Opportunities and challenges in developing **hydrogen storage** within the context of the H_2 market ramp-up

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Hydrogen Tech World Conference 2025

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ENGIE is a driver of the energy transition

IN 2024:

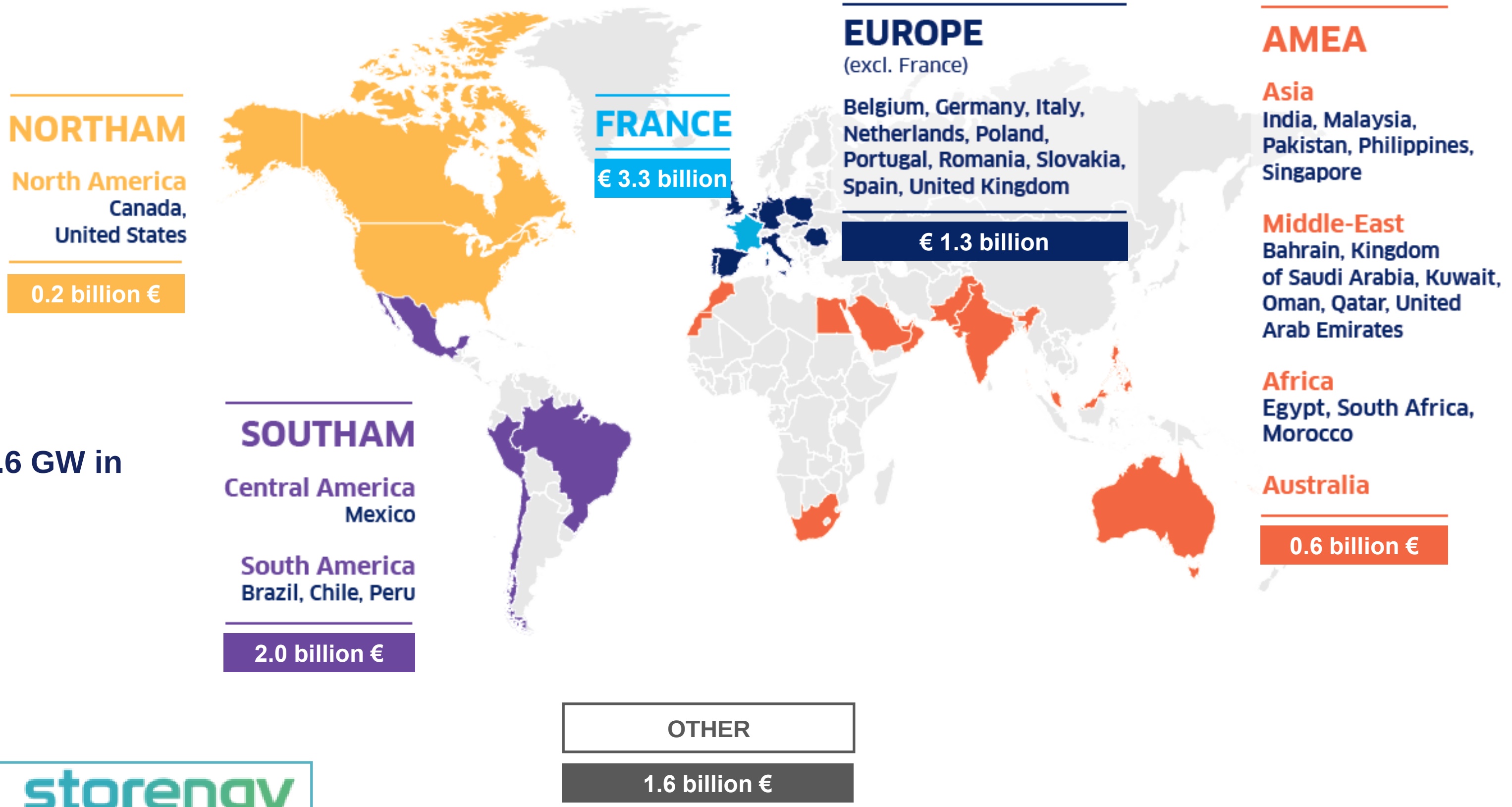
- 97,300 employees
- 73.4 billion € turnover
- 8.9 billion € EBIT
- 10.0 billion invested

Power:

- 60 GW of conventional power
- **46 GW of renewables, 6.8 GW under construction**
- 5,700 km of transmission grid lines
- **2.6 GW of battery storage systems in operation, 2.6 GW in development**

Gas:

- 38,500 km of gas pipelines & 26 compressor stations
- 258,500 km of gas distribution pipelines
- 3 LNG terminals @ 21.5 Gm^3 per year
- 21 storage locations, total capacity of 12.2 Gm^3 storengy
- 26 biomethane plants, totalling 549 GWh per year



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Hydrogen storage as a battery for the energy transition

Power grid relief
- Storage of surplus electricity
- Option for congestion management

→ Less redispatch

Supply & demand
- Balancing supply and demand
- Decoupling generation and consumption

→ Price reduction & price volatility reduction

Optimised power plant operation
- Optimum utilisation of power plants (CHP) possible through storage
- Green energy (electricity & heat) during dark doldrums

→ Secured, economical & environmentally friendly

Optimised electrolyser operation
Fluctuating renewable electricity generation and electrolysis, optimum utilisation of electrolysers possible by storing peaks
→ Cost-effective storage of renewable energy surpluses

H2 import storage
Imports also possible if no immediate purchase and if particularly favourable
→ Availability & price reduction

H2 grid stability
- Equalisation of grid pressure fluctuations
- Availability of power and labour

→ Security of supply & reduction in volatility

Faster decarbonisation
Reducing the use of fossil fuels and accelerating the introduction of hydrogen

Security of supply
Power supply (in the event of import failure and fluctuating generation), storage of large quantities over a long period possible

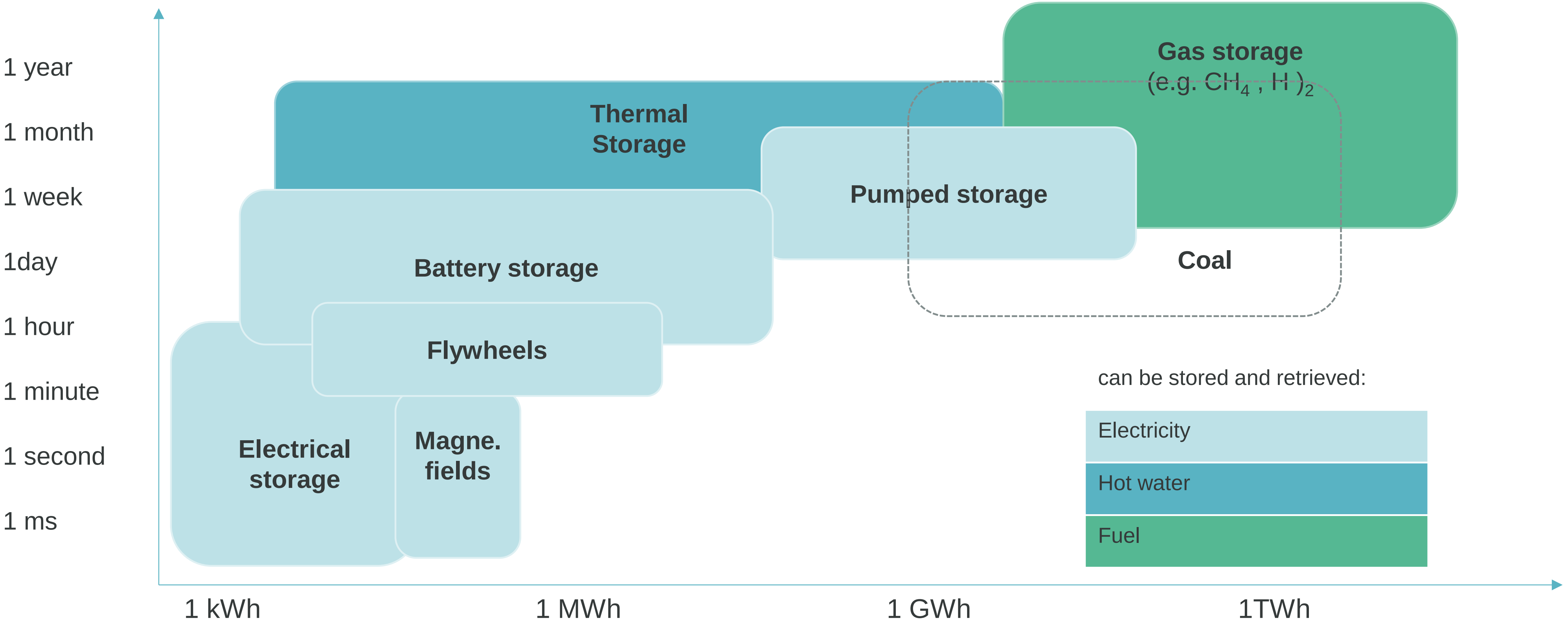
Lower system costs
Efficient design of the entire energy system, cost-efficient through utilisation of the existing natural gas storage infrastructure

