Subsurface energy storage

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Exajoule 10^{18}J storage capacity required

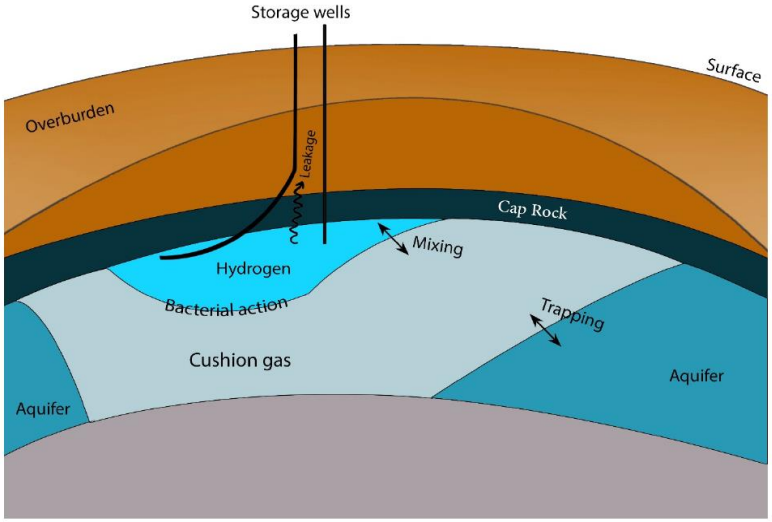
Thermal energy in 1 kg hot water: $E = c\Delta T \approx 0.42$ MJ

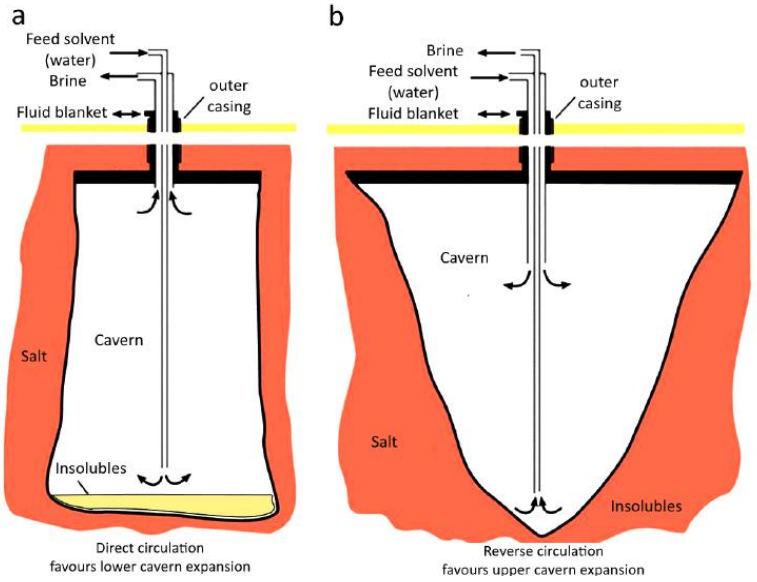
Energy in 1 kg of nitrogen compressed at 10 MPa: $E = \frac{RT}{m}\ln(\frac{P_1}{P_2}) \approx 0.41$ MJ

Heat of combustion of 1 kg of hydrogen: : $E = \frac{H}{m} \approx 120$ MJ

10^{18} J scale (global energy use is approximately 600 EJ) requires storage at the Gt (10^{12} kg) scale globally: long-term intermittency in renewables.

Either store in porous media or engineered salt caverns.



