NEEST

NEW ENERGY & ENVIRONMENTAL SOLUTIONS AND TECHNOLOGIES

TETHYS WEBINAR – GREEN HYDROGEN PRODUCTION

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STORAGE / DISTRIBUTION OF HYDROGEN

Compressed Gas

Liquefaction - Cryocompression

Solid Materials

Underground Storage

Hydrogen - Storage issues

- ✓Gas under normal conditions
- ✓Density (0 °C) 0.0899 kg/m^3 (12 times less than air)
- ✓Low Boiling Point (20K)
- ✓Safety (under specific conditions)

Hydrogen Storage

Under normal temperature and pressure conditions, 1 kg of hydrogen will occupy a volume of 12.15 m^3 and an energy content of 33.5 kWh. Hydrogen presents HIGH energy per unit mass 140MJ/kg but LOW energy density per volume: 12.7MJ/m^3

For hydrogen to become a competitive energy carrier, its volume density must be increased → **reducing the volume that hydrogen occupies under normal conditions**

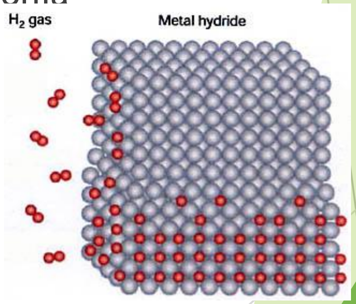
- Compressing the gas (increasing the temperature) → *Compressed Hydrogen Storage*
- Decreasing the temperature below the critical point → *Cryogenic Hydrogen Storage*
- Decreasing the repulsion interaction between the hydrogen molecules by creating bonds with another material. → *Solid-State Hydrogen Storage*

HYDROGEN STORAGE

- One of the major issues regarding hydrogen is its storage
- High energy density per weight / Low energy density per volume

<u>3 main ways to store hydrogen</u>:

- <u>Storage as a compressed gas</u>: By compressing H2, the volume it occupies is reduced thus resulting in higher energy density per volume
- <u>Storage as a liquid</u>: Liquid hydrogen is <u>cryogenic</u> and boils around -252.882 °C.
- <u>Chemical Storage</u>: H2 can be chemically stored in substances like ammonia or various hydrides



