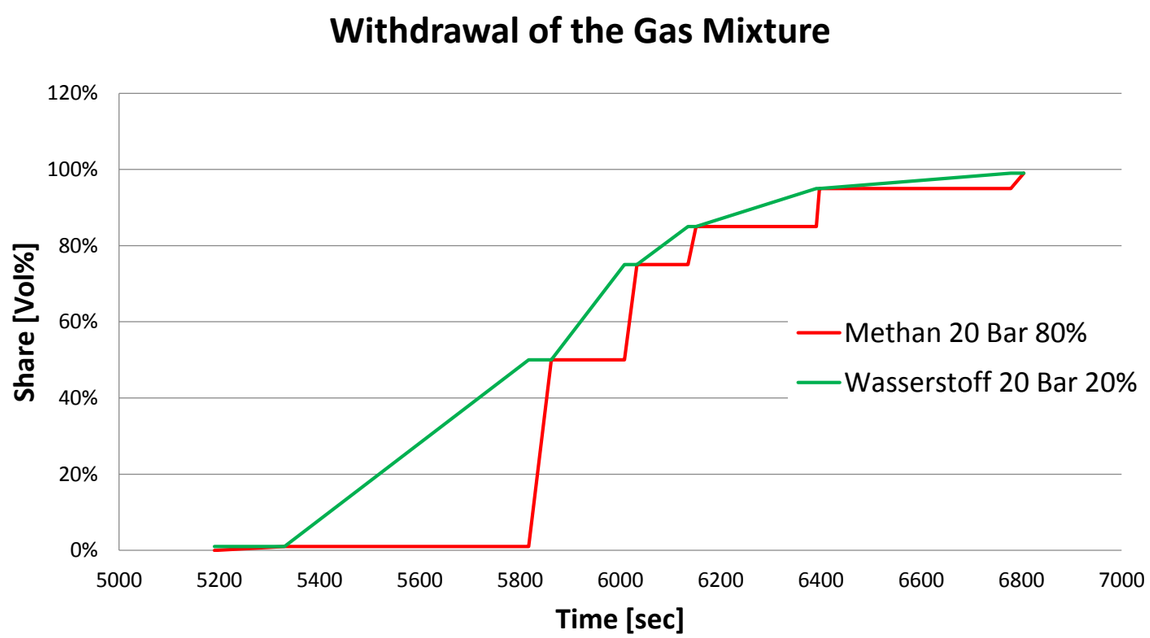
Diffusion



- Further equilibration of hydrogen during long time shut in (no sudden chemical reactions)
- Further experiments are conducted in the follow up project

