Ranking and selection of geological stores

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Hydrogen Storage in European Subsurface

Acknowledgment

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Clean Hydrogen Partnership

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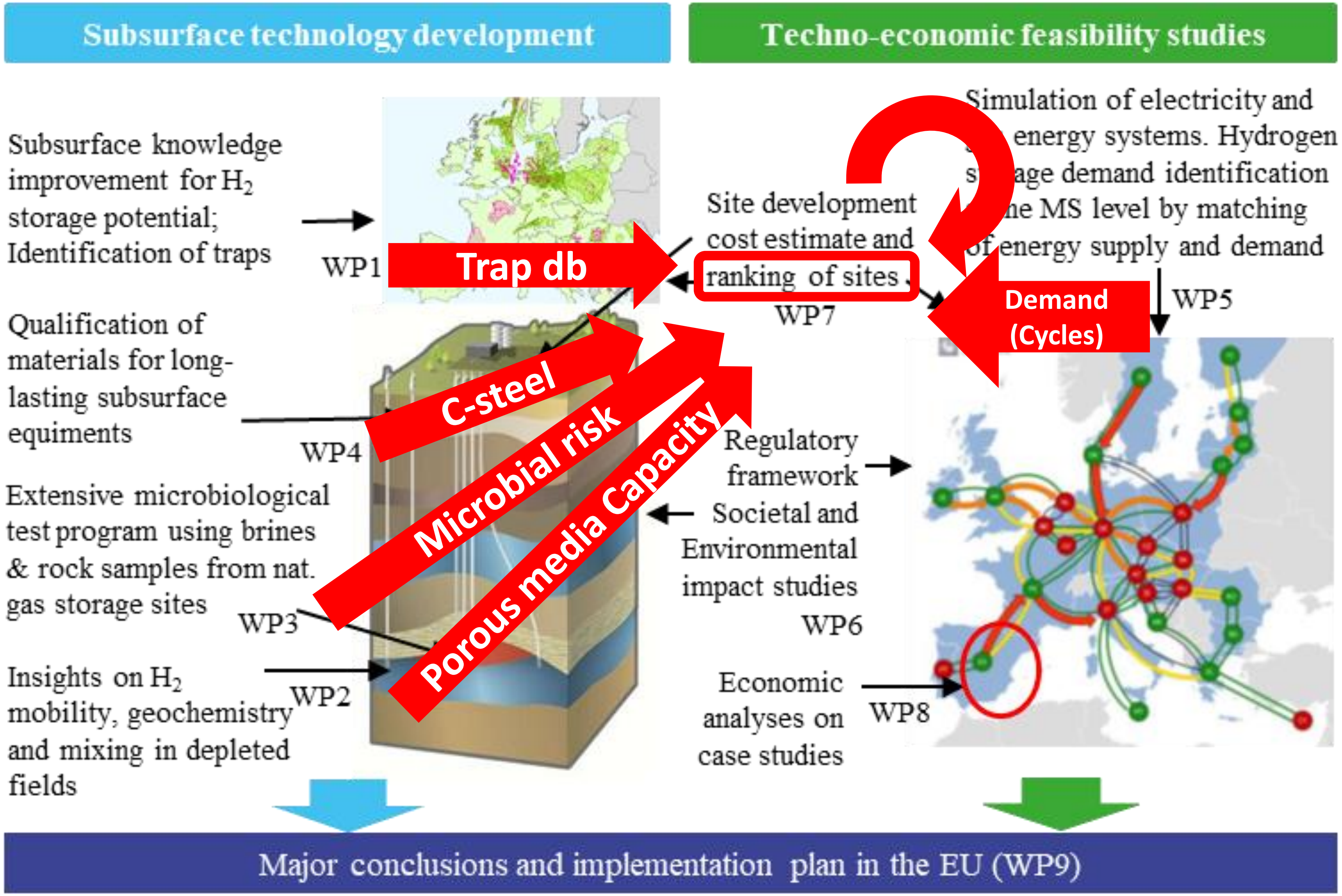
1 Introduction