Energy storage technologies

Primary energy demand in DE:

2023: approx. 3 000 TWh
2030: approx. 2 400 TWh (EnEfG)
2045: approx. 1 500 TWh ?

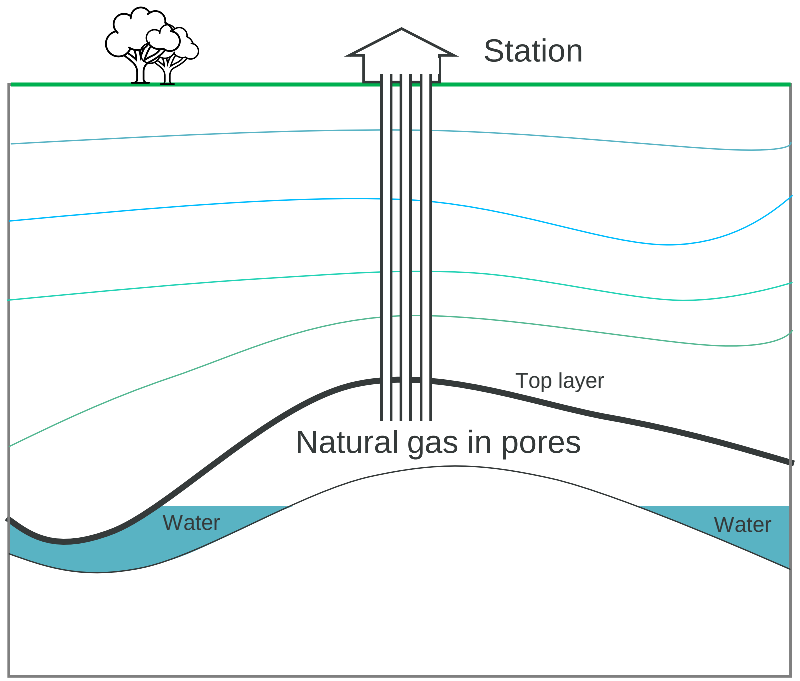
Storage requirement of an energy system: approx. 15-25%



Storage technologies

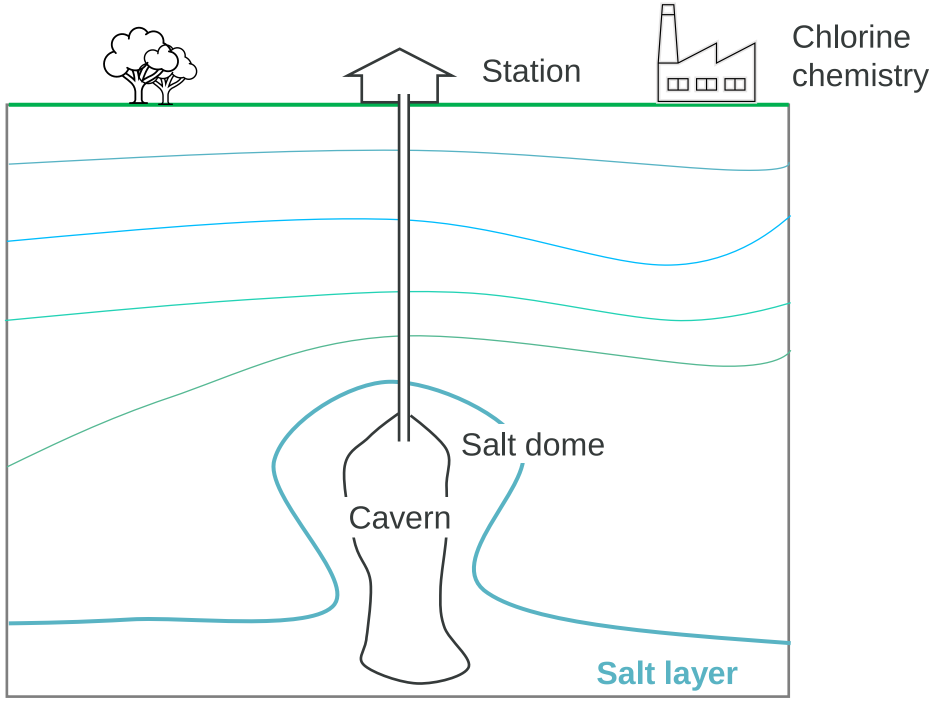
Pore storage

Larger (3 - 30 million m³)
Slower storage and retrieval



Cavern storage

Smaller (250 000 - 750 000 m³)
Faster storage and retrieval



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Methane & Hydrogen use case (Europe)

