

Future roles of Hydrogen in the energy transition and examples of operating and future Hydrogen storages

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- Hydrogen roadmaps
- Hydrogen underground storage developments. Examples of :
  - Historical Hydrogen storages in salt caverns
  - An “Industry transition” from Hydrocarbons to renewable storage
  - Research fields surrounding H2 storage: the ROSTOCK-H project
- A new project of Hydrogen Pilot storage in France: the Stopil-H2 project
- Conclusion

1

Hydrogen roadmaps

Recent major initiatives consider a massive use of Hydrogen for **decarbonization targets** and **green growth**

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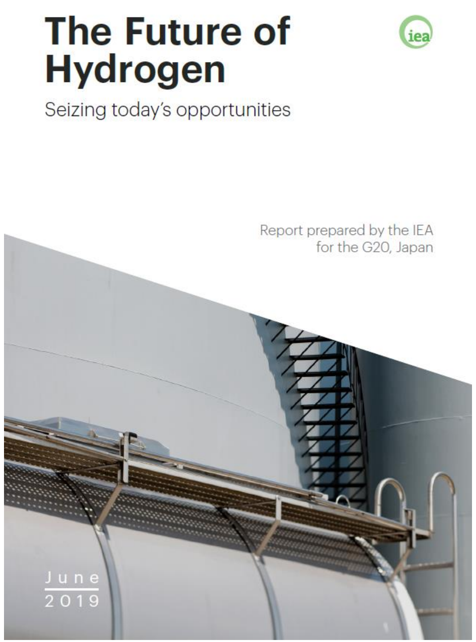
Private