Building over previous work-packages results



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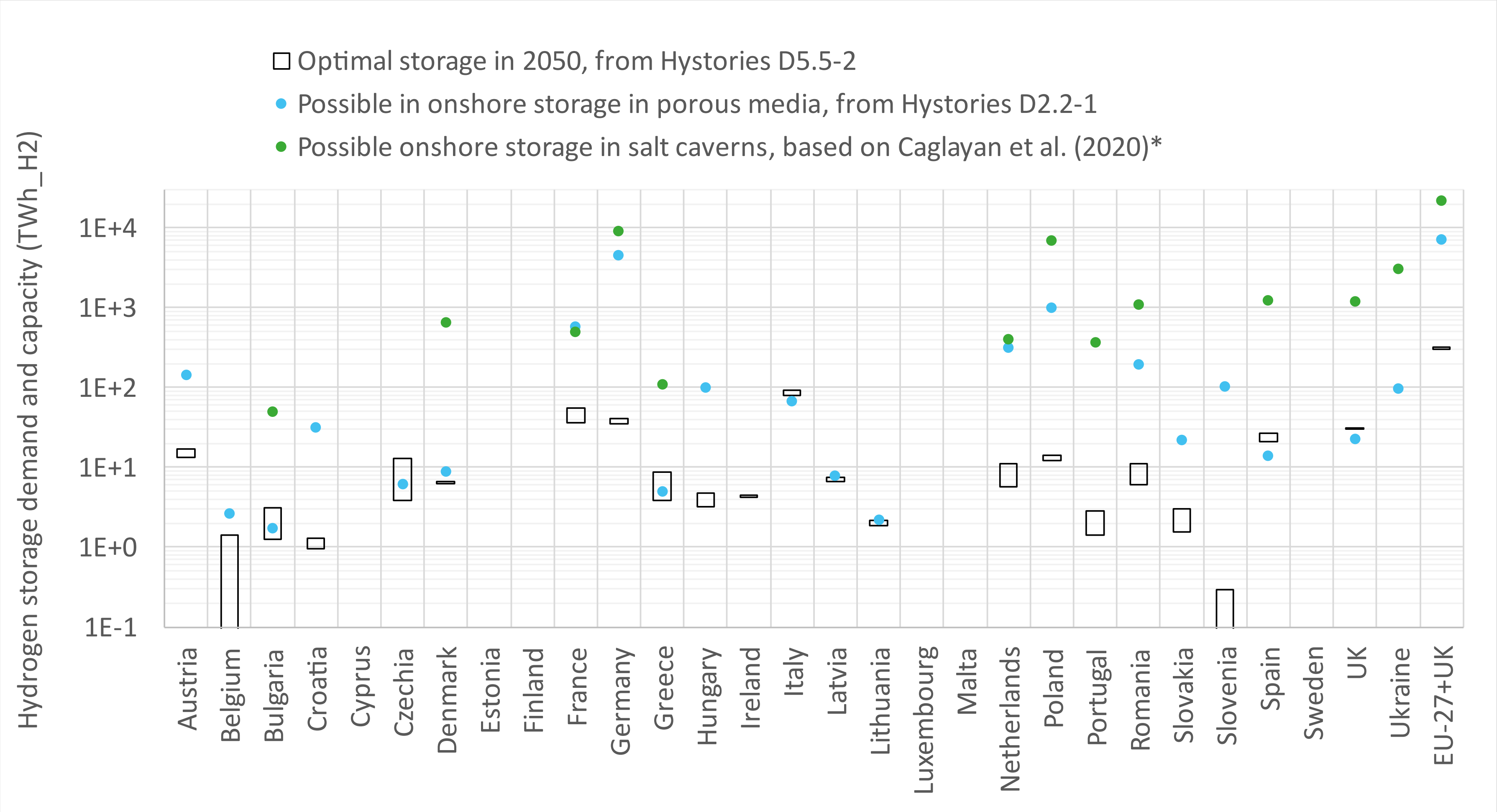
Need for ranking and selection

(High level) Storage technical capacity > storage demand



*: Caglayan et al. (2020) is the source for all countries but Bulgaria (Geostock estimation) and Ukraine (personal communication from Nikolaus Weber)

Technically possible storage higher than the optimum storage capacity from WP5:

- By 40 times in onshore salt caverns alone
- By 12 times in onshore porous media alone

→ Focus onshore

→ Need for ranking

→ 2 Criterias are proposed

Levelised Cost Of Storage (LCOS)

The breakeven selling price of the storage service

Lifetime of the facility (years)

$CAPEX(n) + OPEX_{fixed} + OPEX_{variable} \times P_{out}(n)$

$$LCOS = \frac{\sum_{n=1}^{N} \frac{Cost(n)}{(1+WACC)^n}}{\sum_{n=1}^{N} \frac{P_{out}(n)}{(1+WACC)^n}}$$

MWh produced during year n

Weighted Average Cost of Capital

Suitability mark

- Reflecting the technical readiness and level of technical risks (incl. microbial activity) given the available knowledge for developing a hydrogen storage:

	Weights
READINESS	26,2%
LITHOLOGY_SEAL	19,3%
MIN_SEAL_THICK	7,4%
FAULT_THR_OVERBURDEN	8,7%
ABANDON_WELL_RATIO	9,6%
MICROBIOLOGICAL	20,8%
LITHOLOGY_STORAGE	8,0%

- Built to be complementary to the LCOS

Restrictions, limitations or hypotheses

- Restriction to onshore storages
- Restriction to 3 compression stages. Storages > 500 bar / deeper than 3500 m are not considered
- Cost calculation less accurate when too far from the Conceptual Design
  - sites size capped to the first reached among:
    - the trap capacity for porous media, or the Conceptual Design for Salt caverns (250 MM Sm3)
    - the max « reasonable » compression flow rate for a site (2500 ton/day)
  - Costs optimizations or increases could be found notably when site specificities differ largely from D7.1-1 conceptual design cases. Detailed feasibility study needed
- Conversion of existing sites (e.g. natural gas storage)
  - same cost of the development of a new site, notably to account for the fact that the asset is worth something

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Definition of the storage cycles

