HyUnder Project

(Grant Agreement nº 303417)

Assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe

Overview and tentative results of the HyUnder project

Ulrich Bünger, German Case Study Coordinator, Ludwig-Bölkow-Systemtechnik

Joint NOW GmbH – FCH JU Water Electrolysis Day
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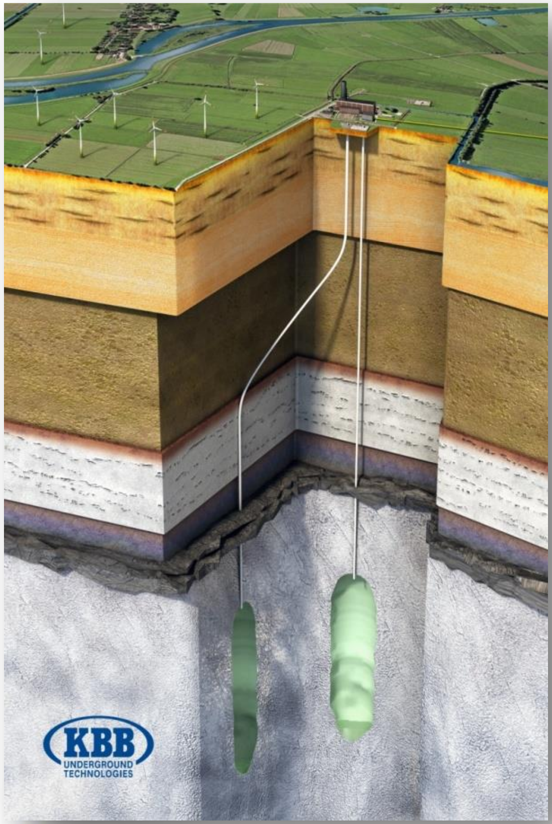
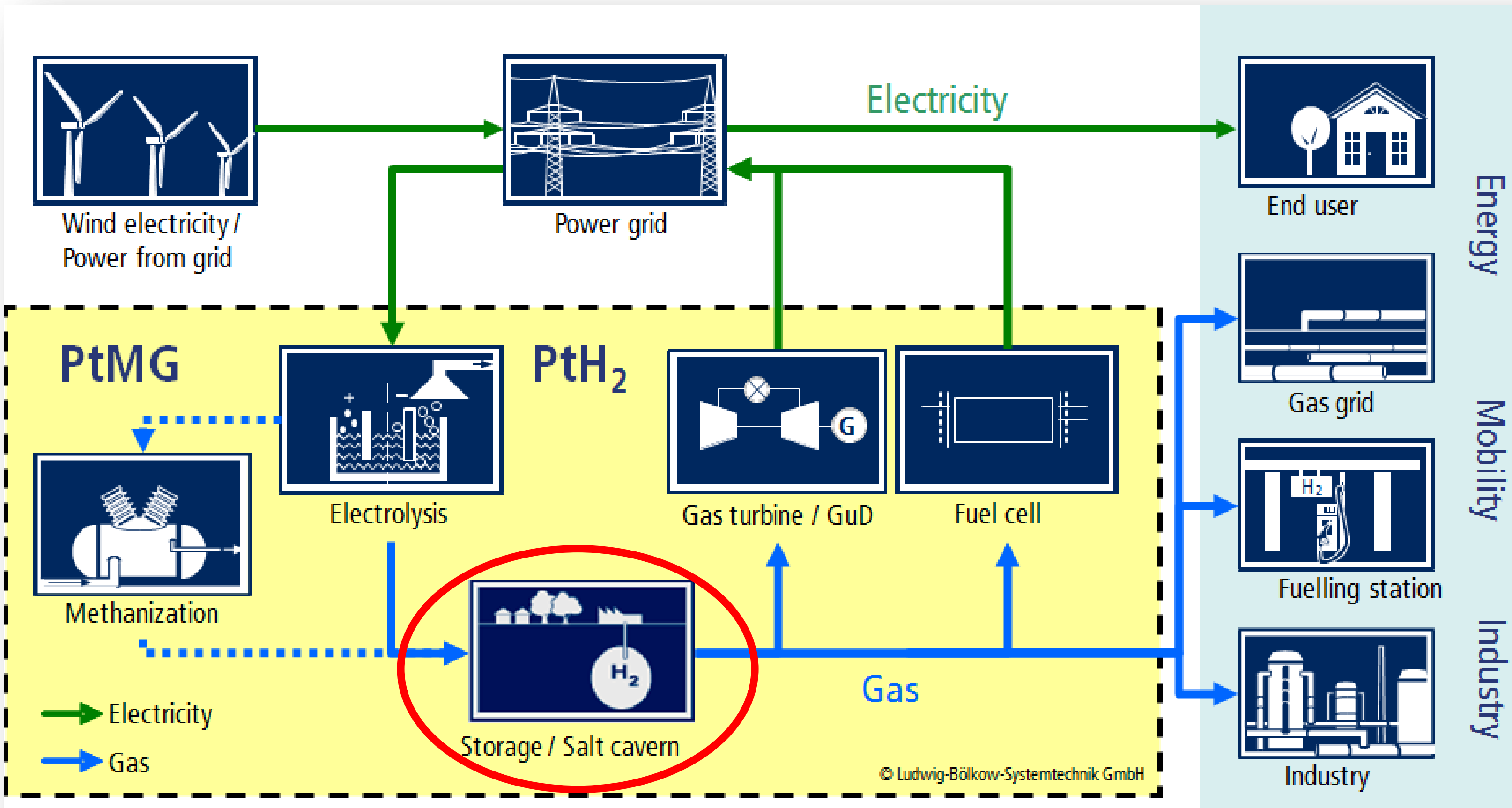
About HyUnder