2017

Public

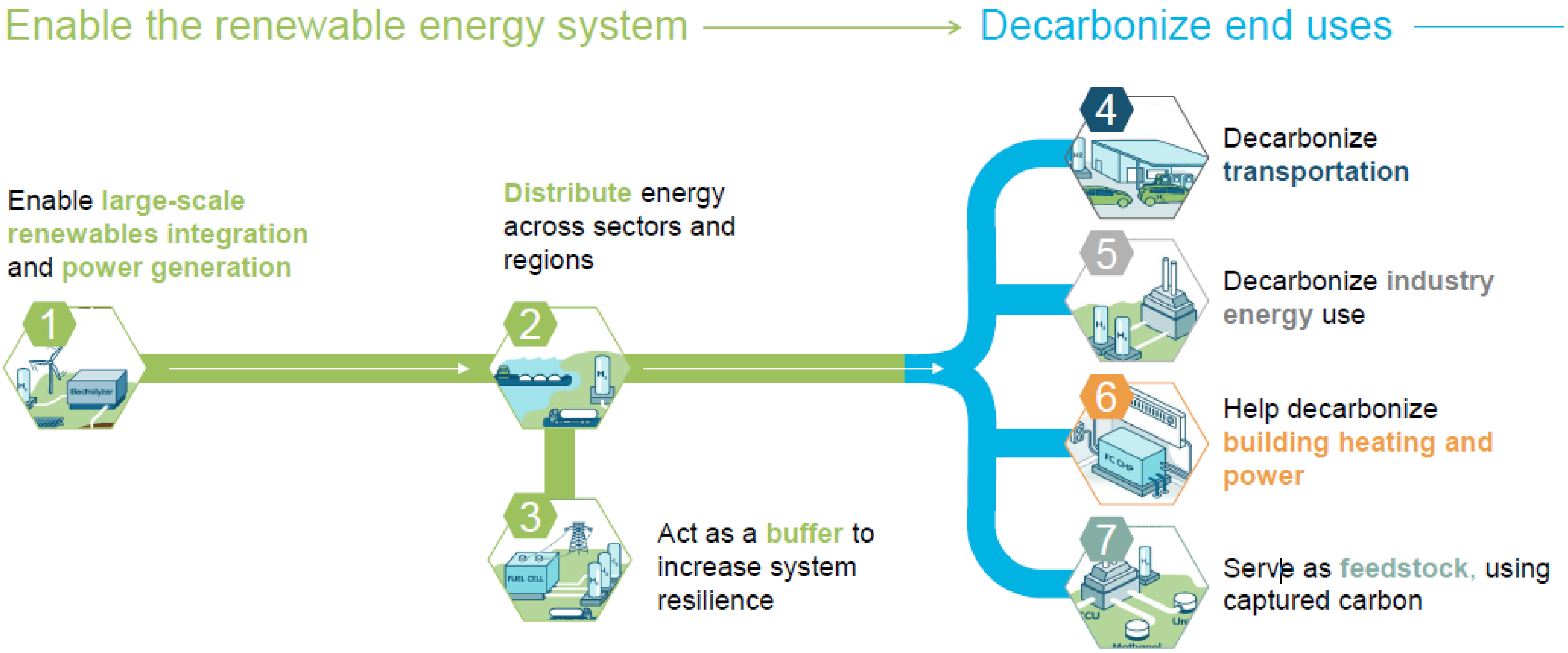
2018

International agencies



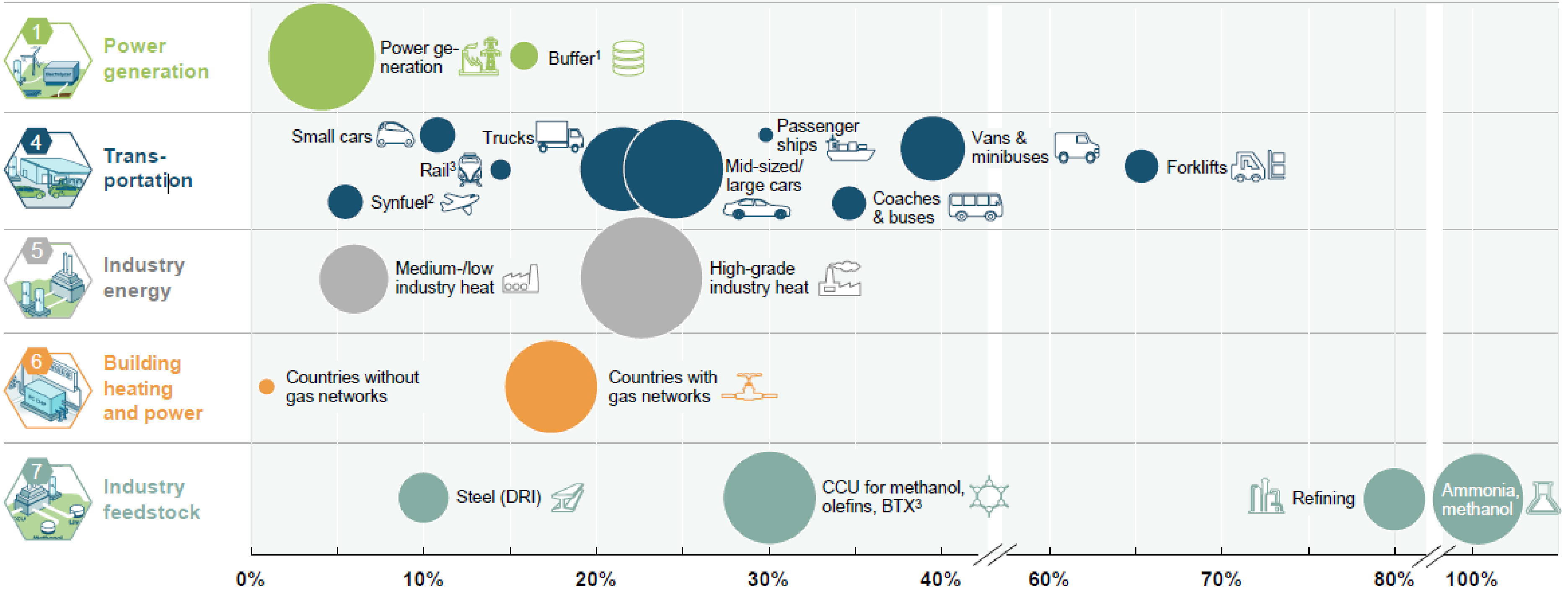
2019

There are seven roles for H_2 in the energy transition



Source: McKinsey and Hydrogen Council 2017

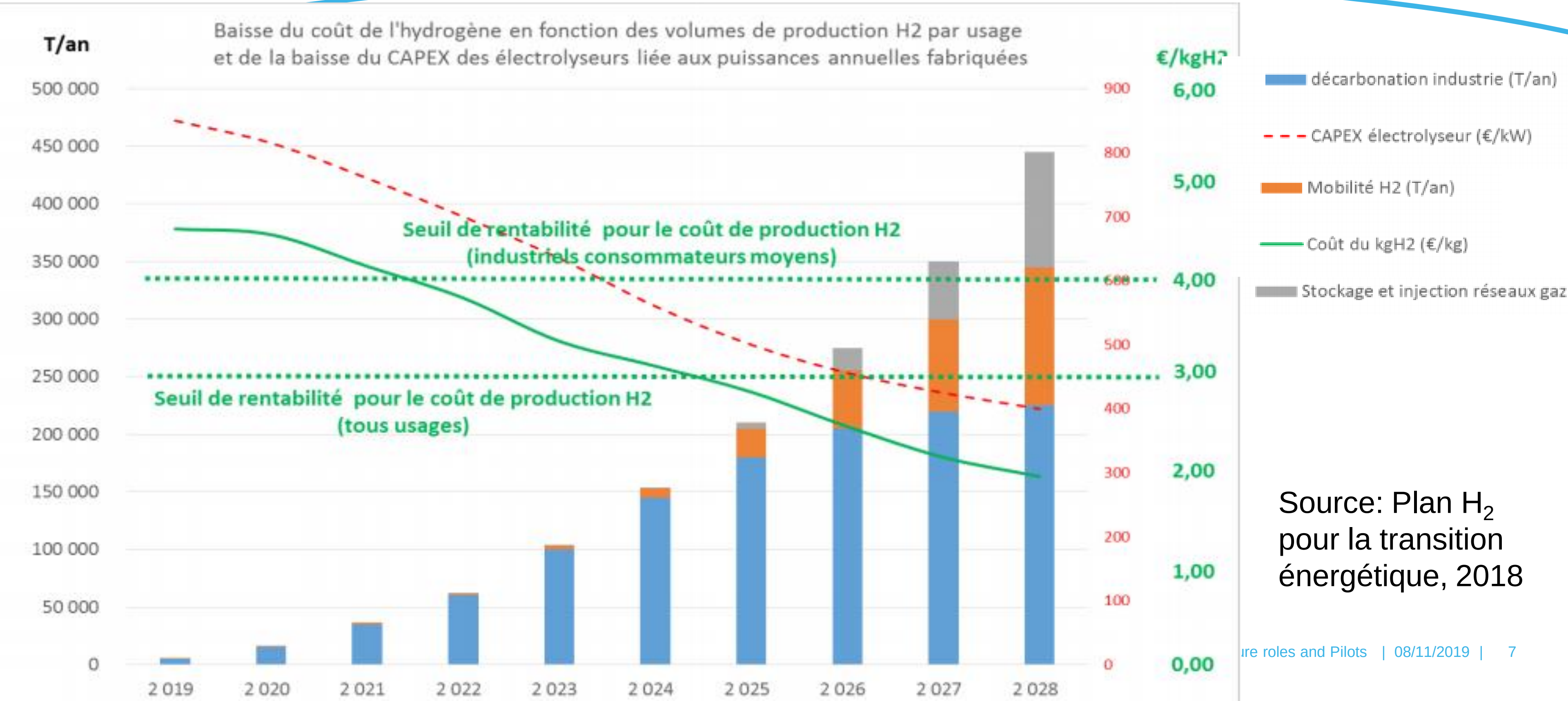
Hydrogen has a significant potential across all applications