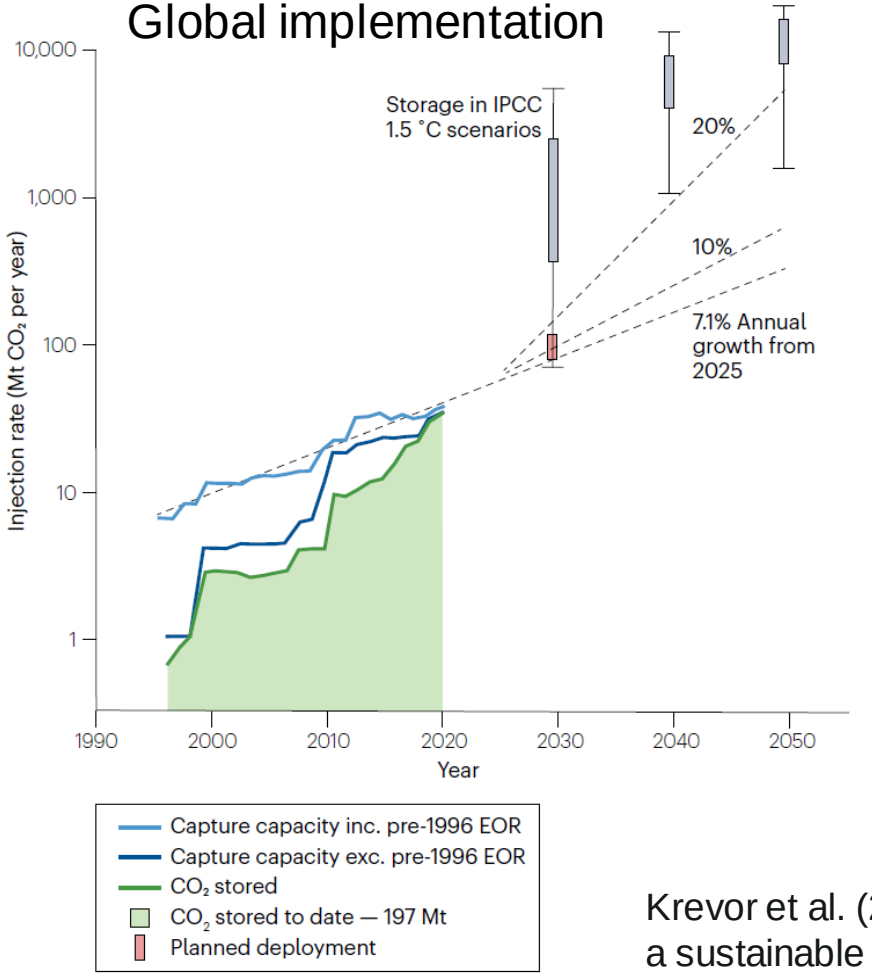


Hematpur *et al. Advances in Geo-Energy Research* (2023)

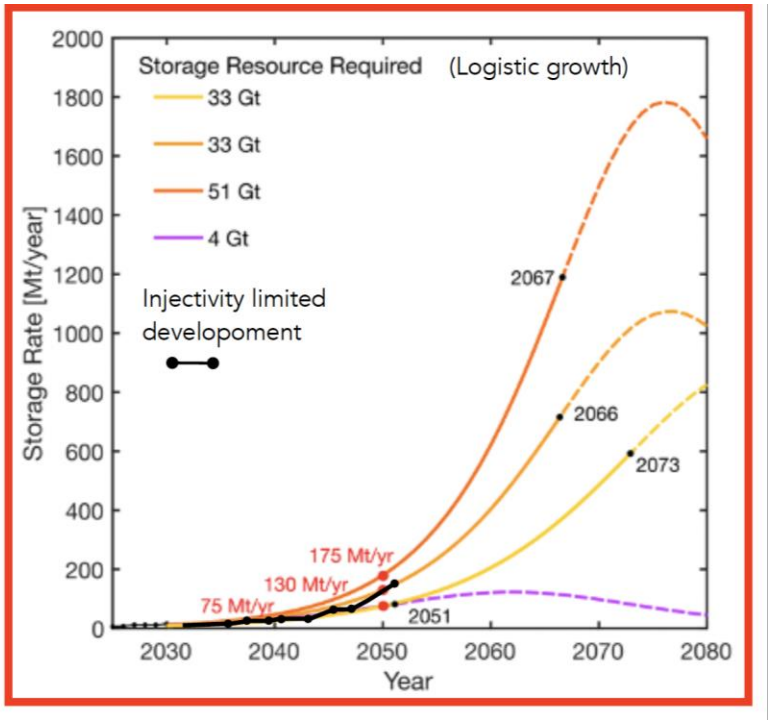
Potential for large-scale storage

On track for Gt-scale storage if current growth rates are maintained.
No significant technical barriers to widespread implementation.
Storage in aquifers and depleted hydrocarbon fields.