- HyUnder, Assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe (www.hyunder.eu)
- Duration 24 months, from 18/06/2012 to 17/06/2014
- Budget: 1.766.516 € / Funding: 1.193.273 €
- 12 project partners from 7 countries
  (DE, FR, UK, ES, NL, RO, BE):
  3 large industry, 7 institutes/consultants, 2 SMEs.
- 17 supporting partners
  9 from energy sector (TSO, DSO, gas, electricity…),
  5 other industry (chemical, gases, automotive)
  3 regional authorities



Hydrogen storage as part of energy chain



Rationale

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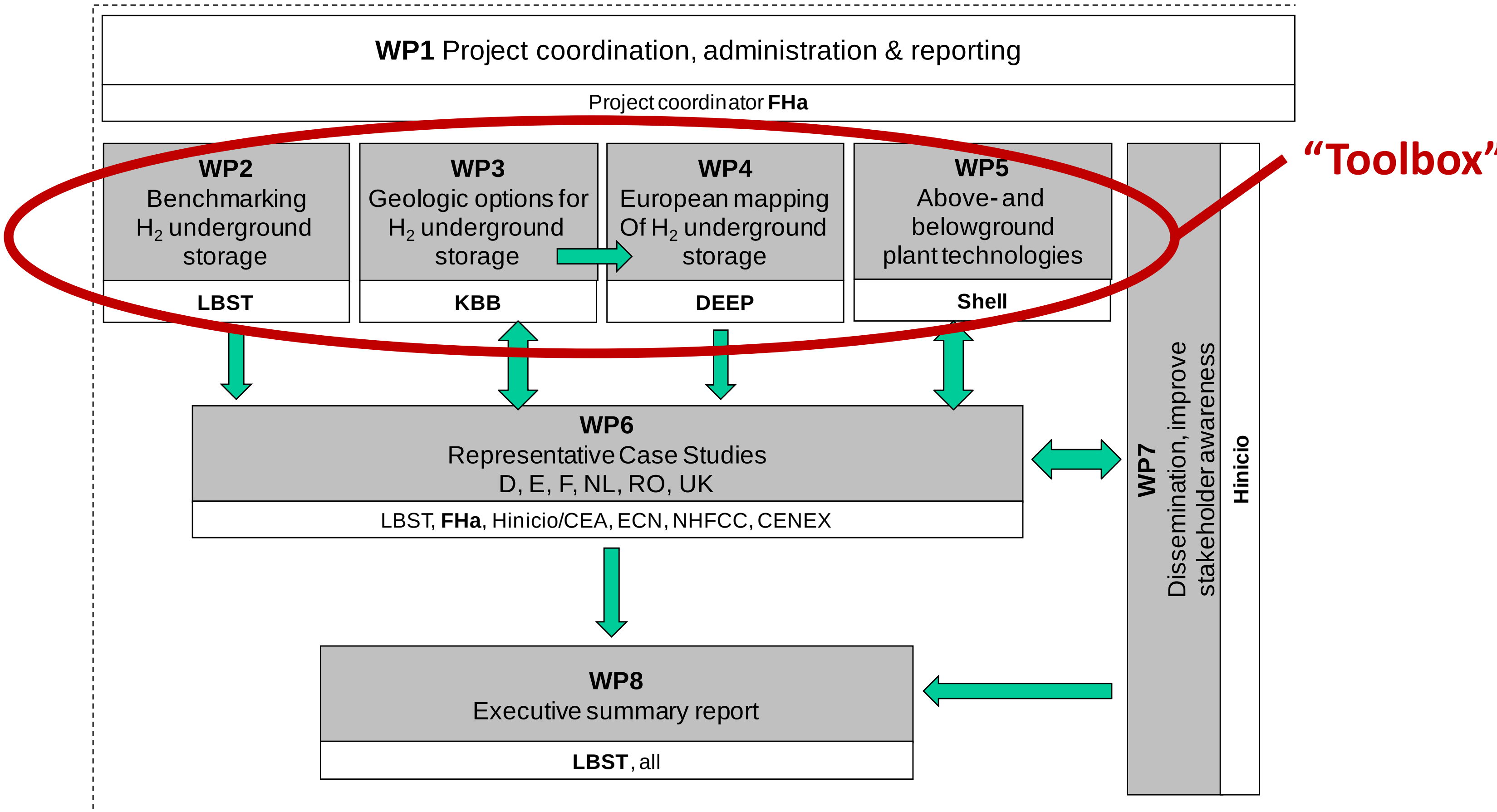
Why storing large scale intermittent renewable energies with hydrogen?