Energy systems require approx. 15-25% of the consumption of storage capacities

Methane in 2021, in Europe:

- 40% Direct space heating
- 28% Industry (incl. feedstock)
- 31% Electricity generation, incl. CHP
- 5% Mobility

IEA, EU, 2021

- In general, since 2022: Security of energy supply
- No rapid decrease in storage requirements
- Minimum filling level specifications must be adhered to
- Synthetic or bio-methane?

→ **Methane cavern storage facilities will be needed in the medium term**

Hydrogen in 2050, in Europe :

- 7% Direct space heating
- 56% Industry (incl. feedstock)
- 30% electricity generation, incl. CHP
- 14% Mobility

EHB, 2021

- **Primarly, massive electrification**
- Can be stored seasonally like Methane
- Secure fluctuating renewable energy supply

→ **Hydrogen storage as a battery for the energy transition**

→ **Little immediate cannibalisation**

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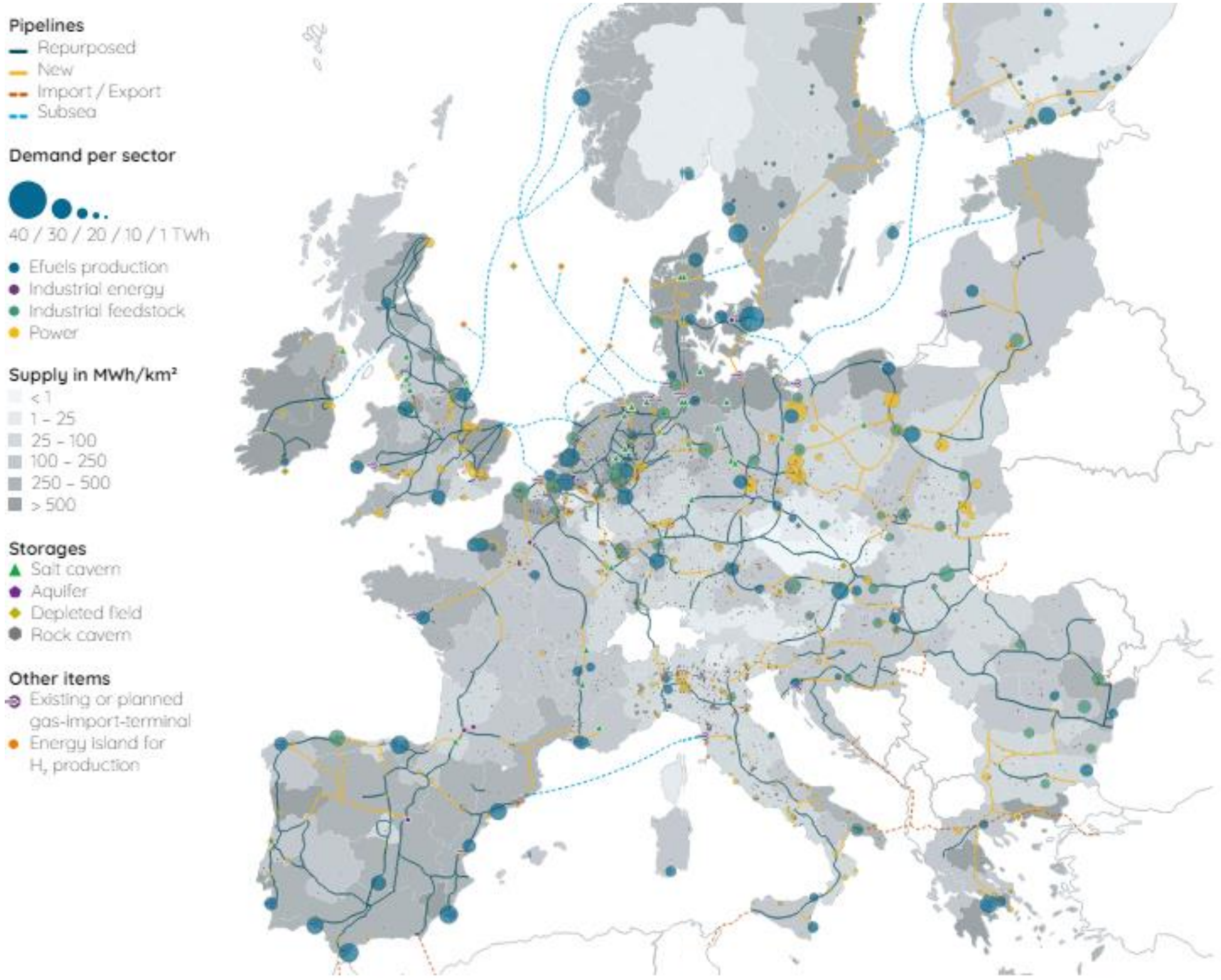
Germany at the centre of Europe's future hydrogen infrastructure