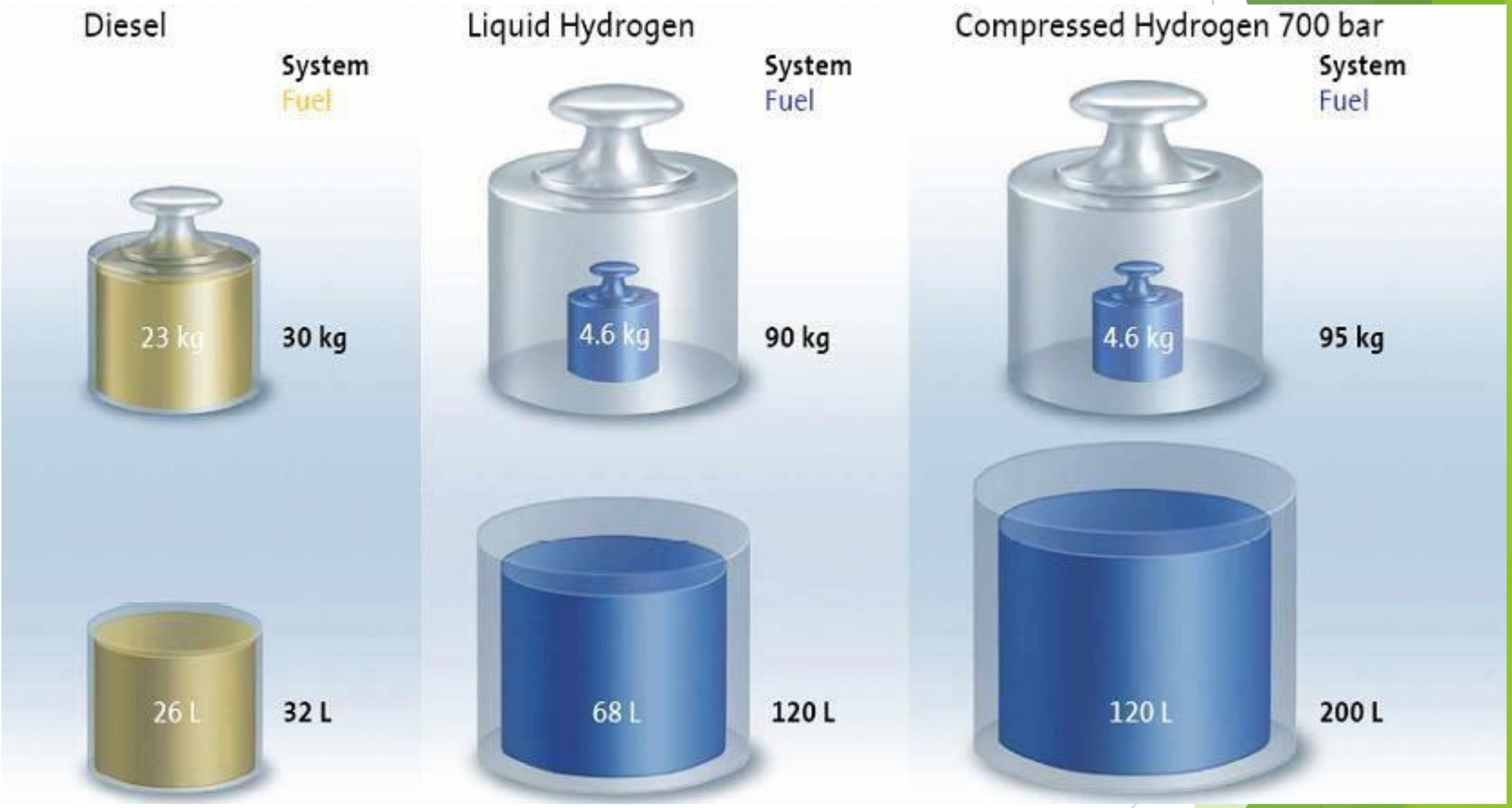
Applications

Stationary Systems

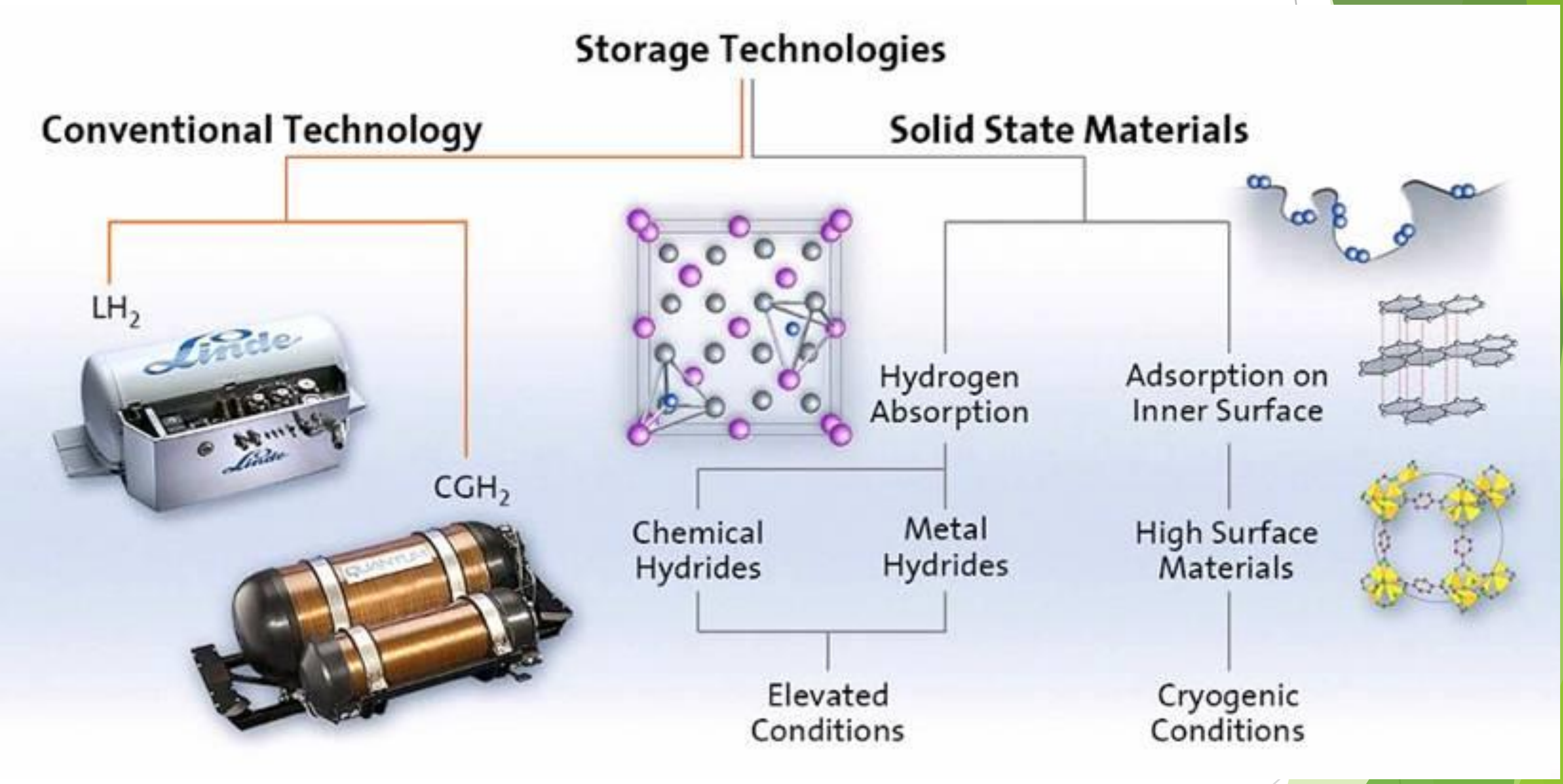
Mobile Systems

Portable Systems

H2 Tank Mass & Volume (autonomy ~600 km)



H2 Storage Technologies



"Conventional" Technologies