- Increasing **fluctuating renewable energy** in the long run → **need for electricity storage** to ensure **network reliability and flexibility**.
- Large scale underground gas storage: **relatively mature solution**
- Thorough evaluation of hydrogen underground storage needed from a technical, economic and societal standpoint, providing understanding of:
  - potential economic returns for **investors**;
  - technical attractiveness for **network operators and energy producers**;
  - potentially addressable markets for **technology developers**;
  - benefits for the society as a whole, and how environmental risks are being evaluated and addressed for **policy makers and citizens**.

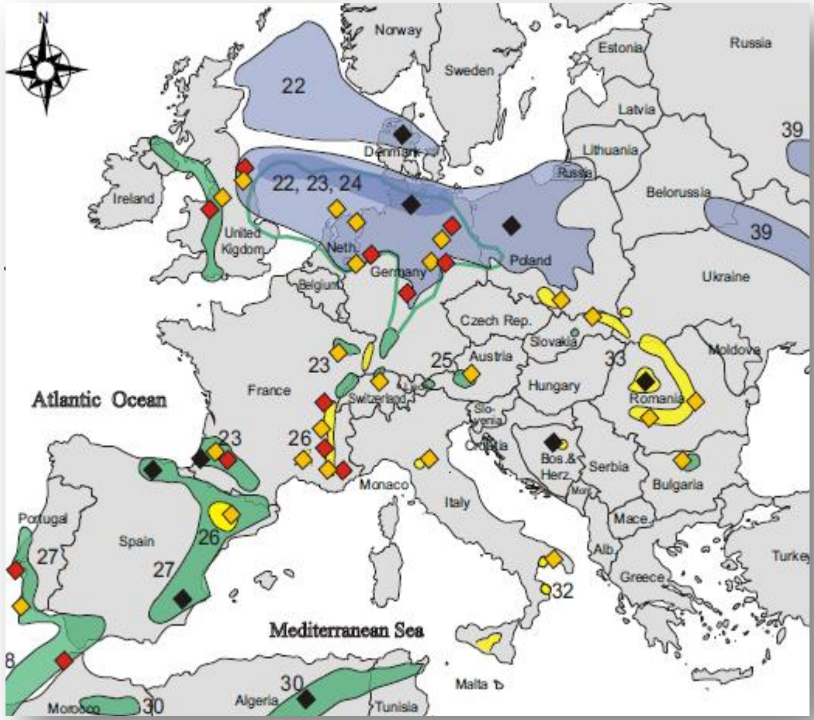
Approach and methodology 1/2



Approach and methodology 2/2

Mixed Regional /European perspective:

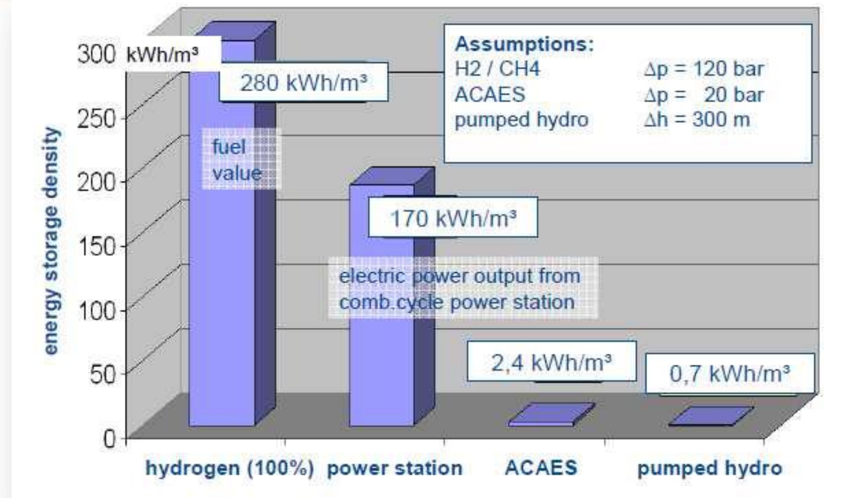
- Development of individual Case Studies on H_2 underground storage for Germany, Spain, the UK, Romania, France and the Netherlands, all based on a common methodology:
  - Compare H_2- vs other storage concepts/technologies.
  - Regional storage prototype location analysis.
  - Identification of ideal geological storage options.
  - Assessment of plant technologies.
  - Economic scenario assessment (static/dynamic).
  - Introduction of hydrogen into different markets.
  - Sensitivity analysis based on scenario assumptions.
  - Comparison of individual Case Study results.
- Synthesize into one EU Action Plan / Roadmap.



