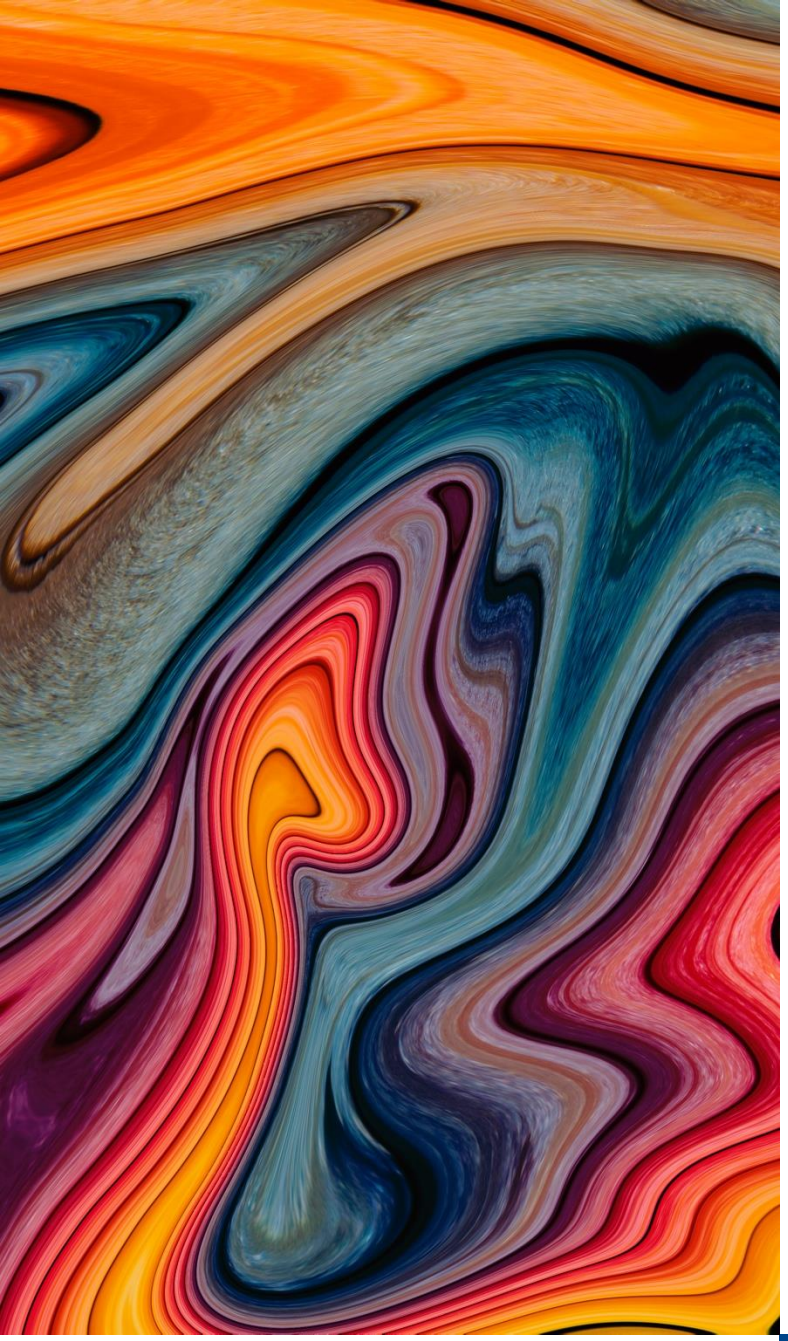


Geostock

WE MAKE THE EARTH THE BEST PLACE
FOR STORING ALL ENERGIES

Discovering Underground H2 Storage

Sept 13, 2023 – Muscat, OMAN

Pascal BAYLOCQ

Agenda

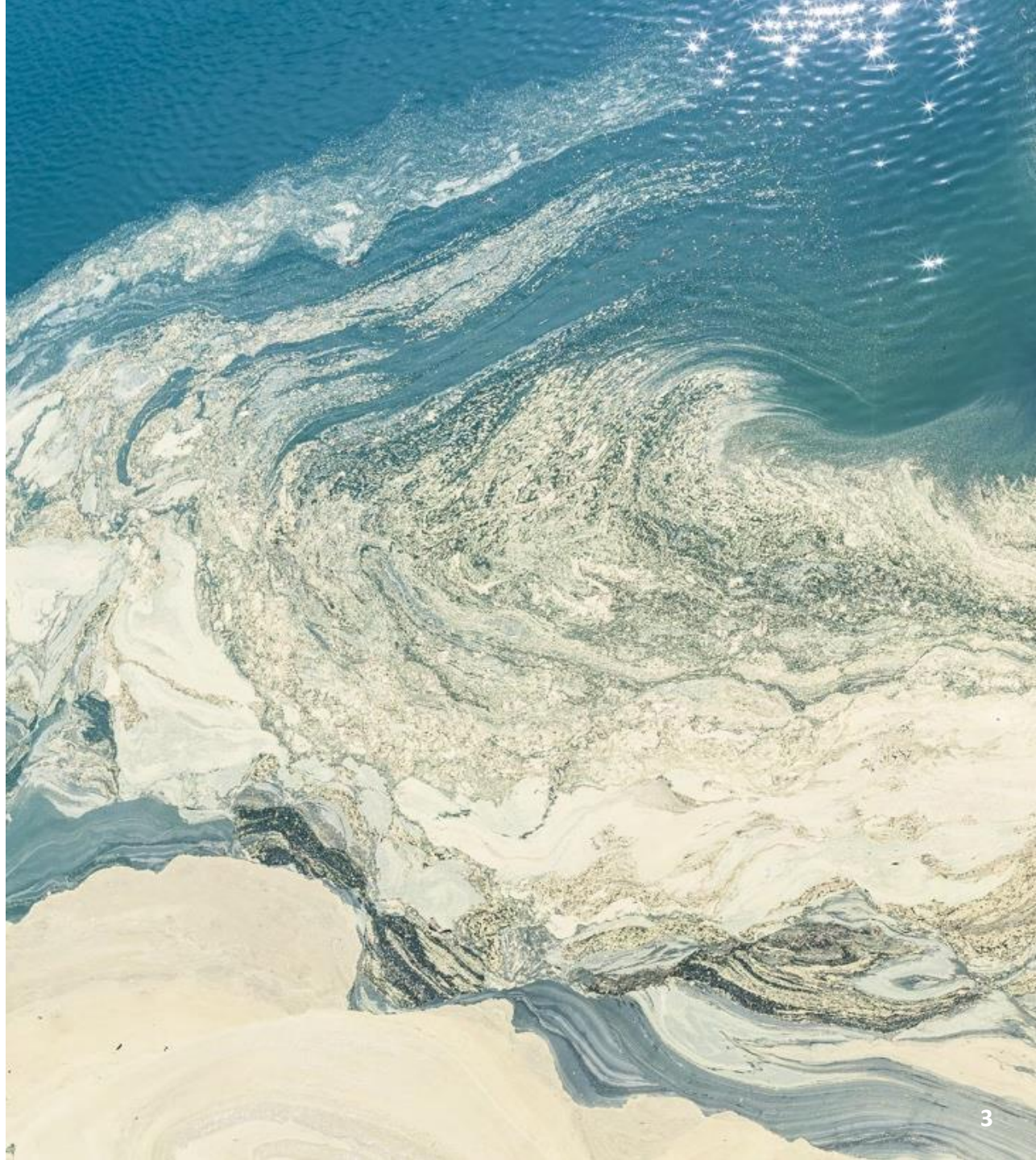
A few words on GEOSTOCK

Energy Underground Storage Techniques

Focus on Hydrogen Underground Storage Techniques

GEOSTOCK in a few words…

- An **international Group**
- A **key player** for **Underground Storage of ENERGIES** : Liquid, Liquefied and Gaseous Hydrocarbons, Hydrogen, Amonia, Compressed air and CO_2 …
- **Consulting, Engineering, Construction management Operation & Maintenance**
- **All Underground Storage Techniques**



Everything started in 1956 when Oil & Gas became Scarce and Expensive, following the Suez Canal Crisis…

1965	1996	2000	2005	2012	Déc. 2012	2021
25% elf	25% elf	50% TOTAL FINA ELF	50% TOTAL	50% TOTAL	10% TOTAL	VINCI 100%
25% TOTAL	25% TOTAL					
25% BP	25% BP	25% BP	25% bp			
25% Shell	25%	25%	25% ENTREPOSE	ENTREPOSE 50%	ENTREPOSE 90%	

VINCI Activity : PPP's & Construction (EPC)