Global implementation

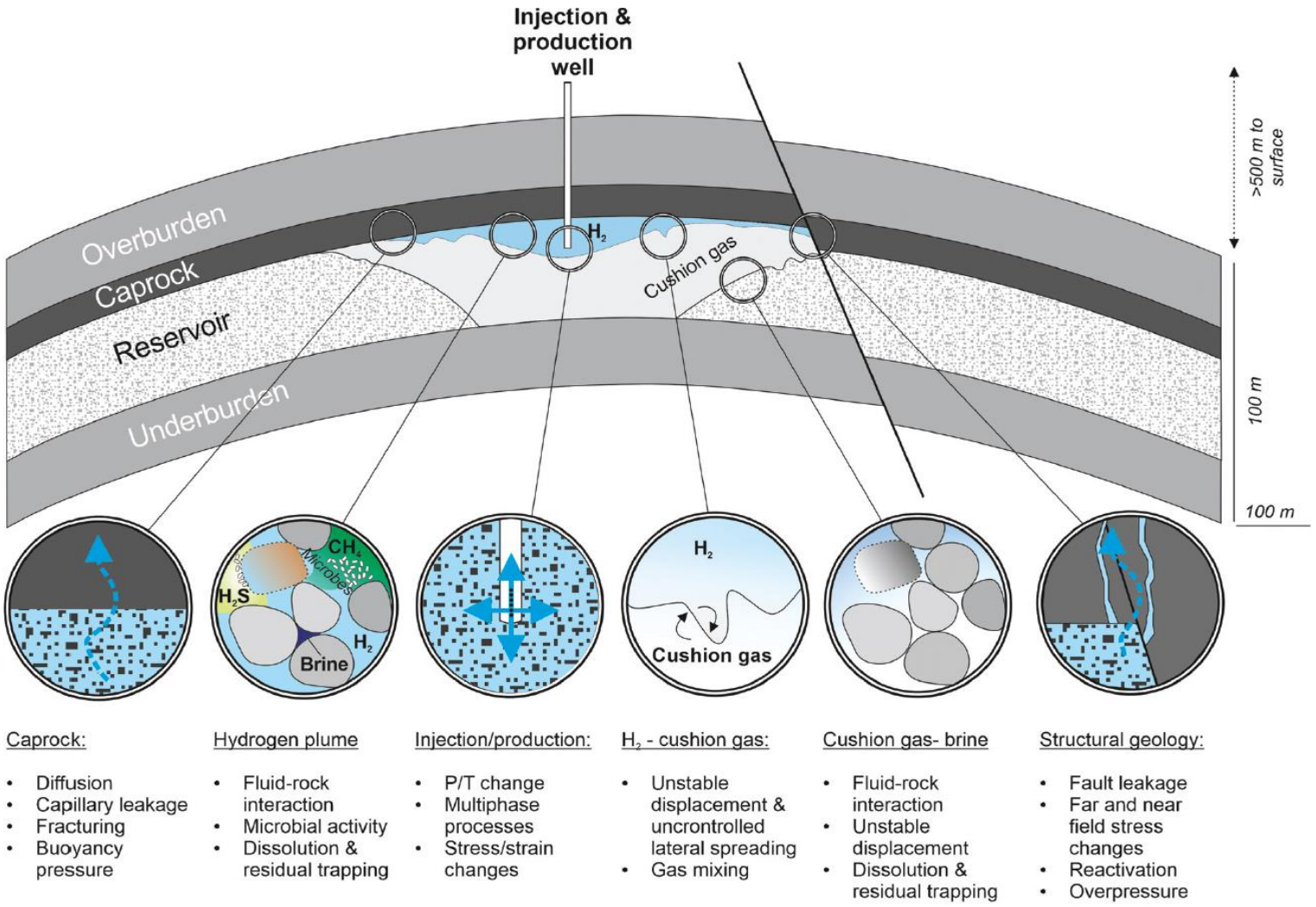


In the UK



Krevor et al. (2023) Carbon dioxide and hydrogen storage for a sustainable energy future. *Nature Reviews*, **4**, 102-118.

