Emerging Fuels Symposium
Athens, Greece • 8–10 May 2024

Working on Finding Out: Current International Trials and Tests

Elizabeth Wheeler

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disclaimer

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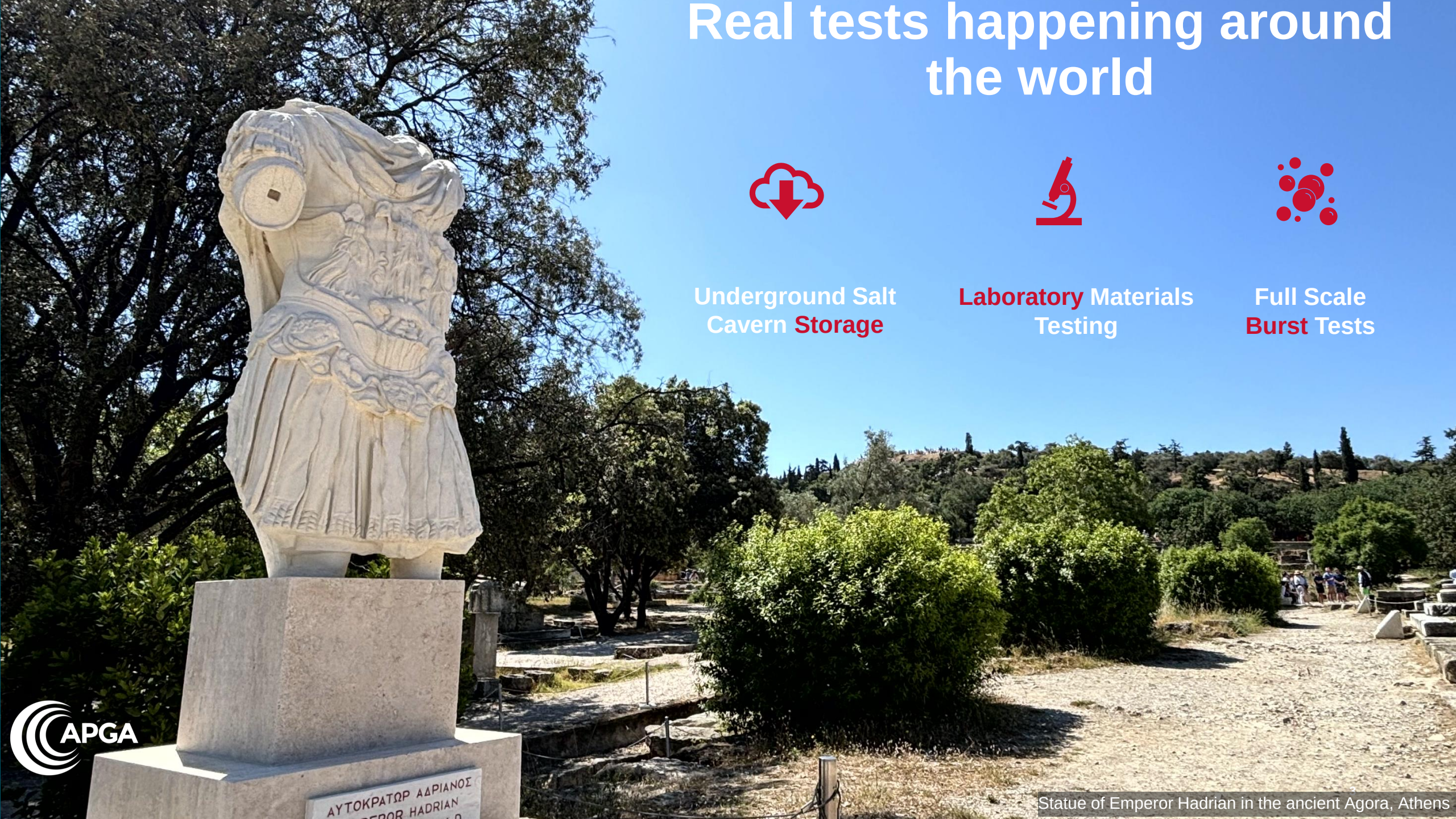
Additional disclaimer: Sincere apologies for the Powerpoint Frankenstein crimes that are committed within this presentation

Real tests happening around the world

Underground Salt Cavern Storage

Laboratory Materials Testing

Full Scale Burst Tests



Statue of Emperor Hadrian in the ancient Agora, Athens

Underground Storage

	Paper Session 2: Hydrogen Storage Chairs: Sarah Hopkin (Shell), David Norman (FFCRC)	
5.	Converting an Existing Salt Cavern to Inject, Store and Withdraw Hydrogen via a "H2-ready" well.	Gregory Blettner (Storengy)
6.	Latest findings from demonstration project HyStock	Dolf Ottens (Gasunie)
	Q&A	
	Paper Session 5: Biomethane/RNG Chairs: Mures Zarea (Engie), TBD	
14.	Reservoir Biogeochemical experiments for RNG acceptance in an aquifer natural gas storage.	Delphine Patriarche (Storengy)

hypster Hydrogen Storage

hystock power to hydrogen


Temple of Hephaestus, Ancient Agora, Athens

Big picture of HyPSTER project

A demonstrator to produce H_2 and store-it underground in salt cavern.

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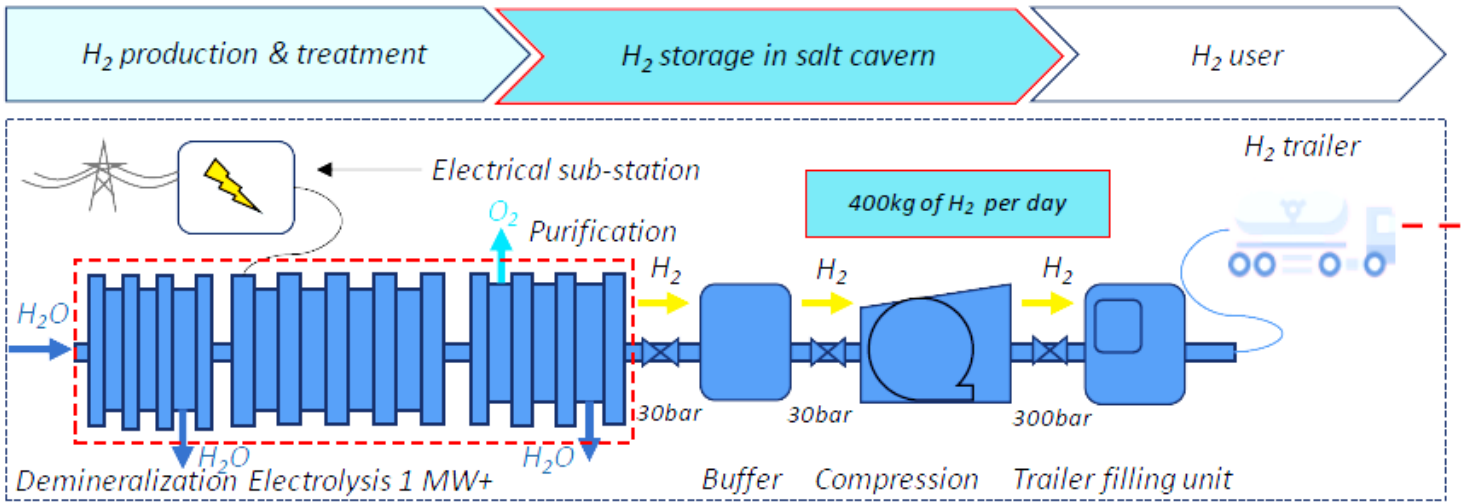
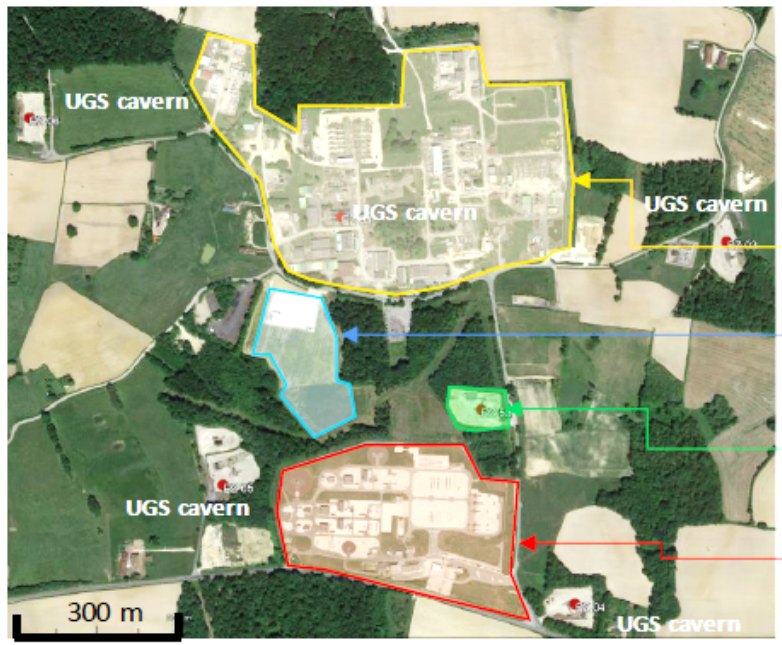




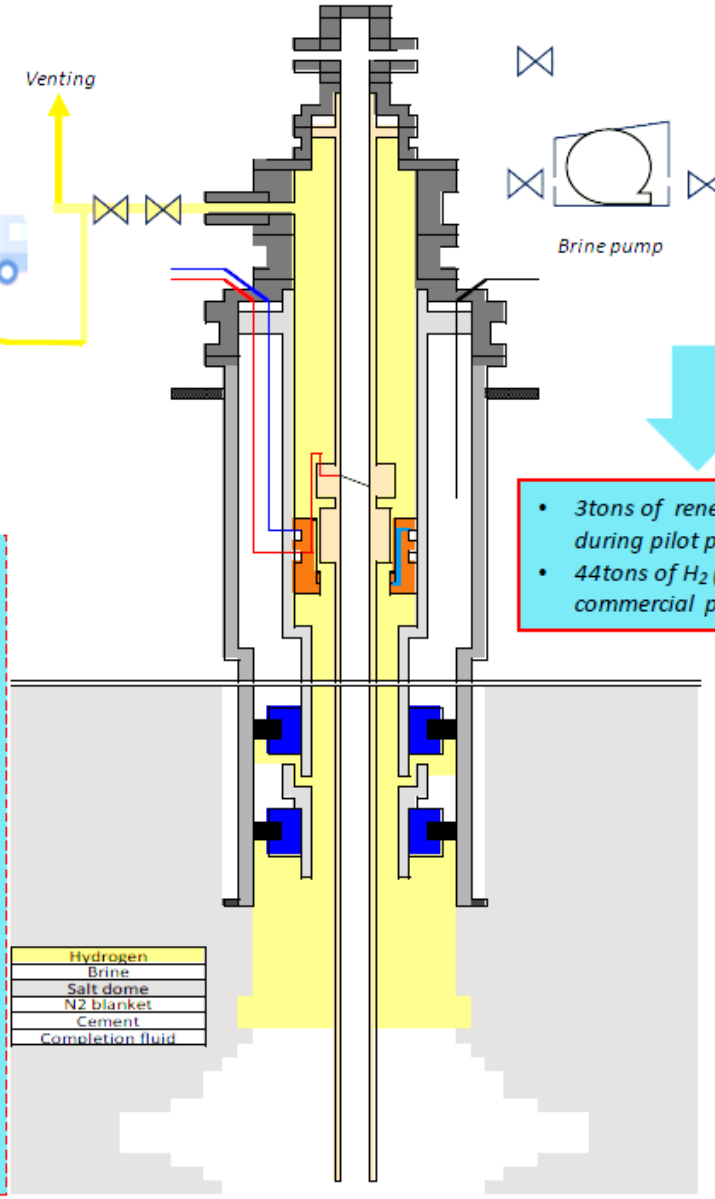
UGS (CH_4) station

H_2 production plateform

EZ53 well & cavern UHS pilot

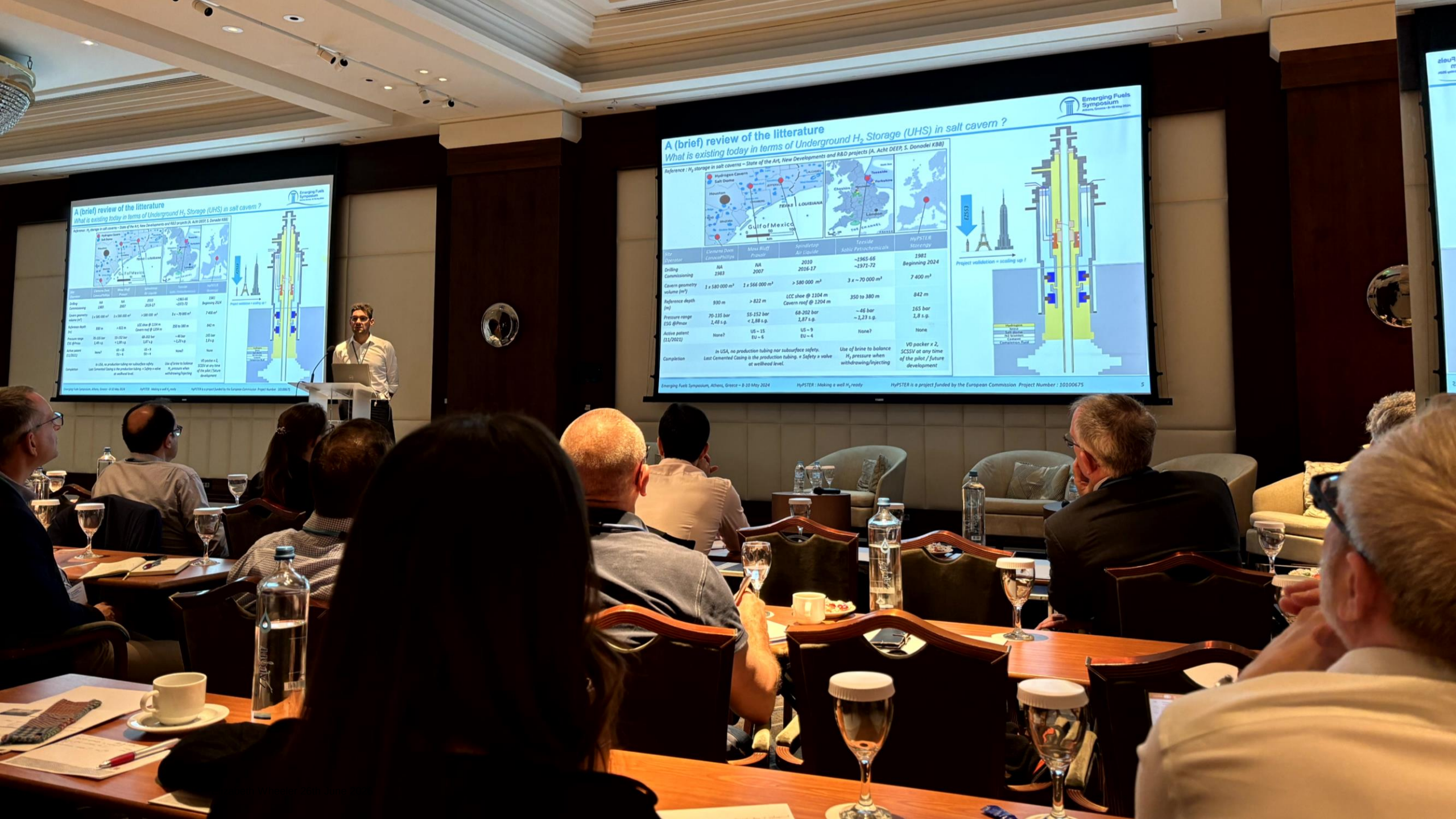
Gas transport network station

1. *Demonstration of the technical feasibility of H_2 storage in salt caverns (safety / environmental + geological impacts).*
2. *Adaptation of equipment to H_2 environnement.*
3. *Hydrogen tightness of the salt cavern.*
4. *Interaction of H_2 in a salt cavern.*
5. *Feedback of the quality of the H_2 leaving the storage facility.*



- *3tons of renewable H_2 during pilot phase.*
- *44tons of H_2 (max) during commercial phase.*

HyPSTER is a project funded by the European Commission Project Number : 10100675


A (brief) review of the litterature
What is existing today in terms of Underground H_2 Storage (UHS) in salt cavern ?
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Reference : H_2 storage in salt caverns – State of the Art, New Developments and R&D projects (A. Acht DEEP, S. Donadei KBB)
Hydrogen Cavern
Salt Dome
Houston
TEXAS
LOUISIANA
Gulf of Mexico
Teesside
Yorkshire
Cheshire
London
CHANNEL
Site / Operator
Clemens Dom ConocoPhillips
Moss Bluff Praxair
Spindletop Air Liquide
Teesside Sabic Petrochemicals
HyPSTER Storengy
Drilling Commissioning
NA 1983
NA 2007
2010 2016-17
~1965-66 ~1971-72
1981 Beginning 2024
Cavern geometry volume (m³)
1 x 580 000 m³
1 x 566 000 m³
> 580 000 m³
3 x ~ 70 000 m³
7 400 m³
Reference depth (m)
930 m
> 822 m
LCC shoe @ 1104 m Cavern roof @ 1204 m
350 to 380 m
842 m
Pressure range ESG @Pmax
70-135 bar 1,48 s.g.
55-152 bar < 1,88 s.g.
68-202 bar 1,87 s.g.
~ 46 bar ~ 1,23 s.g.
165 bar 1,8 s.g.
Active patent (11/2021)
None?
US ~ 15 EU ~ 6
US ~ 9 EU ~ 4
None?
None
Completion
In USA, no production tubing nor subsurface safety. Last Cemented Casing is the production tubing. « Safety » valve at wellhead level.
Use of brine to balance H_2 pressure when withdrawing/injecting
V0 packer x 2, SCSSV at any time of the pilot / future development
EZSS3
Project validation = scaling up !
Hydrogen
Brine
Salt dome
H_2 blankets
Cement
Casing
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HyPSTER : Making a well H_2 ready
HyPSTER is a project funded by the European Commission Project Number : 10100675
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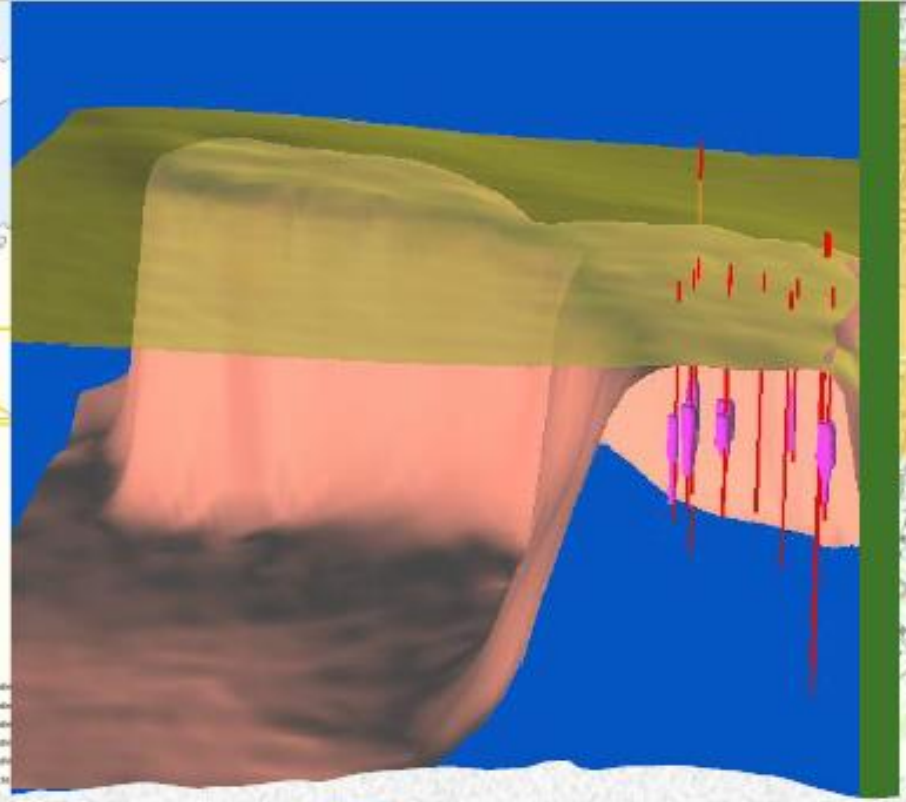
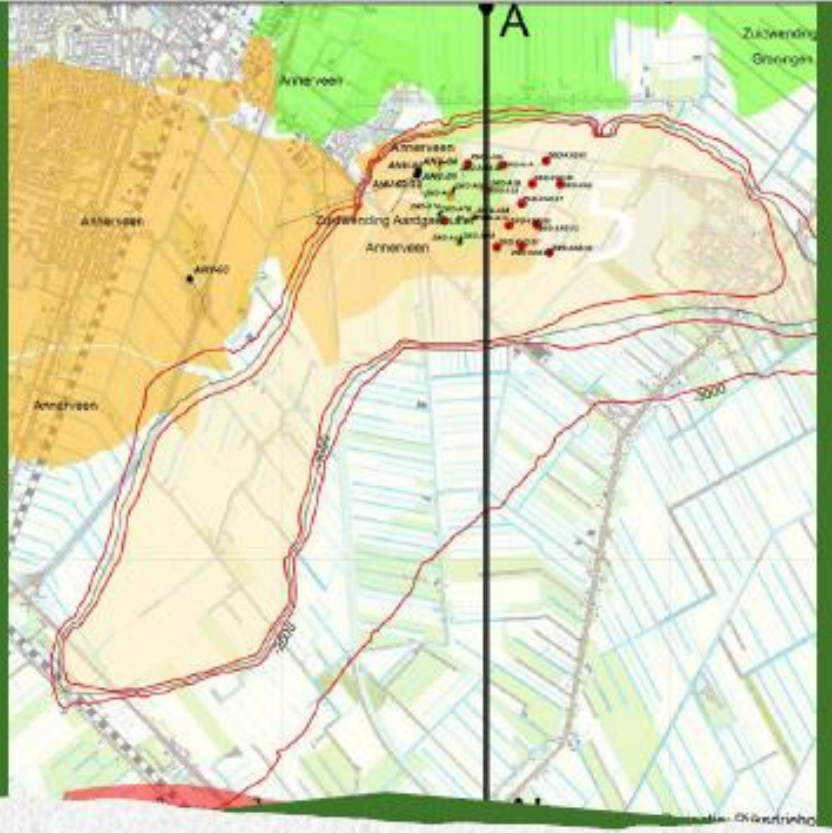
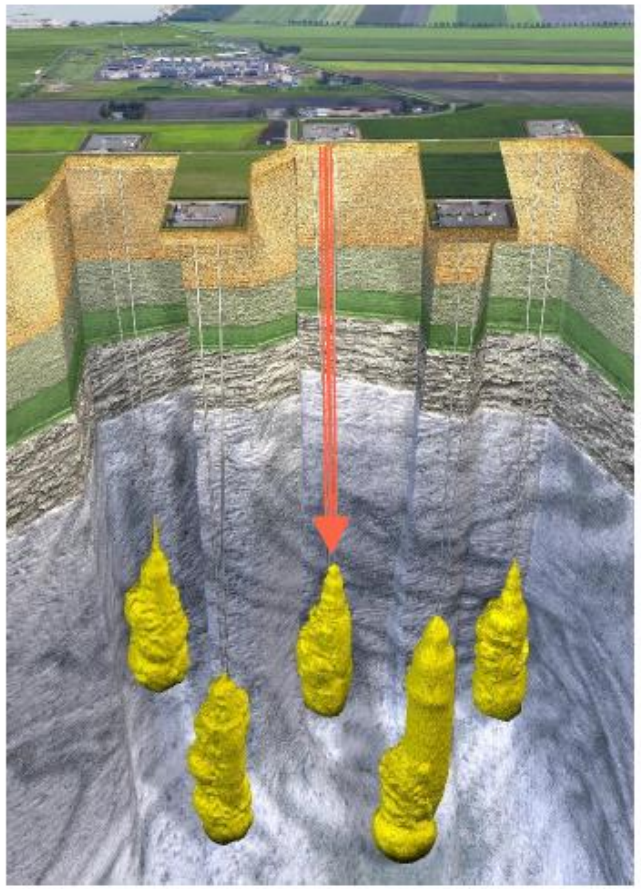




Zuidwending Salt Dome

Characteristics of Salt Caverns



- Very low permeability
  - rock salt is technical tight for gases and liquids
- rock pressure > cavern pressure
- „wall thickness“ >> 100 m (328’)
- overburden = heavy „cover“ ~ 1000 m (3280’)
- Most sensitive point: Man-made well

Observations and findings

- Successful hydrogen storage operation without incidents
- No evidence of hydrogen leakage during the test period
- Cavern integrity test (MIT) successful executed under H_2 (and N_2)
- Equipment based on proven oil and gas design seem applicable for hydrogen application when correct material is selected
- Operational O&G procedures for well interventions (based on IWCF) seem applicable for hydrogen operation

Laboratory Materials Testing

Paper Session 6: Hydrogen Laboratory Testing
Chairs: Mehdi Fardi (Advisian), Nuria Sanchez (OCAS)

17. Investigation of Oxygen Inhibition Effects on Pipeline Steels	Neil Gallon (Rosen)
18. Hydrogen-enhanced FCG and pressure variations	Otto Jan Huising
19. Fracture toughness test methods for material qualification in gaseous hydrogen	Bostjan Bezensek (Shell)
20. Effect of loading mode	Ramgo Thodla (DNV)
Q&A	
Afternoon Coffee	

Panel Session 4: Hydrogen Laboratory Testing

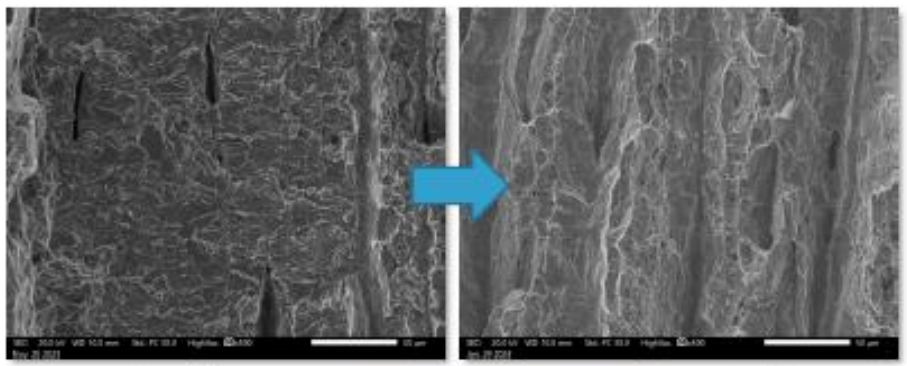
- **4 panelists**

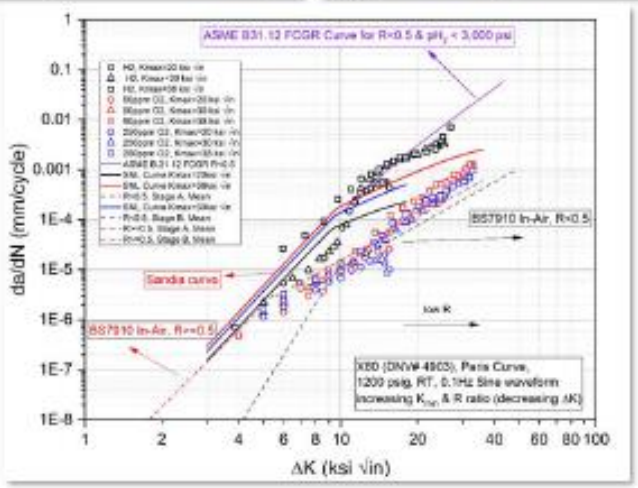

Museum of the Ancient Agora, Athens

Conclusions

- FCGR behavior in high pressure H2 is not sensitive to microstructure or frequency
- FCGR transitions from high acceleration factors at high ΔK to low acceleration factors at low ΔK, the transition is sensitive to hydrogen pressure and R-ratio.
- In high pressure H_2 at high K_{max}, FCGR at low ΔK is high likely due to SCGR.
- SCGR is observed in a range of microstructures in high pressure H_2.
- SCGR appears to be path dependent.

- Laboratory testing has shown oxygen shown to be effective inhibitor to hydrogen embrittlement
- Improvements in both Fracture Toughness and Fatigue performance compared to 100% hydrogen
- Detailed fractography demonstrated ability of oxygen additions to prevent transition to cleavage fracture mechanism





- Further work recommended to confirm behaviour over wide range of microstructures (inc. welds and more legacy pipe grades)
- Need to prove concept at network level and demonstrate efficacy over industrially relevant timescales
- Consequences to upstream and downstream processes also to be considered to understand the full economic impact of the deployment of this technology

Full Scale Testing

Afternoon Coffee

Panel Session 2: Full Scale Testing

In-Service Welding for H2 (& blends) pipelines – Recent & Proposed Full-scale testing
(Bill Bruce, DNV)

HYTAP – Welding on a gaseous hydrogen Line
(Otto-Jan Huising, Gasunie)

EPRG Full-scale fatigue testing
(Gianluca Mannucci, Rina-CSM)

FutureGrid Full-scale Testing – National Gas Transmission
(Robert Best & Pamela Colgan, National Gas)

JEFI-04-08 Full-scale Testing Program
(Mark Cuglietta, CFER)


Propylaia (Acropolis of Athens)

HYTAP- Welding on a gaseous hydrogen Line

Full scale learnings

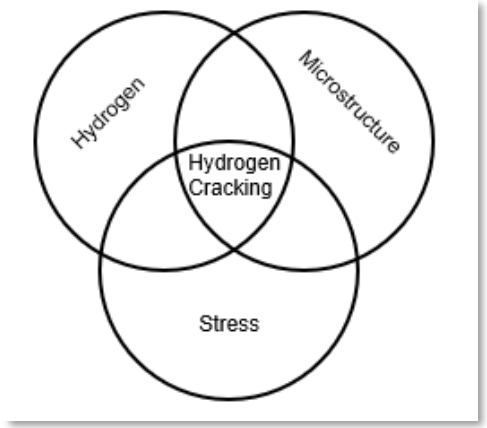
PRCI LEADING PIPELINE RESEARCH

Pipeline Research Council International

DNV

In-service Welding for Hydrogen and Hydrogen Blend Pipelines – Recent and Proposed Full-scale Testing

EPRG



tempting low-H electrode

> *It's better to go slow in the right direction than to go fast in the wrong direction.*
>
> ~ Simon Sinek ~

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For further information

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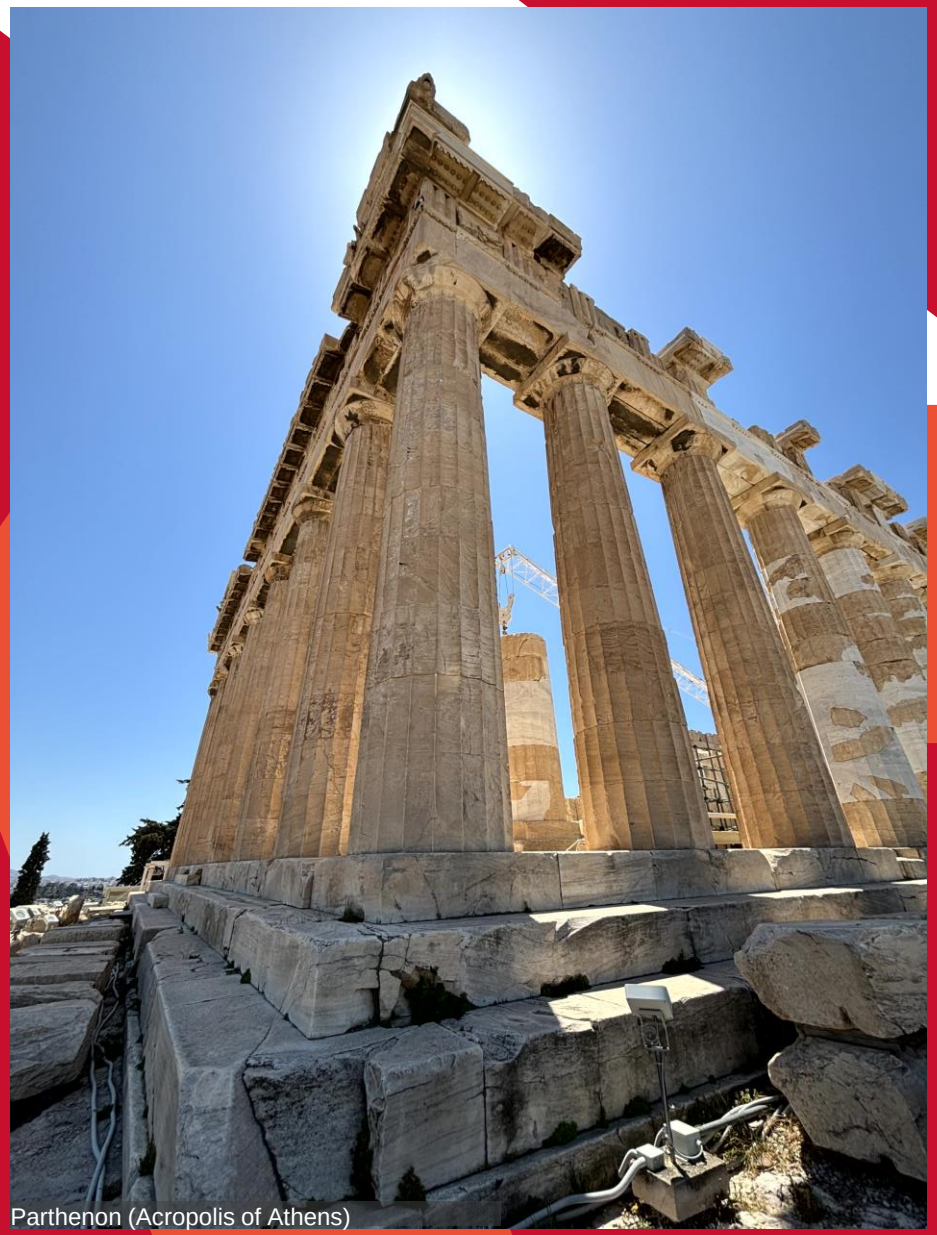

Parthenon (Acropolis of Athens)