Ongoing hydrogen projects in porous reservoir in Hungary

Connecting for a New Future

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HGS / Powered by MVM

AQUAMARINE PROJECT

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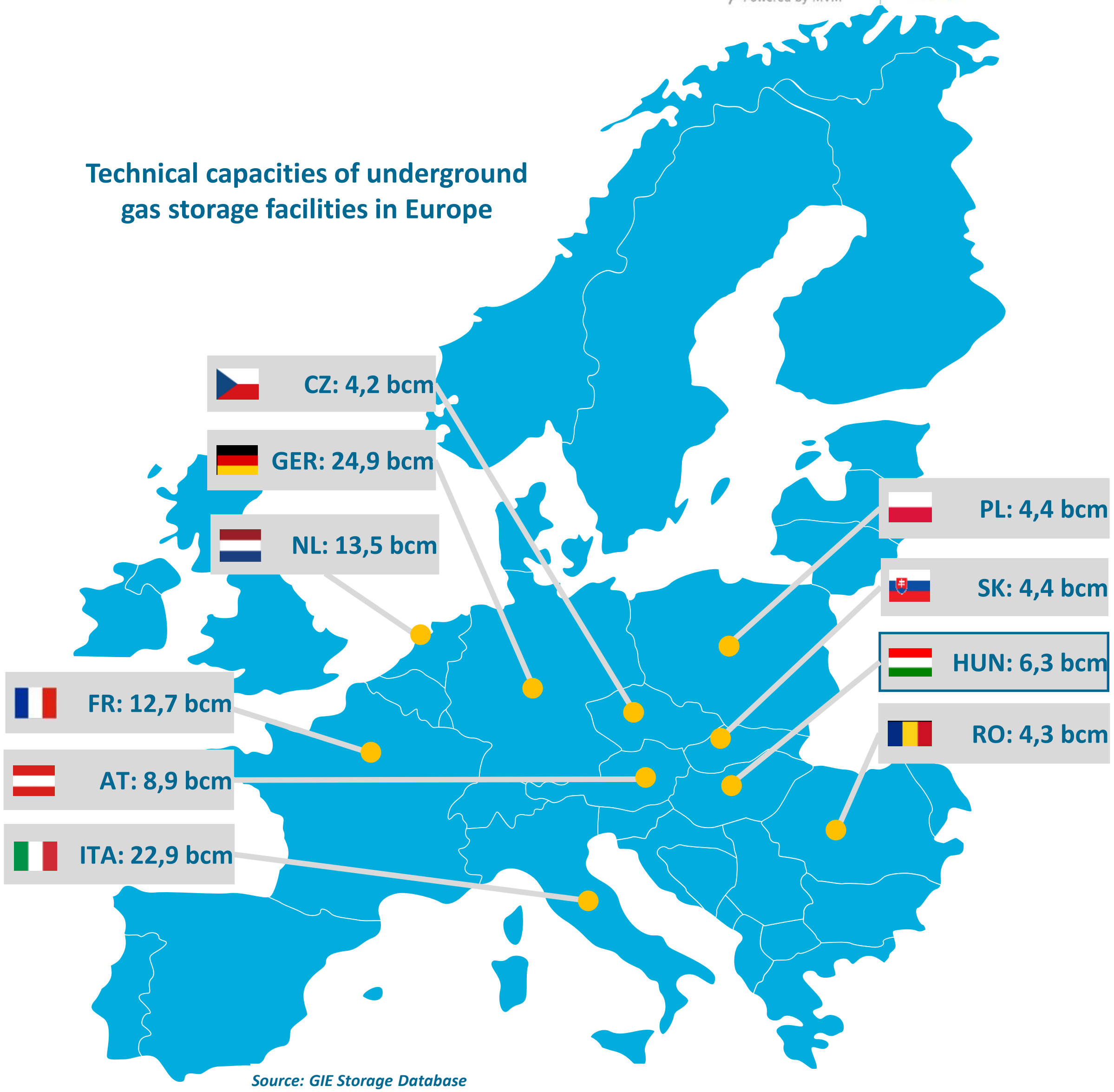
Introduction of Hungarian Gas Storage

Our main activities

- Underground **gas storage operations**
- **Regulated activities** (Mining authorities, Hungarian Energy Authority, Emergency management)
- **Focus on gas storage services** : not allowed to transport or trading natural gas
- **Flexibility services provider**: Demand-supply balancing operations
- **Crucial pillar** in energy security of supply
- Electricity generation permit
- **4 gas storage sites** in Hungary
- Total of **4,4 bcm working gas capacity** (HU gas consumption is around 10 bcm/year) at HGS Ltd
- Sole shareholder: MVM Energy (**100% state owned** company)

Technical capacities of underground gas storage facilities in Europe



Source: GIE Storage Database
https://www.gie.eu/transparency/databases/storage-database/

Hydrogen - How ?

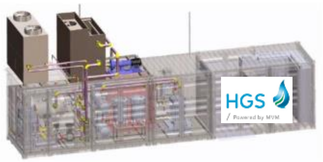
Underground gas storage operations


CH_4

Methane

GREEN electricity surplus

Water



Oxygen

O_2

H_2

GREEN hydrogen

System balancing and energy storage with PEM-electrolysis

Green electricity can be stored and utilised in different energy carriers

Blended gas

- Injection into the transmission system
- Own consumption in compressors / equipment
- Injection into underground storage

AQUAMARINE PROJECT

HyUsPre

Applied R&D programs

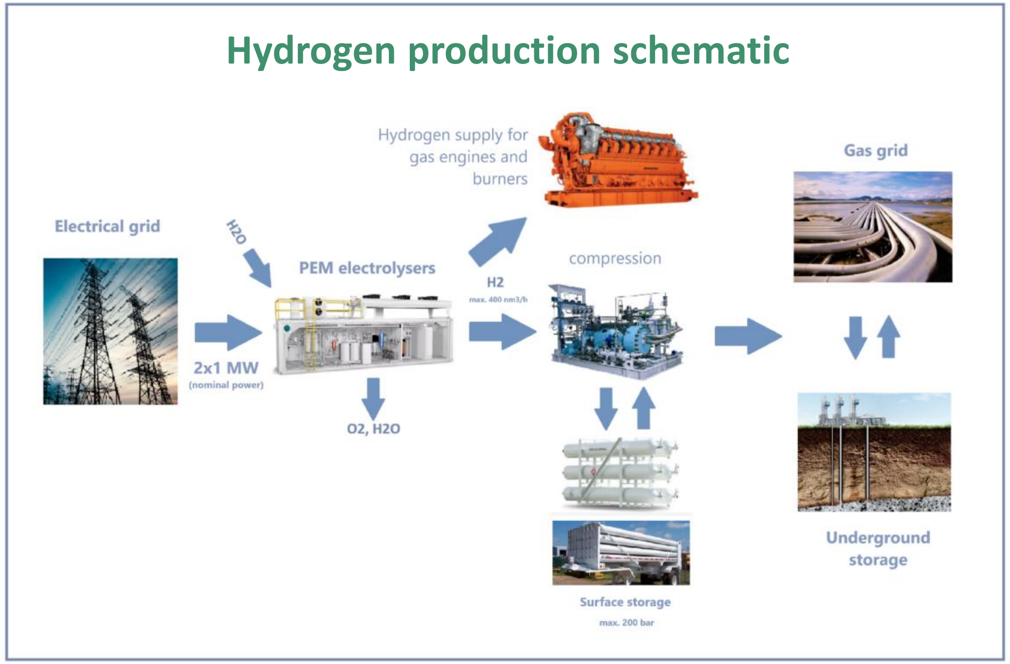
Supporter: TIM KÜLDETÉSÜNK A BIZTONSÁGOS JÖVŐ