Minimize Heat Inflow (300 K → 20 K)

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Optimize Volume / Surface Ratio

Pressure Vessel Equation (700 bar)

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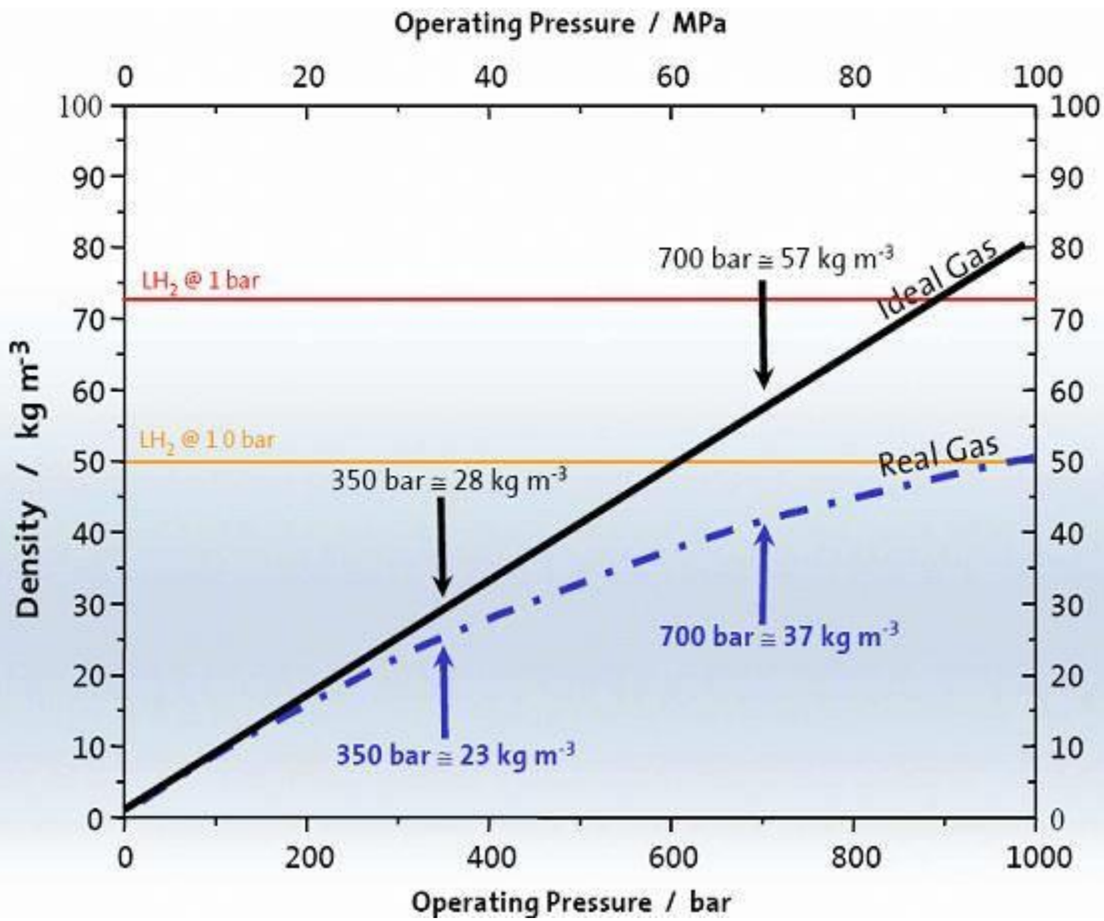
Optimize Geometry