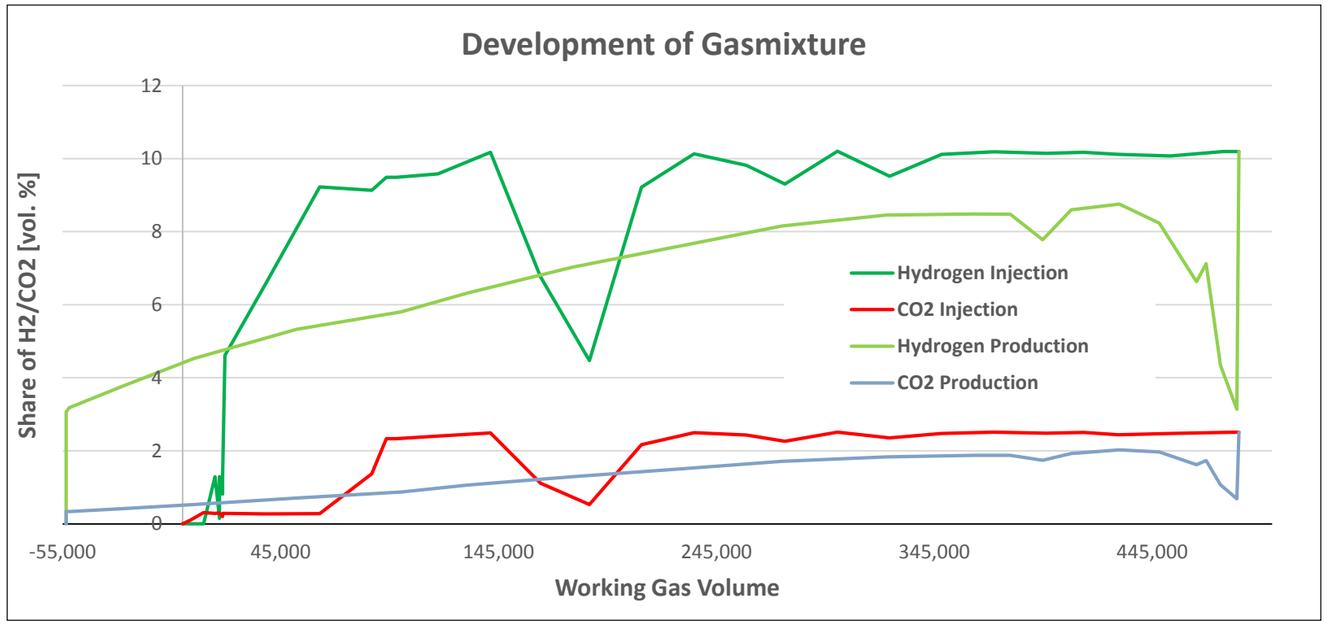
Dispersion





- Break through experiments over 7 meters of porous medium
- Hydrogen is slightly faster than methane
- Effect is independent of flow speed
- Effect is canceled out in wet environment

Dissolution



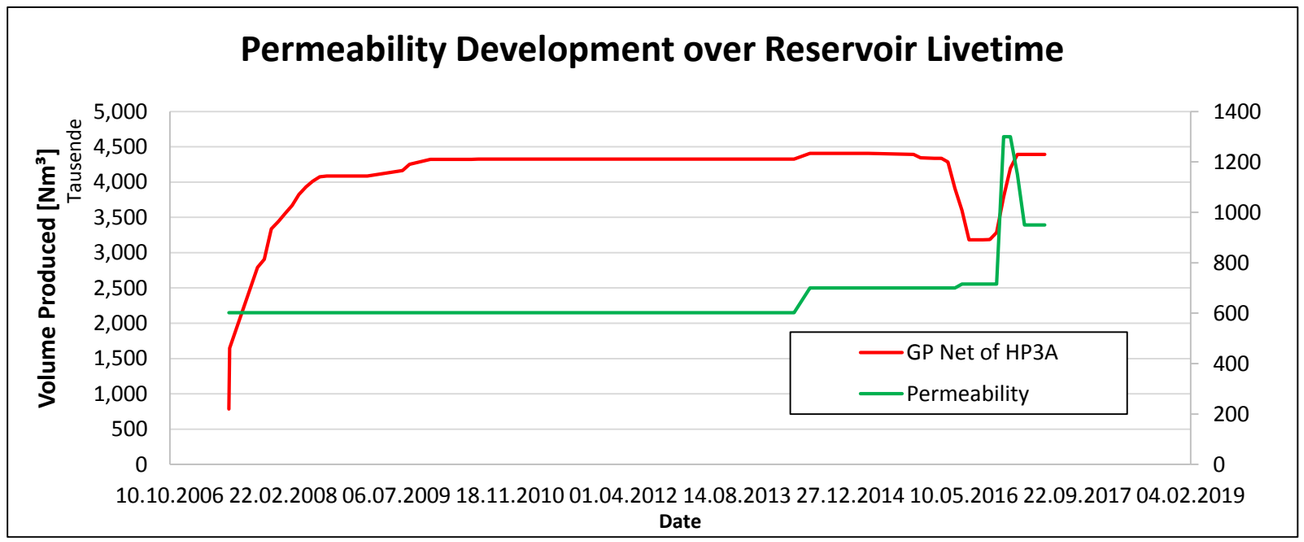
- Dissolution of gas mixture was observed in the lab
- Literature gives a wide range of possible values for hydrogen dissolution in brines (0,8-10 % of injected volume)
- Time dependent process (equilibration)
- Pressure dependent => can be partly recovered
- Kinetics and volume need further research (USC)