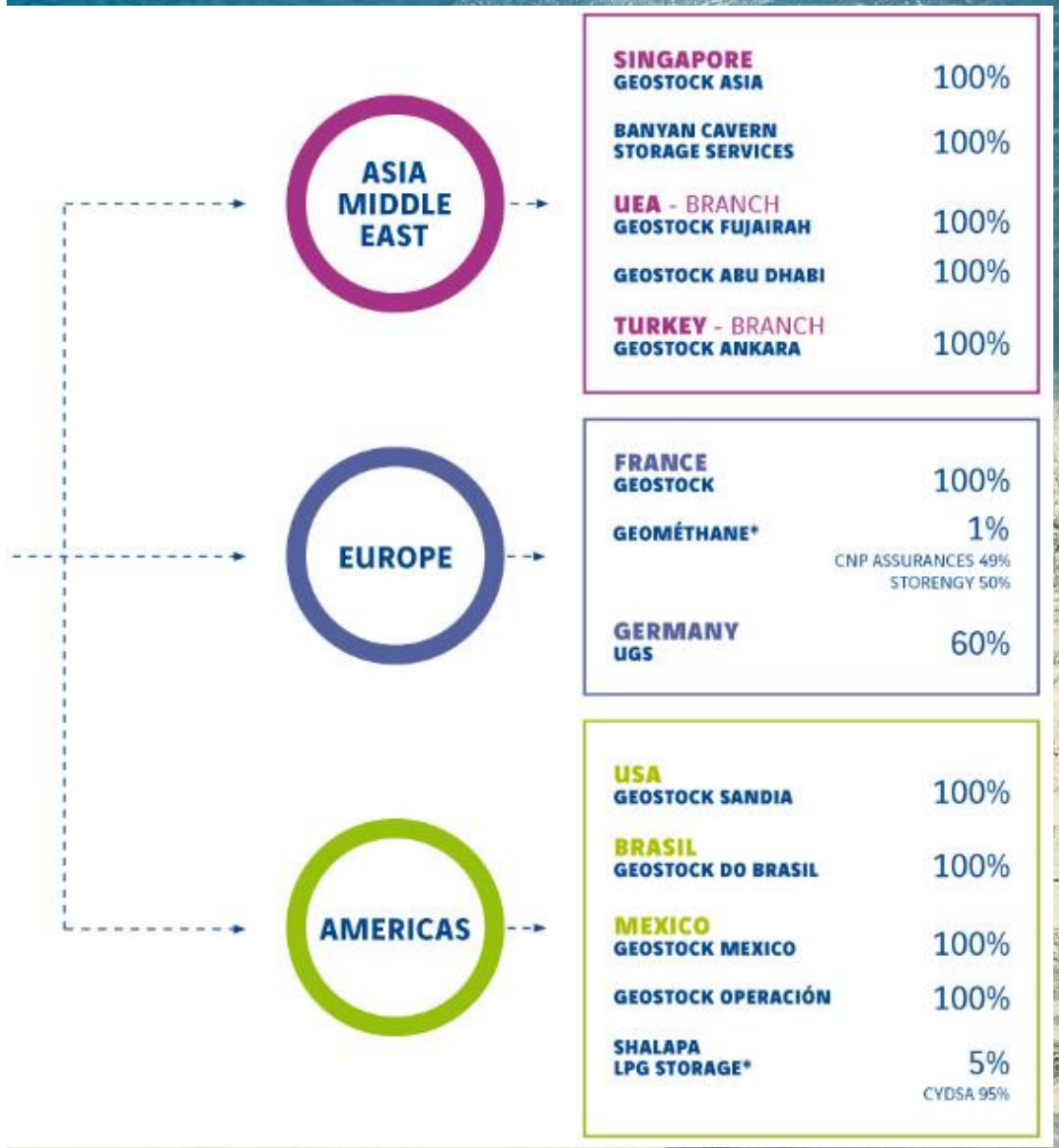
Geostock Group Organization

VINCI CONSTRUCTION | GRANDS PROJETS

Geostock

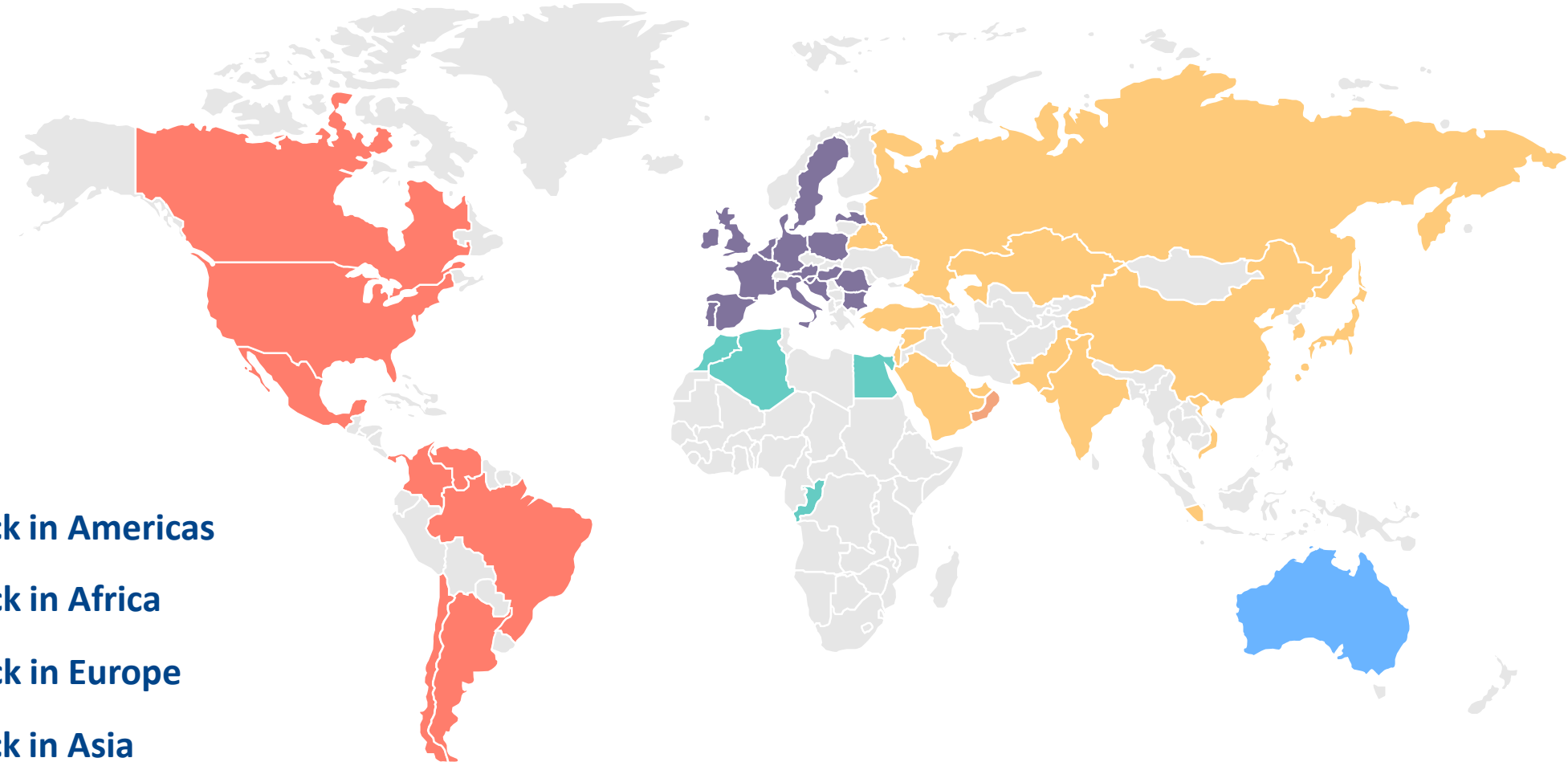
Sales : 91 M€

Headcount : 460 People

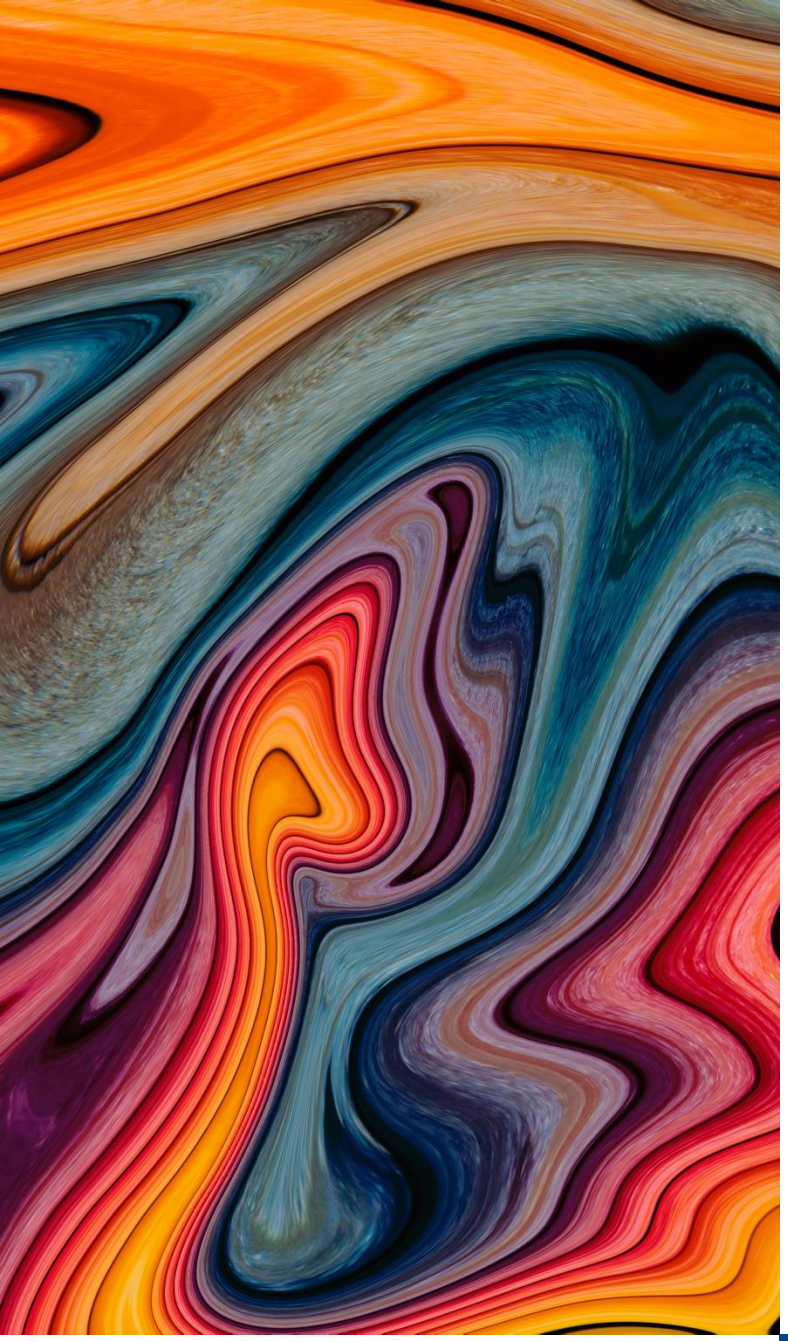


* **Geostock** owns minority shareholdings in underground storage assets operated by or in association with us.

Worldwide Projects in more than 50 countries

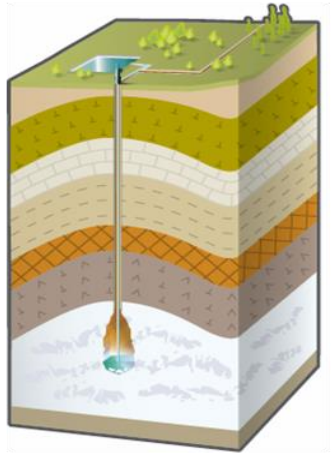


- Geostock in Americas
- Geostock in Africa
- Geostock in Europe
- Geostock in Asia
- Geostock in Oceania



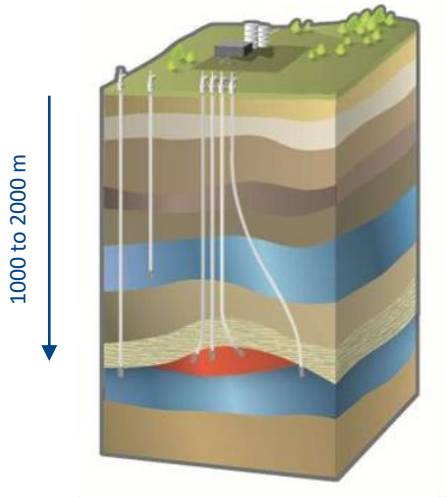
Energy Underground Storage Techniques

Underground Storage Techniques



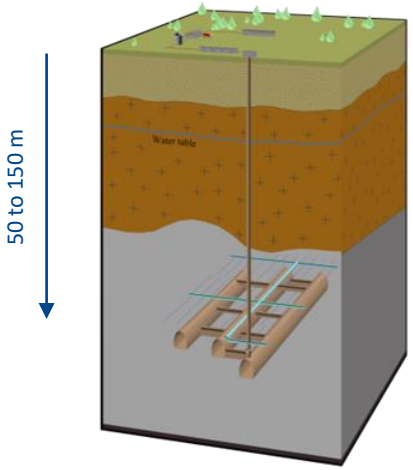
Salt caverns

- Natural Gas
- Liquid Hydrocarbons
- Liquefied Hydrocarbons
- Compressed Air
- Hydrogen
- Effluents



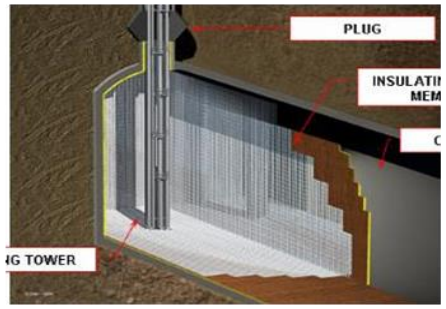
Depleted fields & aquifers

- Natural Gas
- Hydrogen
- Compressed Air
- CO_2
- Effluents



Mined rock caverns (unlined)

- Liquid Hydrocarbons
- Liquefied Hydrocarbons
- Natural gas



Mined rock caverns (lined)

- LNG (Liquefied Natural Gas)
- CNG (Compressed Natural Gas)
- Hydrogen

GEOSTOCK is the only Underground Storage Engineering addressing all the underground storage techniques

Underground Storage Advantages

- Environmentally friendly
- Reduced footprint
- No visual impact
- Social impact reduced

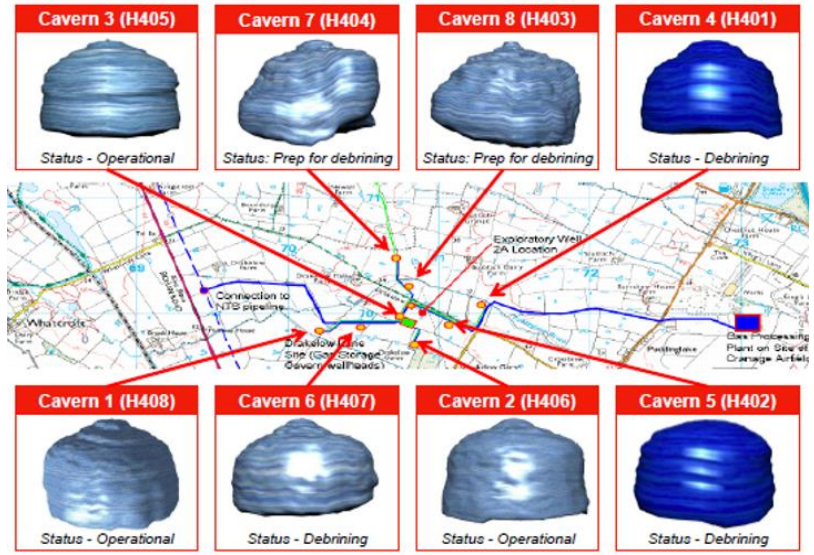
- Cost effective (CAPEX & OPEX)
- Almost ever-lasting
- Low maintenance

- Secure
- Safe
- Earthquake resistant

Salt Caverns examples….

Manosque (France)

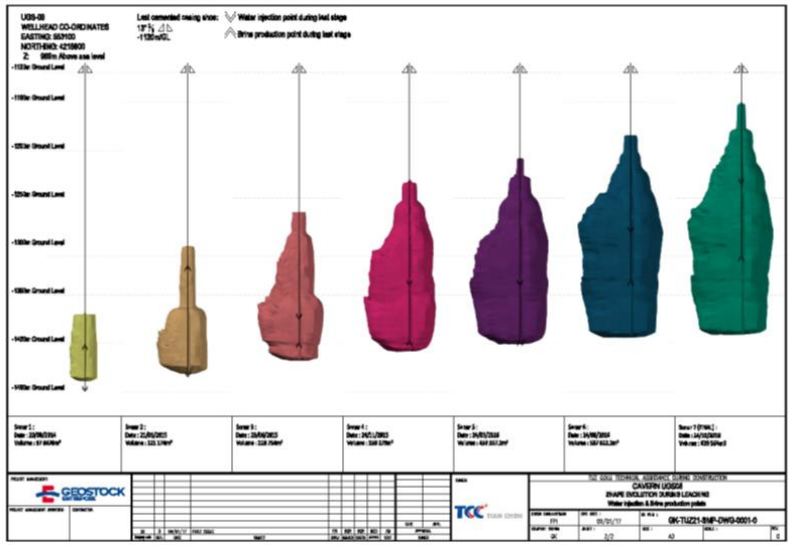
Holford (Grande Bretagne)



Salt Caverns examples….

Mohammedia (Maroc)

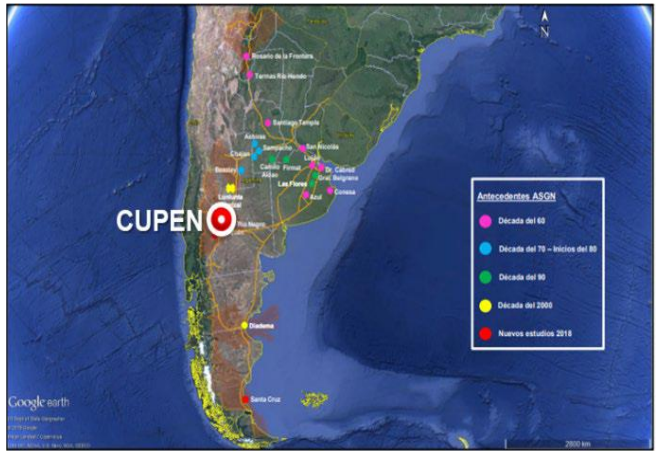
Tuz Golu (Turquie)

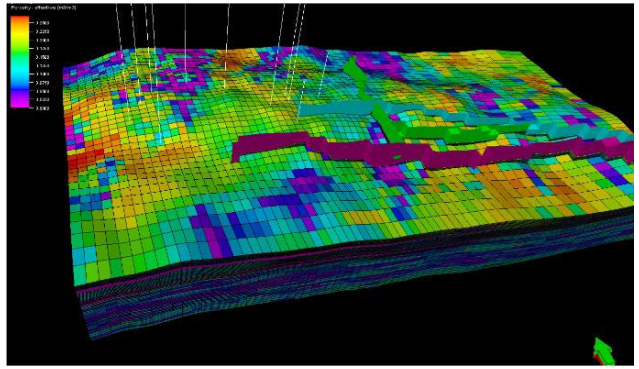


North Dayton Dome (Etats-Unis)

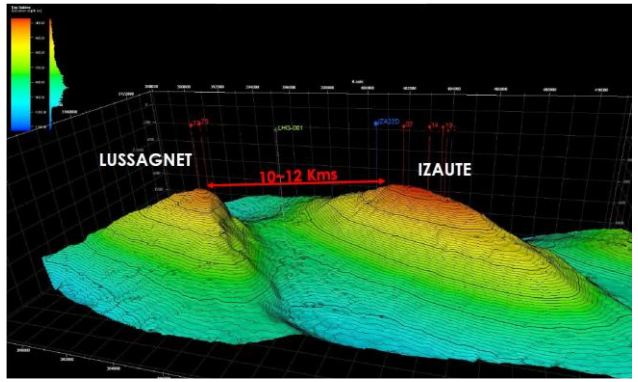
Porous Media examples….

Cupen (Argentina)

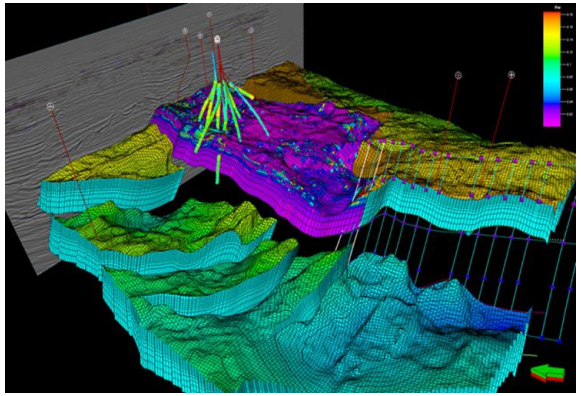




Lussagnet (France)



Gaviota (Espagne)



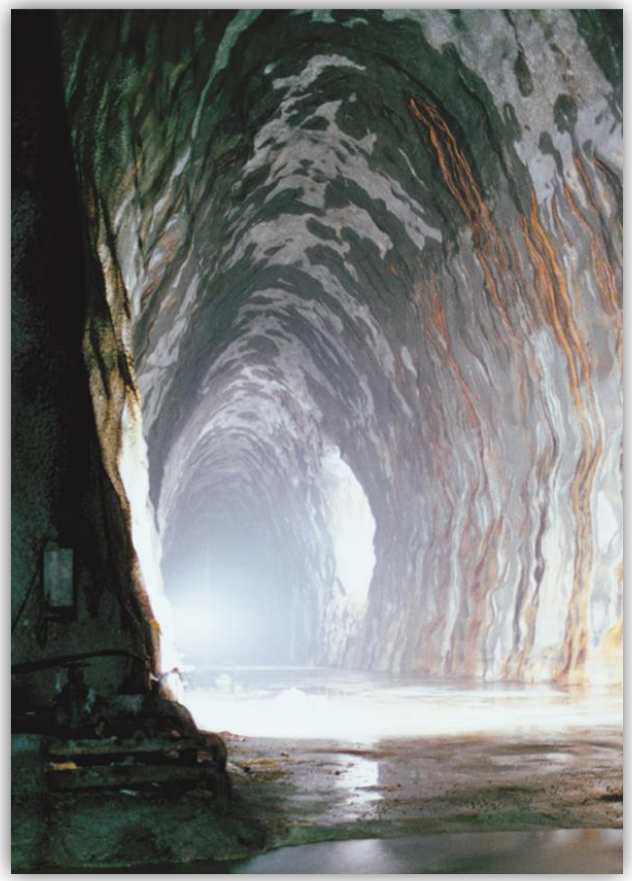
Mined Caverns examples….

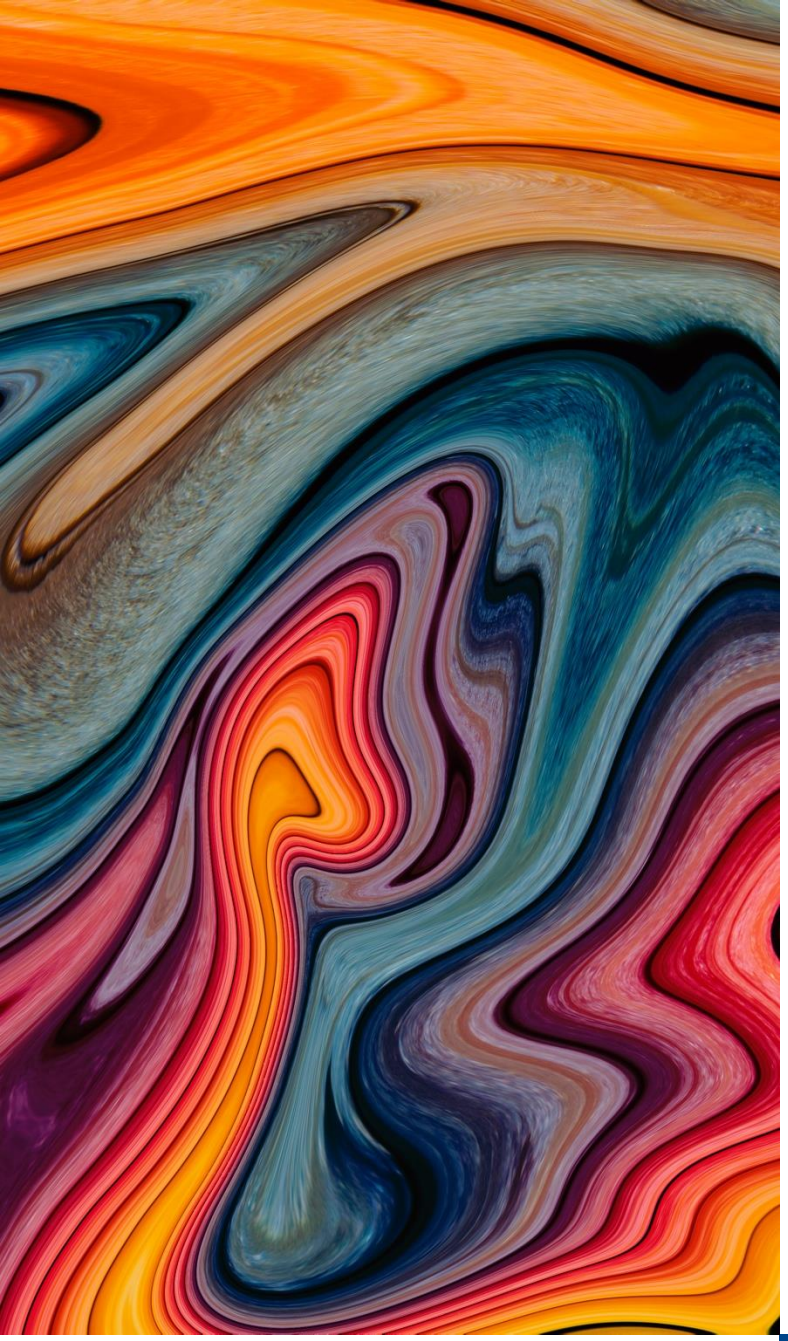
Namikata (Japon)

Shantou (Chine)

Jurong (Singapour)

Inchon (Corée du Sud)





Hydrogen Underground Storage Techniques

Hydrogen Storage Technologies

Storage capacity (tons)

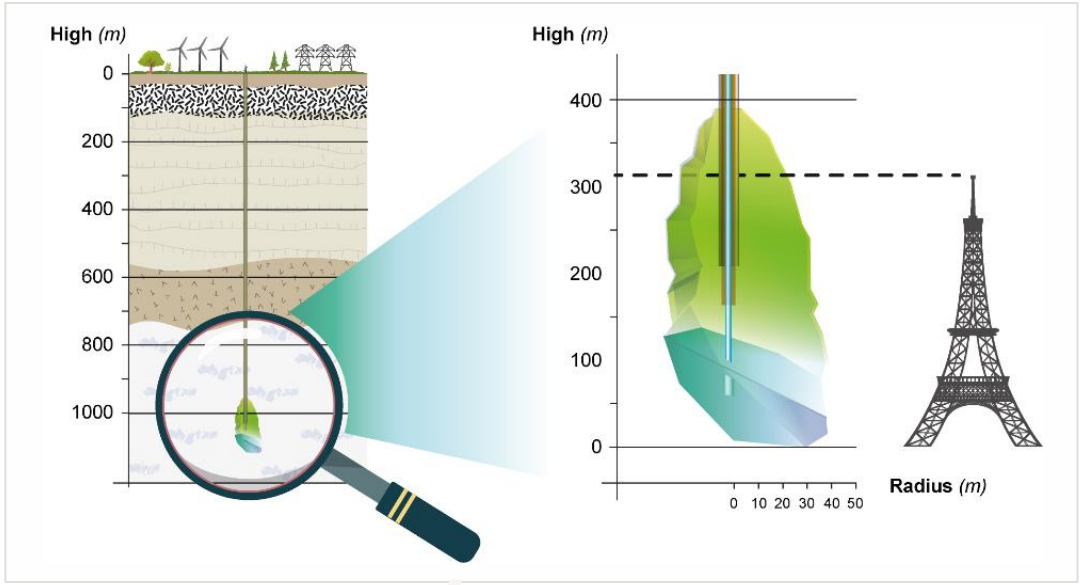
Cost ($/m³)

4 t

High

200 t

Medium



4 000 t

Low

Hydrogen storage capacity - Vision by 2030

Analogy to Oil & Gas storage capacity : Oil → 25% – Gas → 11%

PRODUCTION CAPACITY

6,5 GW of Electrolysers

(French Government, 2020)

STORAGE CAPACITY *

20 to **40** Caverns

PRODUCTION CAPACITY

40 GW of Electrolysers

(European Commission, 2020)

STORAGE CAPACITY *

125 to **250** Caverns

PRODUCTION CAPACITY

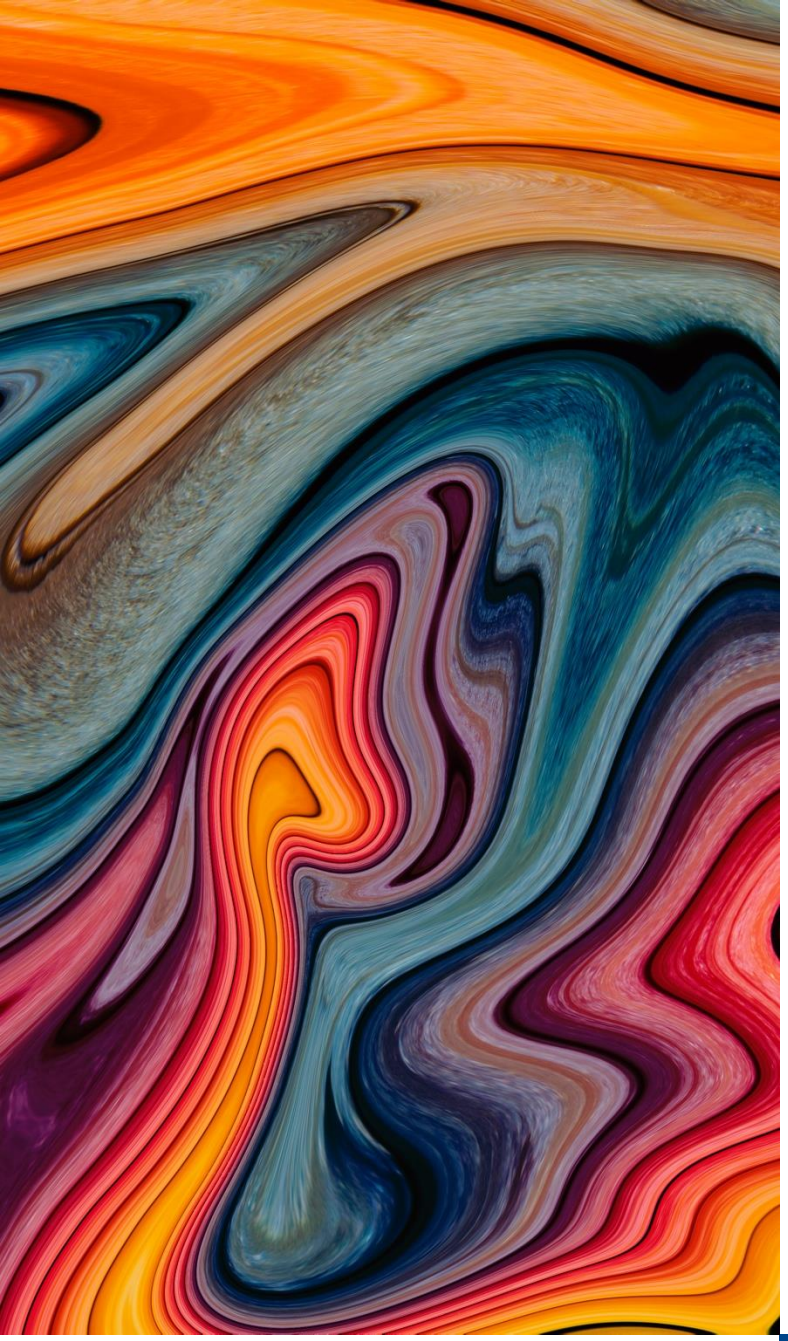
90 GW of Electrolysers

(Hydrogen Council, 2021)

STORAGE CAPACITY *

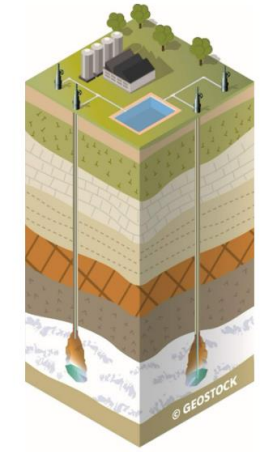
200 to **400** Caverns

There are 1 900 Existing Salt Caverns Worldwide (mainly for Oil & Gas)



Solution 1 - Salt Cavern

Salt cavern for hydrogen storage



SALT CAVERNS

- Liquid & Liquefied Hydrocarbons
- Natural Gas
- **HYDROGEN**
- Compressed Air & Effluents

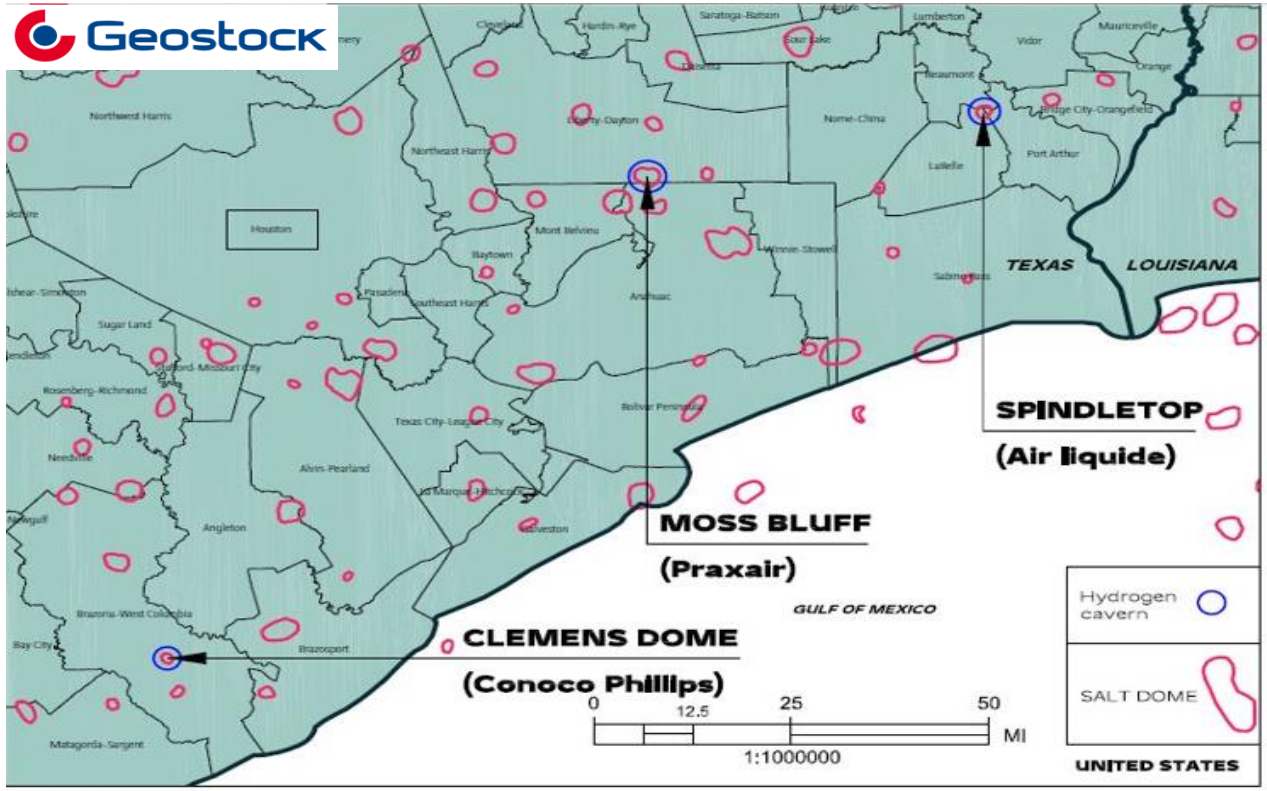
MOST COMMON TECHNIC FOR **H_2 UNDERGROUND STORAGE**

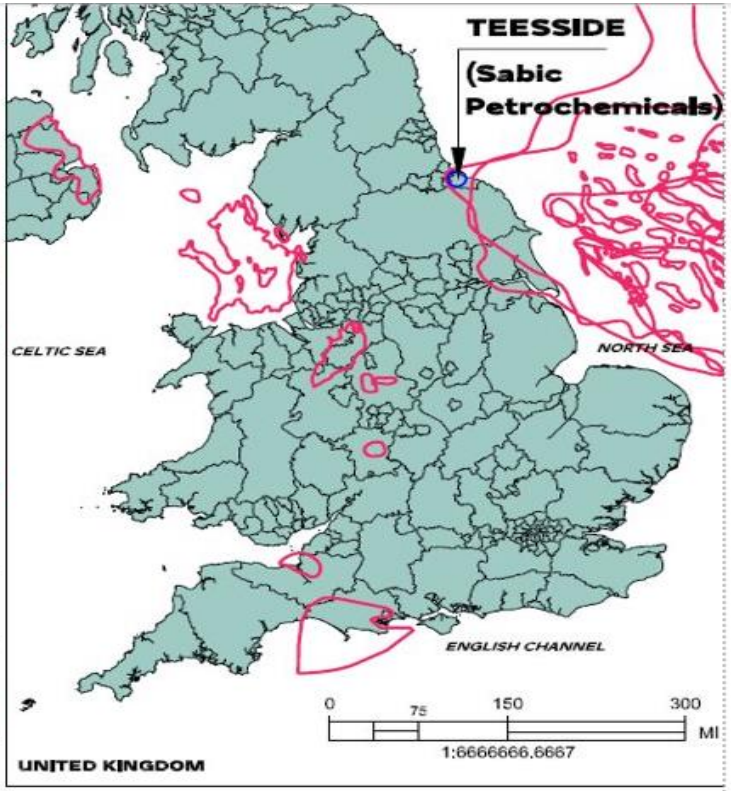
- No Technical Show Stopper
- 1 900 Existing Salt Caverns Worldwide
- 6 Existing Hydrogen Caverns worldwide (US & UK)

There are numerous on going studies in:

- **Conversion of existing underground** storage to H_2 or a mix H_2/CH_4 for asset owners (UK, France, Spain, Germany, Netherland, USA…)
- **Creation of new caverns** (UK, France, Spain, Germany, Netherland, UAE, USA…)

Salt Cavern: Existing H_2 storage

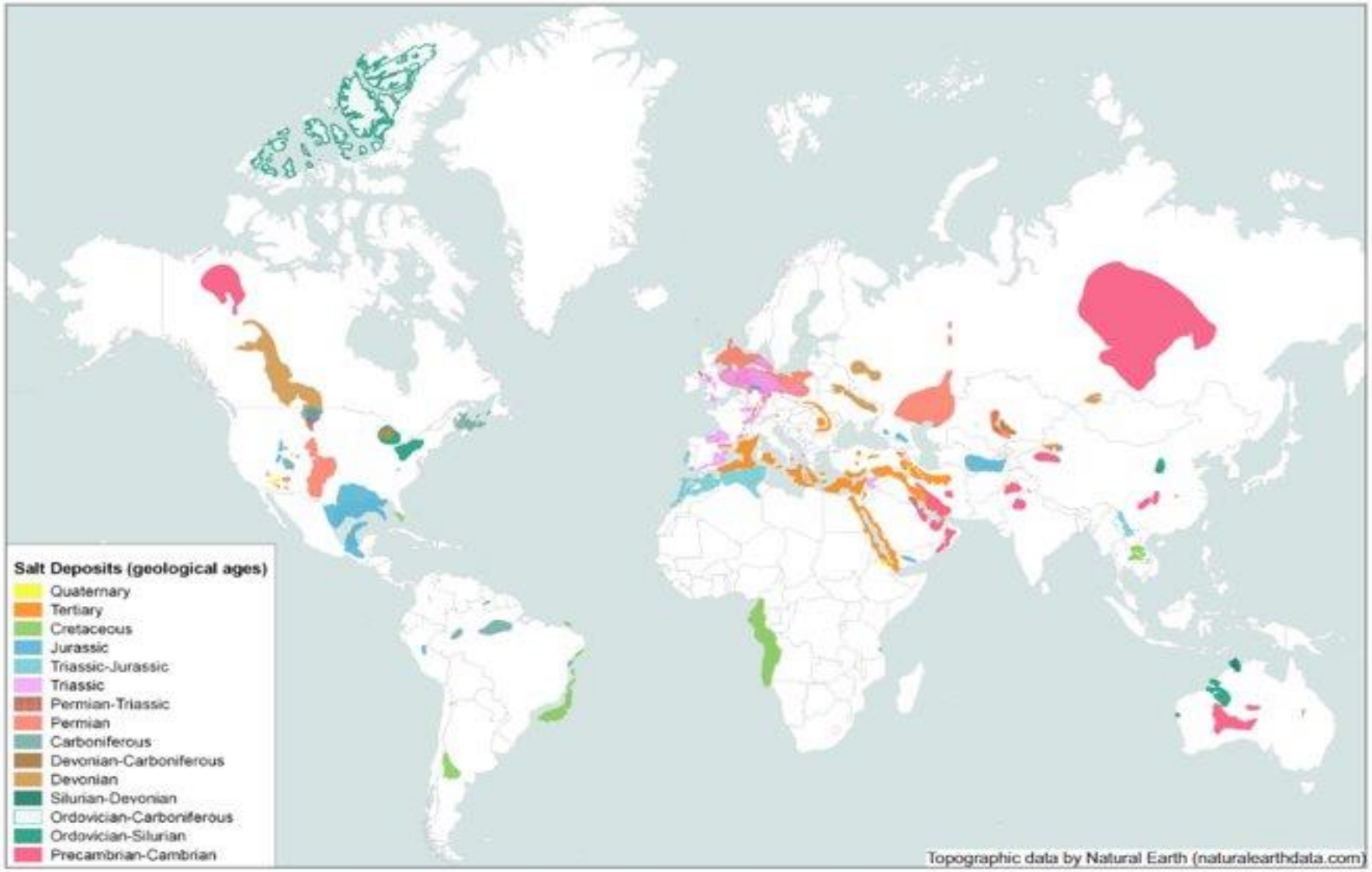




LOCATION	CLEMENS DOME (US)	MOSS BLUFF (US)	SPINDLETOP (US)	TEESSIDE (UK)
Operator	Conoco Phillips	Praxair	Air Liquide	Sabic
Start	1986	2007	2014	1972
Geometrical Volume (m^3)	580 000	566 000	>580 000	3*70000
Geometrical Volume (bbl)	3 648 000	3 560 000	>3 560 000	3*441 000
Pressure range (bar)	70–135	55–152	Confidential	45
Pressure range (psi)	1015–1960	800–2200	Confidential	650

LOCATION	CLEMENS DOME (US)	MOSS BLUFF (US)	SPINDLETOP (US)	TEESSIDE (UK)
Mean Cavern Depth (m)	1000	1200	1340	365
Mean Cavern Depth (ft)	3300	3900	4400	1200
Net energy stored (GWh)	92	120	>120	25
Net energy stored (MMBtu)	3 10^5	4 10^5	>4 10^5	0.8 10^5
H_2 mass (t)	2400	3690	8230	810
Net Volume (std m^3)	27.3 Mm^3	41.5 Mm^3	92.6 Mm^3	9.12 Mm^3

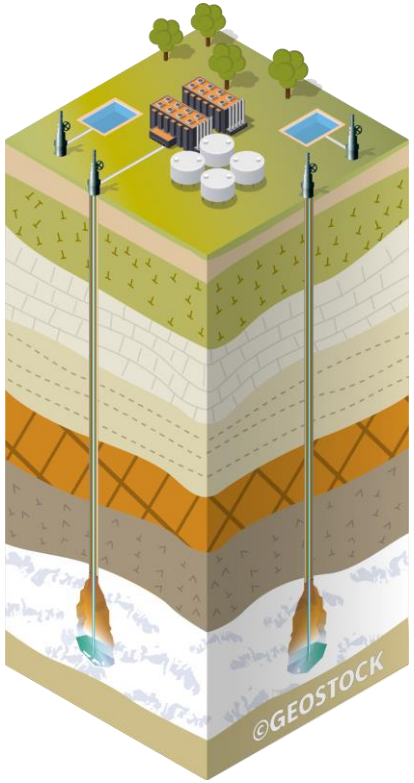
Salt Cavern: A huge potential…but not everywhere



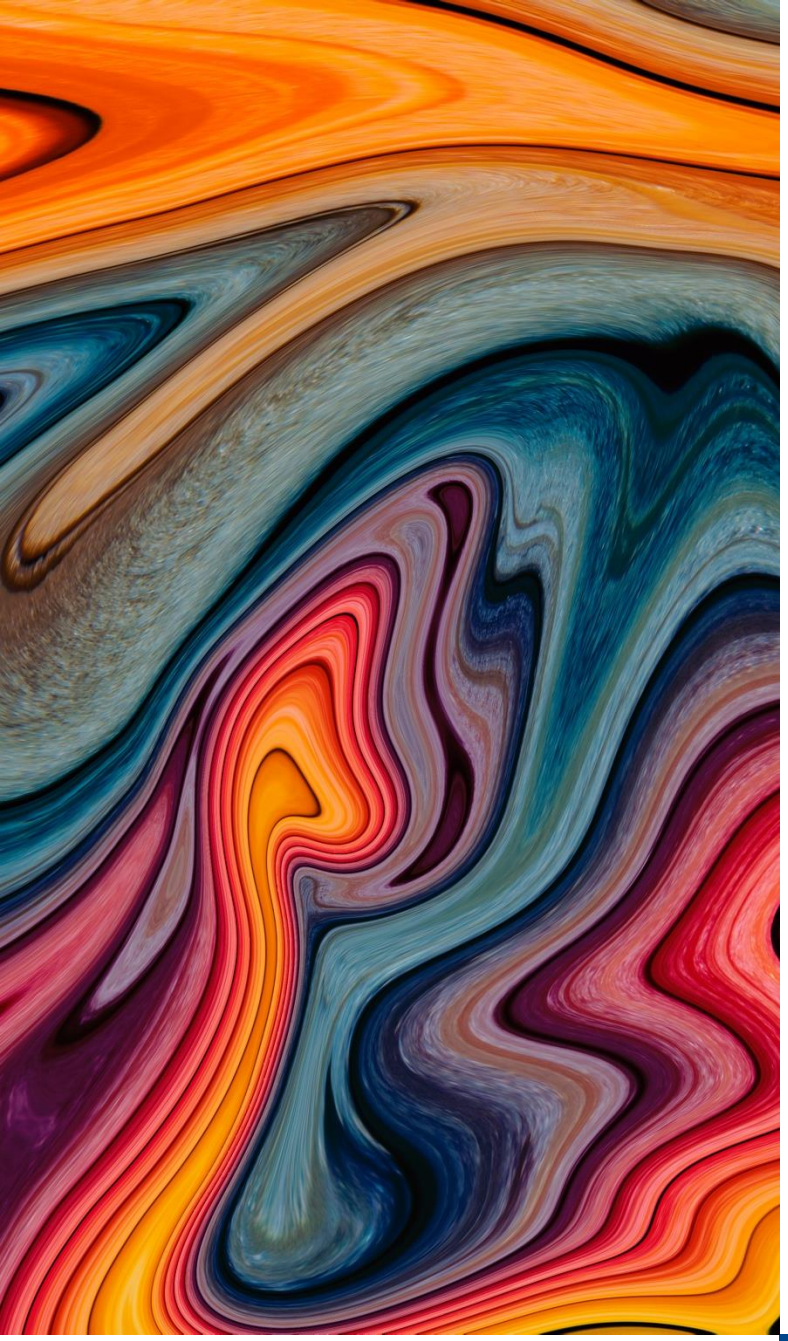
Source: SMRI RR2017-5 / KBB 7035-881211

Salt Cavern: main characteristics, pros and cons

- Large volume, up to 1 000 000 m3
- Working gas up to 10 000 t
- High flowrate
- Low Cost ($/kg)
- Conversion of existing salt cavern storage can be studied case by case



- Required geology not available everywhere
- Water & Brine disposal
- Cushion gas (recoverable)



Solution 2 – Porous Media

Porous media for hydrogen storage

DEPLETED FIELD & AQUIFERS

- Natural Gas
- Compressed Air, CO_2
- **HYDROGEN**

SOLUTION TO STORE VERY MASSIVE VOLUME OF HYDROGENE

- 650 existing sites worldwide (mainly gas)
- Could be in depleted Oil/Gas fields or in saline aquifers
- Operated between 60 bar and 200 bar

There are numerous studies on-going for the **Conversion of existing underground** storage to mix H_2/CH_4 for asset owners (Belgium, Spain, Germany, USA…)

Geostock has been involved, as leader, in the European R&D **HYSTORIES** project (with 17European countries and more than 20 partners).

Porous Media: Past experiences of H_2 storage

➡ **Blends of Hydrogen and other gases have been stored in aquifers and depleted fields**

Town Gas (30% to 50% H_2, stored with other gases) experience until mid 20th century:

➡ **Recently, pilots have been done for storage of H_2/CH_4 mix**

- SunStorage project led by RAG. H_2 (10%) – natural gas blend injection in a small isolated depleted gas field in Lehen, Austria (6 million Nm^3 total gas)
- HyChico project. H_2-natural gas blend injection in a storage reservoir in Argentina

➡ **No commercial storage for pure H_2, but on-going studies**

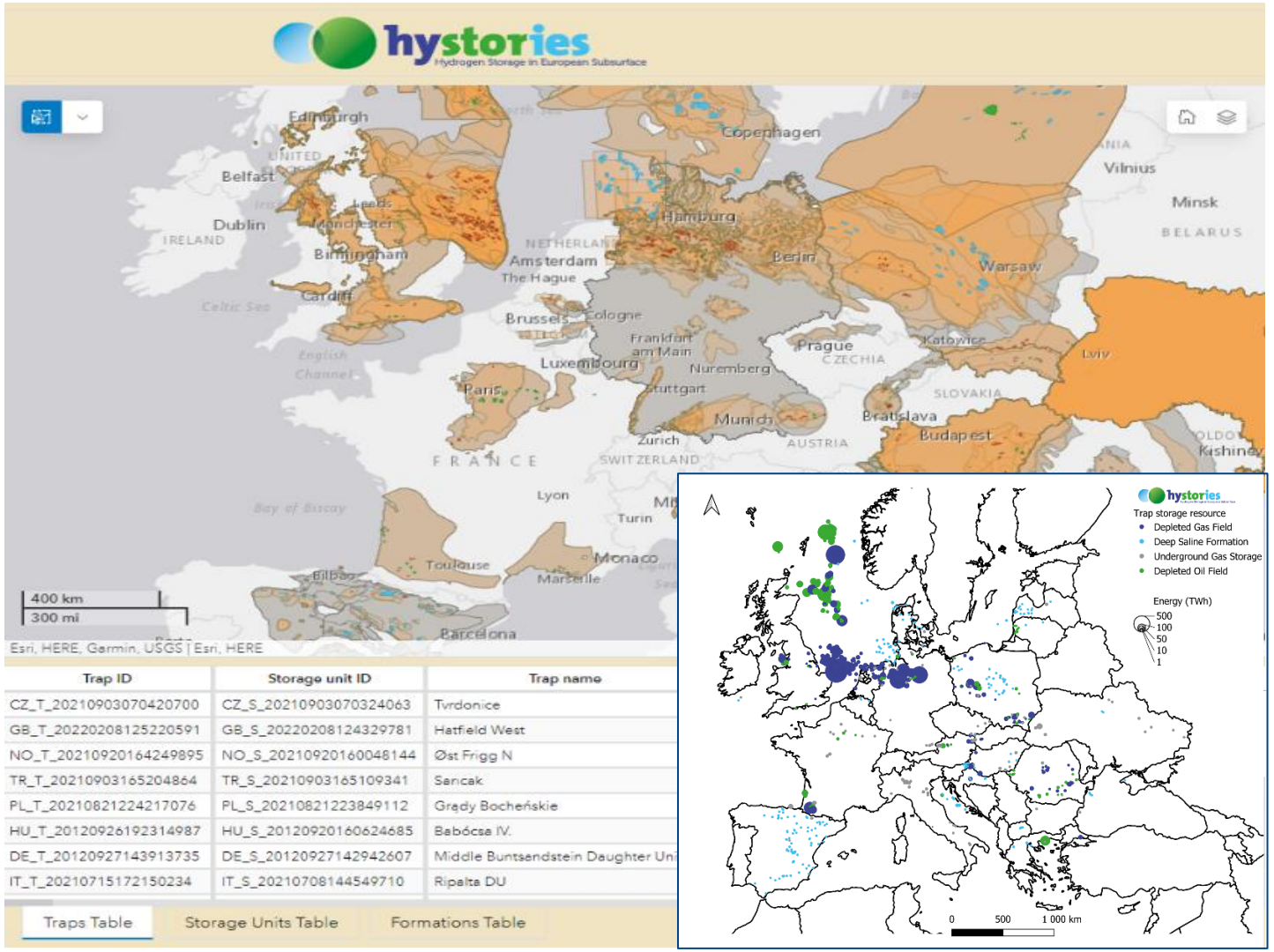
hystories HyStorPor HyUSPRe

STORAGE CAPACITY - European Porous trap Geographical Information System and public database

Identification of more than 900 potential sites

Hystories main development :

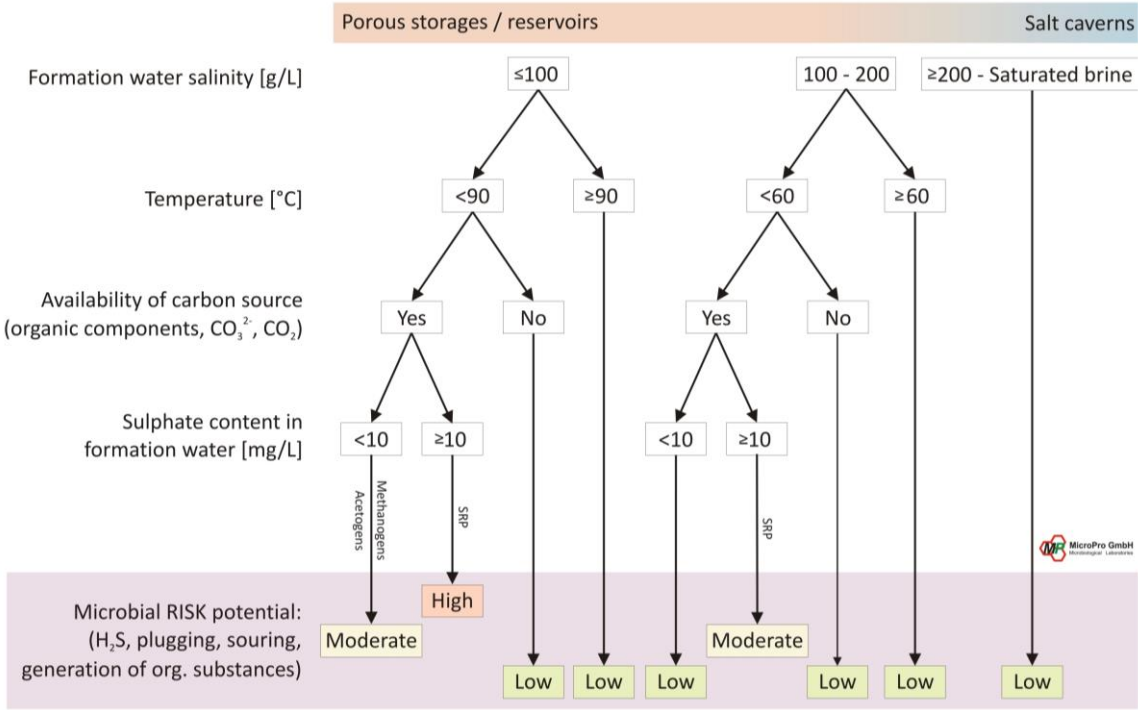
- Storage capacity needed (by 2050) :
  - 15-20% of demand
  - 300 Twh
- Estimated storage capacity onshore : 6 800 Twh
- Estimated storage capacity offshore : 19 000 Twh



Trap ID	Storage unit ID	Trap name
CZ_T_20210903070420700	CZ_S_20210903070324063	Tvrdonice
GB_T_20220208125220591	GB_S_20220208124329781	Hatfield West
NO_T_20210920164249895	NO_S_20210920160048144	Øst Frigg N
TR_T_20210903165204864	TR_S_20210903165109341	Sarıcak
PL_T_20210821224217076	PL_S_20210821223849112	Grądy Bocheńskie
HU_T_20120926192314987	HU_S_20120920160624685	Babócsa IV.
DE_T_20120927143913735	DE_S_20120927142942607	Middle Buntsendstein Daughter Un
IT_T_20210715172150234	IT_S_20210708144549710	Ripalta DU