1 Percent of total annual growth in hydrogen and variable revewable power demand
2 For aviation and freight ships
3 Trains and tramways

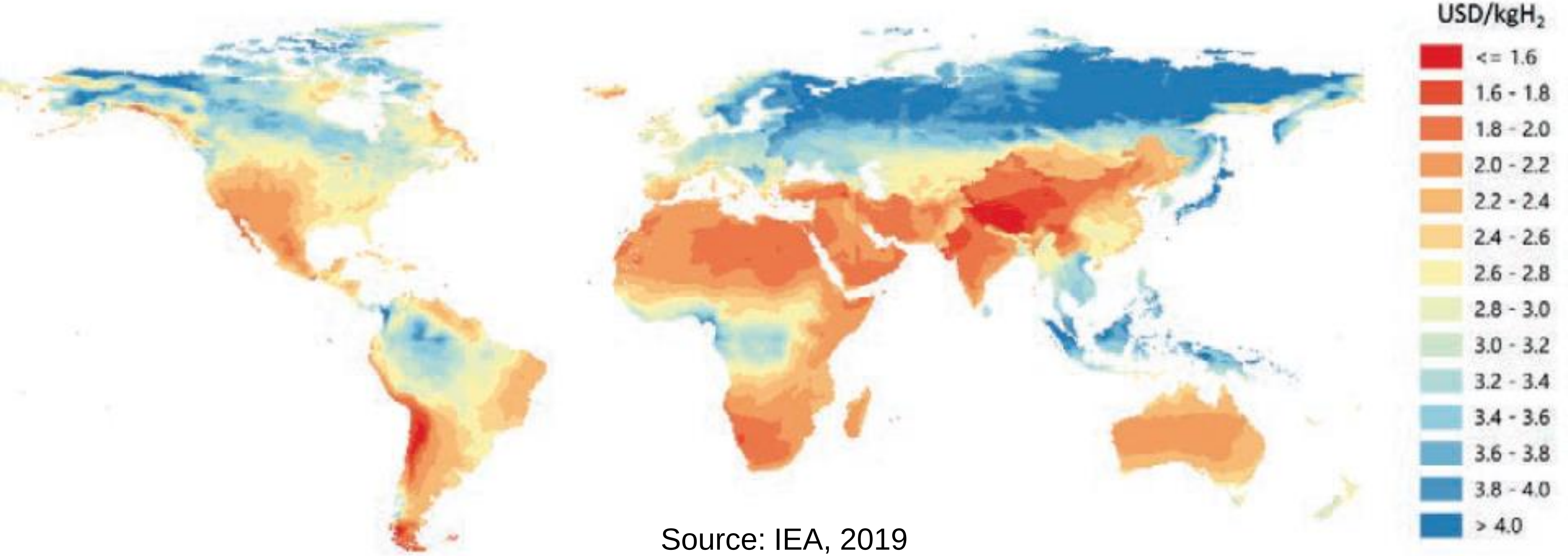
Source: McKinsey and Hydrogen Council 2017

In France, political will to strengthen an industrial H_2 sector. 100 M€ Plan launched.