Reservoir Changes

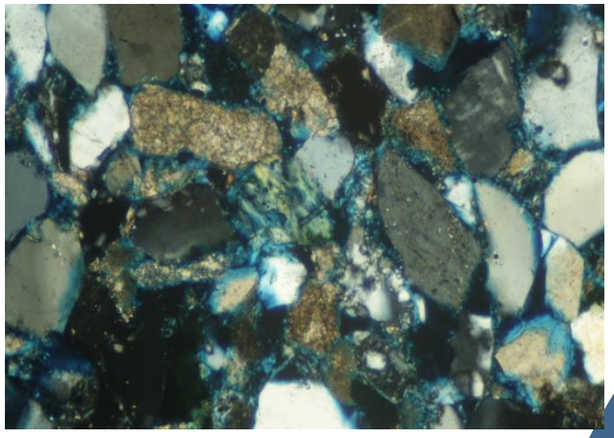
	Wasserpermeabilität k_w [m²]		Gaspermeabilität k_{wg} [m²]	
Monate	vor	nach	vor	nach
2	$2.77\ 10^{-14}$	$2.86\ 10^{-14}$	$2.43\ 10^{-13}$	$2.31\ 10^{-13}$
3	$5.55\ 10^{-14}$	$3.16\ 10^{-14}$	$2.17\ 10^{-13}$	$2.57\ 10^{-13}$
6	$4.07\ 10^{-14}$	$3.75\ 10^{-14}$	$1.60\ 10^{-13}$	$1.45\ 10^{-13}$
9	$3.87\ 10^{-14}$	$2.58\ 10^{-14}$	$1.31\ 10^{-13}$	$1.11\ 10^{-13}$
12	$2.59\ 10^{-14}$	$7.19\ 10^{-14}$	$1.95\ 10^{-13}$	$1.06\ 10^{-13}$

12 months flow through experiments conducted at DBI with 25% and 75% of H_2 in CH_4

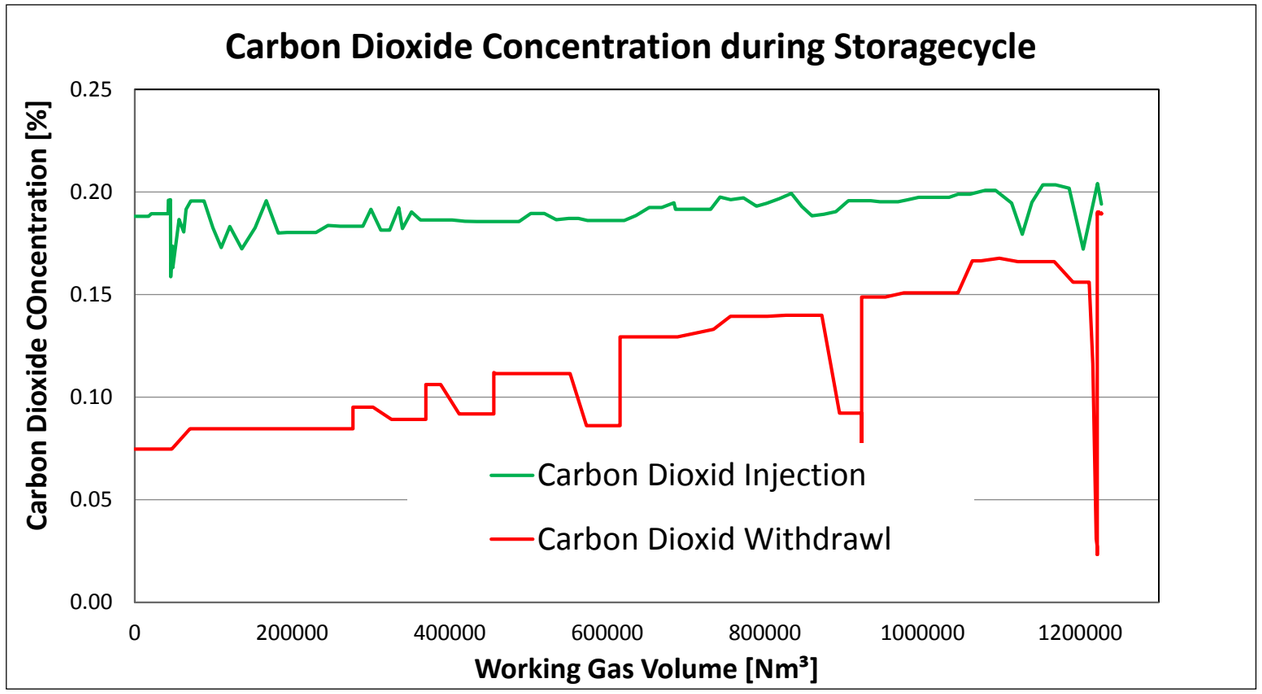
- Permeability changes due to clay swelling confirmed in blind samples
- No dissolution or precipitation observed on micro scale (thin sections)