LCOS is cycle-specific

Zuidswending

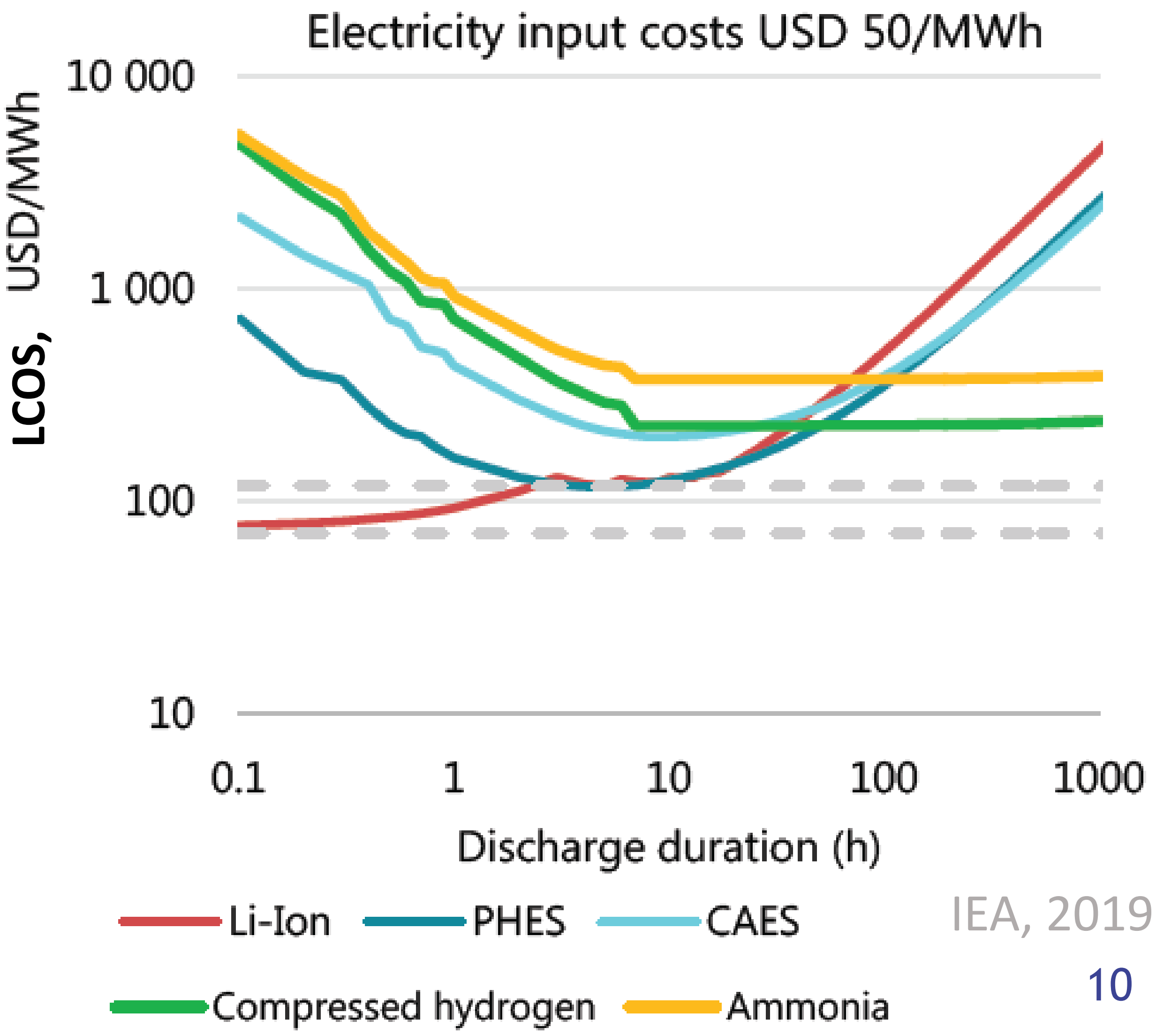
- ~320 MM Nm^3

https://www.energiebufferzuidwending.nl/

Géométhane

- ~ 300 MM Nm^3

https://www.geomethane.fr/



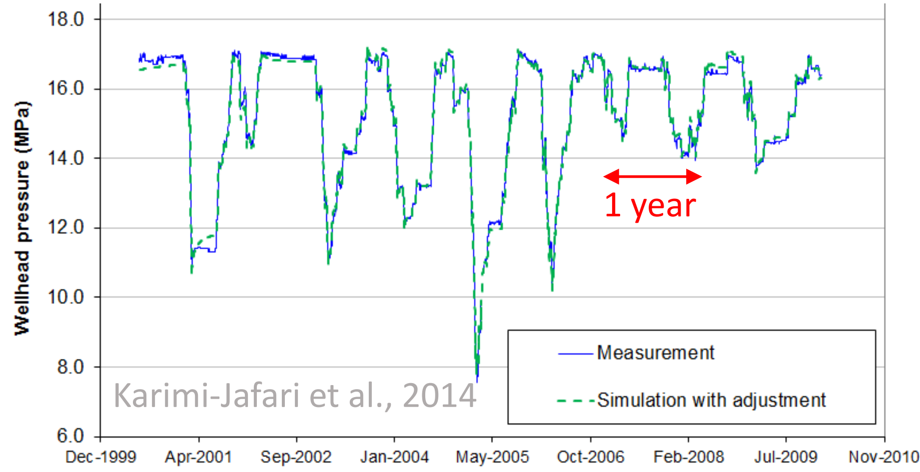
IEA, 2019

What storage cycle should we consider ?
Drivers for underground storage and cycle patterns