H2 density



General Challenge

Low Volumetric Density

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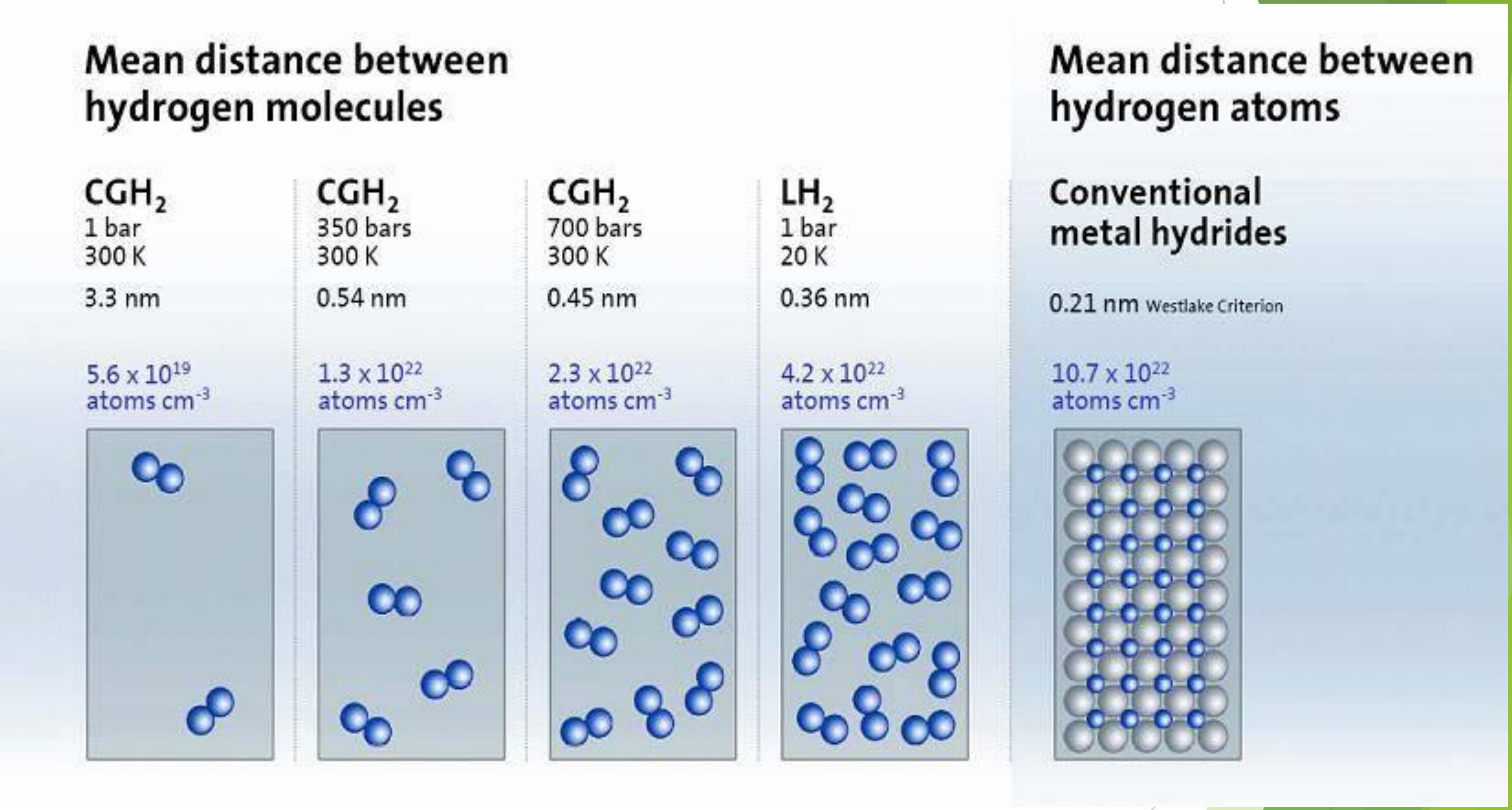
Low Heating Value