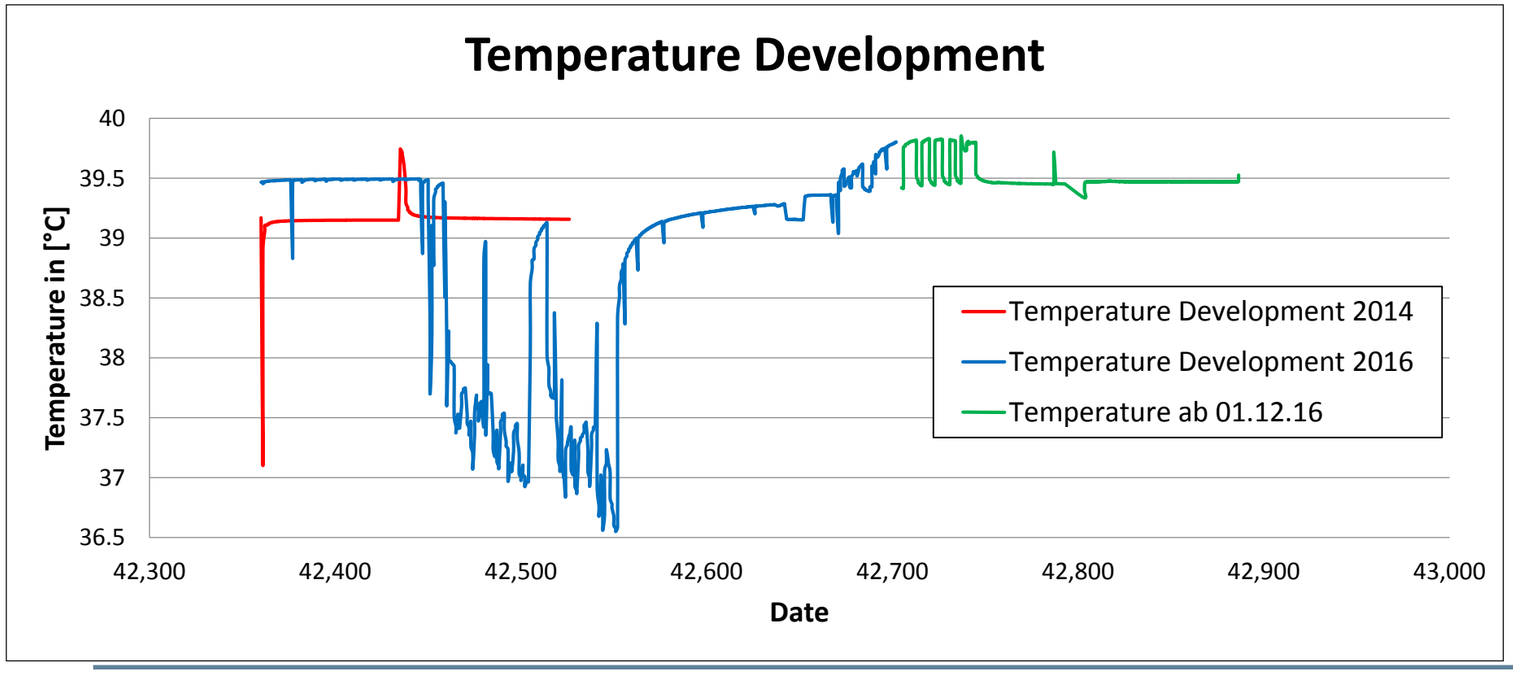


Permeability changes in the reservoir are comparable to common storage operations