Source: KBB

Energy storage needs EU (100% REN)

- Assumption: 100% renewable energy power system
  - 1,300 GW wind, 830 GW PV,
    50% of "excess" generation assumed
- Storage for "excess" capacity:
  - ca. 12 – 15% of annual EU electricity consumption (2007)
  - corresponding to 400 – 480 TWh (60% wind, 40% PV)



- H_2 storage need of 50 TWh (220 GW) of energy capacity (discharge power) @ 60% hydrogen cavern cycle efficiency, H_2out/H_2in
- Beyond EU capacity of pumped hydro and compressed air energy storage!
- Theoretic comparison with large H_2-cavern field ($8x10^6$ m^3) capacity (scaling):
  - H_2-storage capacity 1.3 TWh_{H2}, discharge power 2.6 GW
  - 85 cavern fields

Sources: Greiner, M., et al.; Crotogino, F. et al. – 9th World Salt Symposium; VDE 2008

Potential H_2 demand German Case Study

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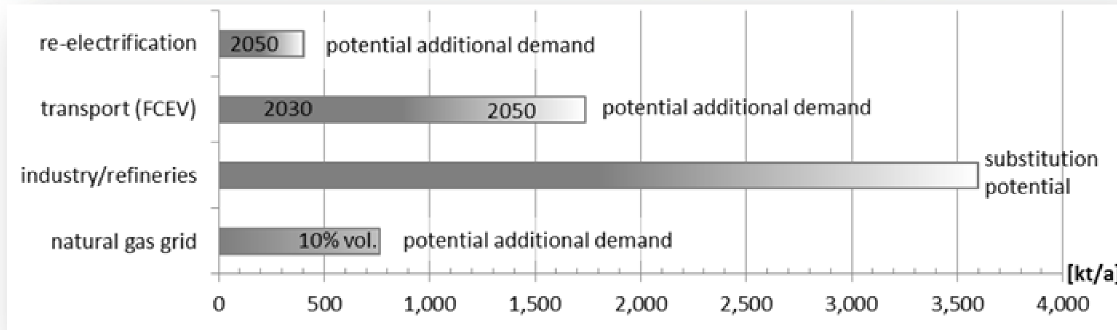
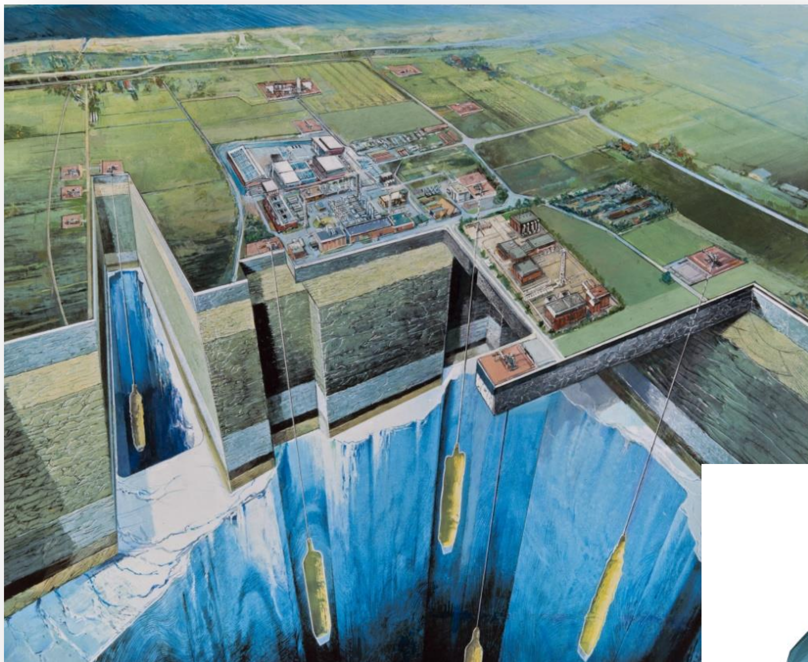
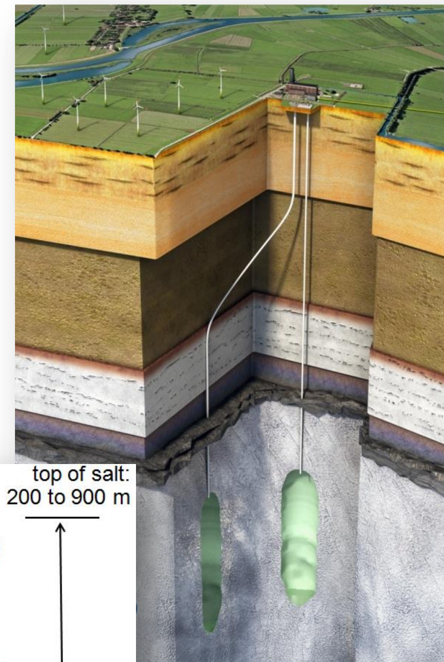
- Industry is largest H_2 user today, shift to renewable hydrogen will depend on H_2 costs