Research challenges



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

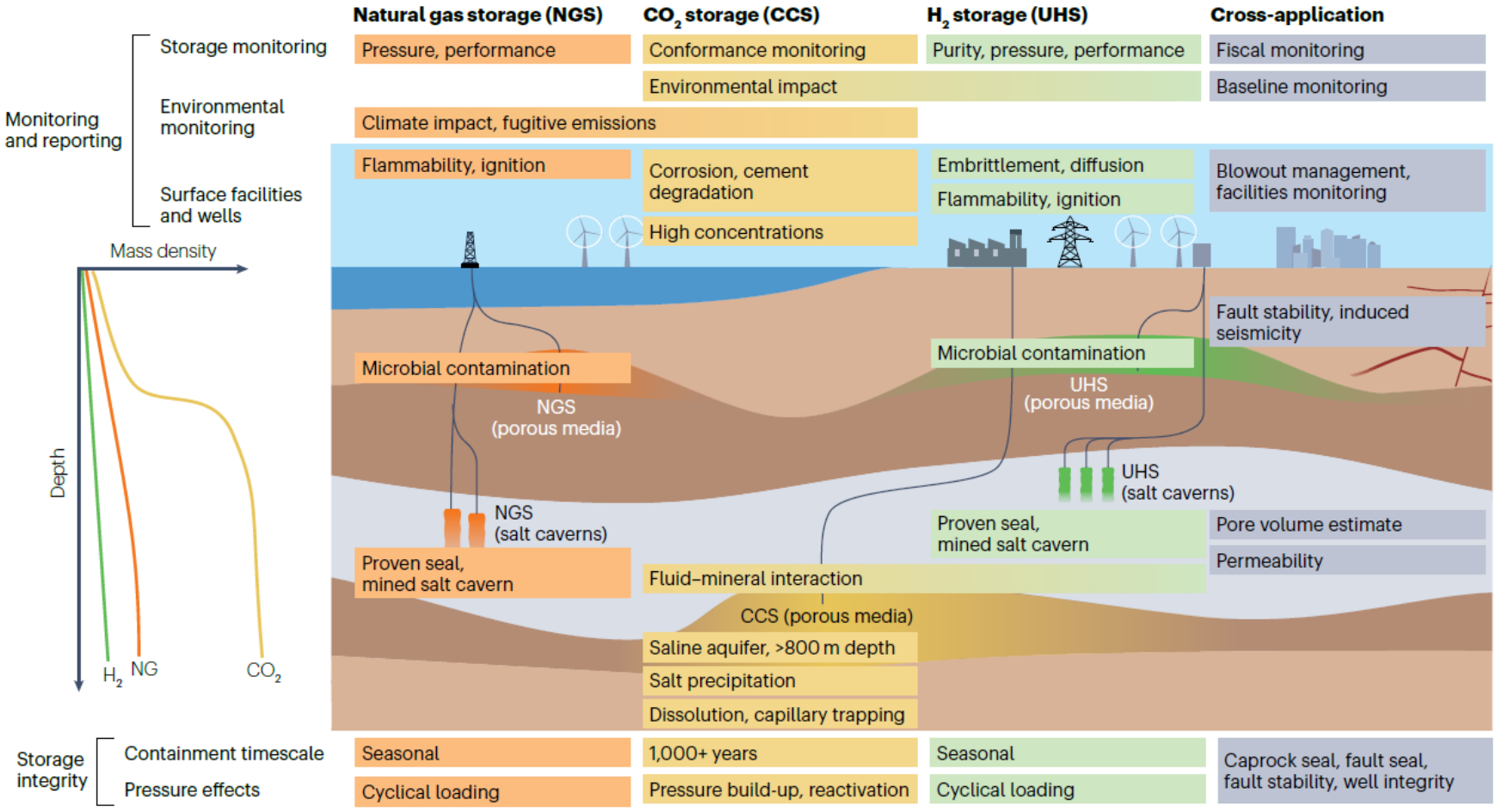
- Fluid-rock interaction
- Unstable displacement
- Dissolution & residual trapping

Structural geology:

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

Heinemann *et al. Energy and Environmental Science* (2021)

Inter-linked challenges in the energy transition



Krevor *et al. Nature Reviews Earth and Environment* (2023)

Net Zero by 2050

Our ambition is to be a net zero company by 2050 or sooner. And to help the world get to net zero. This will mean tackling around 415 million tonnes of emissions – 55 million from our operations and 360 million tonnes from the carbon content of our upstream oil and gas production. Importantly these are absolute reductions, to net zero, which is what the world needs most of all. We are also aiming to cut the carbon intensity of the products we sell by 50% by 2050 or sooner

“The world’s carbon budget is finite and running out fast; we need a rapid transition to net zero”

Bernard Looney, chief executive officer

13th February 2020

A carbon neutral strategy for the oil industry

To commit to be net CO_2 neutral by 2050.

To store a volume of CO_2 *underground* which is at least as large as the CO_2 produced in oilfield operations, refining *and* when the hydrocarbon is burnt.

To lobby governments to make this happen, while informing and engaging with the public.

Major plans in the UK, tax breaks in the US.

Have a commitment to store a percentage of CO_2 that rises to 100% by 2050.