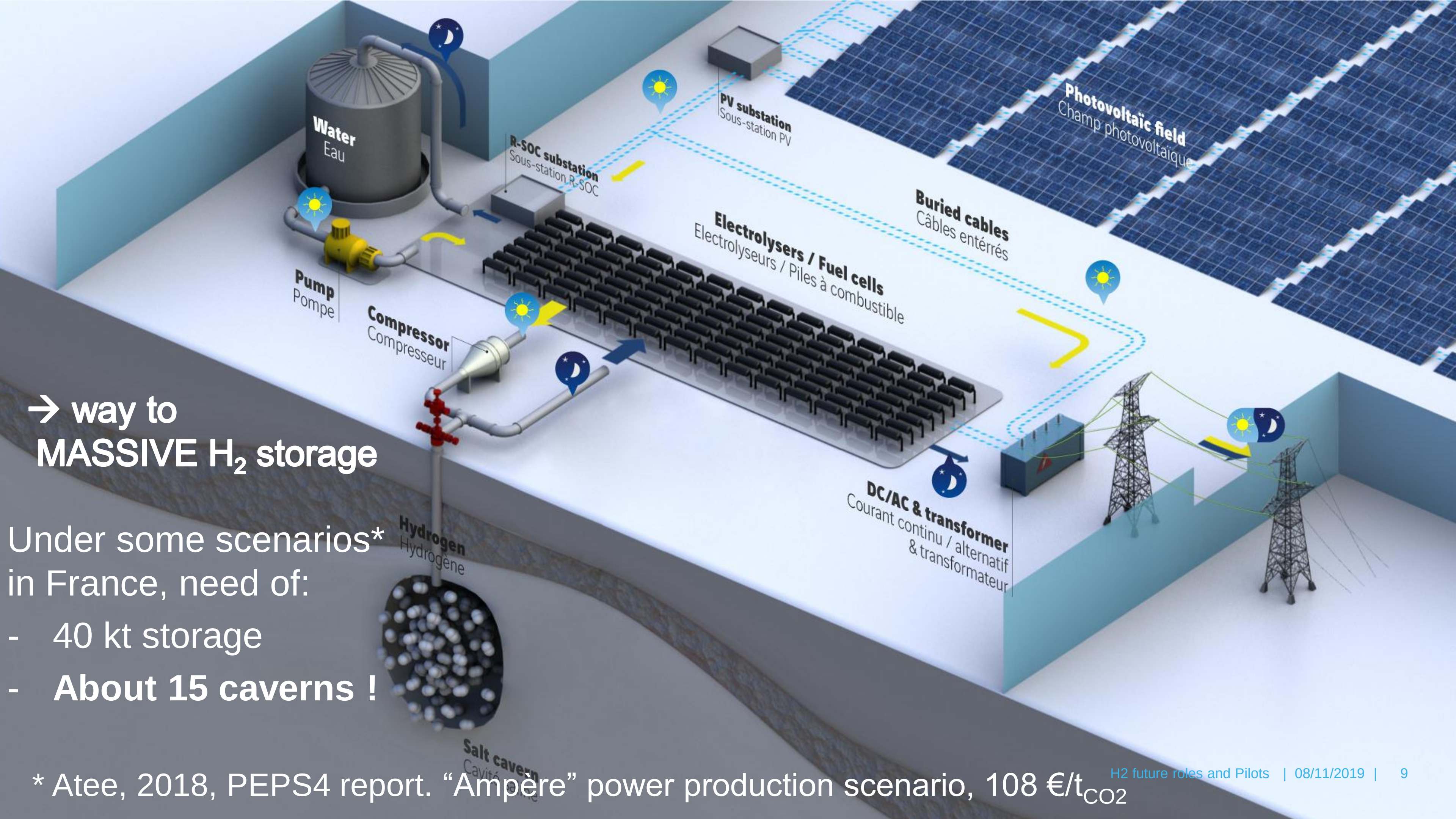


Source: Plan H_2 pour la transition énergétique, 2018

After 2030, the declining costs of solar PV and wind could make them a low-cost source for hydrogen production



Source: IEA, 2019



→ way to MASSIVE H_2 storage

Under some scenarios* in France, need of:

- 40 kt storage
- **About 15 caverns !**

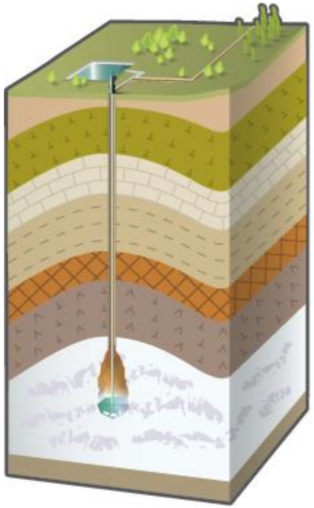
* Atee, 2018, PEPS4 report. “Ampère” power production scenario, 108 €/t_{CO2}

2.1
Historical salt cavern storages of Hydrogen

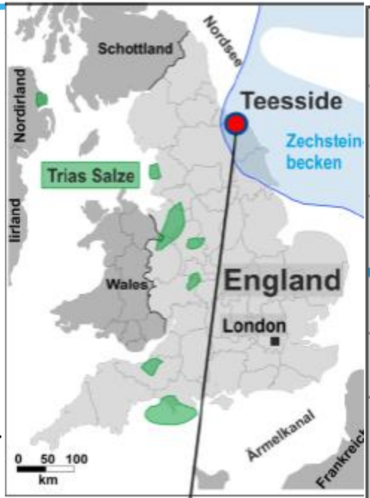
There are 6 H_2 salt cavern storage in operation in the World

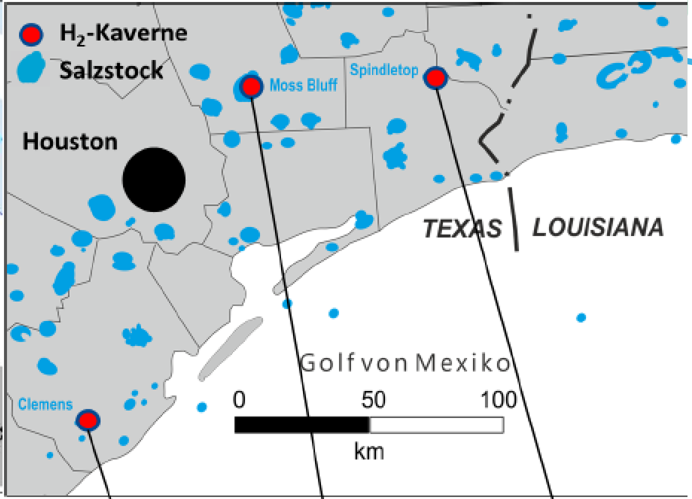
There are > 2000 storage salt caverns in operation in the world