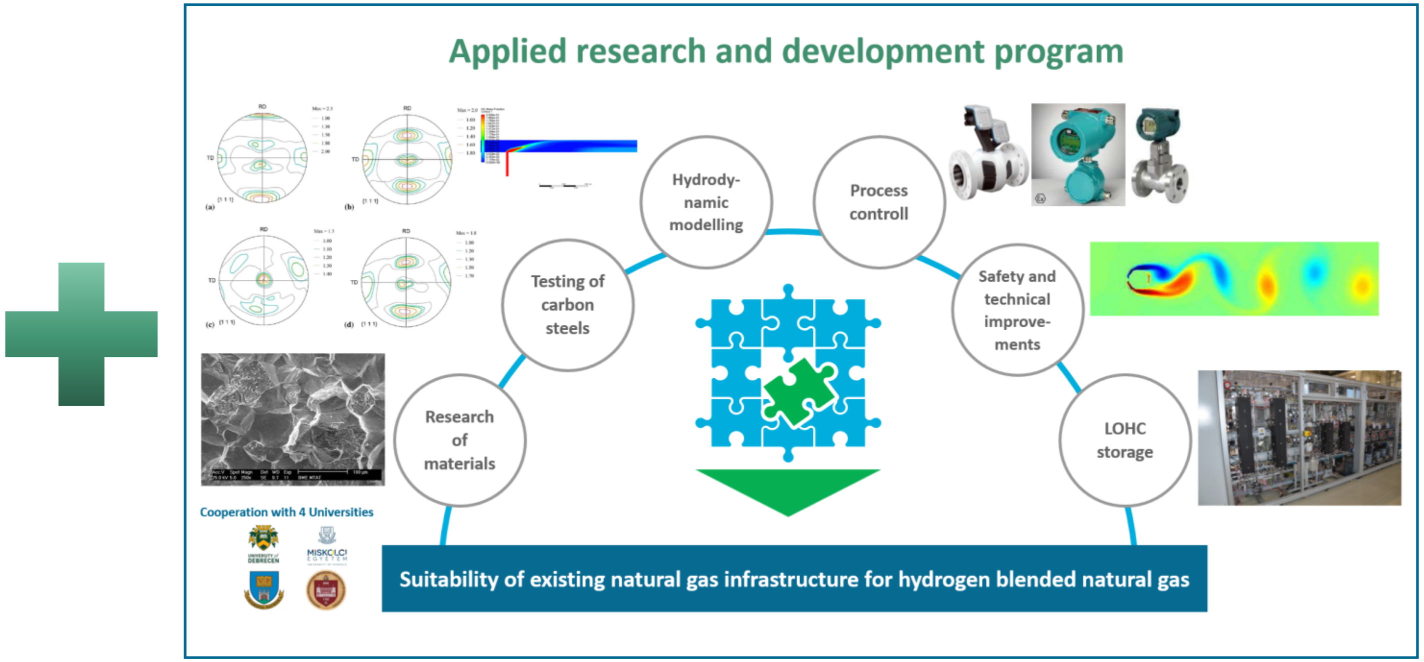
Main characteristics of Project Aquamarine

- **2.0 MW electrolyzer** including H_2 compressor unit with buffer tanks
- **Energy storage** including H_2 production, blended gas to existing methane fueled systems, and also send out to transmission system
- 1 February 2021 – **31 January 2024**
- **Long-term R&D** programs with 5 Hungarian universities and research institutes
- Continuous pioneering in the recent regulatory environment
- **Pilot Project:** effects of hydrogen blended natural gas on the existing gas infrastructure

Supporter:

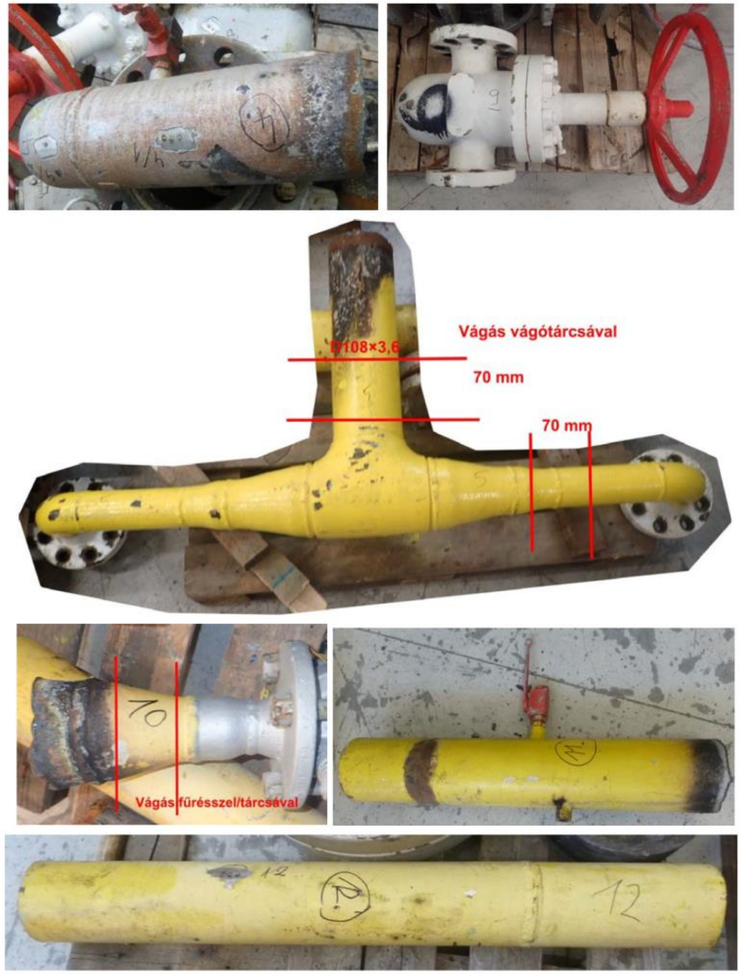
Hydrogen utilisation schematic in Kardoskút UGS





Supporter:

Research of materials – Hydrogen effects



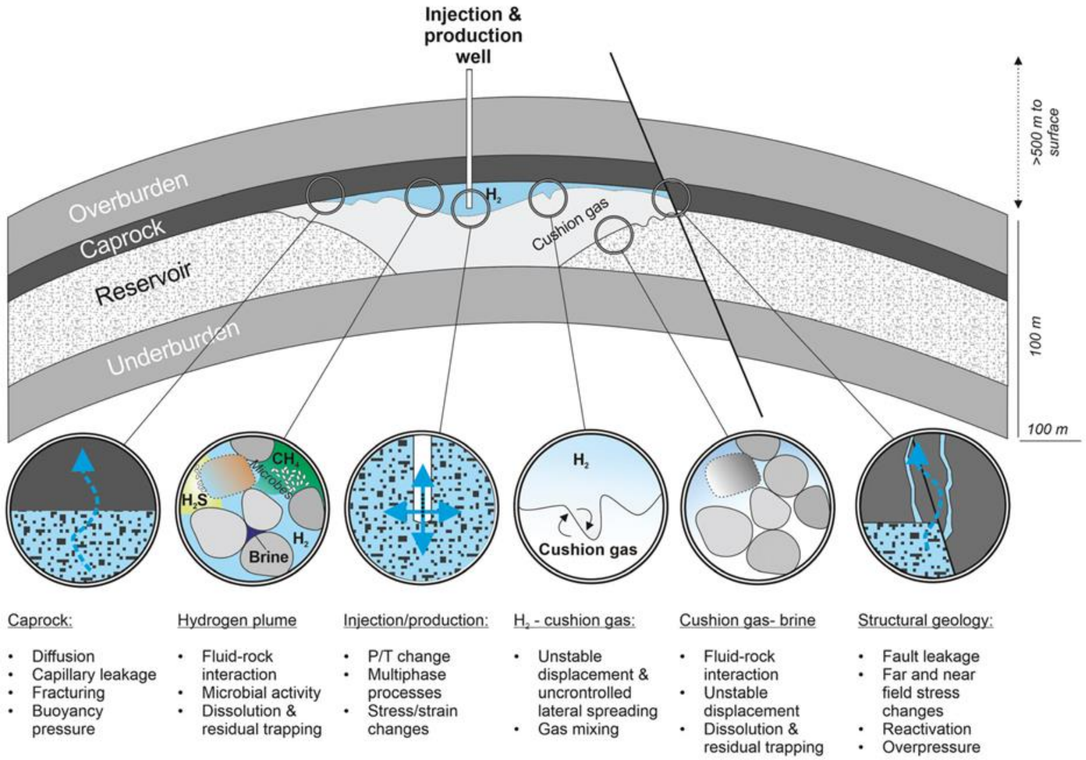
Hydrogenation vessel design (BME)