Expectations until 2045		In Europe	In Germany
Hydrogen demand	[TWh]	1 600	290
Transport lines	[km]	58 000	10 000
Hydrogen storage	**[TWh]**	**300**	**80**

- The European Hydrogen Backbone reduces CO2 emissions by up to 312 million tonnes and saves €330 billion compared to unconnected clusters.
- It is expected that hydrogen will be imported from surpluses from the Mediterranean region, overseas and northern Europe.
- Consumption centres are expected in Northern and Western Europe. **Hydrogen flows will therefore move towards the Northern German plain**.



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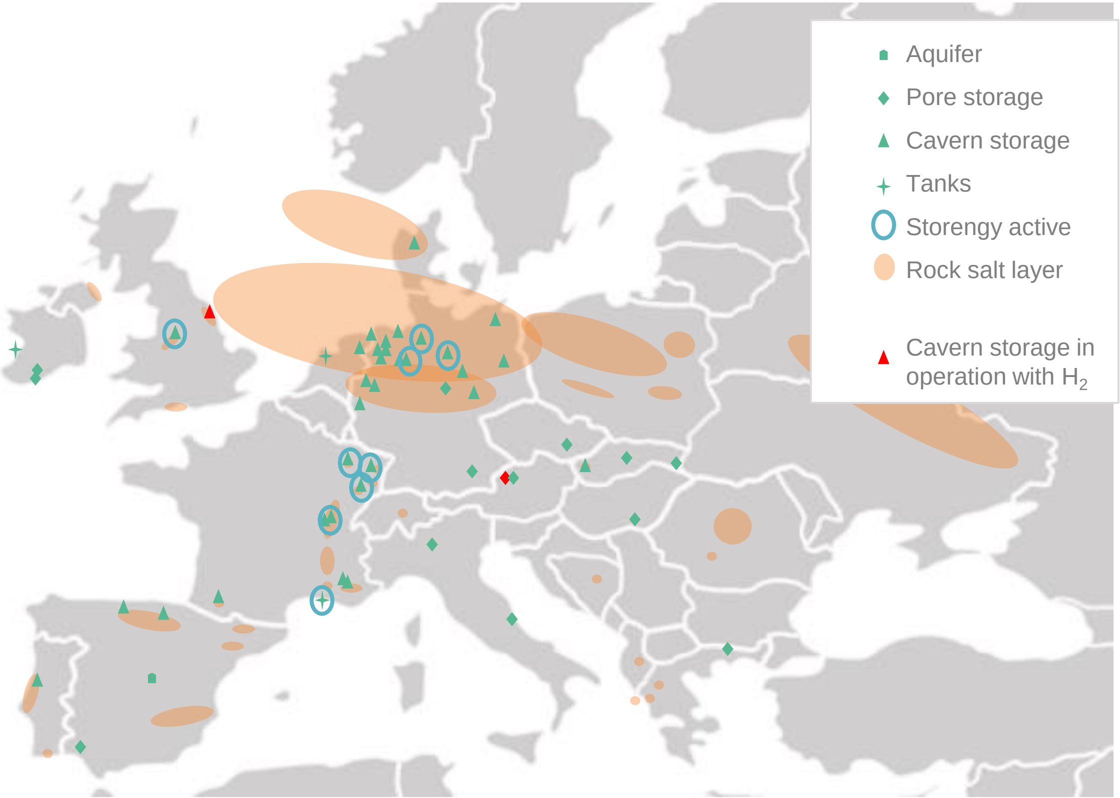
Potential for storage projects in Europe