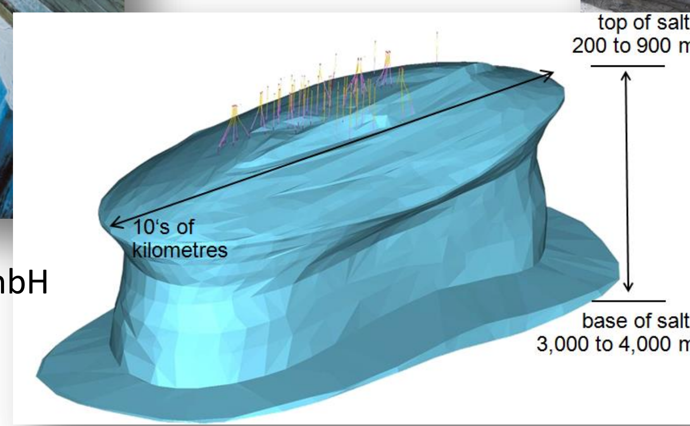


- Transport sector may follow close in the future with best business potentials, but why build a large cavern at initially los costs?
- Following economic assessment, extensive use for re-electrification and use in natural gas grid most questionable
- On the other hand, scaling against hydrogen from surplus electricity (300-1,600 kt/a), the transport sector alone could use up all hydrogen provided by 2050 (1,700 kt/a, @50% fleet share)

Analysis of underground salt structures

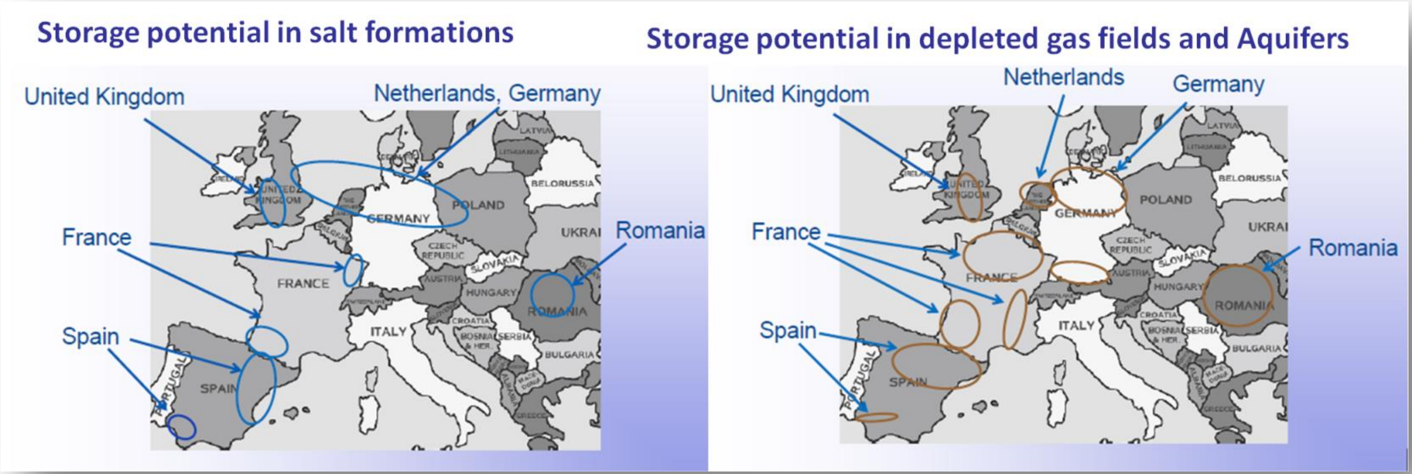






Source: DEEP Underground Engineering GmbH

Storage potential for hydrogen across Europe



Source: DEEP Underground Engineering GmbH

- Working hypothesis is that salt caverns are the most reasonable underground storage technology
- Ample hydrogen storage potentials in salt caverns exist at large scale across Europe, but with regional focus

Plant technologies

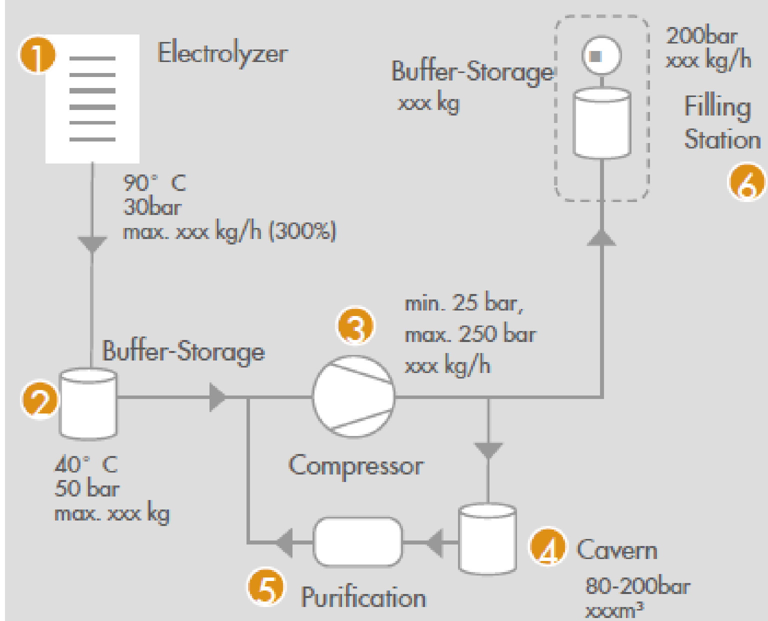
Belowground technology typically comprises:

- Storage cavern (development, O&M)
- Piping
- Safety devices

Aboveground technology typically comprises:

- Electrolysis
- Compressors
- Purification and drying
- Heat exchangers
- System controls
- Safety devices
- Storage means (i.e. buffering purposes)
- Hydrogen turbines

Simplified Process Flow Chart Phase



Source: Shell Global Solutions

Dimensioning of H_2 facility German Case Study

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Determination of the corresponding H_2 demand for each scenario

Mobility (2025/2050):
14,000 km/a
0.54 kg_{H2}/km
320,000 FCEVs
→ 24,000 t_{H2}/a

Industry (2025/2050):
24,000 t_{H2}/a
for a better comparison
with transport scenario

NG Grid (2025/2050):
model result
ca. 24,000 t_{H2}/a
2025: ca. 29 €/MWh
2050: ca. 56 €/MWh

Electricity (2025/2050):
model result
ca. 24,000 t_{H2}/a
2025: ca. 69 €/MWh
2050: ca. 161 €/MWh

Range for electrolysis capacity & required average storage size

Electrolysis capacity (+ compressor in):
model result dependent on utilization
η = 66%; 5% dyring losses
1,000 – 8,000
→ ca. 1,300 - 160 MW_{el}

Storage size:
By experience: ca. 8% - 23% of demand
ca. 1,900 t_{H2} - 5,500 t_{H2}
Ø 3,700 t_{H2} → ca. 500,000 m³

Dimensioning of topside equipment

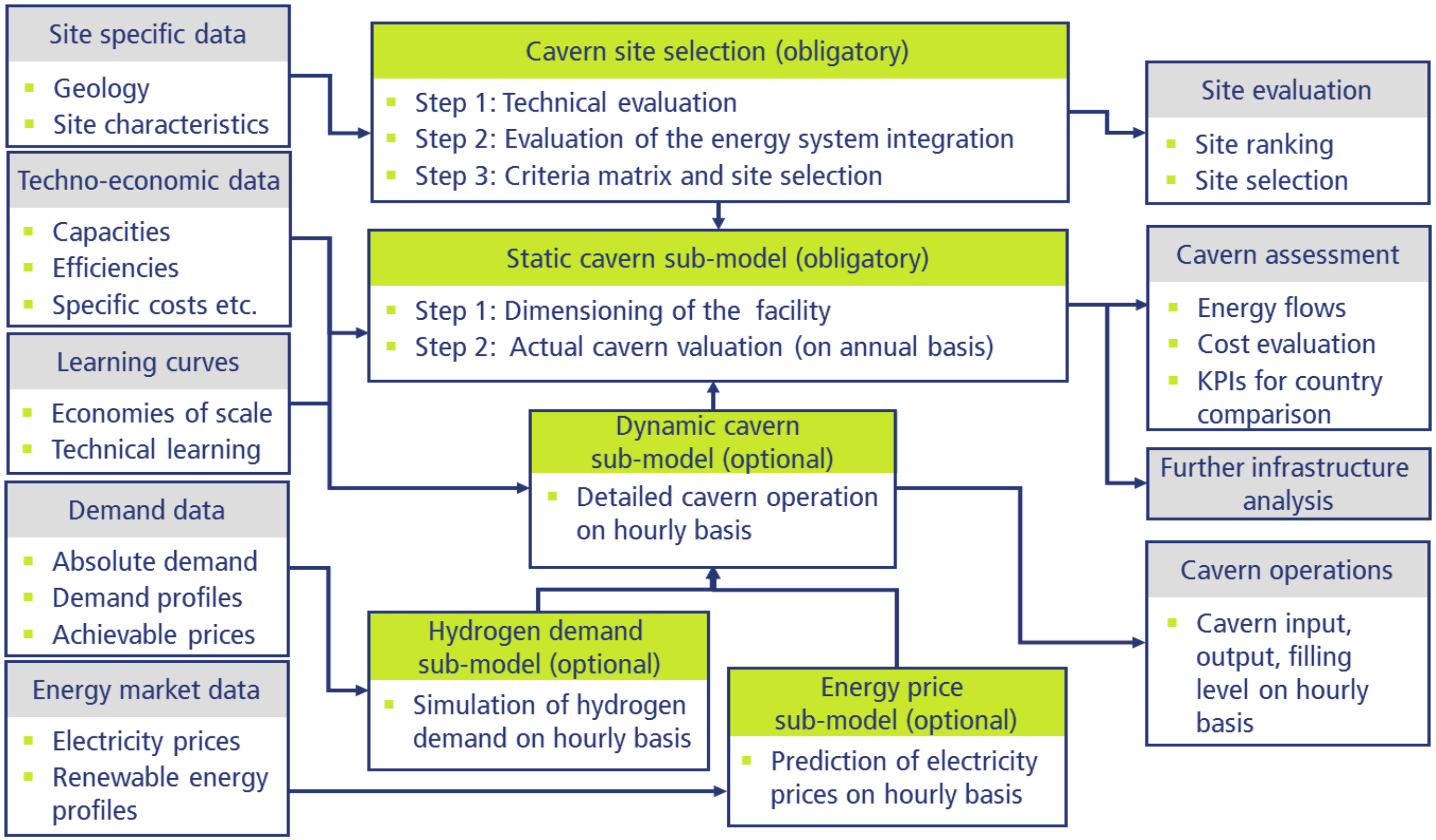
Mobility (2025/2050):
Compressor out + PSA:
Ø-demand * 1.2
ca. 3,300 kg_{H2}/h