LH_2 8.5 MJ / liter

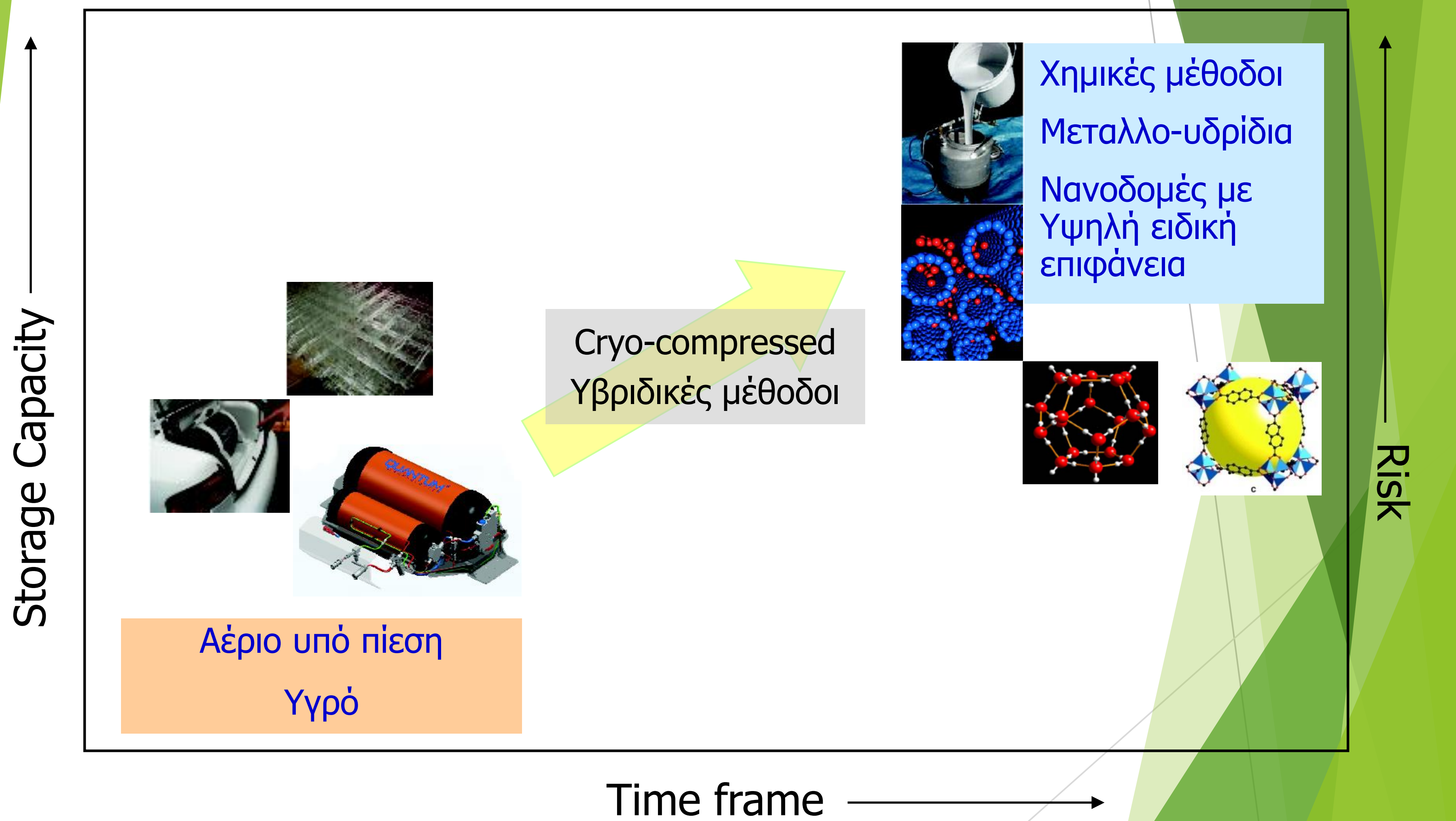
Gasoline 31.7 MJ / liter

Diesel 36 MJ /liter

Storage in solid materials: an interesting option



Research Trends



HYDROGEN STORAGE IN ROAD VEHICLES

- Pressures of 200, 350, 700 bar
- Made of composite materials in steel casings
- Material specifications
  - Mechanical durability (Piercing, crashing durability etc)
  - Low weight
  - Zero H2 permability
  - Efficient thermal behaviour
  - Use of parallel tank configuration
- Pilot application on public transportation vehicles