- **DE expected to be the largest market for H2 in Europe** with high consumption expectations
- **Central location** in Europe, at the centre of the future pan-European hydrogen pipeline network at the intersection of all supply corridors
- **Generous natural resources:** large geological potential for gas storage in salt caverns in DE: 80% of natural gas storage salt caverns in the EU are in DE
- Concentration of initial H2 projects

→ **Rededication potential limited**: natural gas storage capacities will continue to be required in the medium term

→ **(New) salt caverns currently a good alternative**



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FrHyGe Project - France Hydrogen Germany

✓**Subsidy from the Clean Hydrogen Partnership: 20 M€**

✓**17 partners** with 4 different nationalities

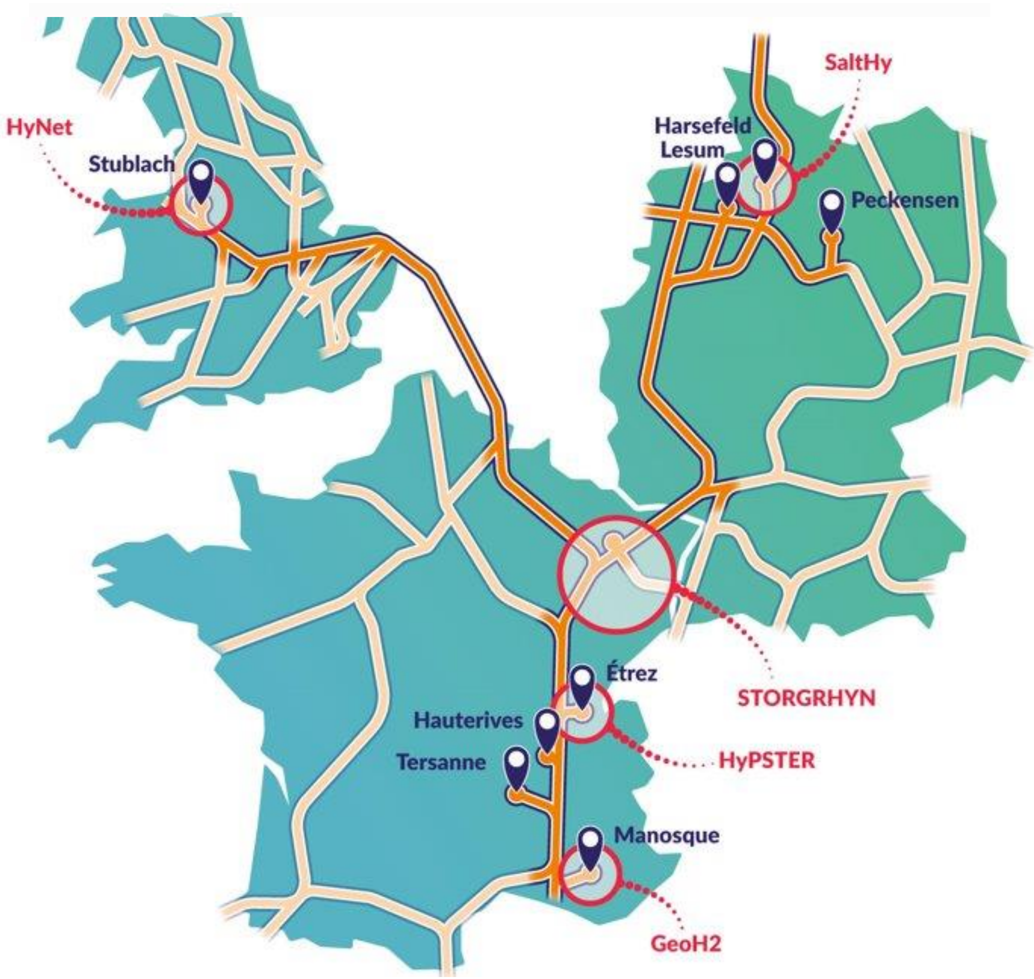
✓Feasibility to **convert caverns** from methane towards hydrogen use (HyPSTER, GeoH2)

✓ Research: At least **100 injection & withdrawal cycles** at various pressures/volumes of **100 tonnes of hydrogen**

✓**Replication** towards other salt fields. Starting with SaltHy

✓Conversion → 5 – 8 years

✓New build → 6 – 10 years



SaltHy

Construction of the **UHS Hollenbeck** hydrogen storage facility in the vicinity of the existing UGS Harsefeld natural gas storage facility

<u>Project scope</u>

UHS surface plant 2028 - 2032

Cavern **UHS** 1 2026 - 2032

Cavern **UHS** 2 2029 - 2034

Conversion UGS K1, K2 2035 (?)

Potential for further caverns

<u>Cavern data (per cavern)</u>

Geometric volume up to 750,000 m³

Gas content: up to approx. 10,000 tonnes

of which working gas: up to approx. 7,500 tonnes

Injection/withdrawal: up to 275,000 m³/h (600t/d)

Engie: "Development status" confirmed

Europe: PCI status confirmed

Europe: CEF funding confirmed

At the moment:

- Mapping
- Preparation of authorisation procedures
- Engineering for surface and underground

- 1st investment decision for realisation of the underground section (borehole and reservoir): Q1/2025

PCI: Project of Common Interest

Planning challenges

- H_2 and CH_4 in separate systems (few synergies)
- Materials: H_2 vs. CH_4 , steels, cements, elastomers
- Coordination (e.g. permits, distances, pressure, gas purity)
- Interpretation

1 Grid Availability, dimensioning & connection ?

2 Filters & measuring devices New

3 Compressor Dimensioning & quantity ?

4 Cooling Dimensioning & quantity ?

5 Rock layers Suitability ?

6 Salt layer and salt dome Suitability ?

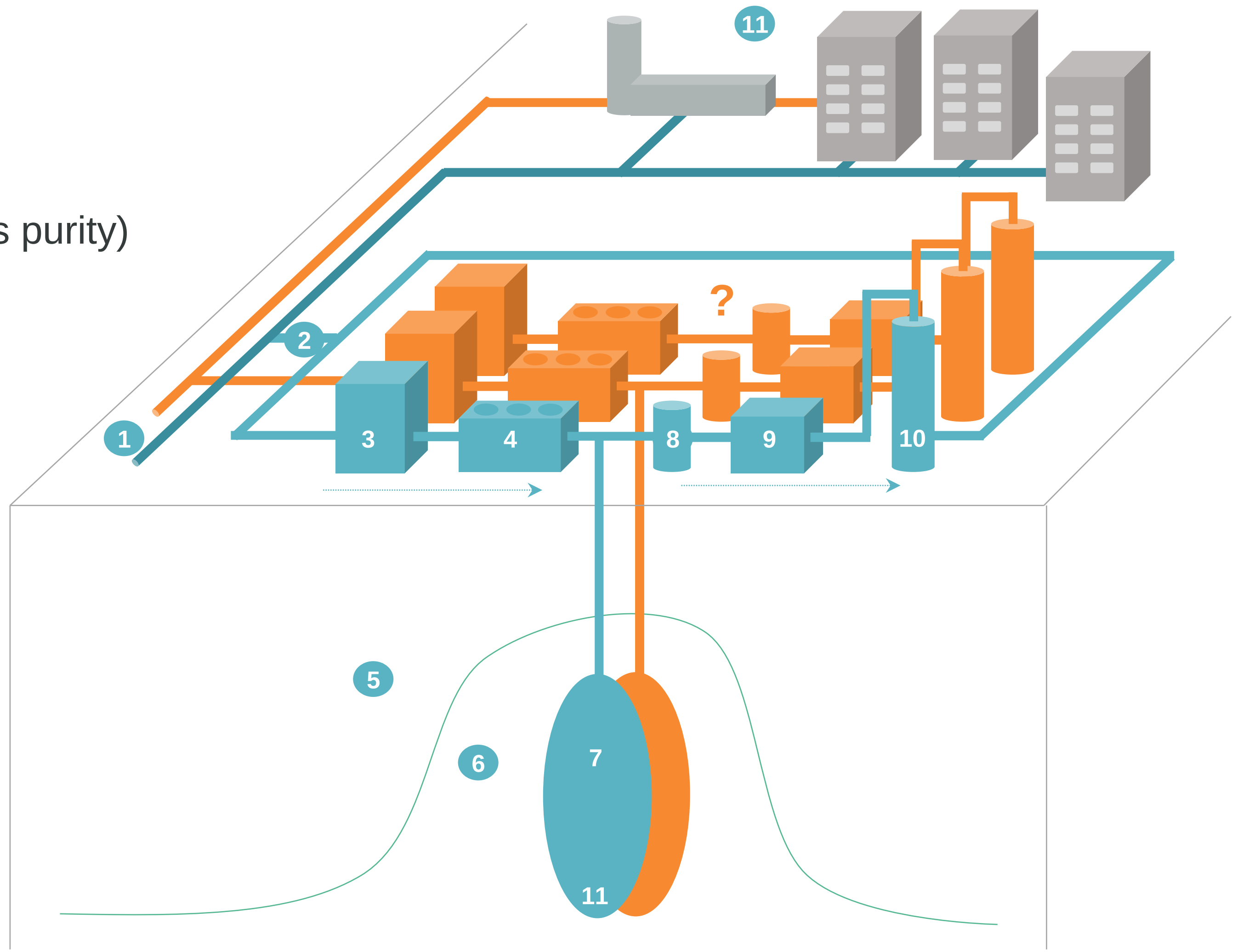
7 Cavern with working gas and cushion gas Volumes ?

8 Preheating Cooling: Dimensioning & number ?

9 Pressure control Design ?

10 Drying Dimensioning & quantity ?

11 Consumers & Suppliers Load curves, cycling and new life ?



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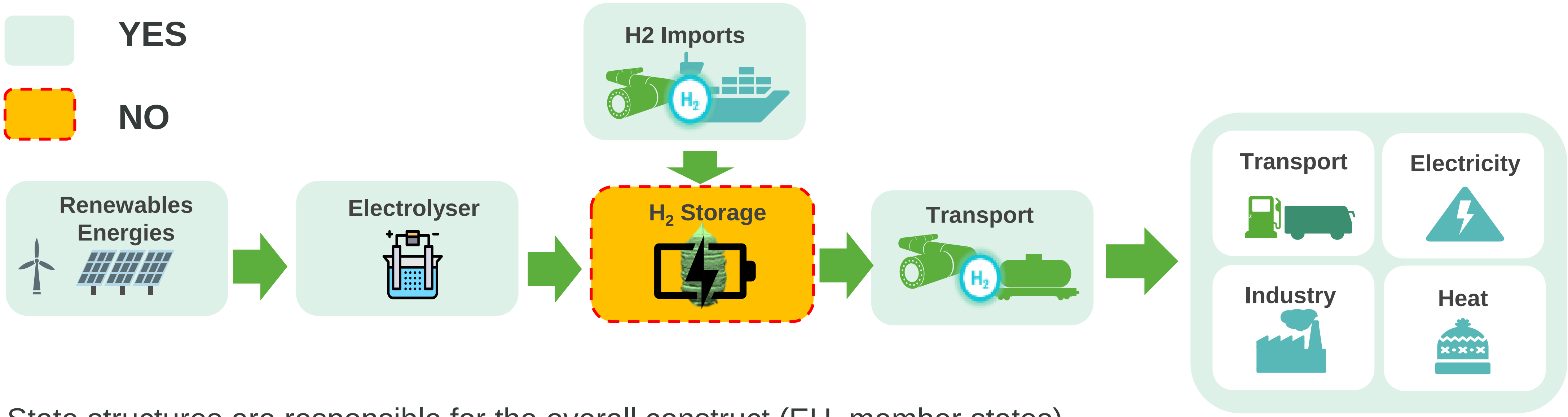
Goal: A balanced value chain

Incentives currently in place, foreseen or in discussion:



1. State structures are responsible for the overall construct (EU, member states)
2. Investors will make the best possible investment
3. Storage systems are indispensable for the hydrogen value chain
4. Germany is a great place for underground gaseous storage
5. Today, a lack of favourable regulatory frameworke means investment signals are weak

Recommendation for action

1. Set clear goals, objectives (SMART) and targets (quantified and dated).
2. Accompany the ramp-up through volume allocations, e.g. by auctioning storage capacities.
3. Establish a clear regulatory framework for the economic operation of storage facilities as early as possible.
4. Establish customised funding and financing mechanisms.
5. Clarify open questions regarding development and operation:
   a. Permitting issues
   b. Purity level of the hydrogen
   c. Pressure control throughout the system
   d. Grid utilisation fees

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Thank you

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