MFGT's new test piece
(patent application)

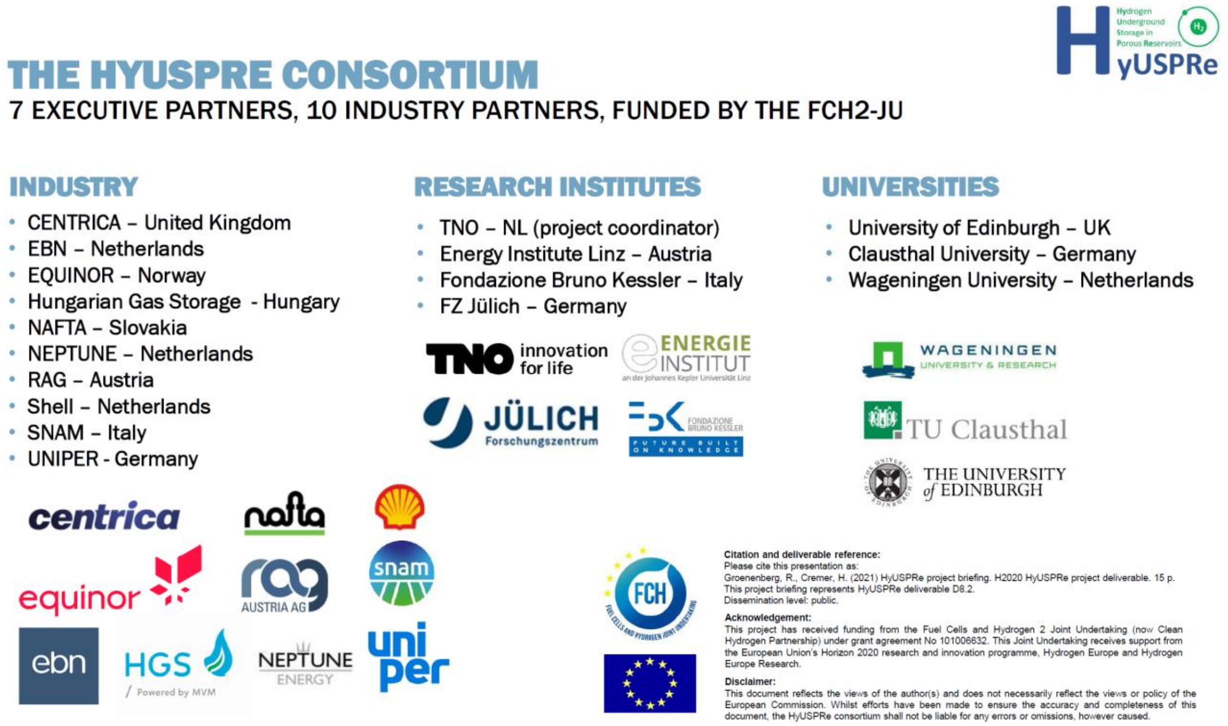
Hydrogen permeation test chamber

Supporter:

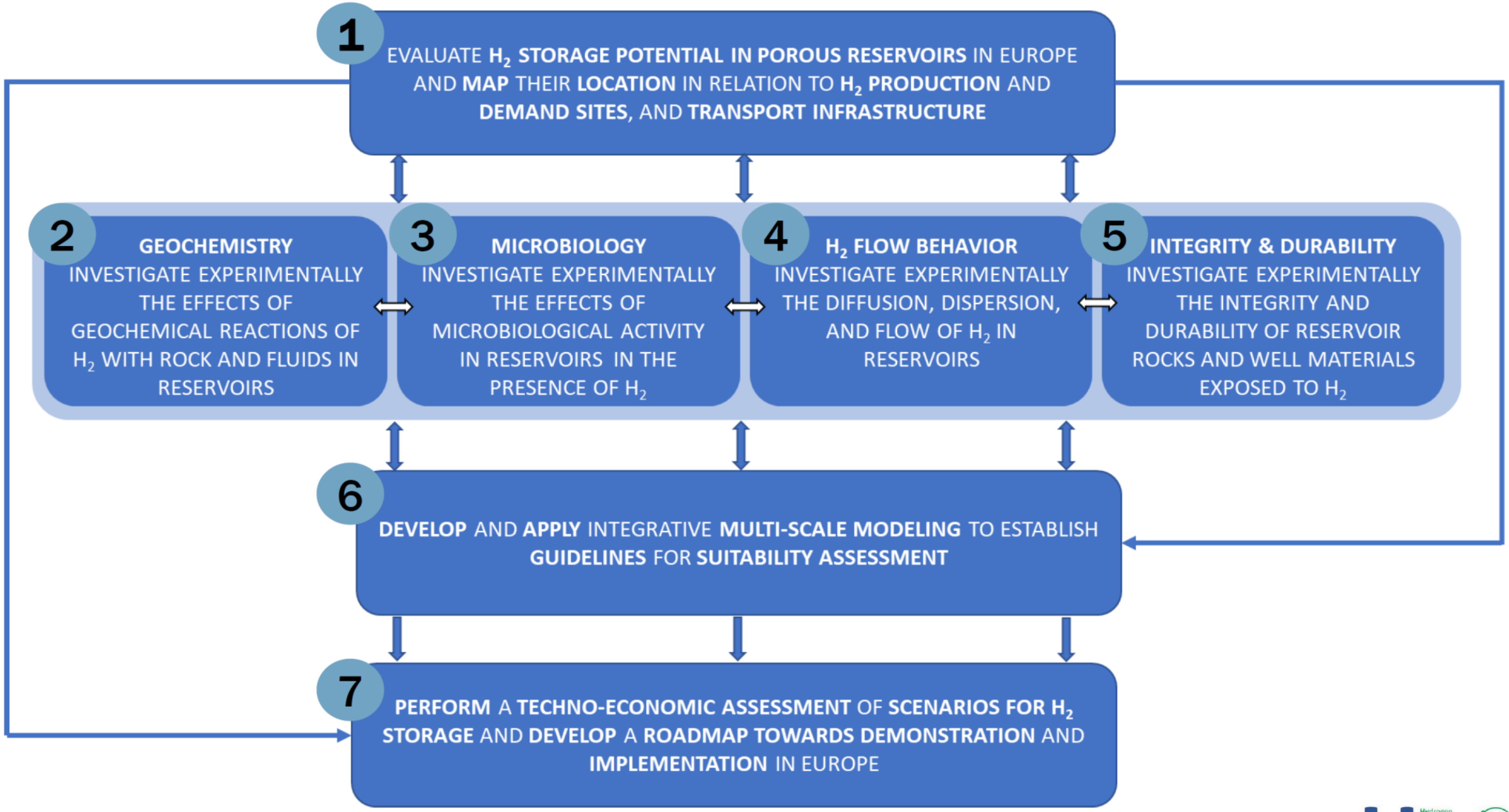
HyUSPRe consortium



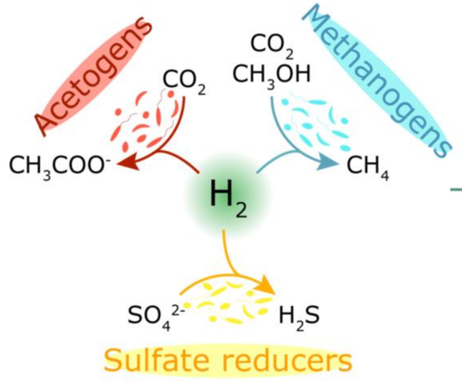
Source: Heinemann, N., Alcalde, J., Miocic, J. M., Hangx, S. J. T., Kallmeyer, J., Ostertag-Henning, C., Hassanpouryouzband, A., Thaysen, E. M., Strobel, G. J., Schmidt-Hattenberger, C., Edlmann, K., Wilkinson, M., Bentham, M., Haszeldine, R. S., Carbonell, R., & Rudloff, A. (2021). Enabling large-scale hydrogen storage in porous media – the scientific challenges: Energy & Environmental Science. Energy Environ. Sci.. https://doi.org/10.1039/D0EE03536J

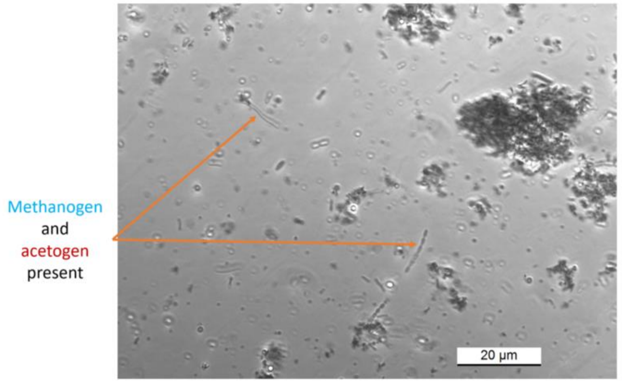


Research activities



Microbiological activity in the reservoir

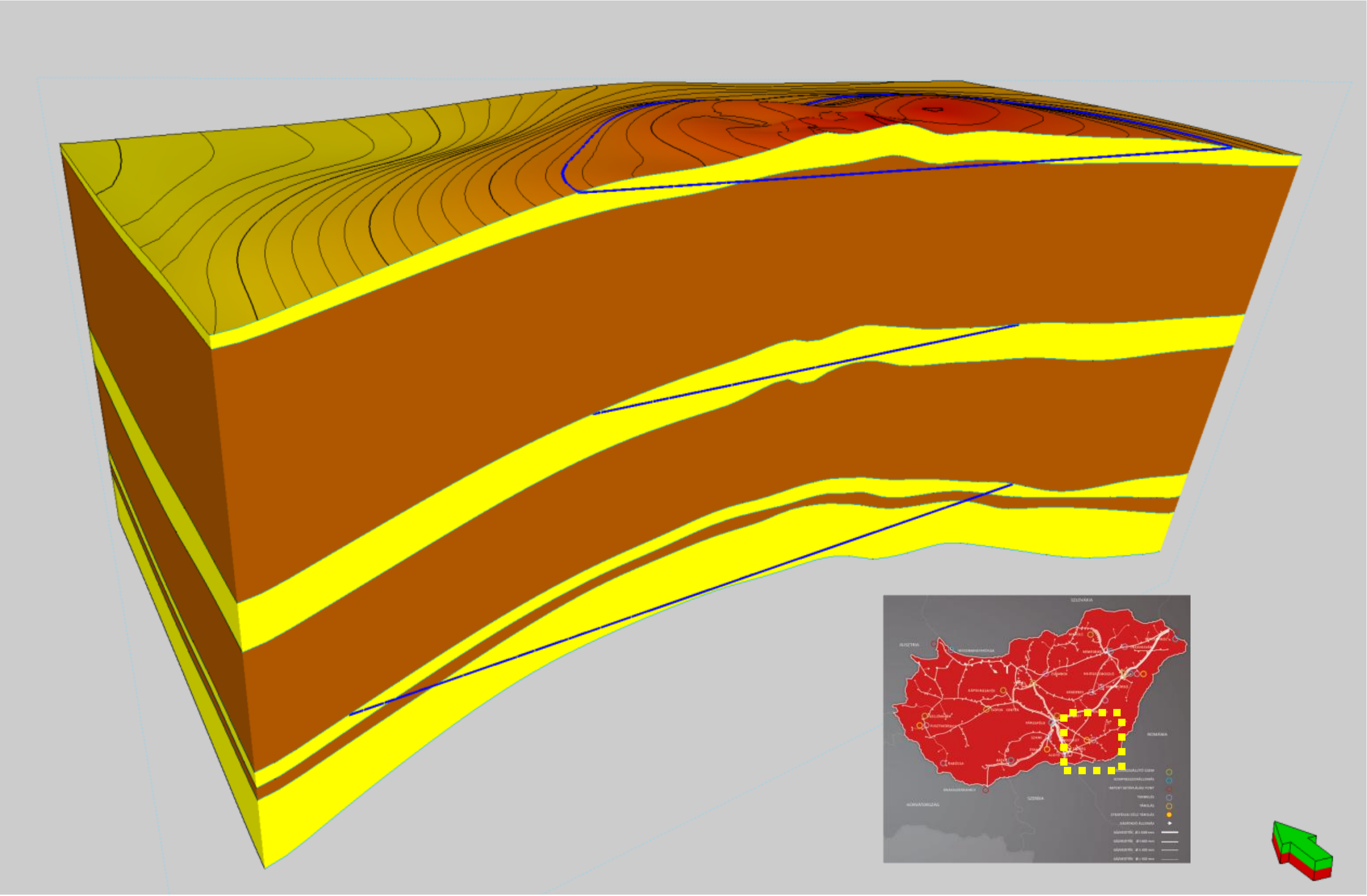




- Loss of H_2 through microbial metabolic processes (methanogenesis, sulfate-reduction and acetogenesis)
- Generation of H_2S through microbial sulfate-reduction
- Loss of H_2 injectivity due to near well bore plugging by bio-based solids (microbes, Extracellular Polymeric Substances (EPS), FeS, etc.)