Conversion

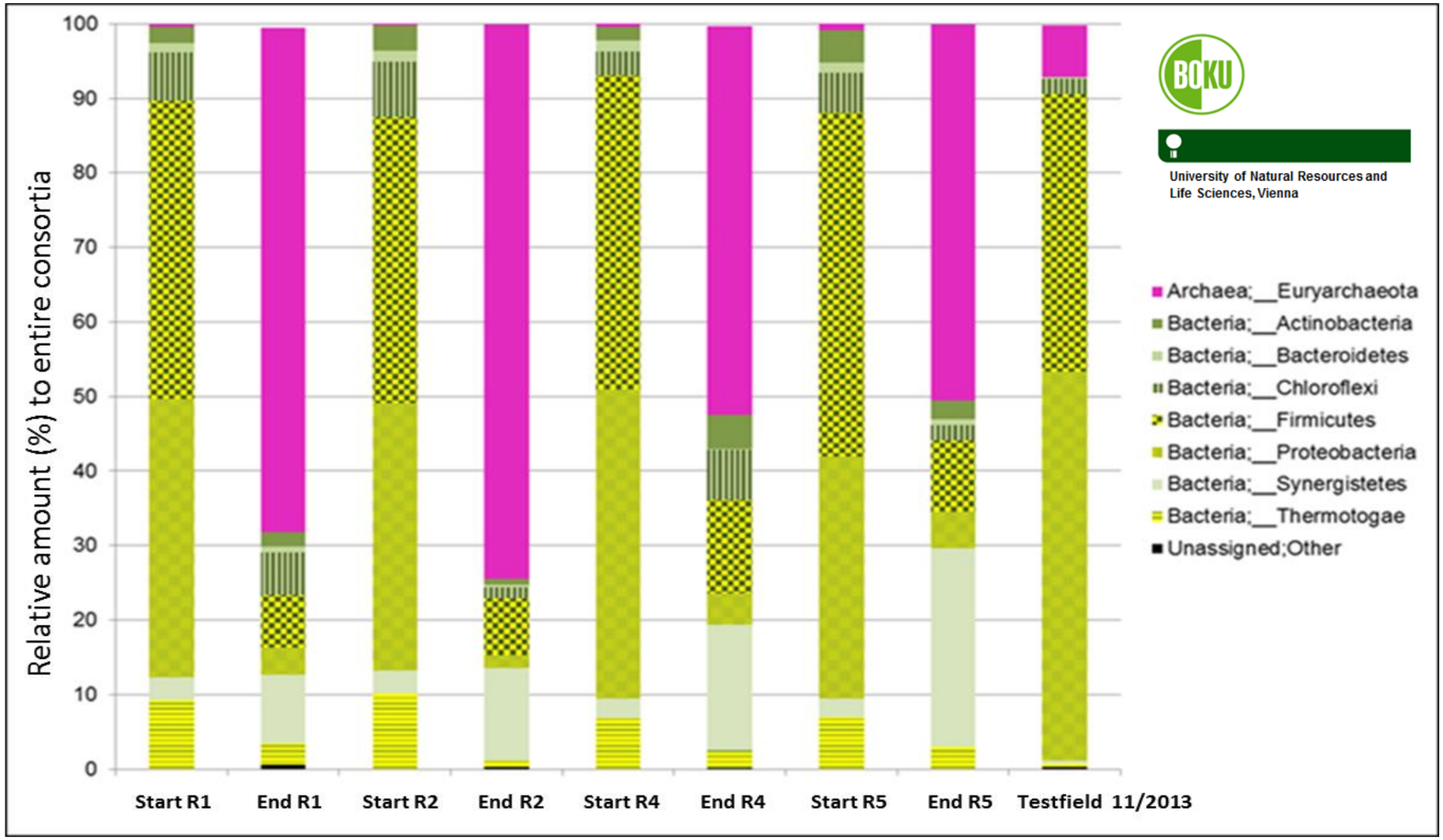




- No H_2S was measured
- Acetate traces where found in the water samples
- No evidence of iron reduction
- Confirmed in Lab and Field-experiments
  - Roughly stoichiometric pressure drop
  - Change of initial microbial consortia towards a higher population of methanogenic archaea