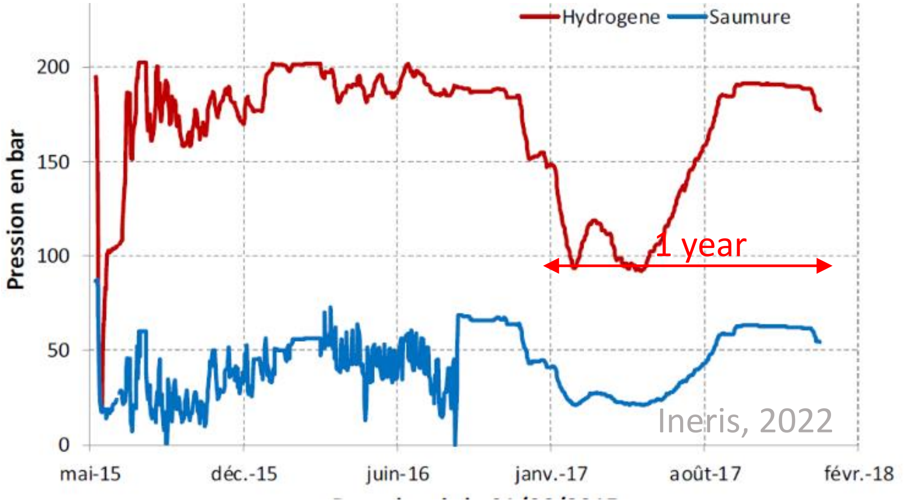
- Why should we store underground ?
  - CO_2: for not having it contribute to greenhouse effect
  - Oil: for geopolitical reasons
  - Natural gas, to cope for high seasonality in demand (historically), for trading (now) and geopolitical reasons (tomorrow ?)
  - LPG, H2 (historically) : as a buffer of a feedstock / commodity
  - Green H2: for Power to power ? To mobility ? To gas ? To industry ?

- Storage cycle duration
  - > 10000 years
  - Many years (3 years)
  - Seasonal (weeks)
  - Many years (weeks)
  - RES production variability ? Consumption ?

Géométhane (Fr.) natural gas cavern



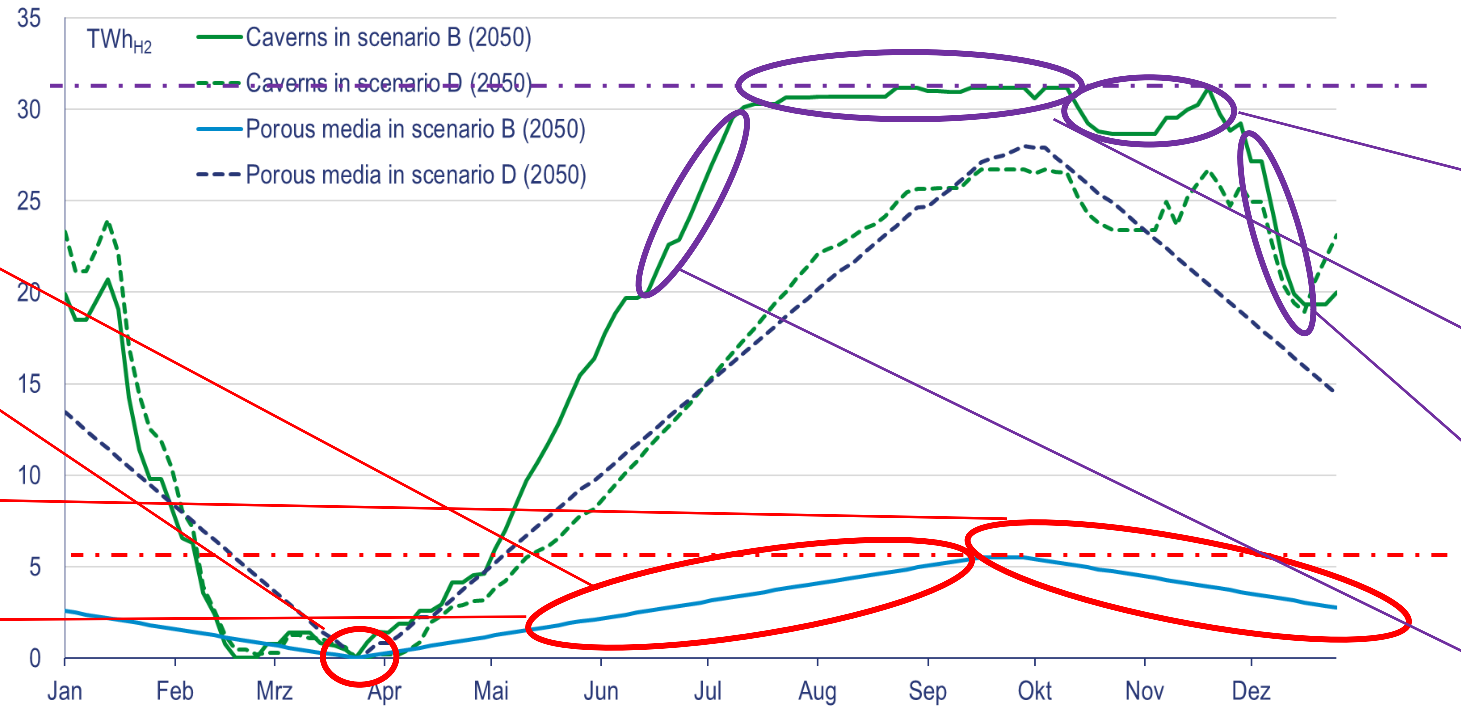
Air Liquide Spindletop (TX) H2 cavern



When intuition is not enough : definition of 2 cycles based on WP5 energy modelling work