Hydrogen tanks used for on- board applications

Pros

- Big storage capacity
- Relatively low cost

Cons

- Safety, especially in transportation applications
- Incapable of working under changing pressure

H2 TRANSPORT & DISTRIBUTION

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H2 Large scale underground storage

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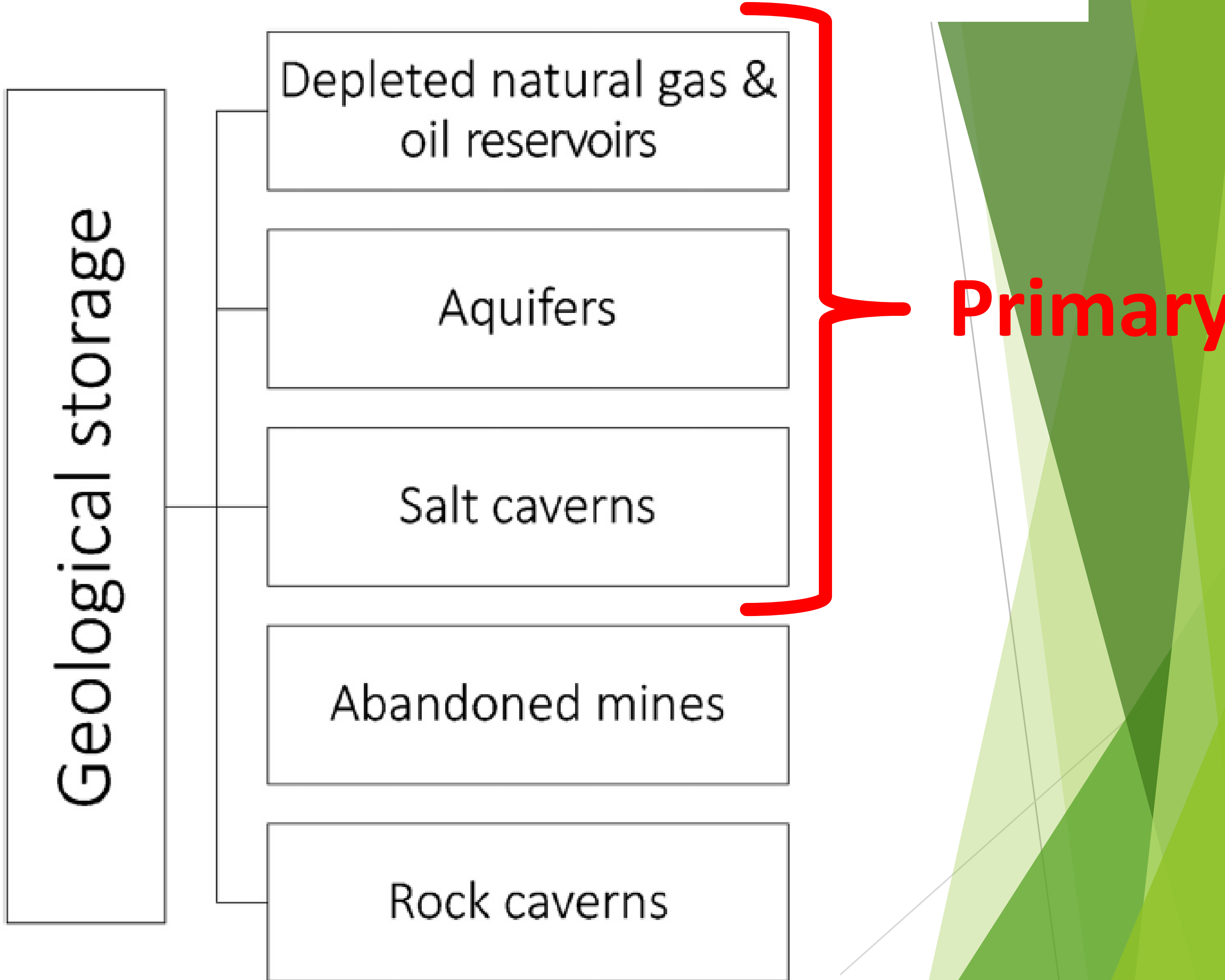

Fig. 9 – A scheme for types of geological storage.

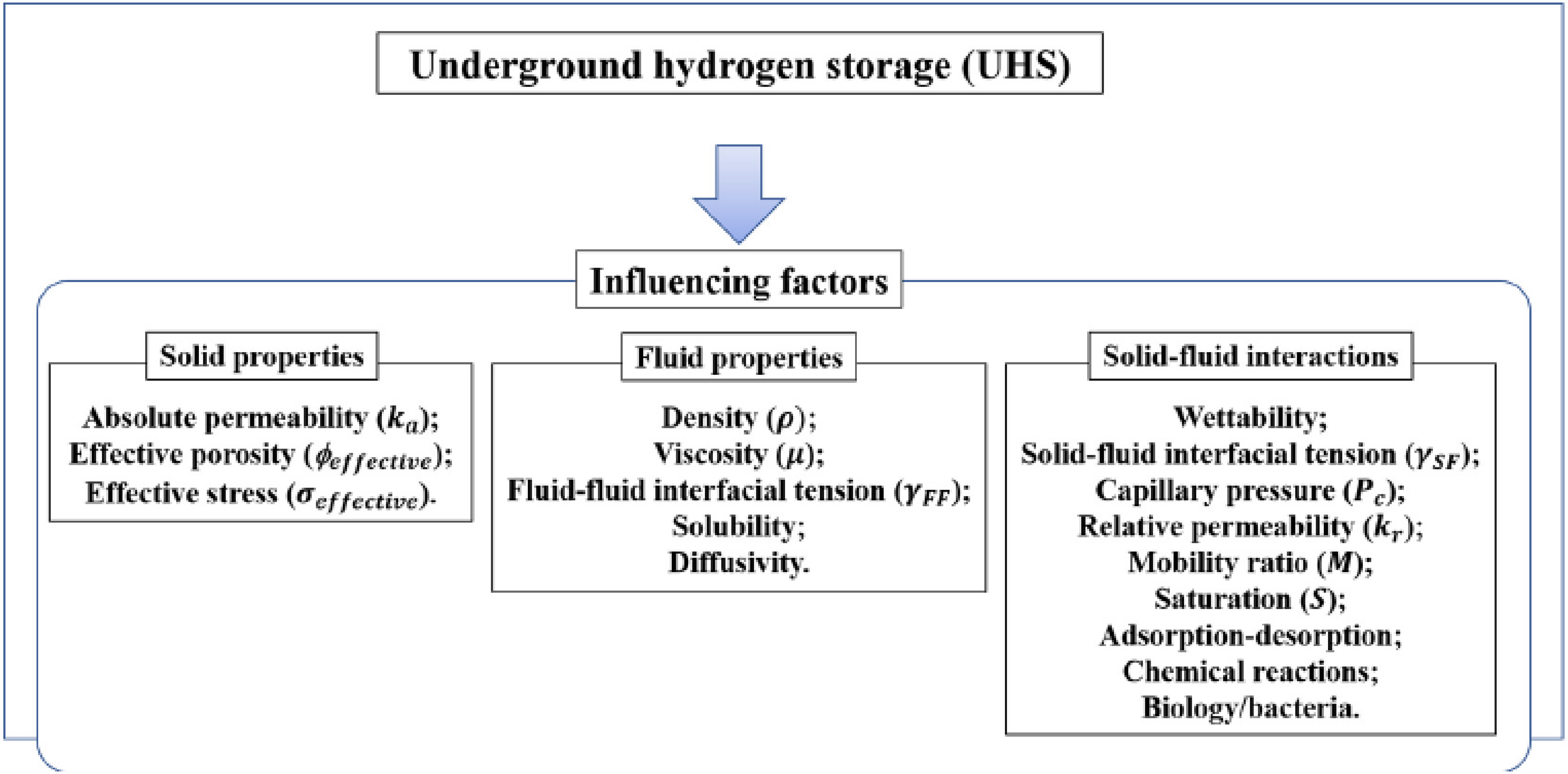

Fig. 1. Multi-scale parameters relevant in underground hydrogen storage.

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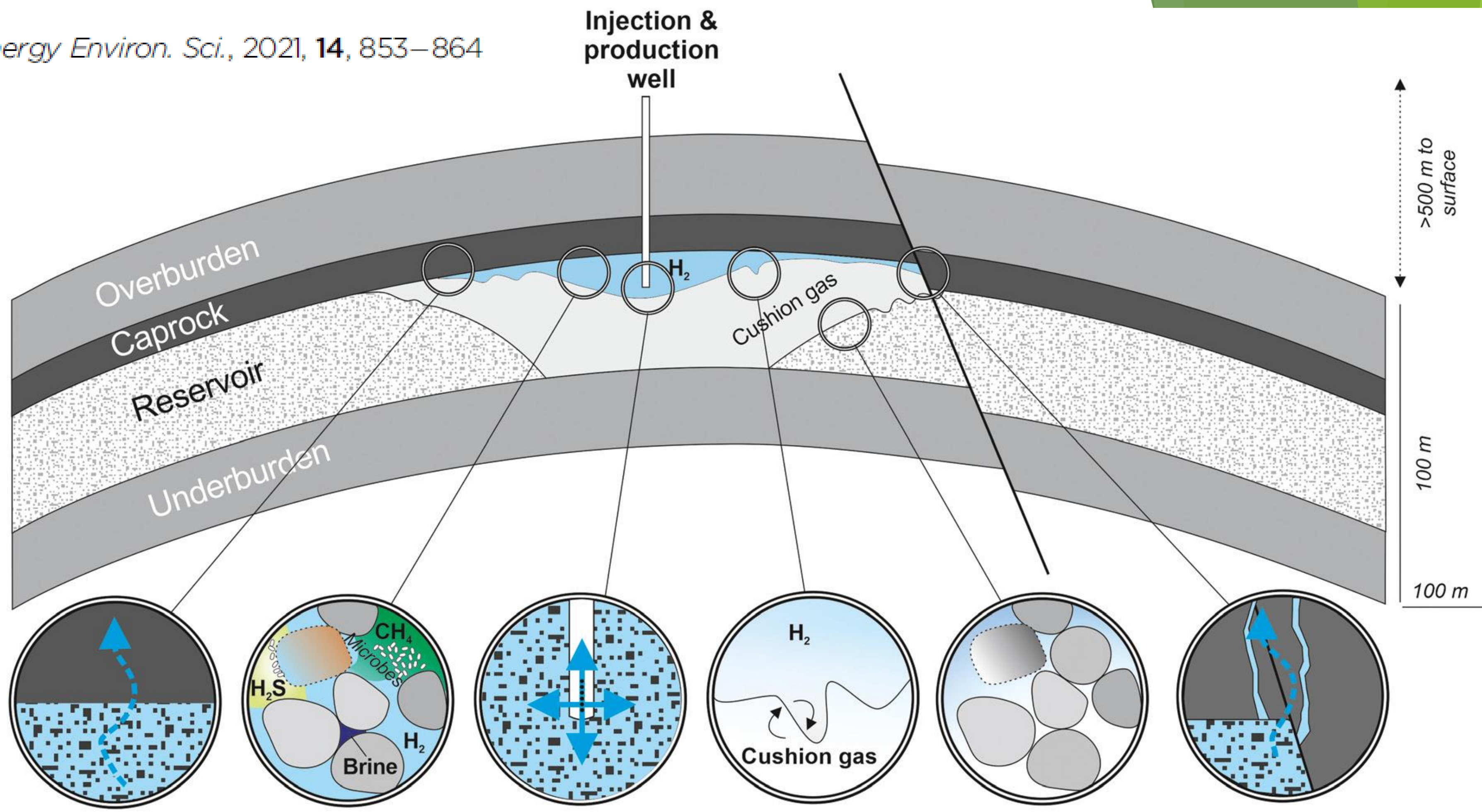

Caprock:

- Diffusion
- Capillary leakage
- Fracturing
- Buoyancy pressure

Hydrogen plume

- Fluid-rock interaction
- Microbial activity
- Dissolution & residual trapping

Injection/production:

- P/T change
- Multiphase processes
- Stress/strain changes

H_2 - cushion gas:

- Unstable displacement & uncrontrolled lateral spreading
- Gas mixing

Cushion gas- brine

- Fluid-rock interaction
- Unstable displacement
- Dissolution & residual trapping

Structural geology:

- Fault leakage
- Far and near field stress changes
- Reactivation
- Overpressure

Fig. 2 Hydrogen storage in porous media highlighting all geological uncertainties considered in this paper. Note that both depth, formation thickness and horizontal do not represent scientifically justified ranges but are included to provide an idea of the magnitude of the operations.

Salt Caverns for Gas Storage

- Used to store gases including hydrogen since the 1950s
- Sites have traditionally been developed after salt extraction by the chlorine industry
- Over 30 caverns in use in the UK today
    - mainly used for NG
    - 1 in use for hydrogen
    - internal wall properties prevent leakage and contamination of the hydrogen
- Lowest cost direct storage mechanism for large hydrogen volumes
- Possibility to use Larne salt caverns for hydrogen storage