  Negative isotopic value shift

Changes in microbiology



Underground Sun Storage

UNDERGROUND SUN.STORAGE

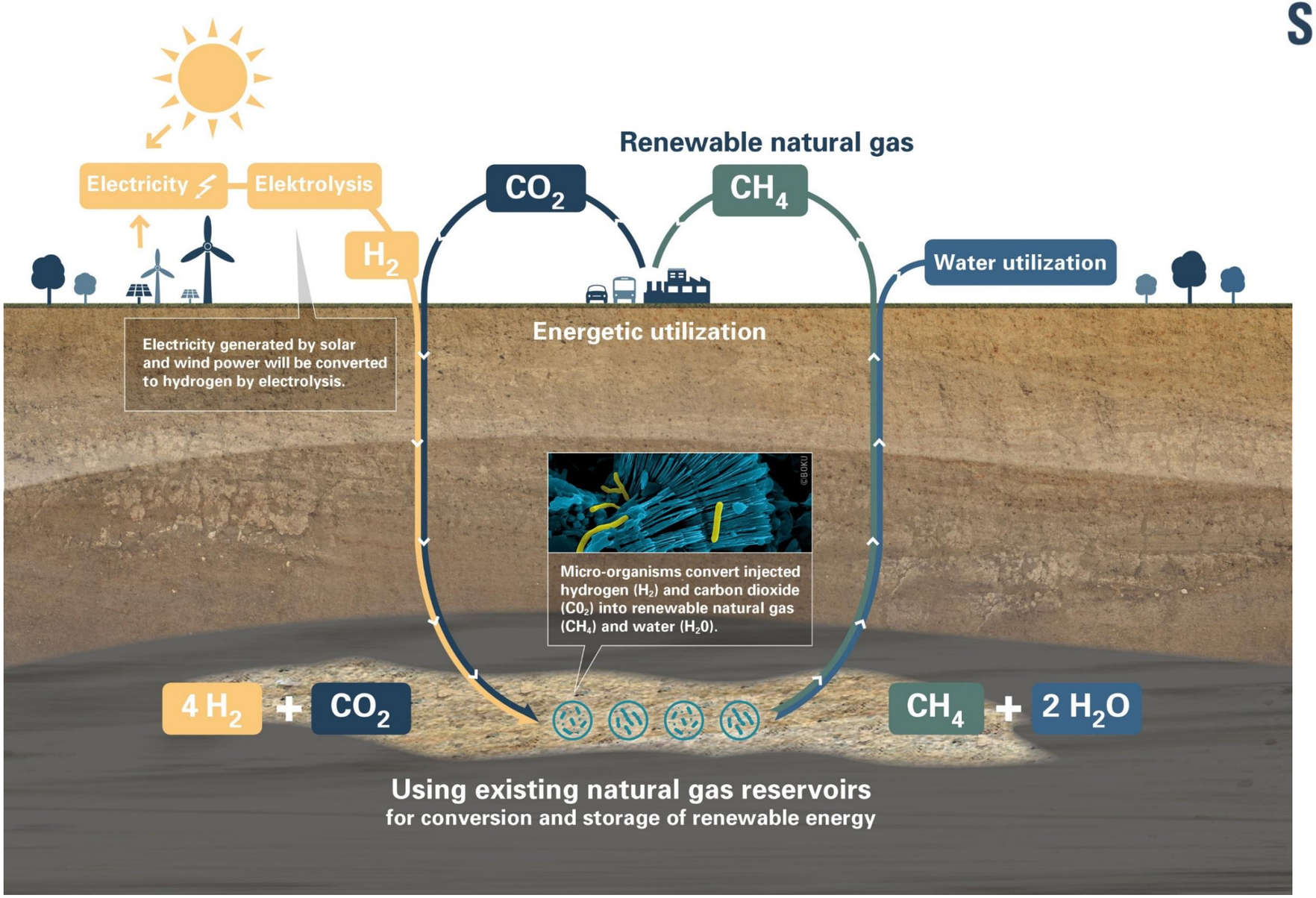
- Renewable Energy can be stored as Hydrogen in underground gas reservoirs.
- 10 % share of H_2 tested
- Project confirmed scale up potential to RAGs commercial facilities
- Open: Assignability to other geological reservoir settings
- Key Parameters Identified
- 100 % Hydrogen in natural gas reservoirs is the next development objective
- https://www.underground-sun-storage.at/