- 1st gas storage in 1961



Adapted from Acht & Donadei, 2012





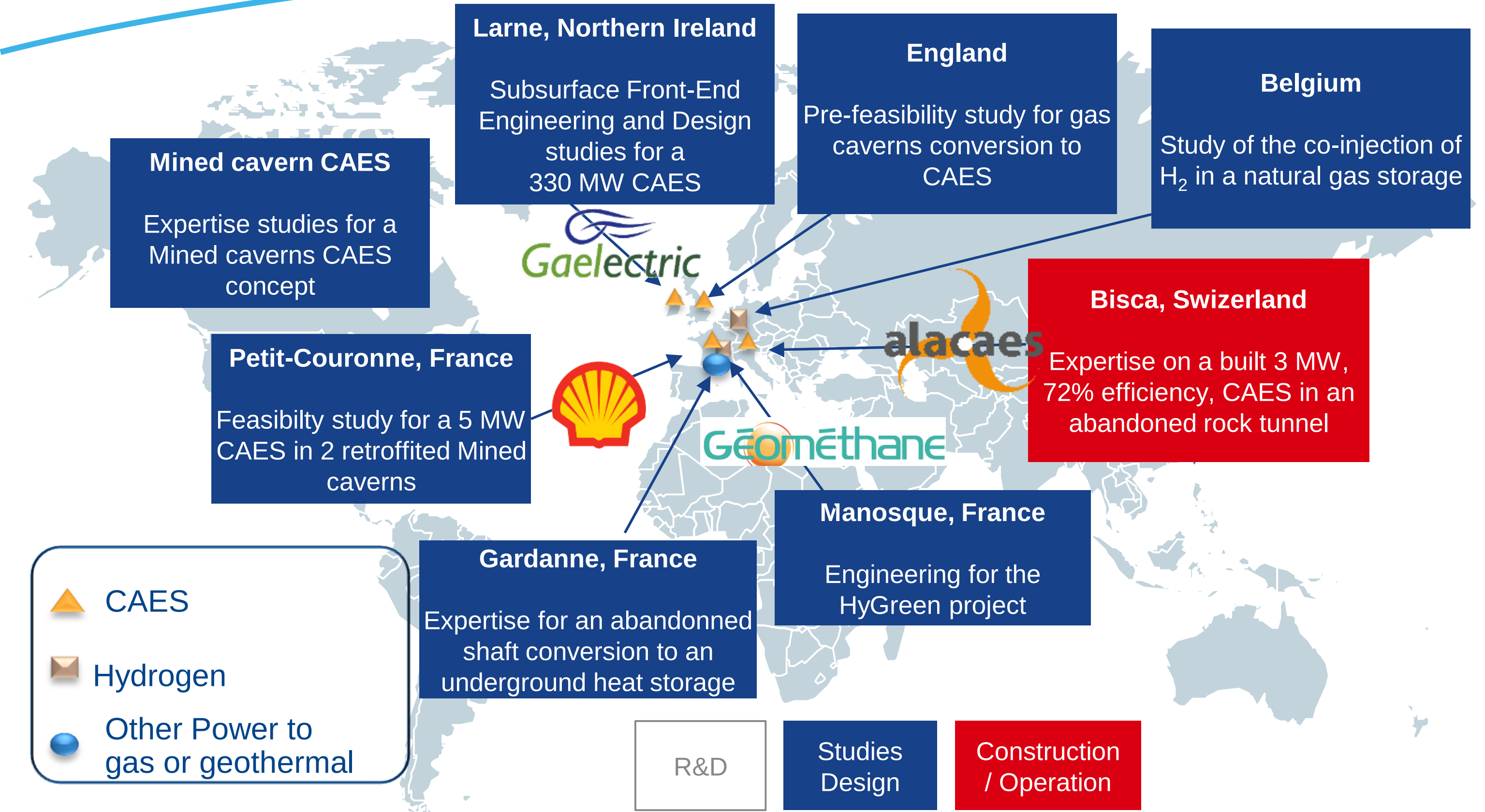
	Teesside (Sabic Petrochemicals)	Clemens Dome (ConocoPhillips)	Moss Bluff (Praxair)	Spindletop (Air Liquide)
Start up	1972	1983	2007	2014
Volume (m^3)	3 * 70 000	580 000	566 000	906 000

2.2

An industry transition from hydrocarbons to renewable energy storage. Geostock case study.

“Geostock case study”: Main references for Hydrocarbon underground storages. **Realisations !**

"Geostock case study": Main references for carbon-free energy storage since 2015. (Almost only) **studies !**



Participation to public collaborative R&D projects

- SACRE
- FluidStory
- ROSTOCK-H
- Stopil-H2
- Blockfall
- CO2-dissolved
- Miss-CO_2

Consortiums including:

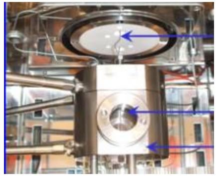
storengy, BROUARD CONSULTING, MINES ParisTech, AIR LIQUIDE, l'X École Polytechnique, INERIS, brgm, EDF

2.3
Research subjects surrounding the H2 storage: ROSTOCK-H project

ROSTOCK-H 2016 – 2020 project

Objectives:

- Improve understanding of H_2 behavior and reactivity with the salt
- Develop multi-scale numerical models predicting the geochemical and thermo-hydro-mechanical behavior of H_2 in the salt cavern
- Assess the safe operating conditions and associated monitoring
- Assess the economic viability
- Improve the social acceptance



Consortium:

Co-funding:

3

Research subjects surrounding the H2 storage: STOPIL H2 project

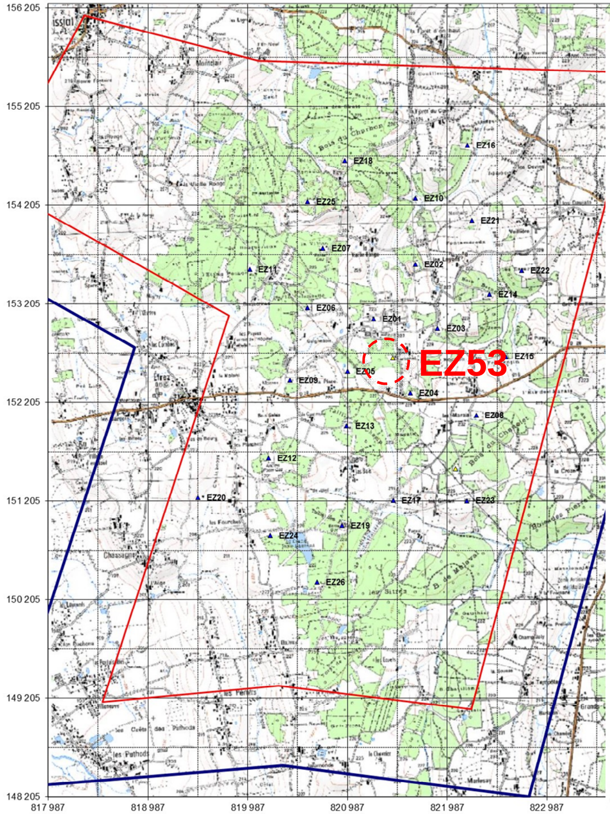
STOPIL-H_2

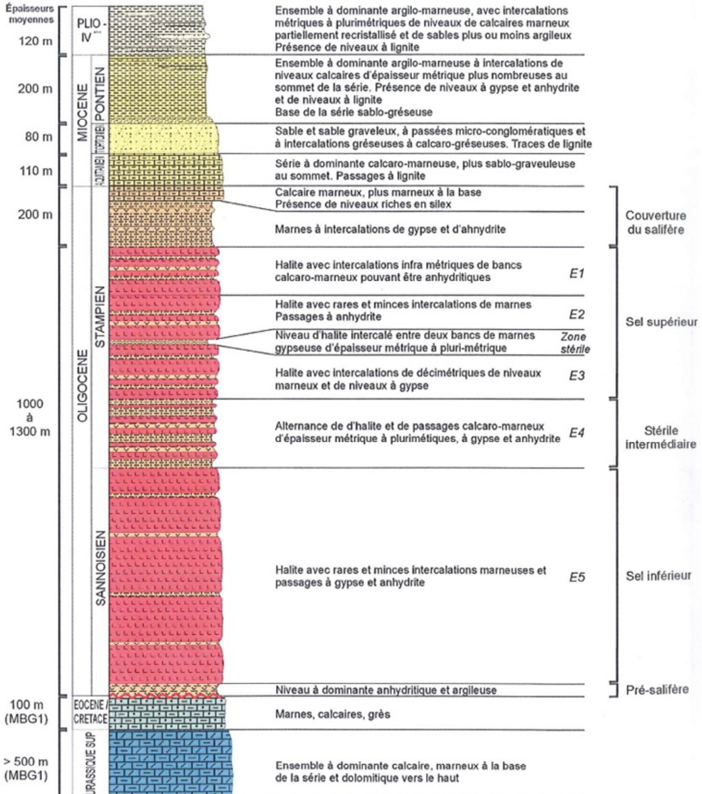
Development of a industrial pilot of hydrogen storage in a real salt caverne in France

Consortium:

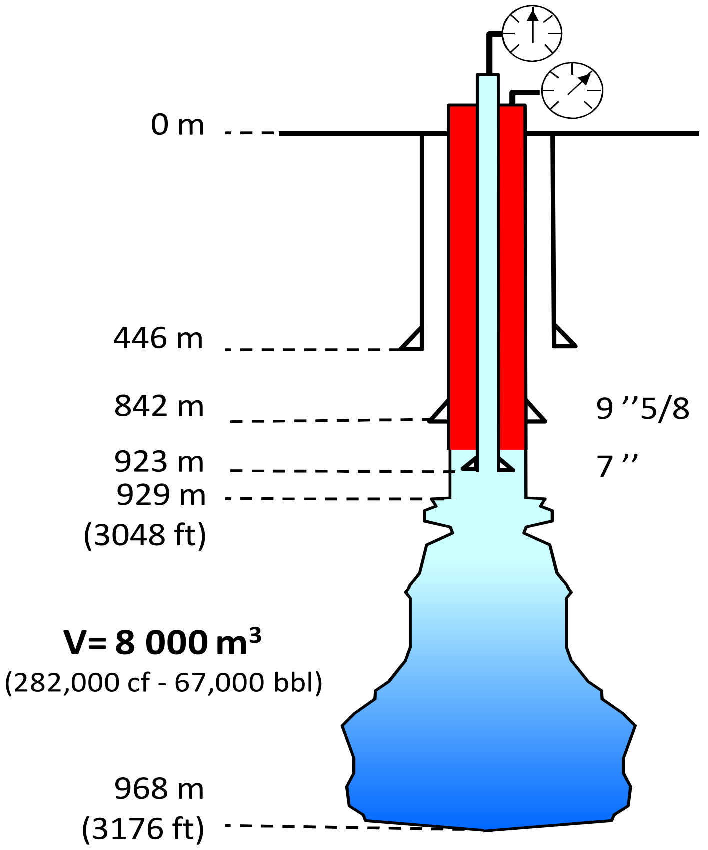
Co-funding:

Experimental site



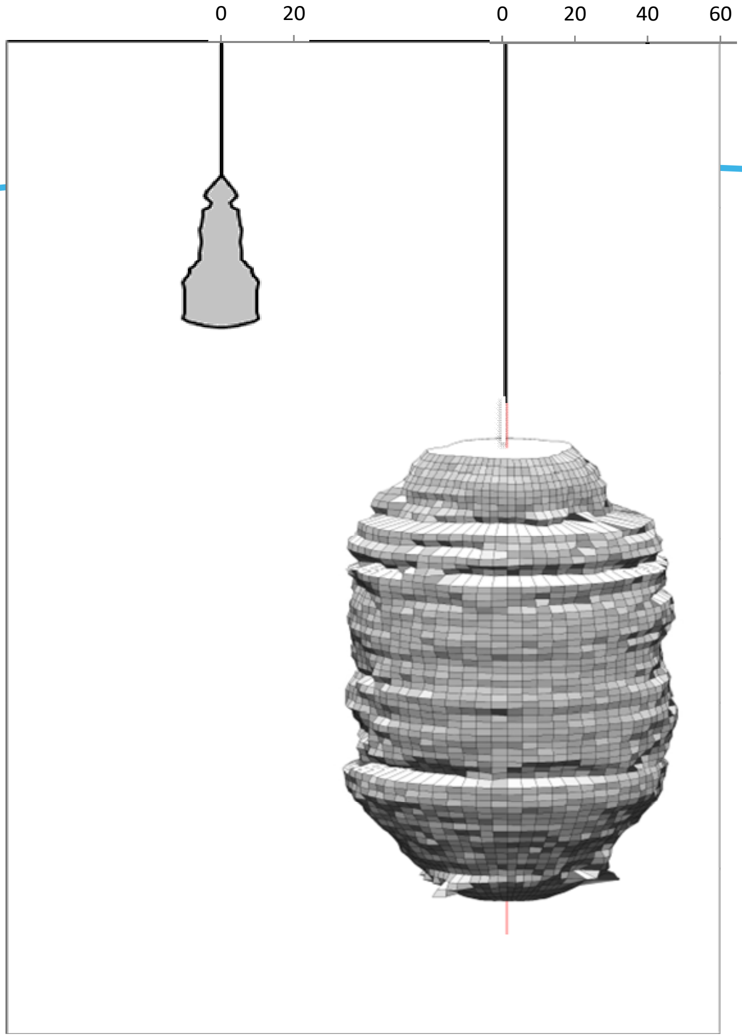


The EZ53 Cavern



Light hydrocarbon

Brine



EZ53 (upper layer)

Geometric volume :

7 000 m3

Hydrogen volume

- **total :** 900 000 Nm3
- **usable :**
  - 500 000 Nm3
  - 1.7 GWh
  - 44 tons H_2
- **Pmin** : 60 bar
- **Pmax** : 165 bar

EZ21 (deeper layer)

Geometric volume :

570 000 m3

Hydrogen volume

- **total :** 100 000 000 Nm3
- **usable :**
  - 70 000 000 Nm3
  - 250 GWh
  - 6 300 tons H_2
- **Pmin :** 60 bar
- **Pmax :** 240 bar

Phase 1 : Feasability

- Technical specifications
- Monitoring specification
- Financial aspects
- Safety
- Authorization

Phase 2 : Realization in EZ53

- In situ experiment
- Measurements
- Injection and withdraw

Phase 3 : Interpretation

- Tightness,
- Hydrogen behavior,
- Cavern behavior.

Objectives of the STOPIL H2 project

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- Tightness test
  - Based on the standard procedure of M.I.T. (Mechanical Integrity Test)
  - First test with nitrogen
  - Then same test with hydrogen

- Hydrogen operation test
  - Filling the upper part of the cavern with hydrogen
  - Simulation of injection and withdrawing
  - Final depressuration

the “Mechanical Integrity Test”

Aim: check the tightness and the strength of the completion (tubing + packer + casing shoe)

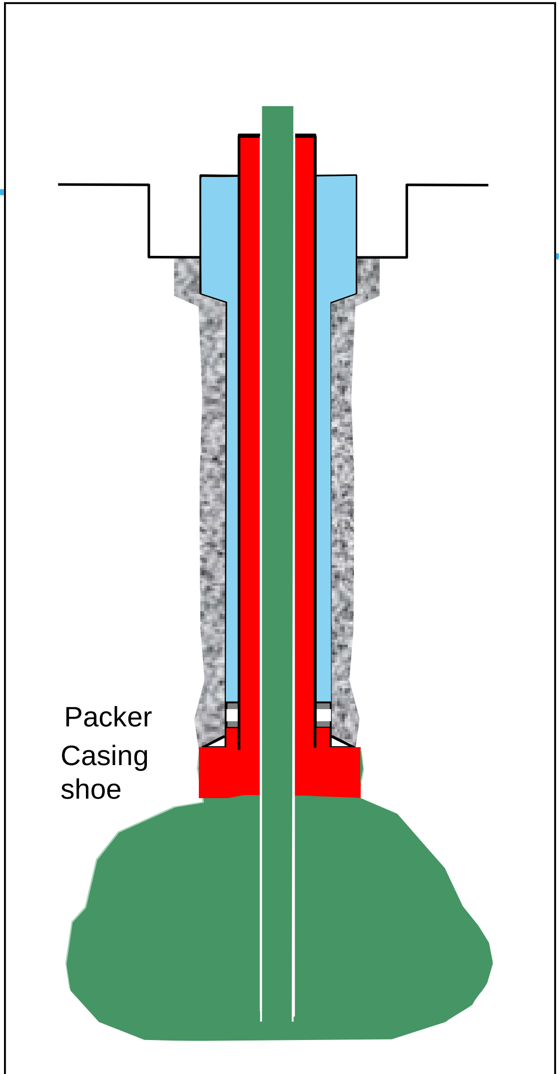
Fluids: Nitrogen and brine

Pressure test: based on Maximum Operating Pressure

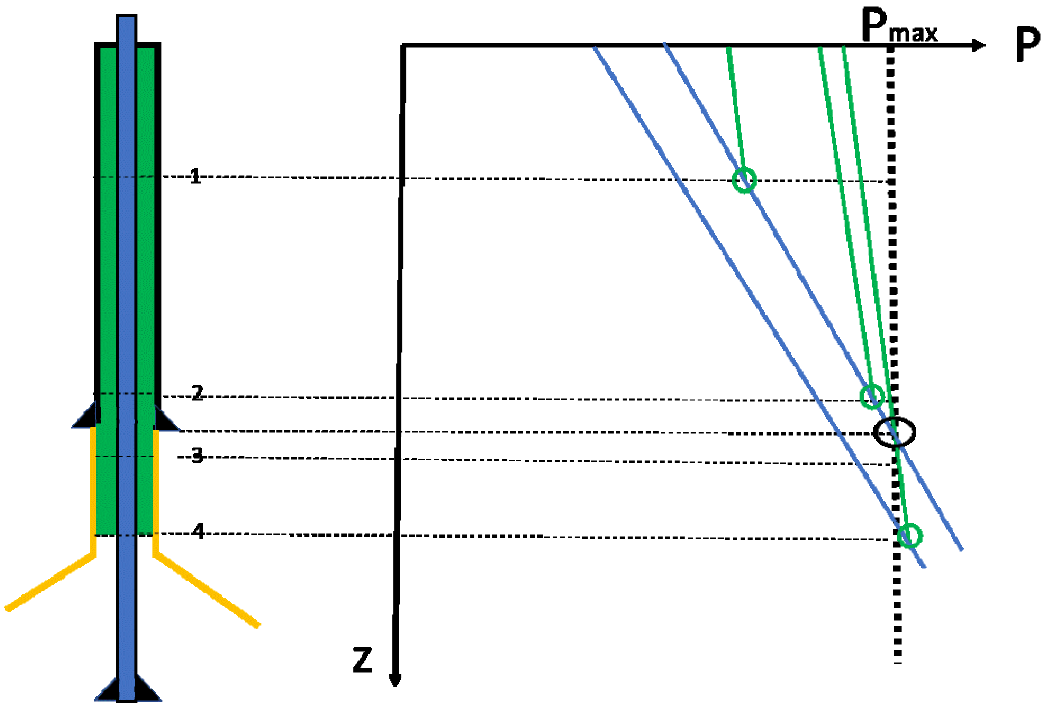
Operation:

- Inject nitrogen
- Inject brine until Ptest
- Measure the depth of interface by log + T°
- Keep steady during 48h
- Measure the depth of interface a second time by log + T°

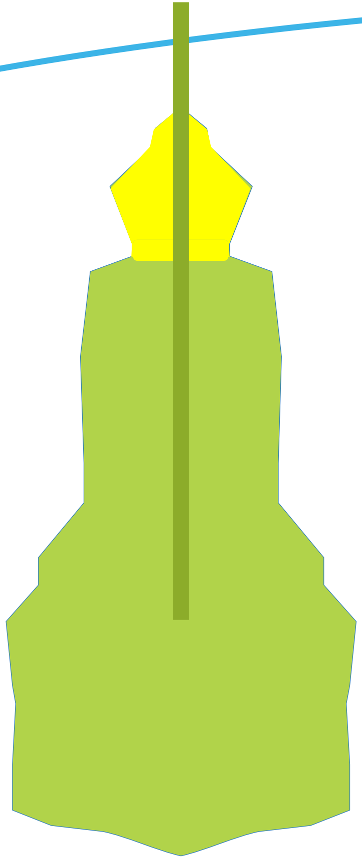
⇒ **Estimation of “apparent leak” trough casing, casing shoe or packer (by interface level difference)**



Special test for STOPIL H2 : 4 steps of test



Hydrogen cycling



- Pressure variations of hydrogen by injection and withdrawal of brine
- Simulation of different cycles
- Final withdrawal of hydrogen

Also included in the project:

- Laboratory tests
- Risk assesment
- Relation with French Administration
- Cost estimation of phases 2 and 3
- …