Seasonal cycle:

- 1.1 full cycle equivalent per year
- Load Factor = 68%
- Storage to Withdrawal Capacity ratio = 115 days
- Withdrawal to Injection Ratio (WTIR) = 1.0



Fast cycle :

- 1.9 full cycle equivalent per year.
- Load Factor = 29%
- Storage to Withdrawal Capacity ratio = 18 days
- WTIR = 2.2

→ Focus on 2050 and Scenario D (more imports, coherent with RePowerEU) to define:

→ a Seasonal cycle, typically the WP5 optimum for porous media

→ a fast cycle, typically the WP5 optimum for salt caverns

→ However, no project is bonded to use a particular technology to meet these demand

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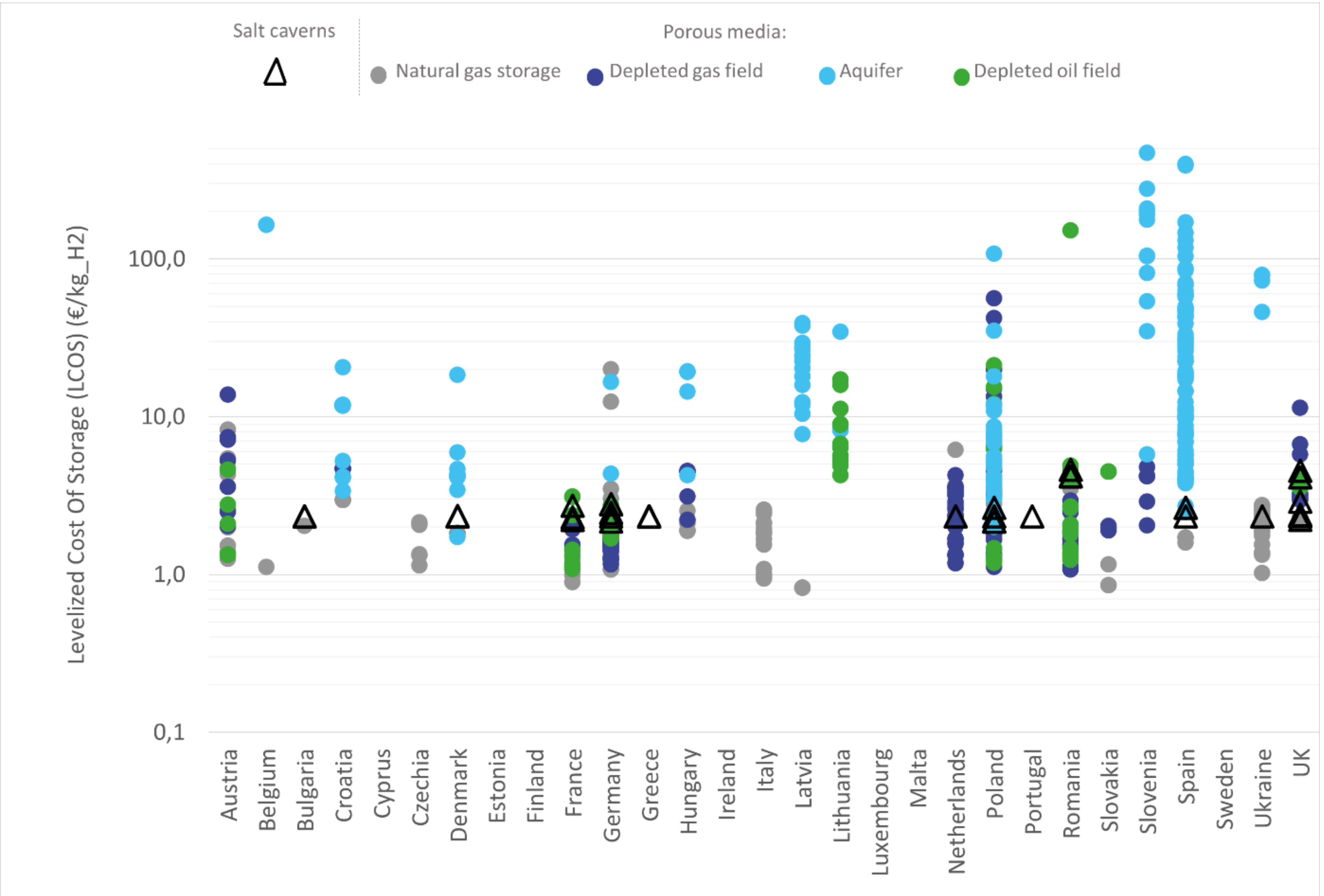
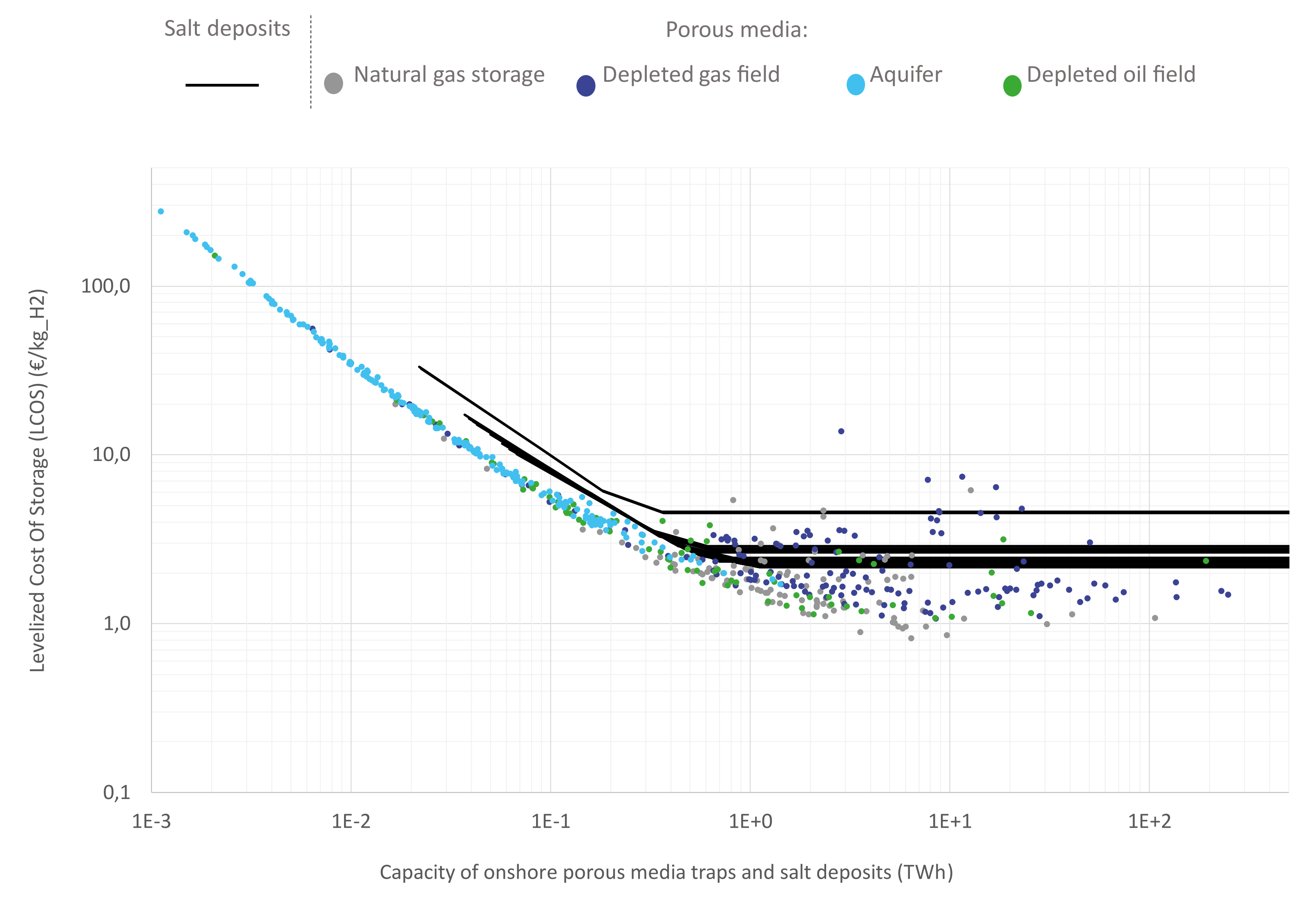
Levelized Cost Of Storage (LCOS) results