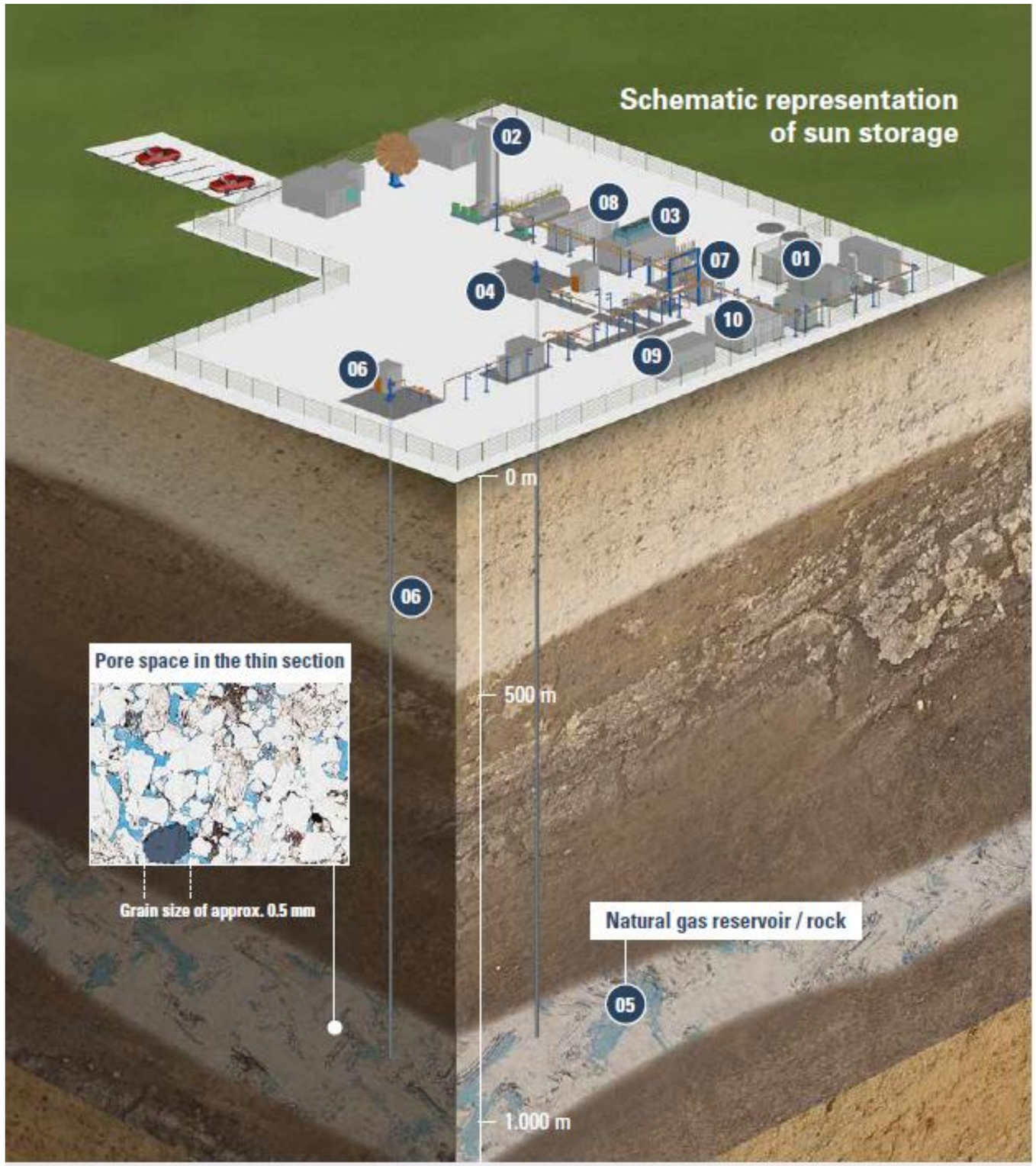
Open Questions

- Further research on diffusion is needed (USC)
- Dissolution of hydrogen into the reservoir brine is still not fully understood (external)
- Microbial activity throughout the reservoir needs further investigation (USC)
- Models to predict chemical and biological behavior of hydrogen bearing reservoirs are still not market ready and need further development and data (open)
- Rubber seals and elastomers still need further investigation (USC)
- Movement of hydrogen in the reservoir should be tested over longer distances. (USC)