Industry (2025/2050):
Compressor out + drying:
Ø-demand * 1 (pipeline)
ca. 2,800 kg_{H2}/h

NG Grid (2025/2050):
Injection + drying:
Capacity Europipe II (24 bn Sm³/a)
2% → ca. 5,000 kg_{H2}/h

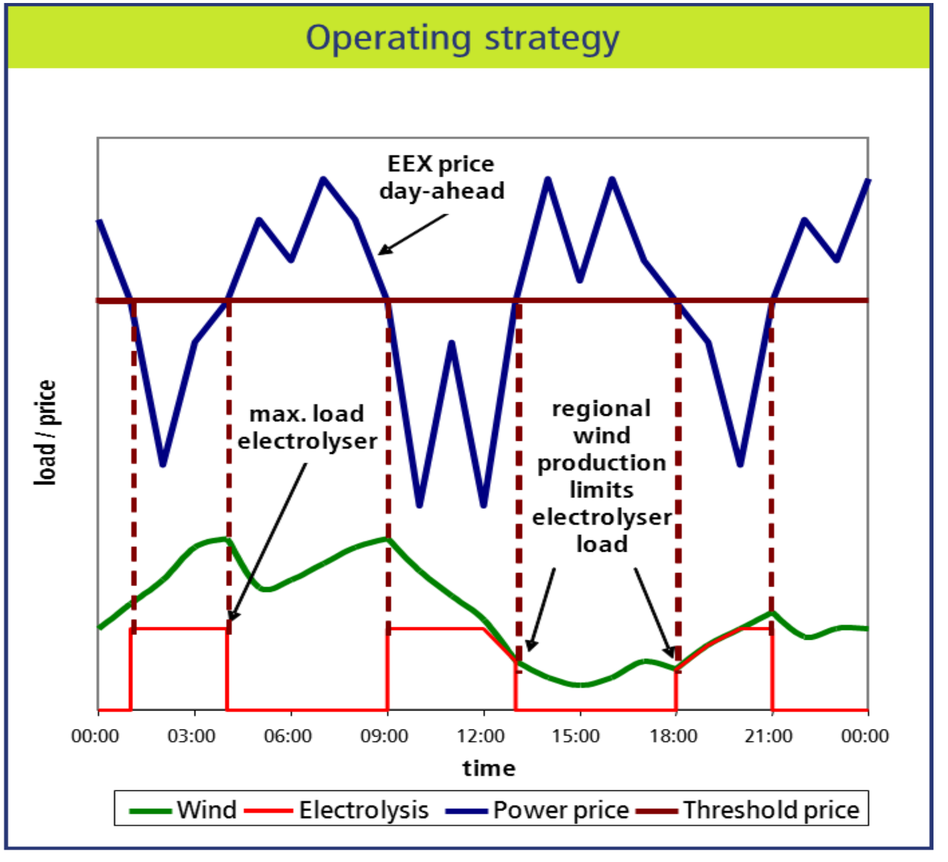
Electricity (2025/2050):
CCGT + drying
η = 61%
400 MW_{el} → 19,700 kg_{H2}/h