Seasonal cycle, full unloading in 115 days
LCOS results



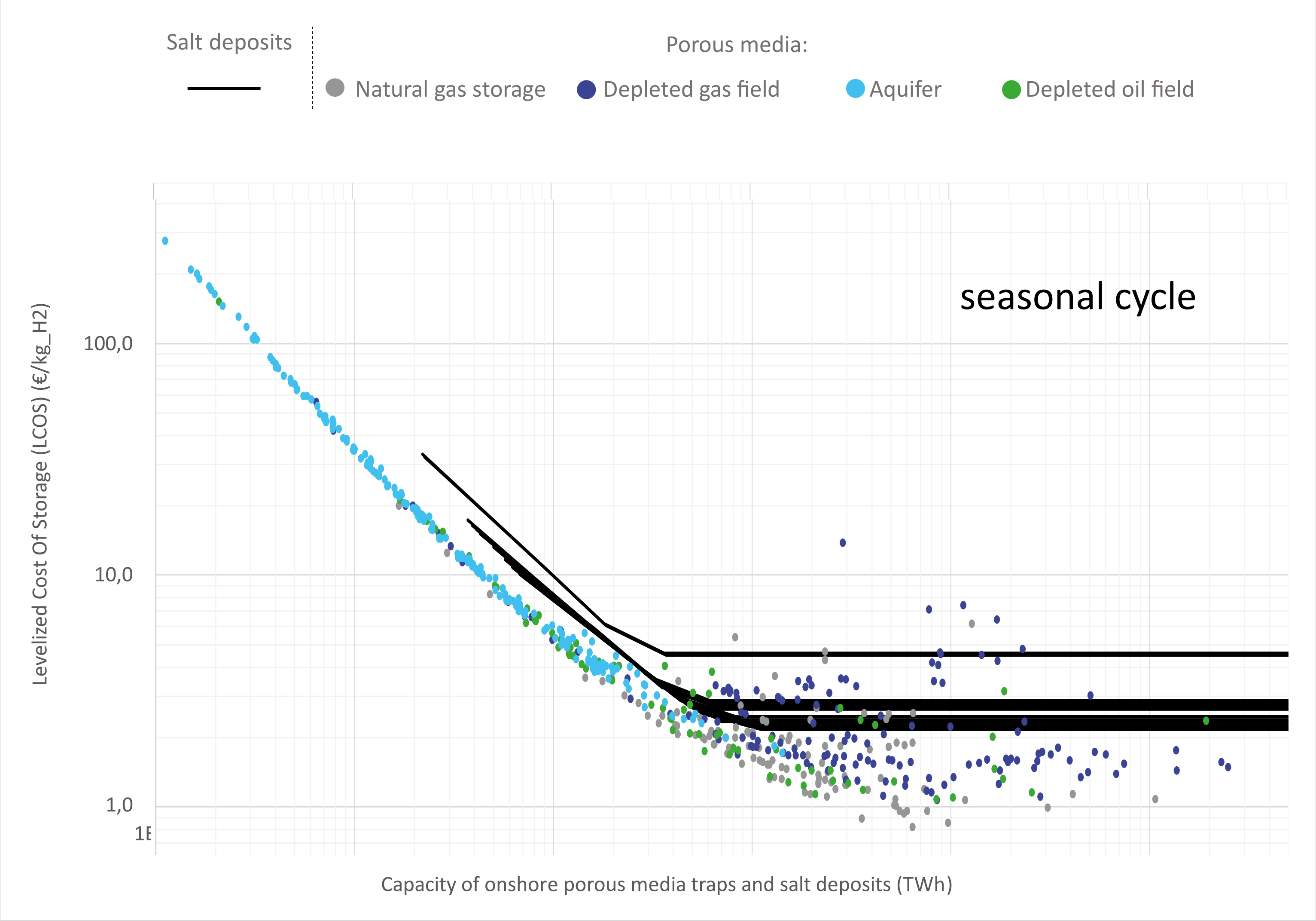
- Porous storages are found cheaper than salt caverns
  - coherent with natural gas storage as known today
- A large range of costs is found, especially for porous media
  - Geological diversity
  - Small capacity traps

Seasonal cycle, full unloading in 115 days
LCOS and capacity results



- Solid line for salt deposits
  - no clear maximum to the size of a project in a given region
- Dots for porous traps solid
  - X-axis represents the maximum, but a smaller capacity can be developed

Fast cycle, full unloading in 18 days
LCOS and capacity results



- Generally for salt caverns

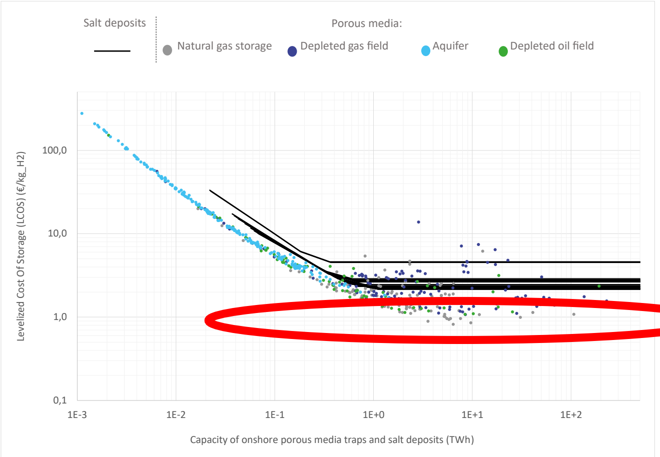
$LCOS_{fast} < LCOS_{seasonal}$

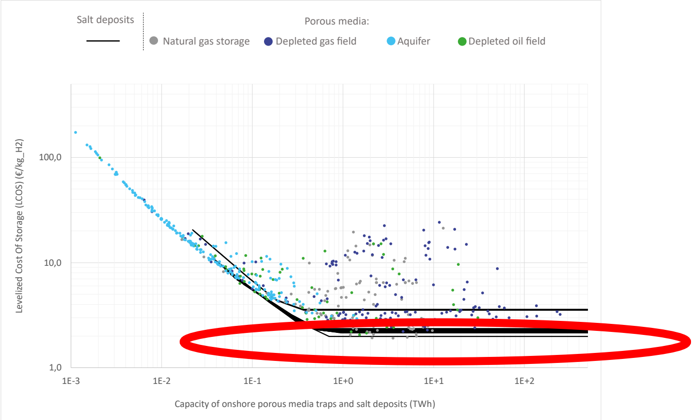
- Generally for aquifers and depleted fields

$LCOS_{fast} > LCOS_{seasonal}$

Higher flow rates increases the subsurface cost for porous storages (nb. of wells), and the surface cost for both (but it's a bigger share for porous than for salt, notably for purification)

LCOS if developping only the cheapest sites in Europe





When developing the cheapest sites of EU-27+Ukraine+UK in either salt or porous media to reach 325 TWh working gas capacity, the LCOS is:

	aquifer and depleted fields	Salt caverns
Seasonal Full unloading in 118 days	**1.1 €/kg** (32 €/MWh; 90 k€/MMSm^3)	**2.3 €/kg** (70 €/MWh; 200 k€/MMSm^3)
Fast Full unloading in 18 days	**2.6 €/kg** (77 €/MWh; 216 k€/MMSm^3)	**2.0 €/kg** (59 €/MWh; 170 k€/MMSm^3)