Convert a one way industry into a sustainable cycle industry

UNDERGROUND SUN.CONVERSION





01 Elektrolysis
02 CO_2 - tank
03 Compressor station
04 Injection well
05 Gas reservoir
06 Withdrawal well
07 Drying unit
08 Gas conditioning
09 Electricity grid connection
10 Control unit / EMSR

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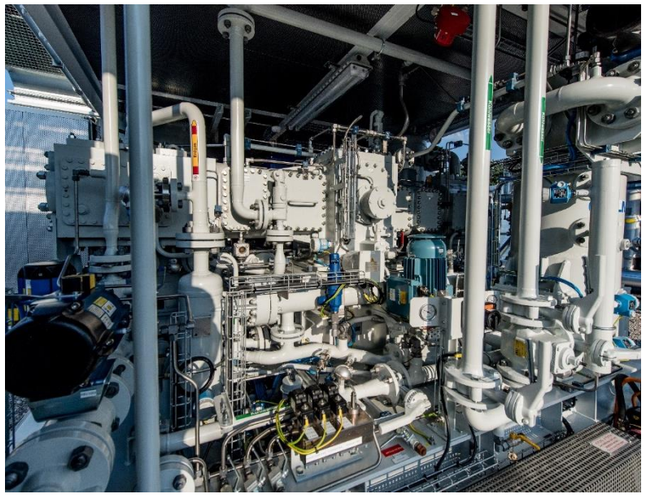
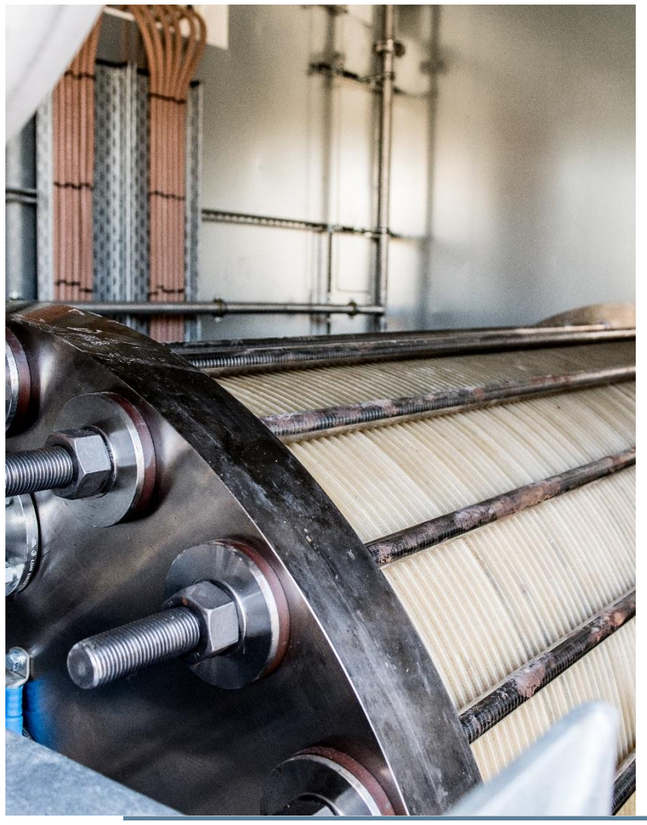
In-situ Field Experiments

- Construction work finished
- Commissioning finished
- Batch experiments ongoing
  - First Batch finished 03/2019
  - Second Batch finished 07/2019
  - Injection third Batch finished 09/2019
- Second well – May /2019
- Cycle Experiments till end of 2020

Scientific Preparation





- Further Research on microbial conversion in the Lab
  - Gas mixtures with up to 40% of hydrogen
- Simulation of biomass development in the subsurface
- Material testing of steels, cements and elastomers in CO_2/H_2 atmospheres under elevated pressure and temperature conditions

Conclusion

- State of the art underground gas storage facilities are essential for Europe´s security of energy supply
- Increase of erratic renewable energy generation and the integration of natural gas and electricity markets in turn will generate additional demand in seasonal and high-capacity large scale storage options
- Underground Sun Storage as well as Underground Sun Conversion technology can solve the problem of seasonal power storage
- Generation of renewable natural gas closes a sustainable natural carbon cycle
- Integration of renewable gas combines the benefits from classical natural gas infrastructure and the sociopolitical target of renewable energy supply

Contact

UNDERGROUND SUN.CONVERSION

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