Case Study – Kardoskút UGS

Geological Summary



Pusztaszőlős Field is a reservoir triple, located in South Hungarian neogene formations having a paleozoic basement with an area of c. 4.16 km2

I. – Selected for hydrogen injection

II. – UGS gas reservoir

III. – UGS gas reservoir

Average depth is ranging from 995 to 1145 m ss

The three reservoirs are separated by shale, shaly marl as seals

Average reservoir thicknesses are ~10, ~16 and ~31 m

Simulation Summary

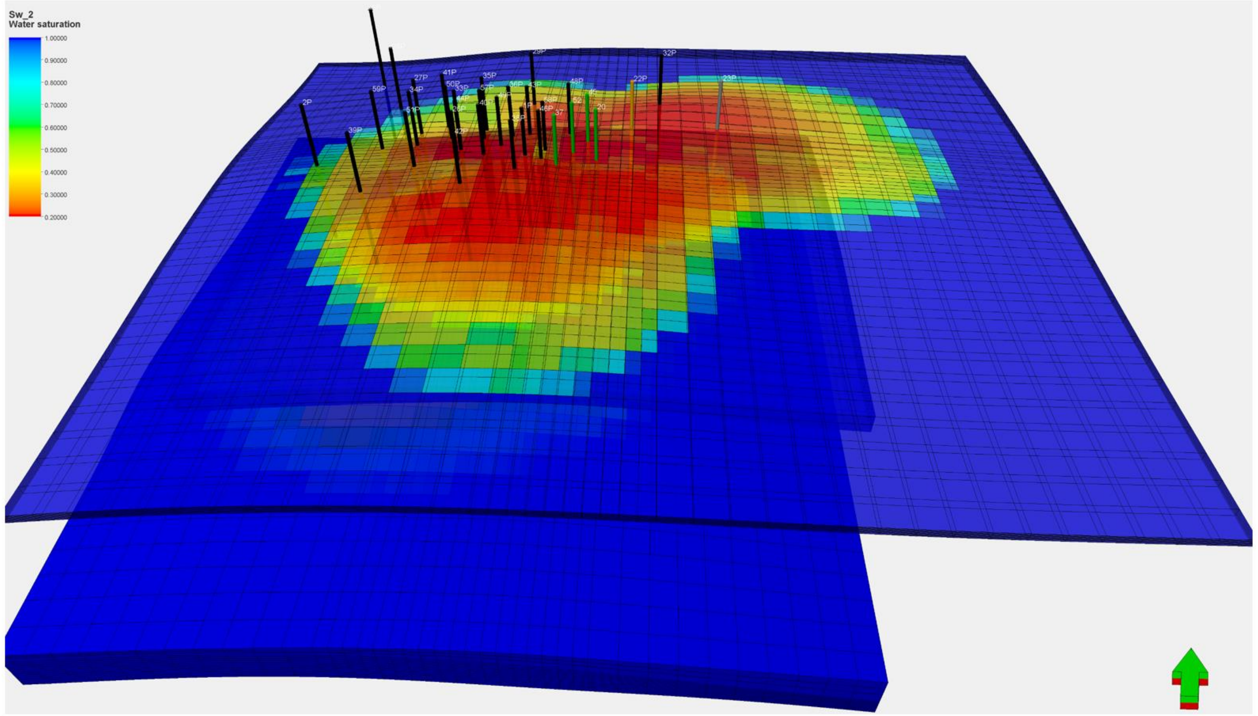
Main rock properties/characteristics are as follows:

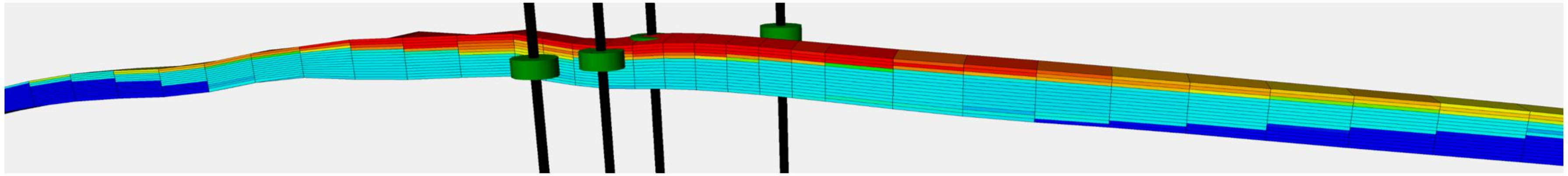
Rock type	Unsonsolidated sandstone, aleurolite and shaly marl
Wettability	Strongly water wet
Average connate water saturation	S_{wc} = ~ 0.1
Average porosity, average	22 - 30 %
Permeability range	~300 – 400 mD

Reservoir	# of sublayers
III./1.	15
III./2.	6
III./3.	10
II.	10
I.	15

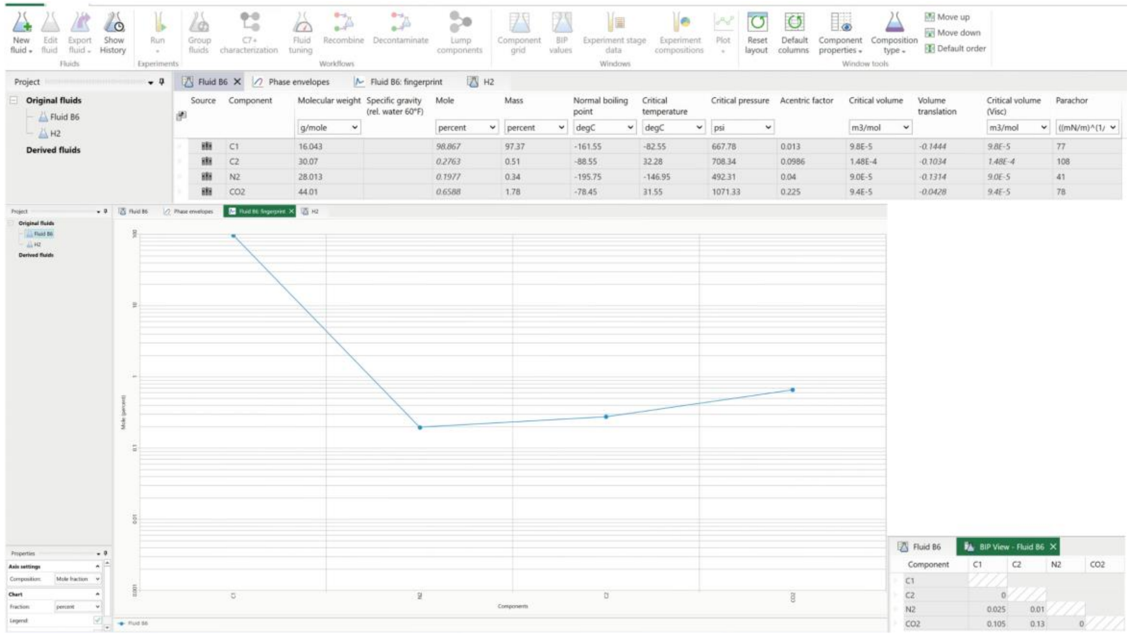
Component	Mol%
methane	95.7200
ethane	1.8175
propane	0.3634
i-butane	0.0553
n-butane	0.0559
i-pentane	0.0120
n-pentane	0.0086
hexane	0.0044
heptane	0.0029
octane+	0.0015
N_2	1.0300
CO_2	0.9285
Gas density, kg/m^3	0.713
Relative density, kg/m^3	0.58

Simulation Dynamic Model (Tartan grid)