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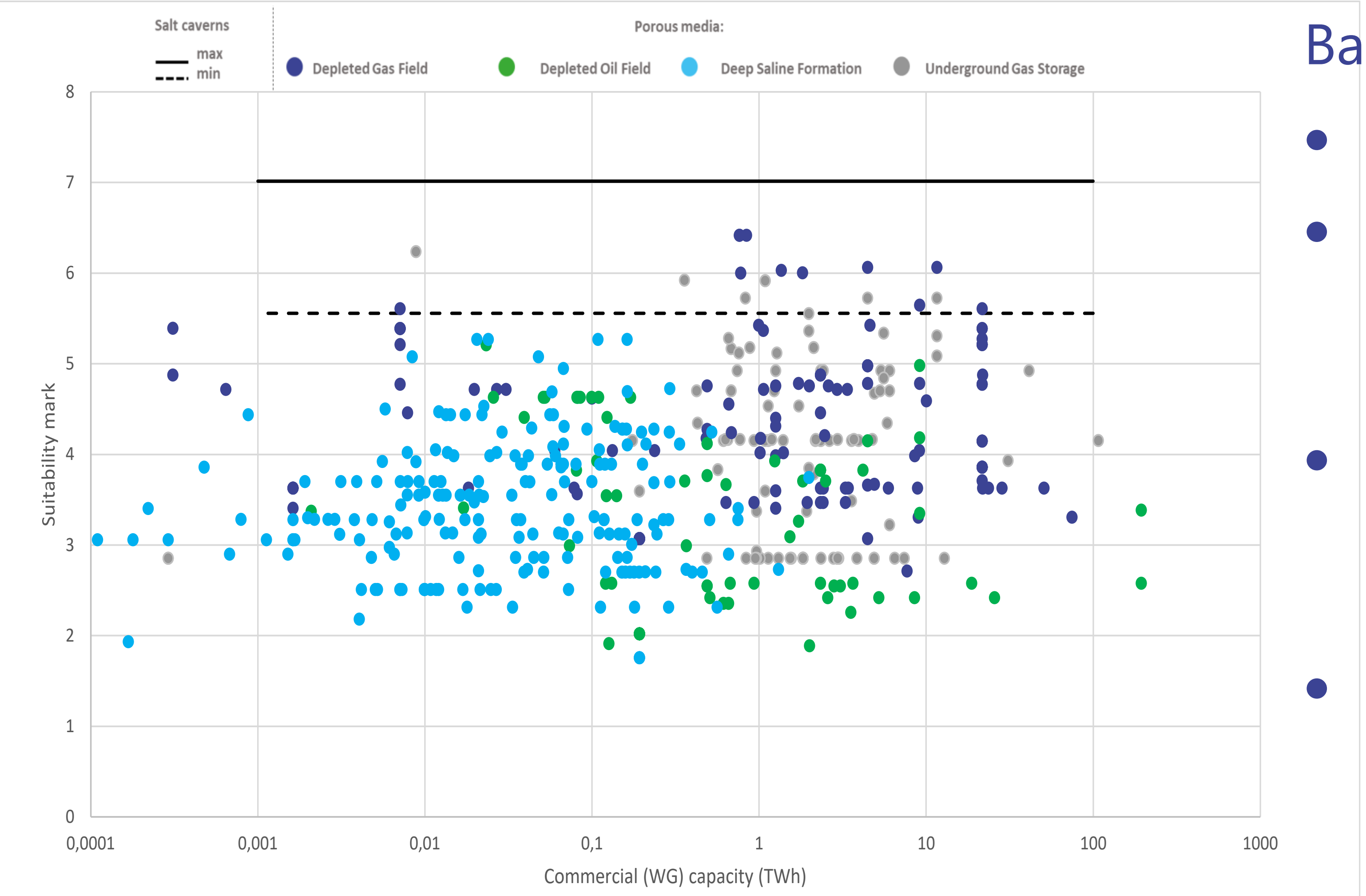
Suitability mark results

Suitability mark vs. capacity results



Based upon:

- Readiness level identified in WP2
- Lithology of the seal (Sandstone, Carbonate, Limestone, Clay, Shale, Salt…) from WP1 database
- The known fault in the primary caprock above the storage formation from WP1 database
- The number of plugged and abandoned wells in the trap from WP1 database
- Microbial risks of the trap from WP3

6 Conclusions

Summary and main conclusions

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- (High level) onshore technical capacity is orders of magnitudes higher than demand, for both salt and porous media → Need for ranking and selection
- Capacity, technical risk in developping a site are site-specific. LCOS too, and is cycle-specific.
  - → LCOS applied to relevant and known subsurface specificities
  - → Complementary suitability mark. Technical readiness / risk
- Application to 805 porous media traps, 18 bedded salt and salt domes

→ LCOS increases significantly when the storage site capacity is smaller

→ LCOS covering the demand as low as:

Cycle	Porous storage	Salt
Seasonal	1.1 €/kg	2.3 €/kg
Fast	2.6 €/kg	2.0 €/kg

→ Suitability mark higher for salt caverns, then existing porous natural gas storages and depleted fields

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WWW.UNILEOBEN.AC.AT

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Clean Hydrogen Partnership

Thank you !

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