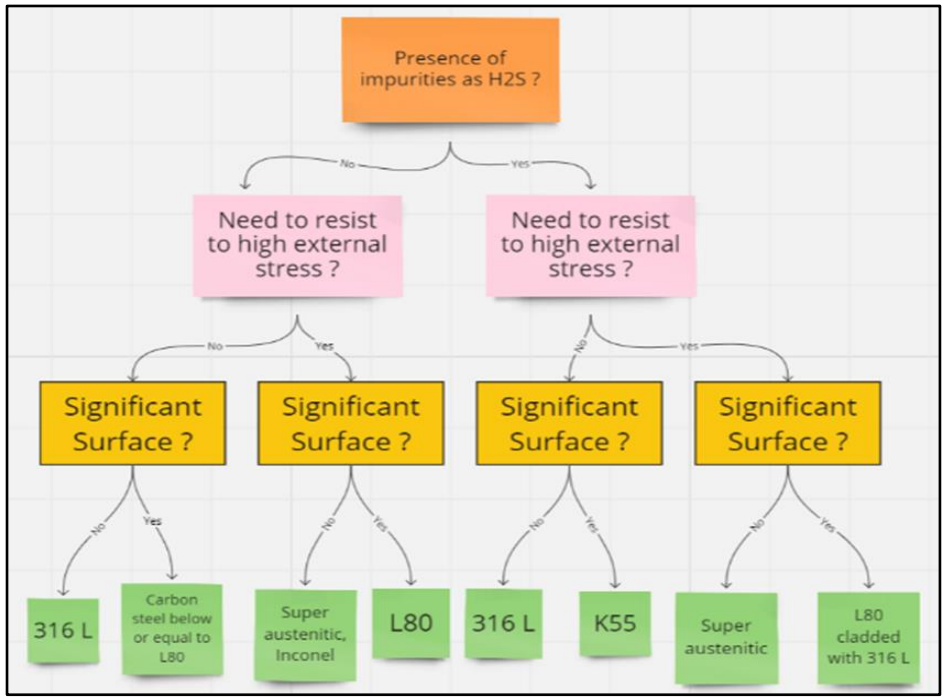
Main Technical Issues to be addressed case by case

Microbiological activity → H2S, bacteria, precipitations….



Simplified chart for a risk assessment for UGS based on temperature, salinity, carbon and sulphate availability.

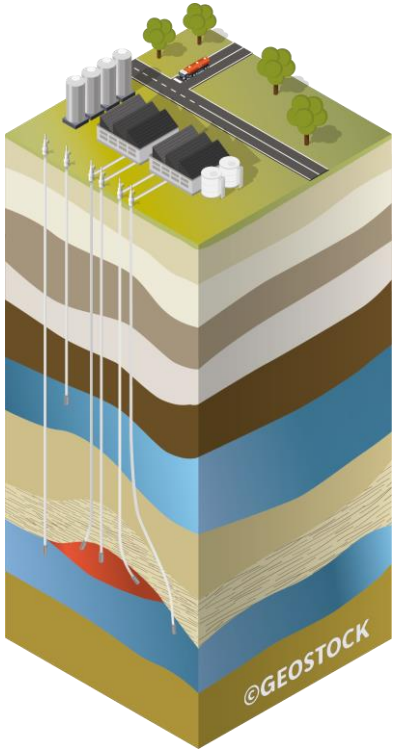
Steal specifications → there are existing guidelines



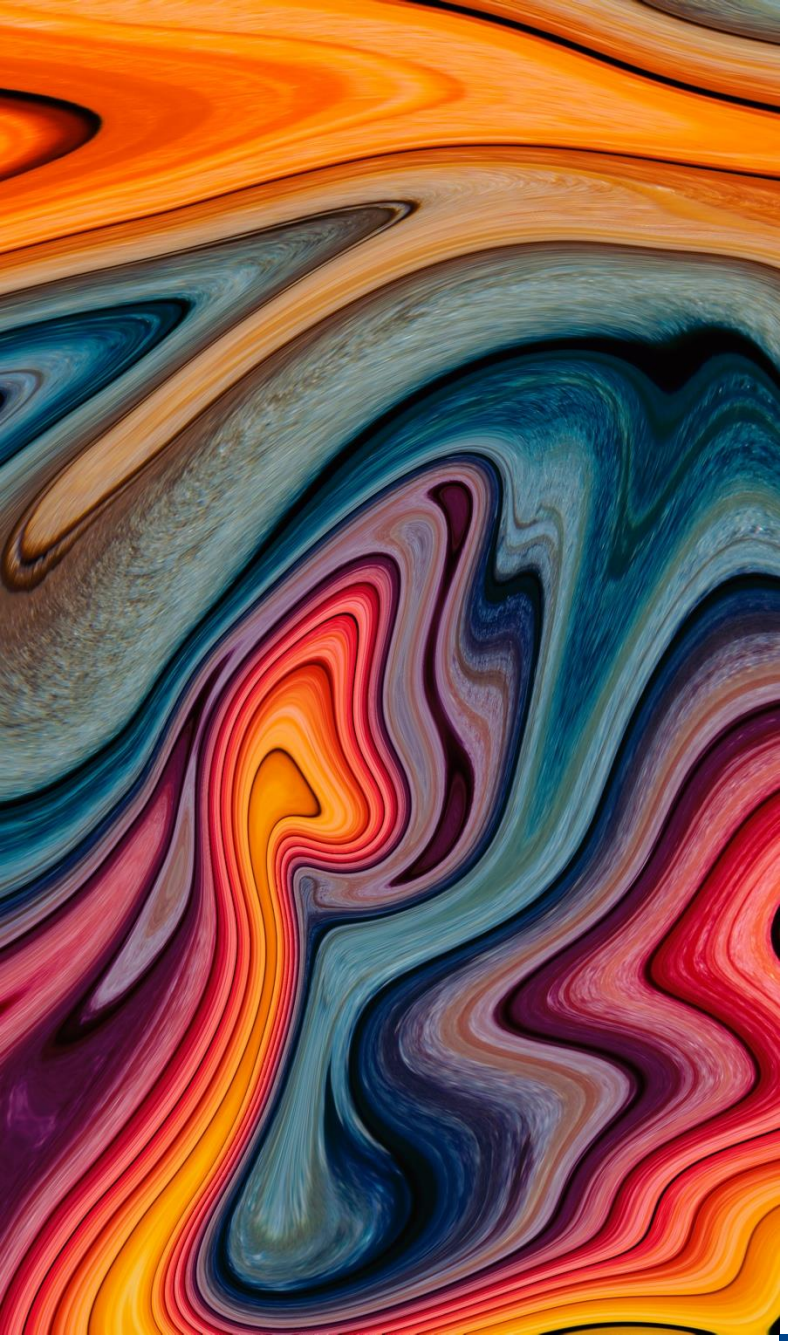
Proposed material selection flowchart for wells in hydrogen environment (gas). This list of materials is not exhaustive and other alternatives could be proposed.

Porous Media: main characteristics, pros and cons

- Very large volume, average 500 millions Sm3
- Huge working gas capacity (> 40 000 t)
- Low Cost ($/kg)



- Required geology not available everywhere
- Cushion gas to be injected
- Microbiological activity to be checked



Solution 3 – Lined Mined Cavern for Gaseous Hydrogen

Lined Mined Caverns (LRC) for hydrogen storage

LINED ROCK CAVERN

- Natural Gas
- Liquid & Liquefied Hydrocarbons
- **HYDROGEN AND AMONIA**

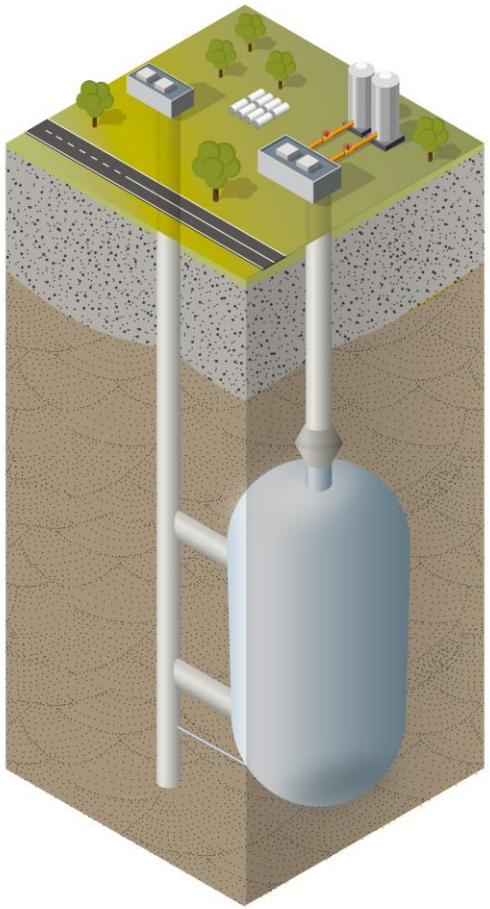
UNDERGROUND STORAGE IN THE HEART OF AN INDUSTRIAL CLUSTER

- 450 existing unlined-mined caverns worldwide
- Limited geological constraint due to the presence of a liner → easier to be located in the heart of industrial clusters

Existing LRC facilities for Natural Gas (Skallen in Sweden - 1999) and H2 (Hybrit Pilot in Sweden - 2022)

Many LRC studies on going (France, UK, Spain, US, Australia…).

Lined Mined Cavern (LRC) for gaseous hydrogen



- Physical volume around 100 000 m3
- Operated between 20 bar and 200 bar
- Working gas capacity between 300t and 2000 t

High pressure storage
(up to 200 bar)
1 case for nat. gas

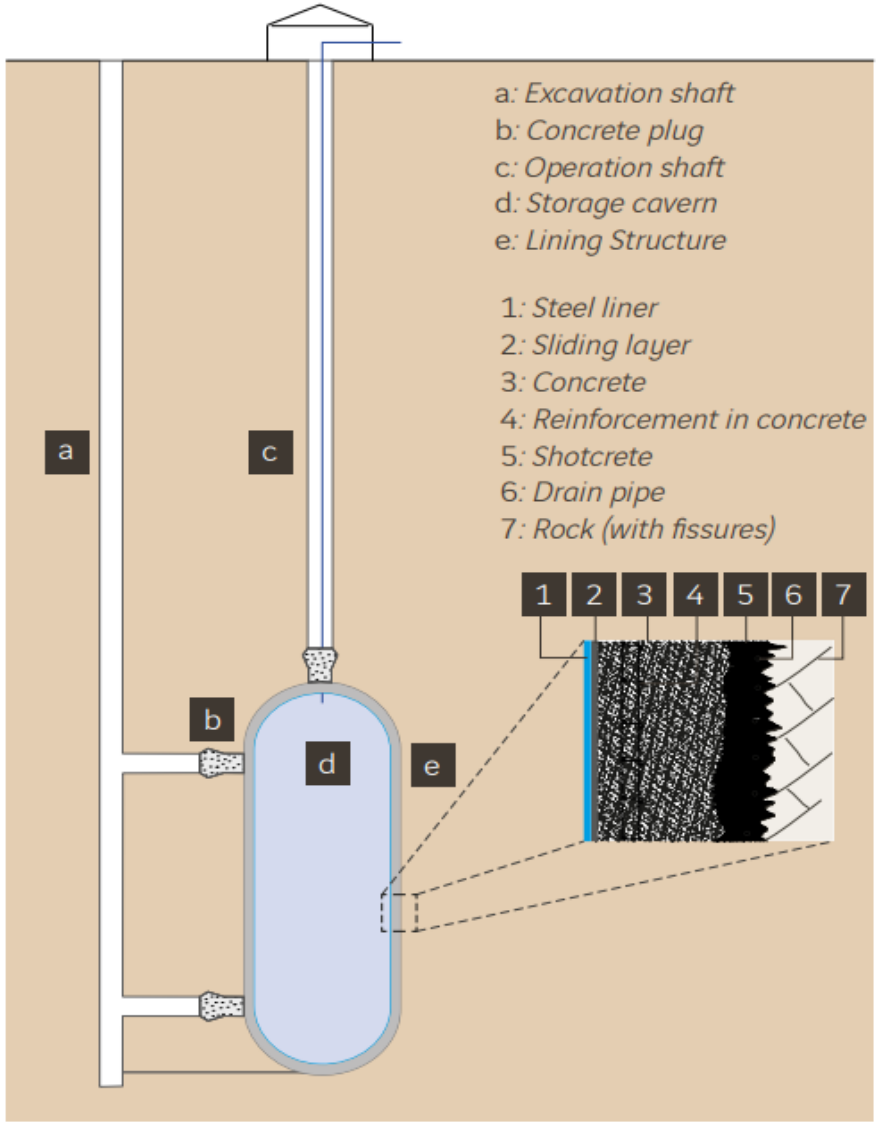
Lined Rock Cavern
Source: Thermie B,OG./270/97/SE/FR

Lined Mined Cavern (LRC) for Gaseous Hydrogen

Since recently 2021-2023, several studies in Europe for:

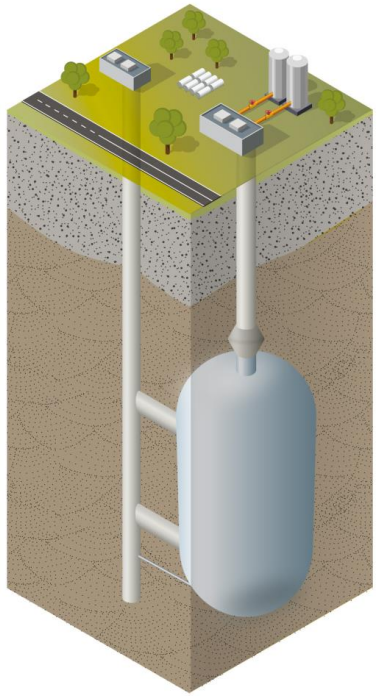
- the **feasibility of lining existing rock caverns** storage,
- and the **creation of new LRC.**

for H_2 , NH_3 and CO_2

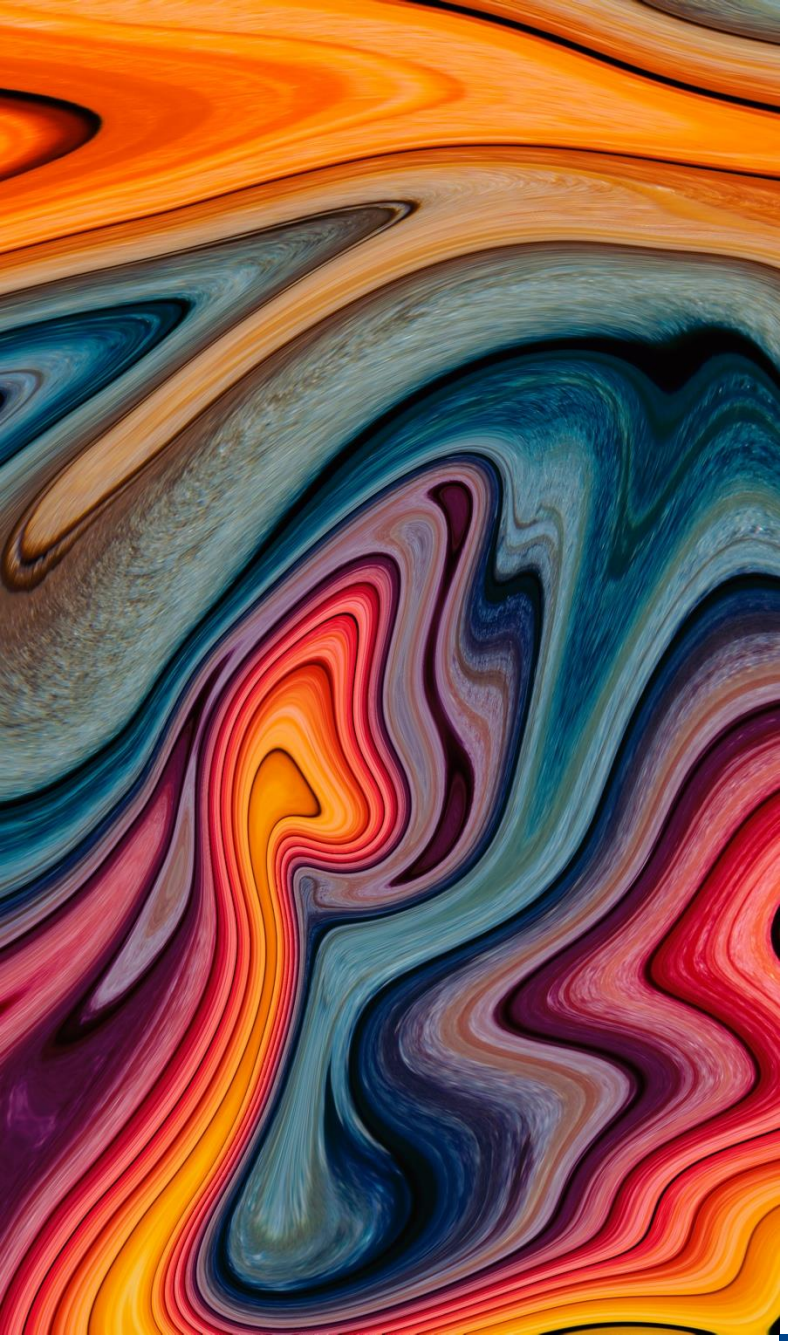


Lined Mined Cavern (LRC) : main characteristics, pros and cons

- Can be done almost everywhere
- High flowrate
- Low volume of cushion gas



- Not as mature as Salt Caverns & Depleted Fields / Aquifer



Storage Costs

Hydrogen storage costs

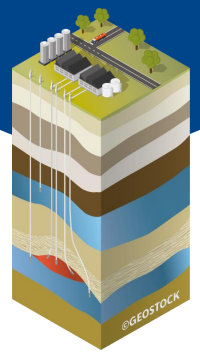
CAPEX for underground storage are very site specifics and depend on many parameters.

The figures below are only to make an overall comparison between the different techniques, and to show the huge interest of underground storage compared to above ground storage for the storage of gaseous hydrogen:

Assuming a CAPEX of 500 million €

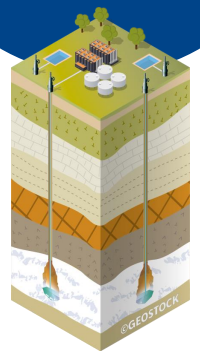
Porous Rock

15 000 t
to
30 000 t



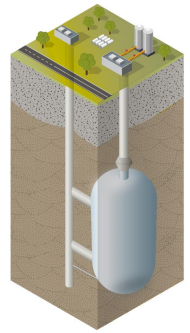
Salt Cavern

15 000 t
to
20 000 t



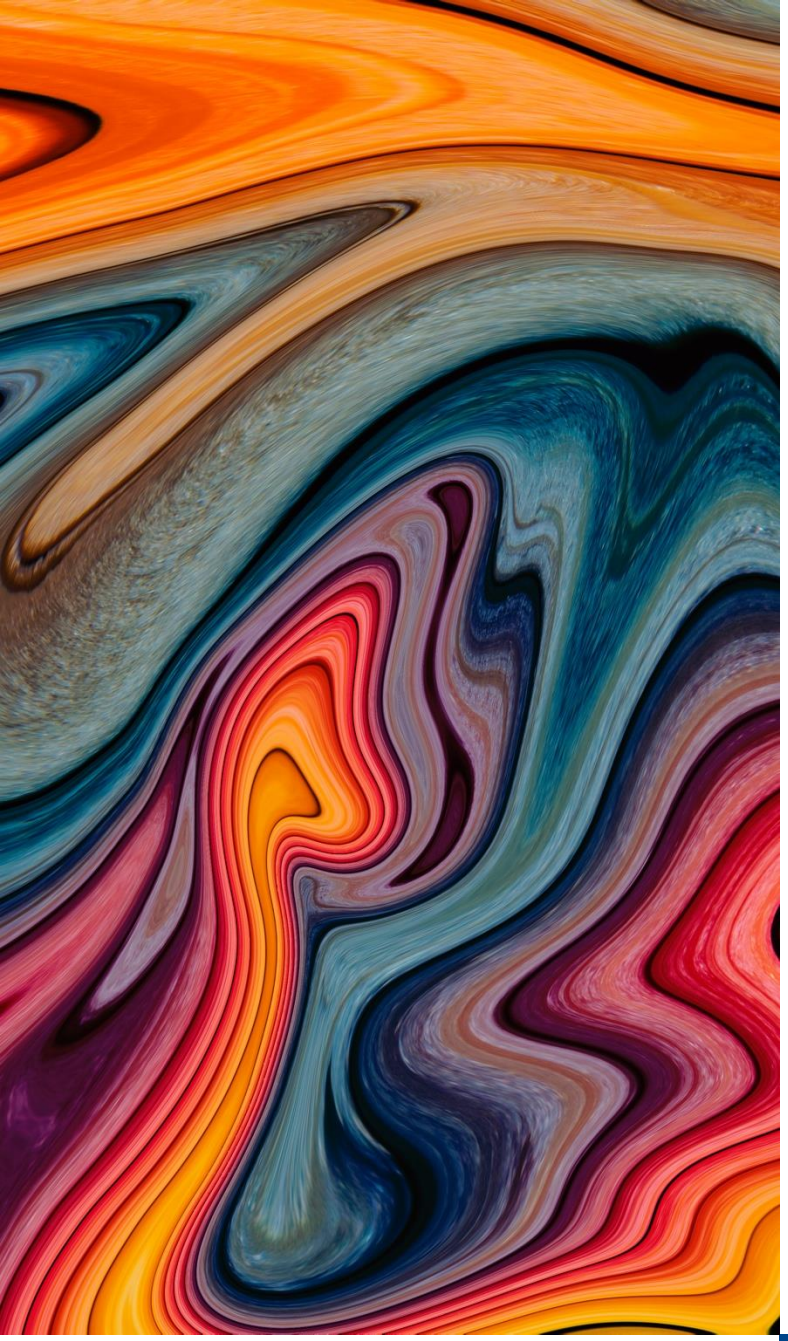
Lined Mined Cavern (LRC)

600 t
to 1200 t



Above ground storage

250 - 500 t



Thanks for your attention

Geostock

WE MAKE THE EARTH THE BEST PLACE
FOR STORING ALL ENERGIES

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