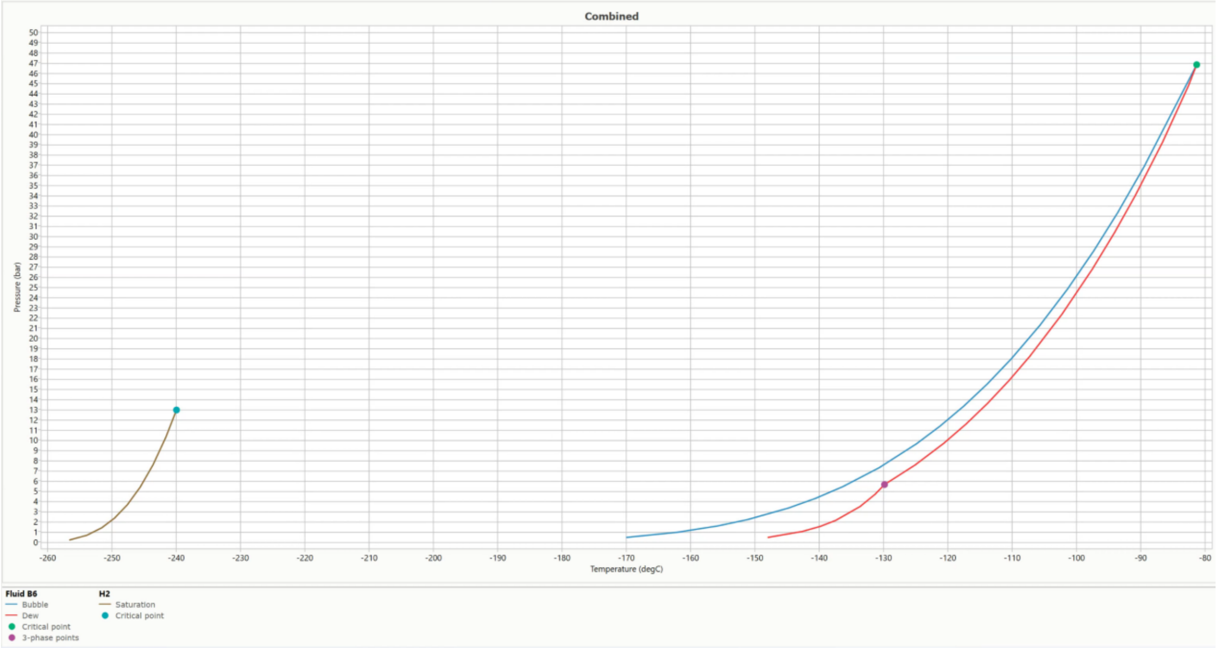




From Black-Oil Eclipse 100 to Compositional Eclipse 300



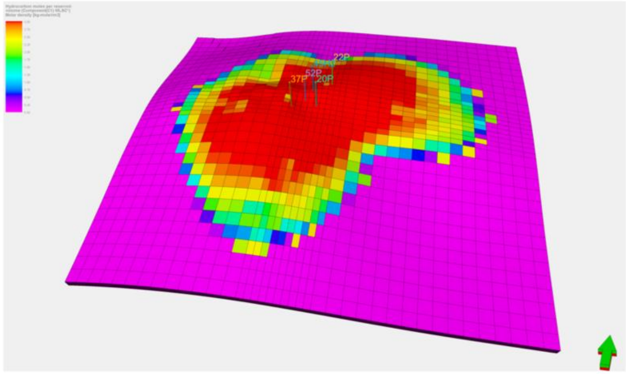
Component Name	Critical Temperature K	Critical Pressure Barsa	Molecular Weight Kg/Kg-M	Critical Volume M3/Kg-M	Critical Z-factor
H2	15.42000	12.99000	2.020000	0.3020107E-01	0.3060000
CO2	286.7600	73.87000	44.01000	0.8843552E-01	0.2740000
C1	200.0000	50.00000	18.05000	0.8680129E-01	0.2610000
H2S	355.8200	89.37000	34.12000	0.9334980E-01	0.2820000



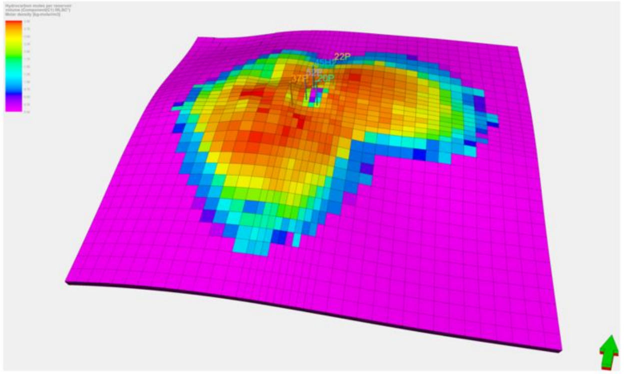
From Eclipse 100 to Eclipse 300 - Initialization

```
-----------------------------------------------------------------------------------------------------------------------------12
FIP                     Fluid in place report                                  0.00000     Days  report step 0,  1 Jan 2022
Run on  3/06/2022 at 09:08:21 version 2021.2   cpu       0.67 elapsed       1.44 memory       45 Mb

-----------------------------------------------------------------------------------------------------------------------------

Fluid in place totals
---------------------

Average pressure  PV weighted:           111.241 Barsa
                  HCPV weighted:         110.656 Barsa

Total pore volume at P(ref)            20.461579        M RM3

Total pore volume                      20.461737        M RM3

Hydrocarbon pore volume                 3.580365        M RM3

Average X permeability BV weighted       277.364294     MDarcy
Average Y permeability BV weighted       277.364294     MDarcy
Average Z permeability BV weighted       277.364294     MDarcy
Average porosity BV weighted               0.291413      M3/M3
Average cell thickness DX*DY weighted      0.569991     Metres

Average oil     saturation              0.000000
Reservoir volume of oil                 0.000000          RM3

Average water  saturation               0.825021
Reservoir volume of water              16.881372        M RM3

Average gas    saturation               0.174979
Reservoir volume of gas                 3.580365        M RM3

                       Moles                    Surface volume                 Mass               Material
                                                                                                  balance
          ---------------------------  ---------------------------  ---------------------------  ---------
  Water        884.124560       M Kg-M      16.398130       M SM3     15927.503943       M Kg    1.000000
  HydroC        15.013748       M Kg-M     359.694197       M SM3

                       Moles                    Wet gas volume                 Mass               Material     Mole fraction
                                                                                                  balance
          ---------------------------  ---------------------------  ---------------------------  ---------    ------------
H2               0.000000         Kg-M       0.000000         SM3         0.000000         Kg    1.000000       0.000000
CO2         150137.478269         Kg-M       3.596942       M SM3         6.607550       M Kg    1.000000       0.010000
C1              14.863610       M Kg-M     356.097255       M SM3       268.288167       M Kg    1.000000       0.990000
H2S              0.000000         Kg-M       0.000000         SM3         0.000000         Kg    1.000000       0.000000

Average hydrocarbon molar density          0.734 Kg-M/RM3
Average water       molar density         43.209 Kg-M/RM3
```

Molecular diffusion



t = 0



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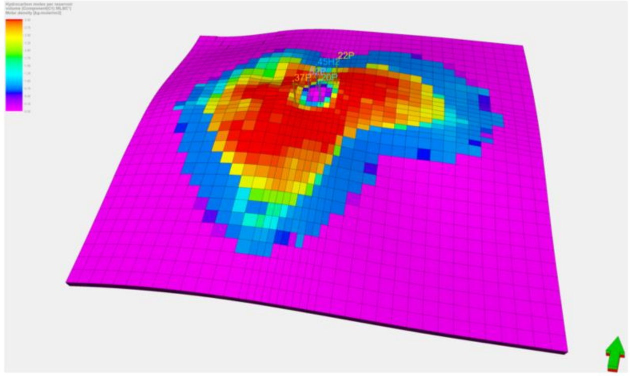
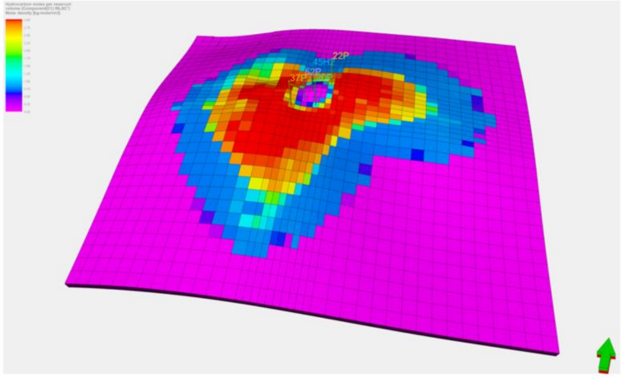