Generic economic modeling approach



Source: Ludwig-Bölkow-Systemtechnik GmbH

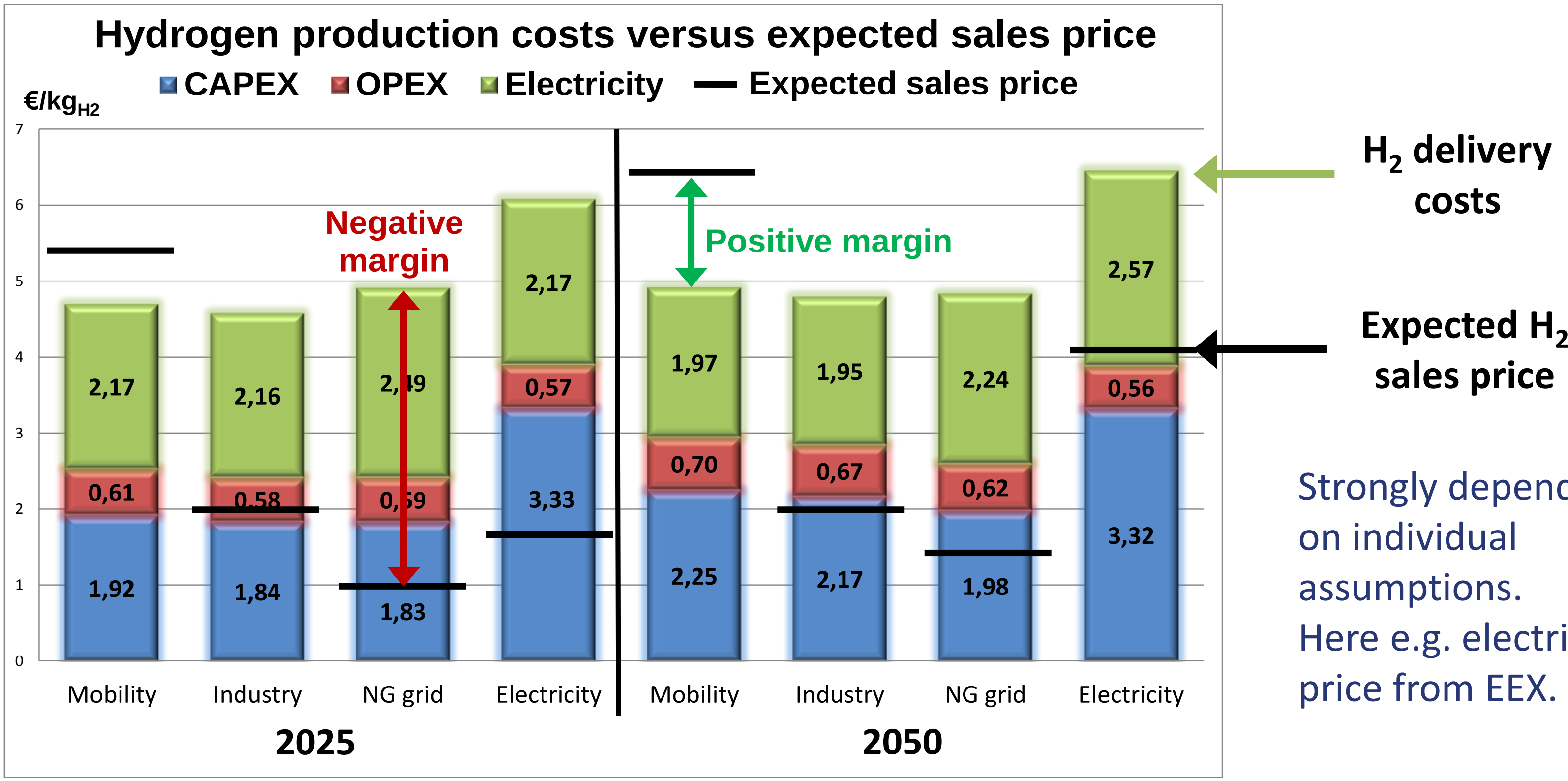
Generic electrolyser operation scheme



Source: Ludwig-Bölkow-Systemtechnik GmbH

Tentative results – German Case Study

- In short-term only transport sector could generate business cases



Strongly depending on individual assumptions. Here e.g. electricity price from EEX.

Tentative conclusions from Case Studies

- Renewable electricity surplus could be basis for H_2-storage at large scale in long-term.
- H_2 underground storage technically feasible for large-scale storage of renewable electricity.
- Geological conditions and locations for salt caverns good but regionally limited, some excellent.
- Existing natural gas storage sites available and preferred initially.
- Electrolysis dominates total costs of H_2 storage facility (> 80% @ 50% utilization).
- H_2 storage at large scale commercially very challenging; only transport sector and possibly industry applications offering short- to medium-term commercial perspectives.
- H_2 production from electrolysis and underground storage apparently need pull from mobility sector, otherwise unlikely to be implemented widely.
- Sensitivity analysis suggests that
  - not all options have been understood for electricity sector (energy balancing services not fully considered), mostly depending on electricity market development and
  - smaller cavern size for transition phase has negligible effect on cavern costs.

Mismatch between common sense based insight that large scale H_2-for-electricity storage is indispensable and missing business case perspective from modelling. Better understanding of future energy markets needs to be developed.

Expectations

Project Future Perspectives

- Opportunities for increasing cooperation and for building alliances: strengthen the relationship of the **energy sector** with the (smaller) hydrogen community. Opportunities for a **European approach** may arise.
- Opportunities for international collaboration: the project has already attracted the attention of **non European companies**, which contribute and cooperate by information exchange.
- Opportunity to contribute to the future FCH JU Programme: the project effectively paves the way for a real **demonstration** in underground storage.

To know more…

http://www.hyunder.eu/

Supported by:

Contact:

Project coordination: jsimon@hidrogenoaragon.org
German Case Study: ulrich.buenger@lbst.de

Thank You!!