t = 14



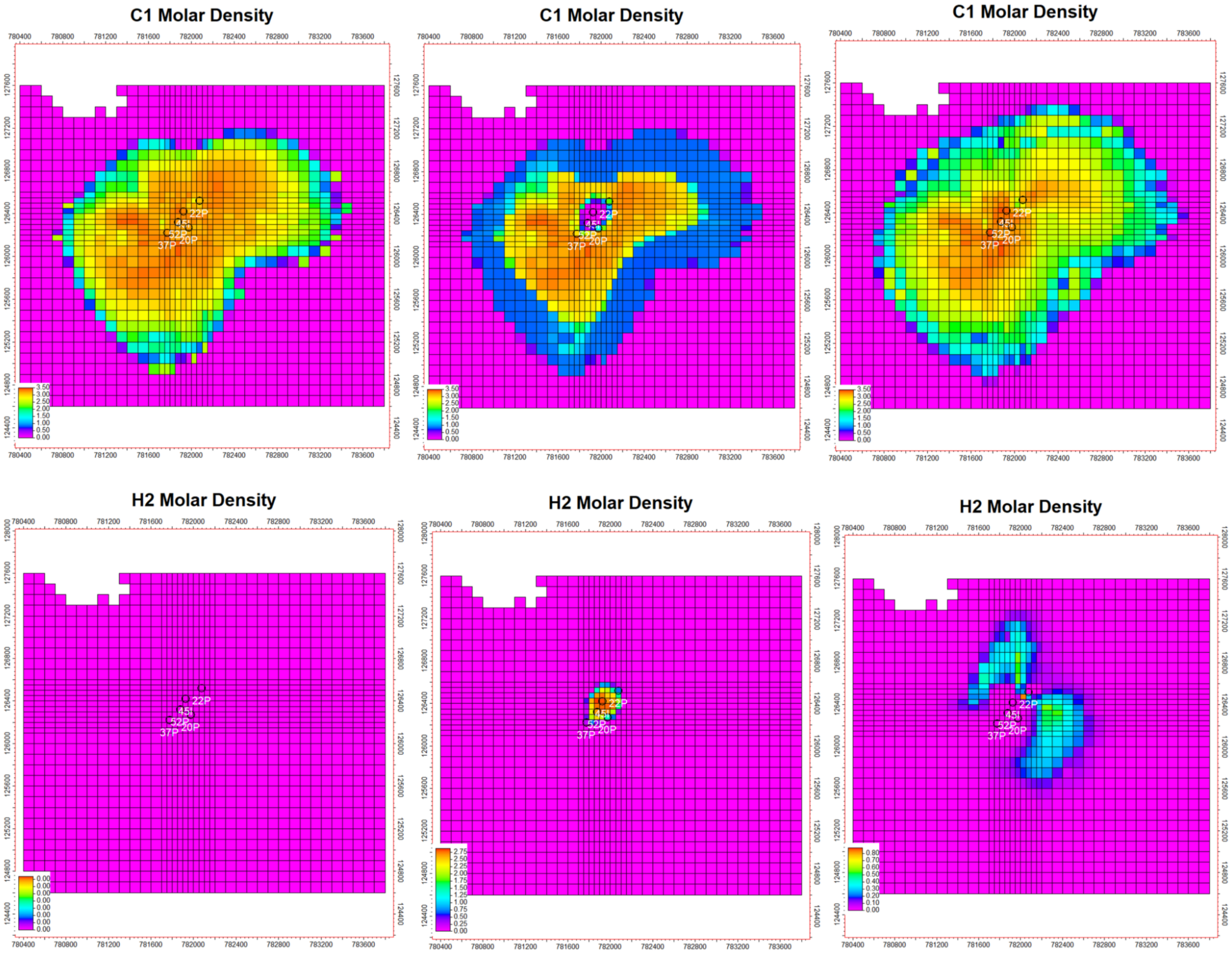
t = 24

- Effective molecular diffusion coefficients
- Mechanical dispersivities
- Relative permeability curves
- Validate compositional modelling

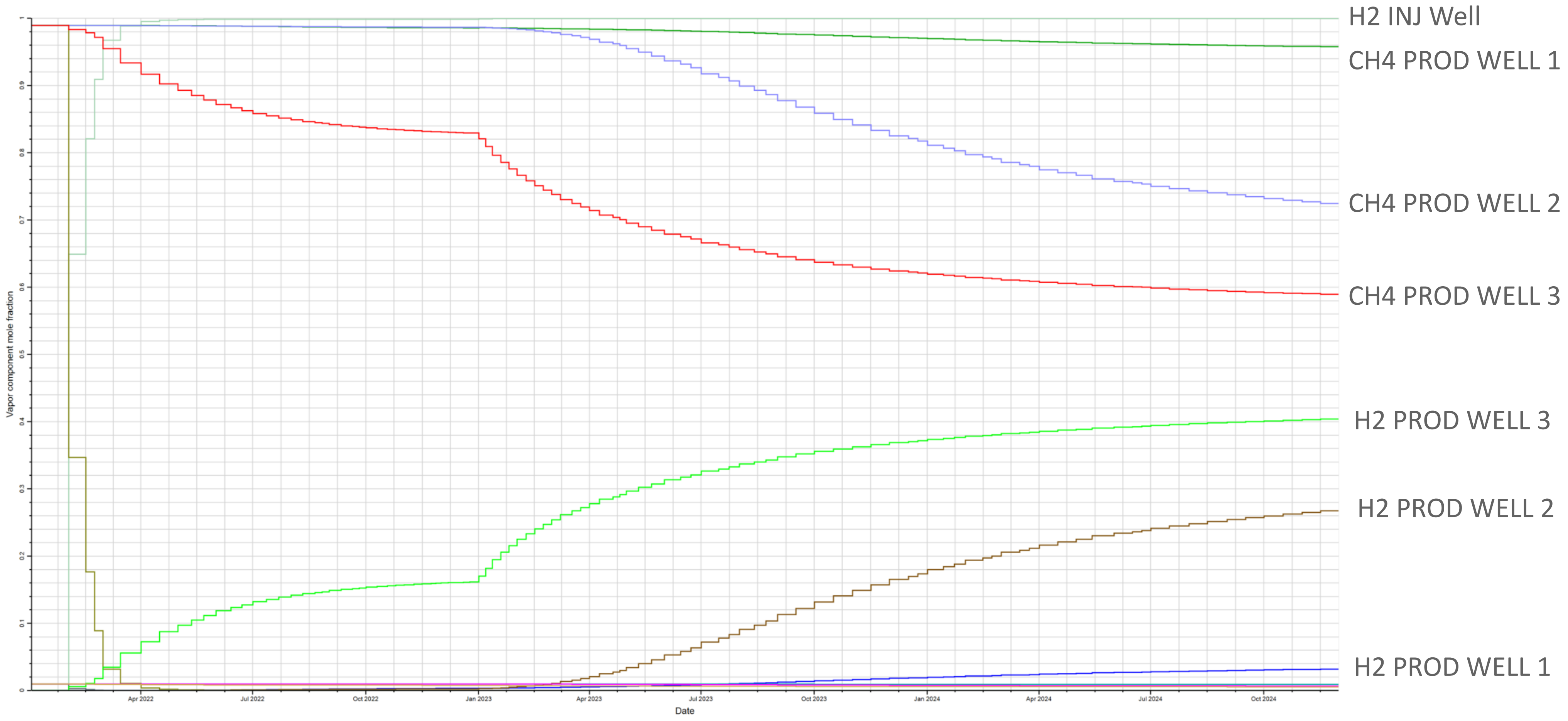
- We have developed a simulation model to follow the movement of injected hydrogen in the reservoir

- This model was used to determine the losses of hydrogen due to diffusion and to other processes (dissolution, methanisation, etc.)

- Hydrogen natural gas mixture is actually injected into a porous gas reservoir (10 vol% H2)

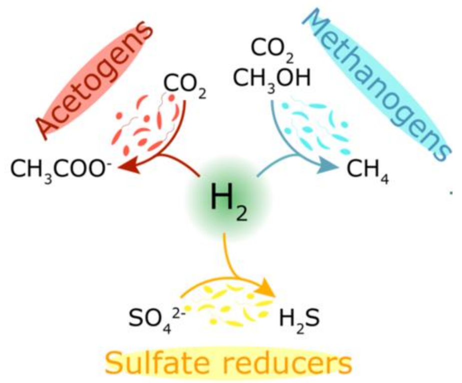


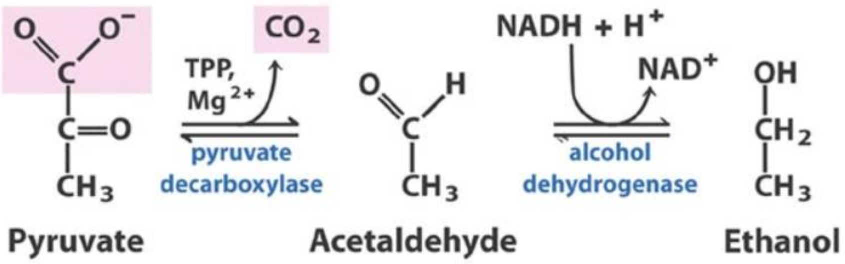
Vapour component mole fraction

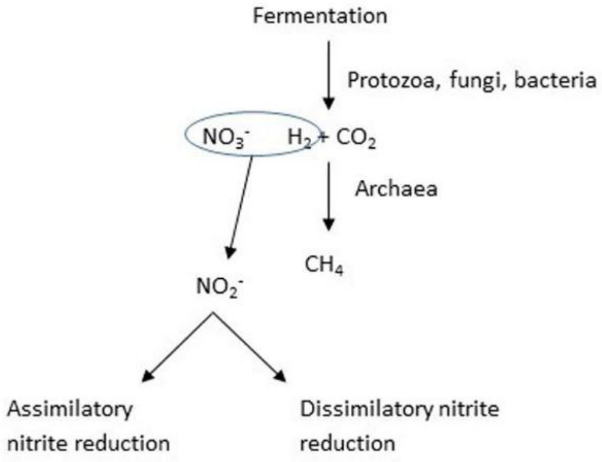


Microbiological processes

Microorganisms can also turn H2 into methane, model must be matched against experiments

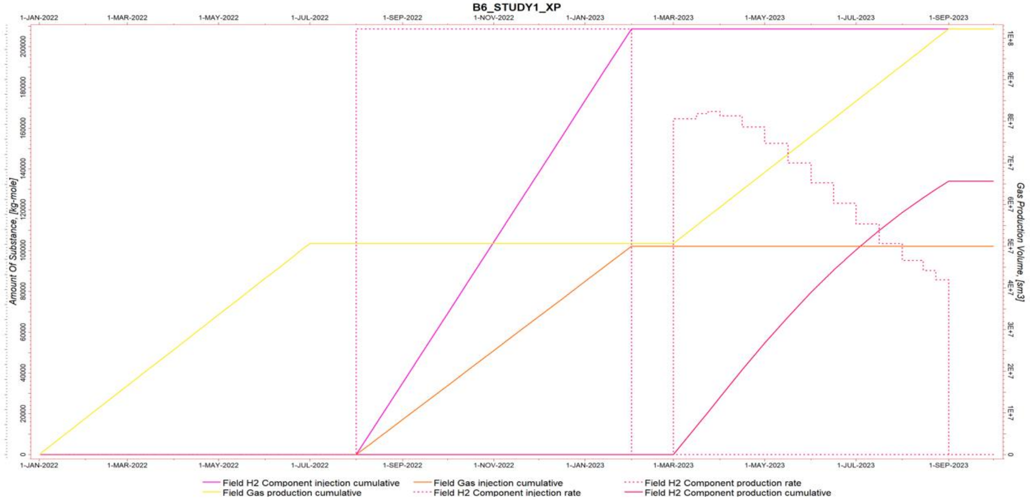


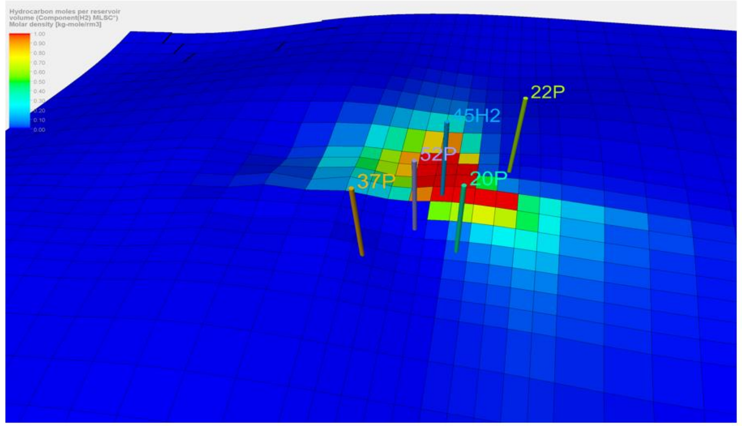


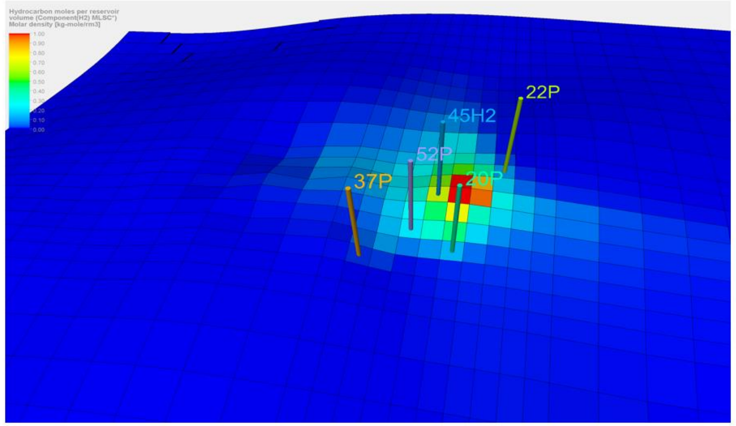


SLB-Private

How much percent of H2 can be produced after 1 cycle ?







Conclusion

- Hydrogen storage is one of the **main pillars** of Hungary's National Hydrogen Strategy
- Long-term collaboration with European Research Institutes, Universities and Gas Storage Companies
- Consortium for **developing hydrogen technologies** in UGS circumstances
- Amendment of the mining law – in progress
- **Matchmaking** of our ongoing projects – fuel cells, LOHC, coating, methanation
- **Aquamarine + (2023):** Knowledge Center of H2 Technologies

Sector coupling - flexible services

Integration of new hydrogen technologies in existing infrastructure

Alternative hydrogen storage technologies

Supporting technical engineering process

Experience in applied research programs

Engineering principles of process control system and instrumentation

Testing equipment of material samples

Demonstration plant in Kardoskút UGS

Our partnerships

Thank you for your kind attention

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Supporter: