Edinburgh: 1770 CO2 discovery

UKCCS RESEARCH CENTRE

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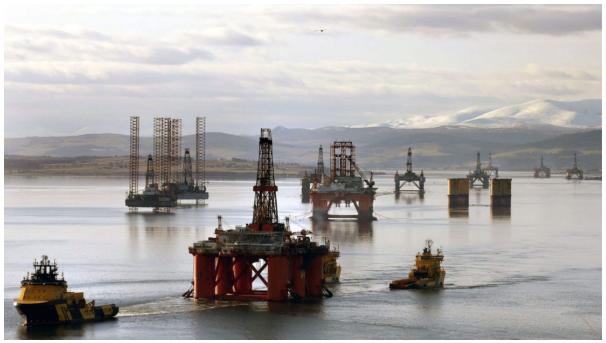
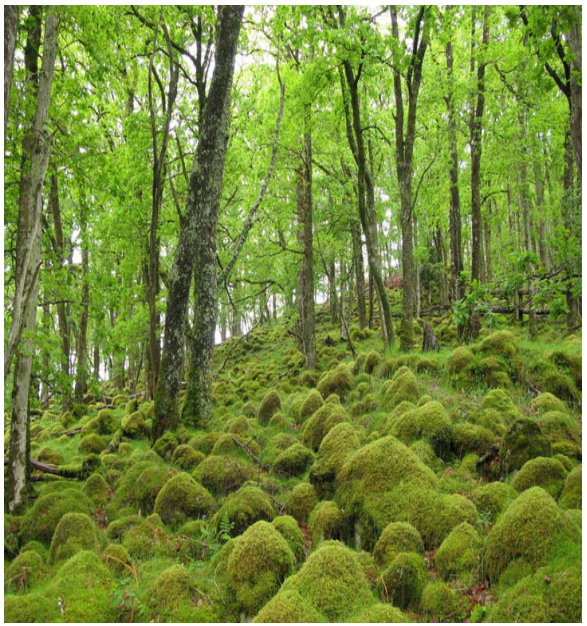
Re-Storing carbon
CCS advantages and problems

Industry

Oil and Gas



Nature



Stuart Haszeldine

Professor of Carbon Capture and Storage

University of Edinburgh

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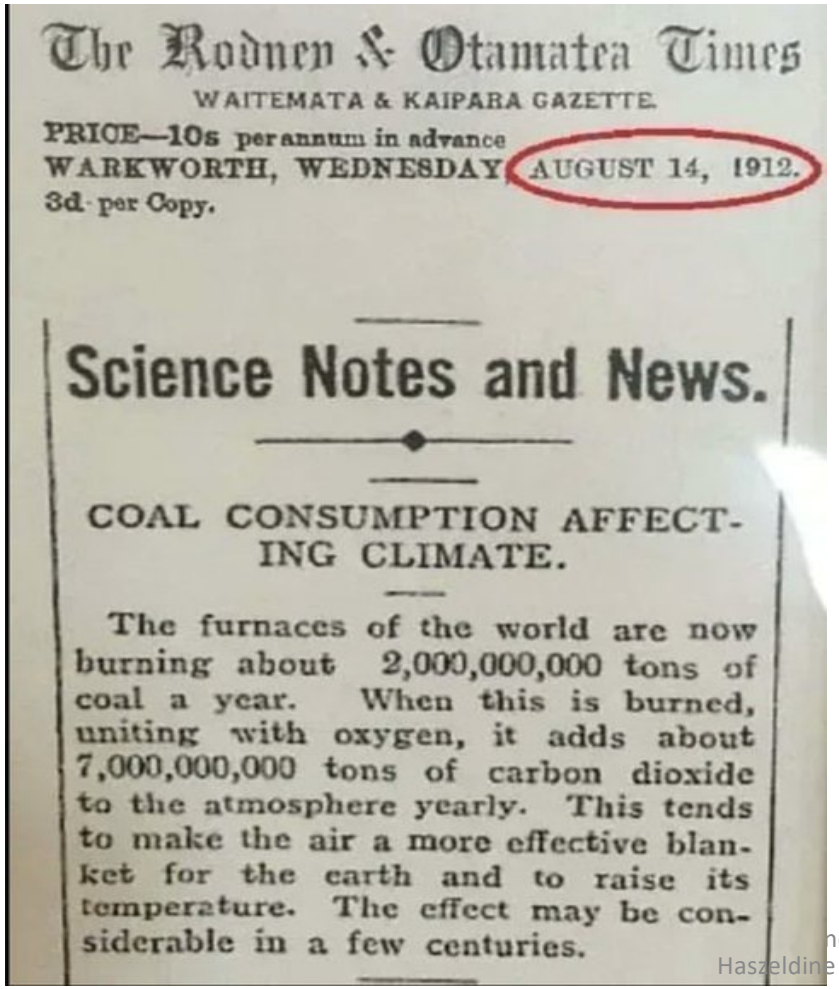
Is excess CO2 new news?



The Rodney & Otamatea Times
WAITEMATA & KAIPARA GAZETTE.
PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

382 *On the Heat in the Sun's Rays.*

ART. XXXI.—*Circumstances affecting the Heat of the Sun's Rays*; by EUNICE FOOTE.

(Read before the American Association, August 23d, 1856.)

MY investigations have had for their object to determine the different circumstances that affect the thermal action of the rays of light that proceed from the sun.

Removal of CO2 from air to control climate : Invented 1938 in Edinburgh. Guy S Callendar 1938 The artificial production of carbon dioxide and its influence on temperature *Q. J. R. Meteorol. Soc.* **64** 223–40

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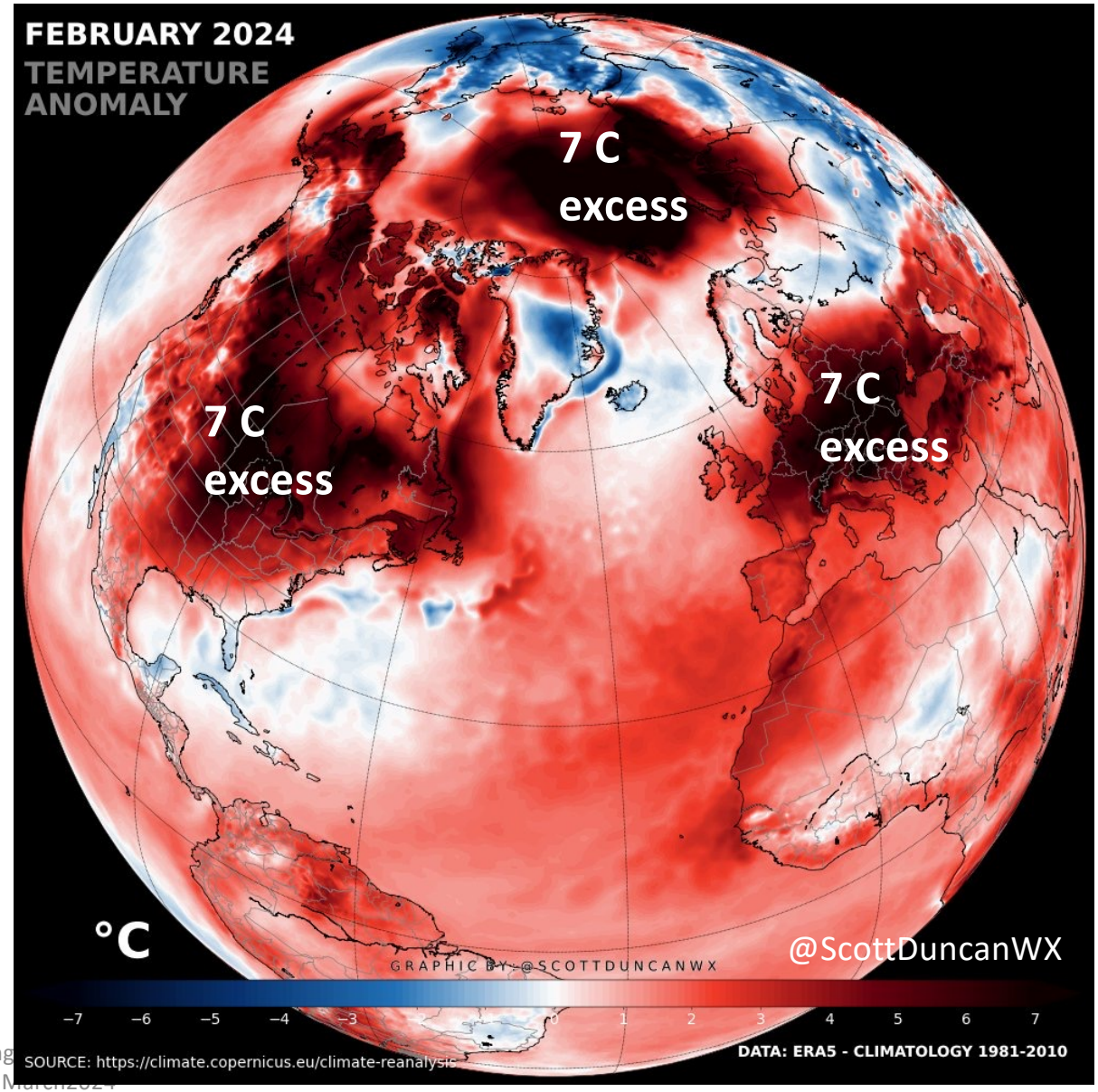
CO2 disadvantage February 2024

2023 – record year – exceed 1.5C
February 2024 record February

Projected 2024 record warming
Due to lack of sulphur aerosols from shipping



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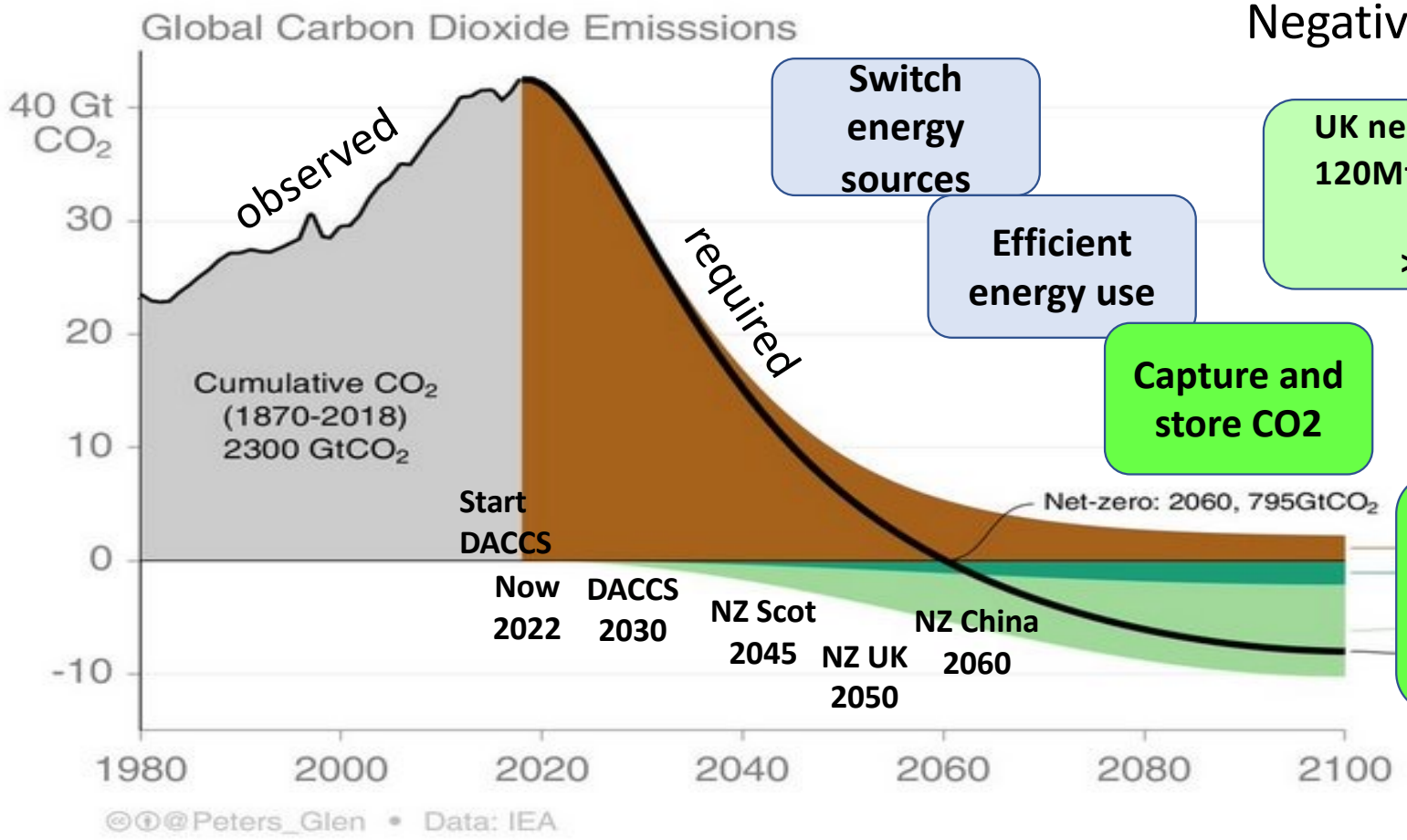
CO2 advantage
Path to Net Zero – need CCS and NET
Possible – but how likely?

Increase 2.5% /yr (3ppm)
Decrease 10% /yr for 1.5C
Decrease 4.5%/yr for 2C.
Negative past 2050 forever



Switch energy sources

Efficient energy use

Capture and store CO2

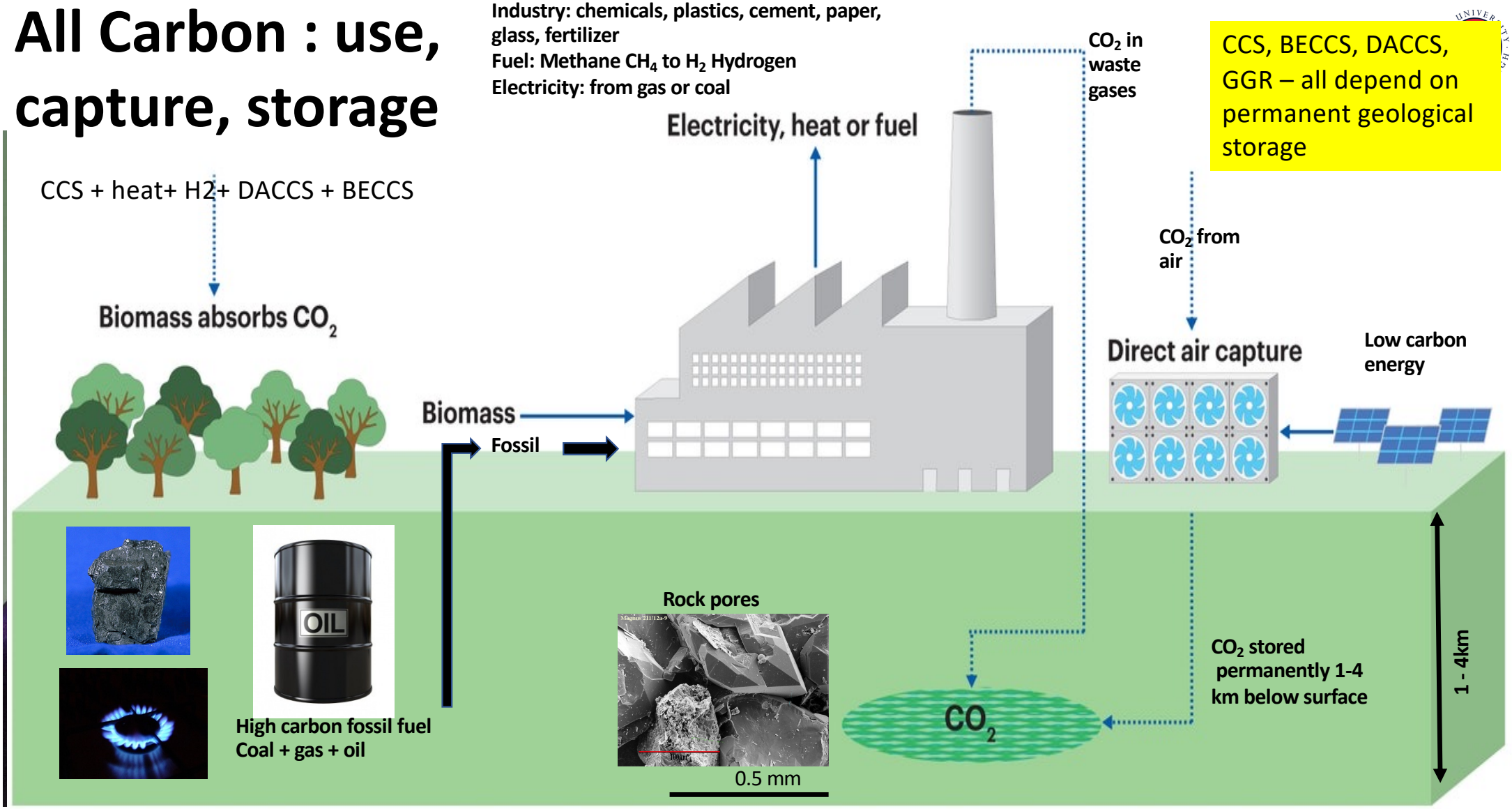
UK needs > 30 Mt/yr by 2030, 120MtCO2 /yr stored by 2050 AND > 50Mt/yr CO2 GGR

GGR to balance residual CO2 emissions with air and ocean removals

Stuart

All Carbon : use, capture, storage

CCS + heat+ H2+ DACCS + BECCS



CCS, BECCS, DACCS, GGR – all depend on permanent geological storage

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Geological containment makes CO2 storage permanent

NOT a waste – avoids tax
Duration more than 10,000 years

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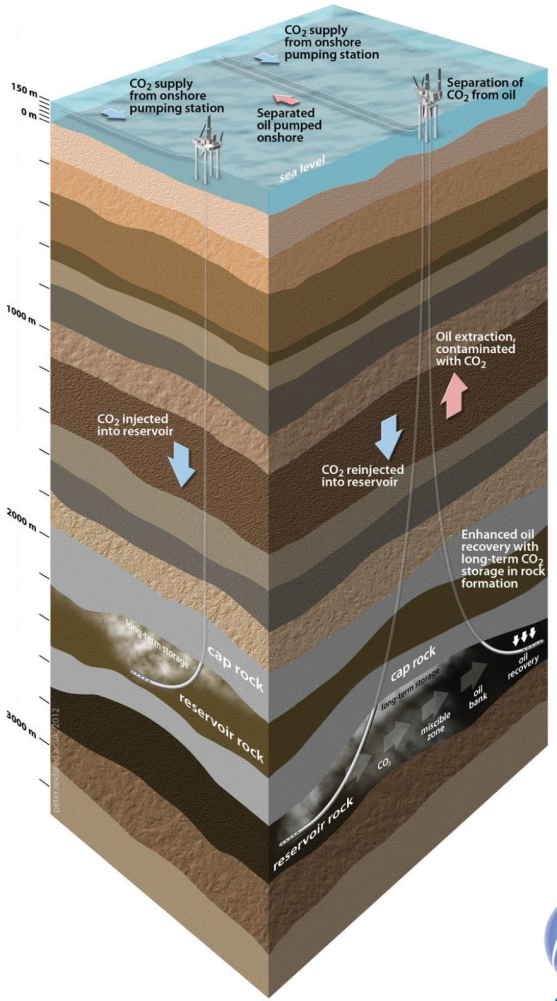
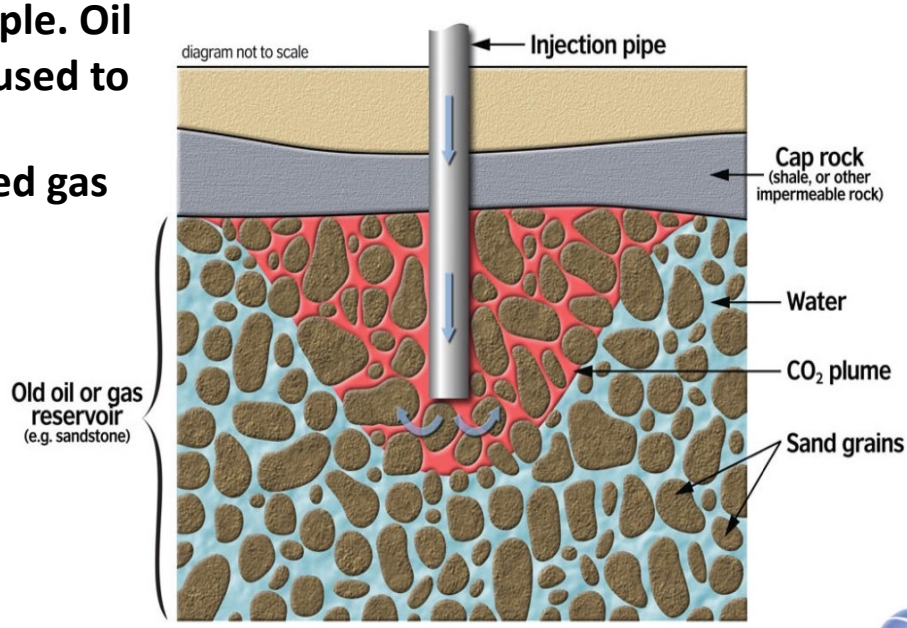
Geological containment CO2



CO2 storage is very deep at 1-4km, and remote from people. Oil industry boreholes can be used to inject into ”saline aquifer” reservoir (left), or a depleted gas or oilfield (right)



CO2 is liquified by pressure, and injected into microscopic pores between sand grains. That CO2 (red) displaces the ambient salty water (blue), and is physically retained by an overlying cap rock (grey)

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Geological containment 4 processes

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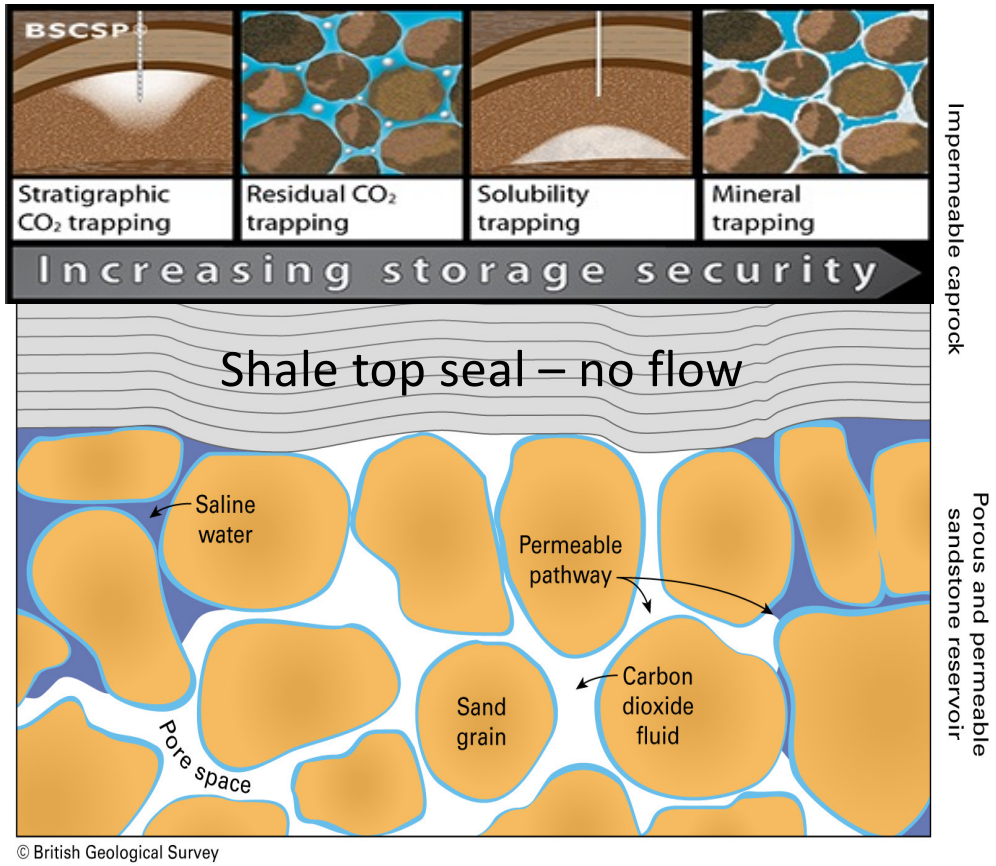

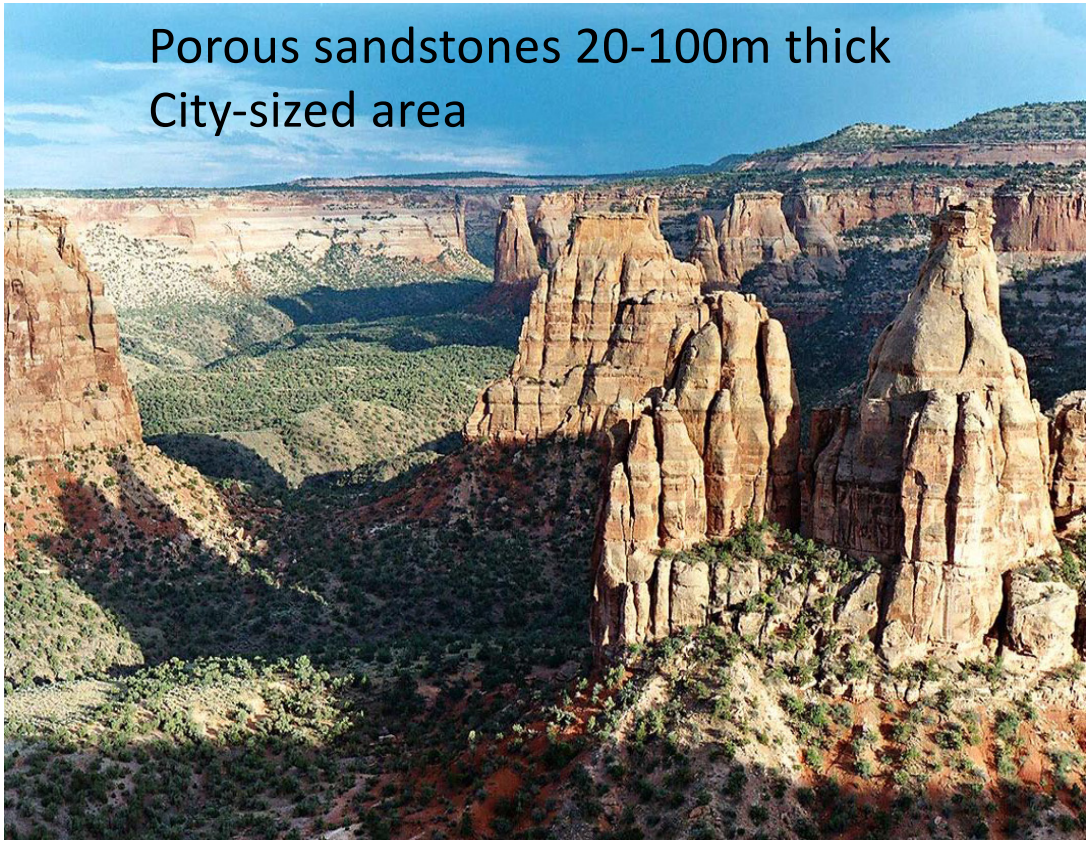

Porous reservoir : Physical trap, dissolves in porewater, residual saturation droplets. minerals

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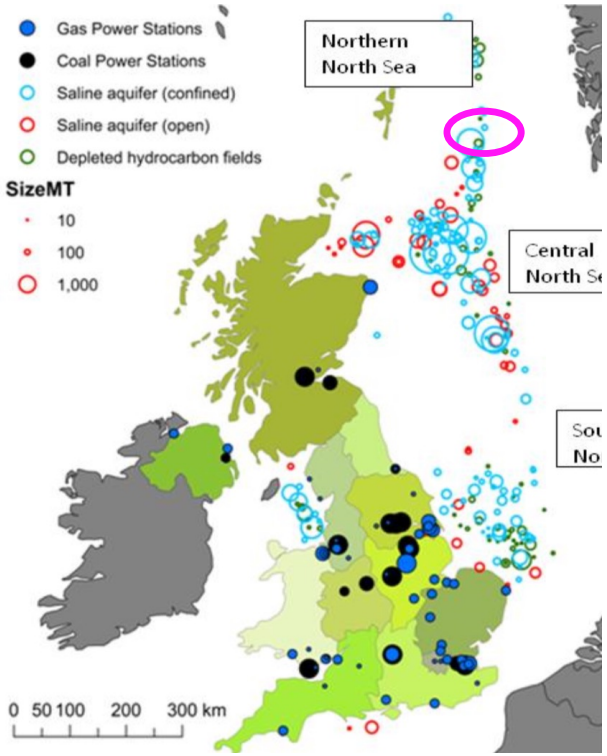
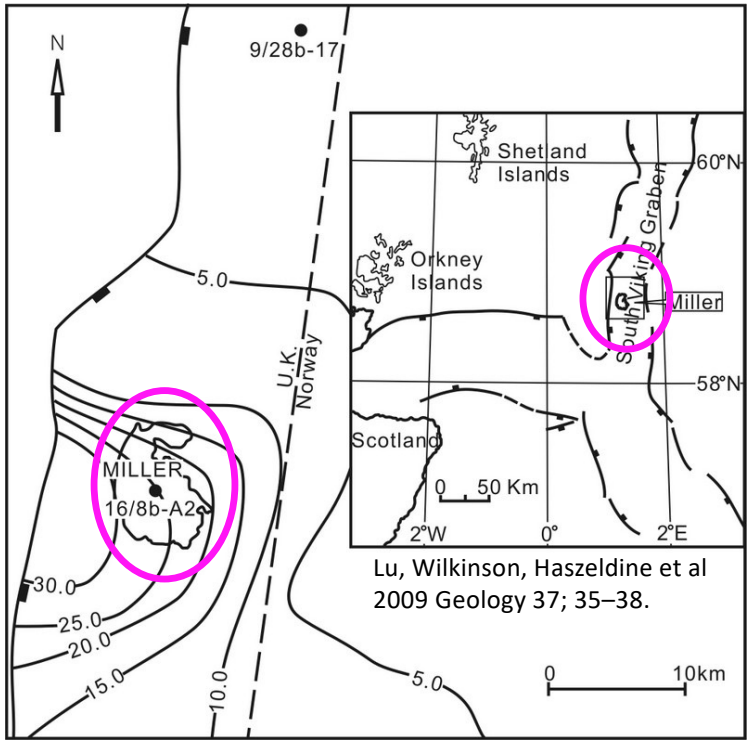
Map UK CO2 storage sites offshore

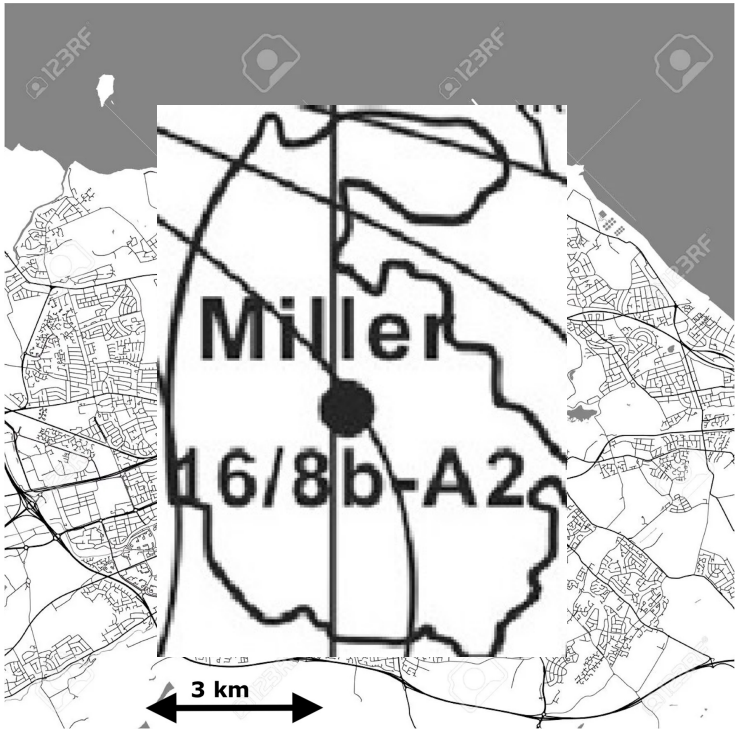


Miller field, North Sea Natural CO2 content



Lu, Wilkinson, Haszeldine et al 2009 Geology 37; 35–38.

Edinburgh city and permeability streetmap



Typical small CO2 storage site was Miller oilfield (BP project DF1 2005) injecting 1.3 Mt CO2/yr for 20 years. Similar size to Edinburgh city. Spacing of boreholes 500m requires interpolation of reservoir

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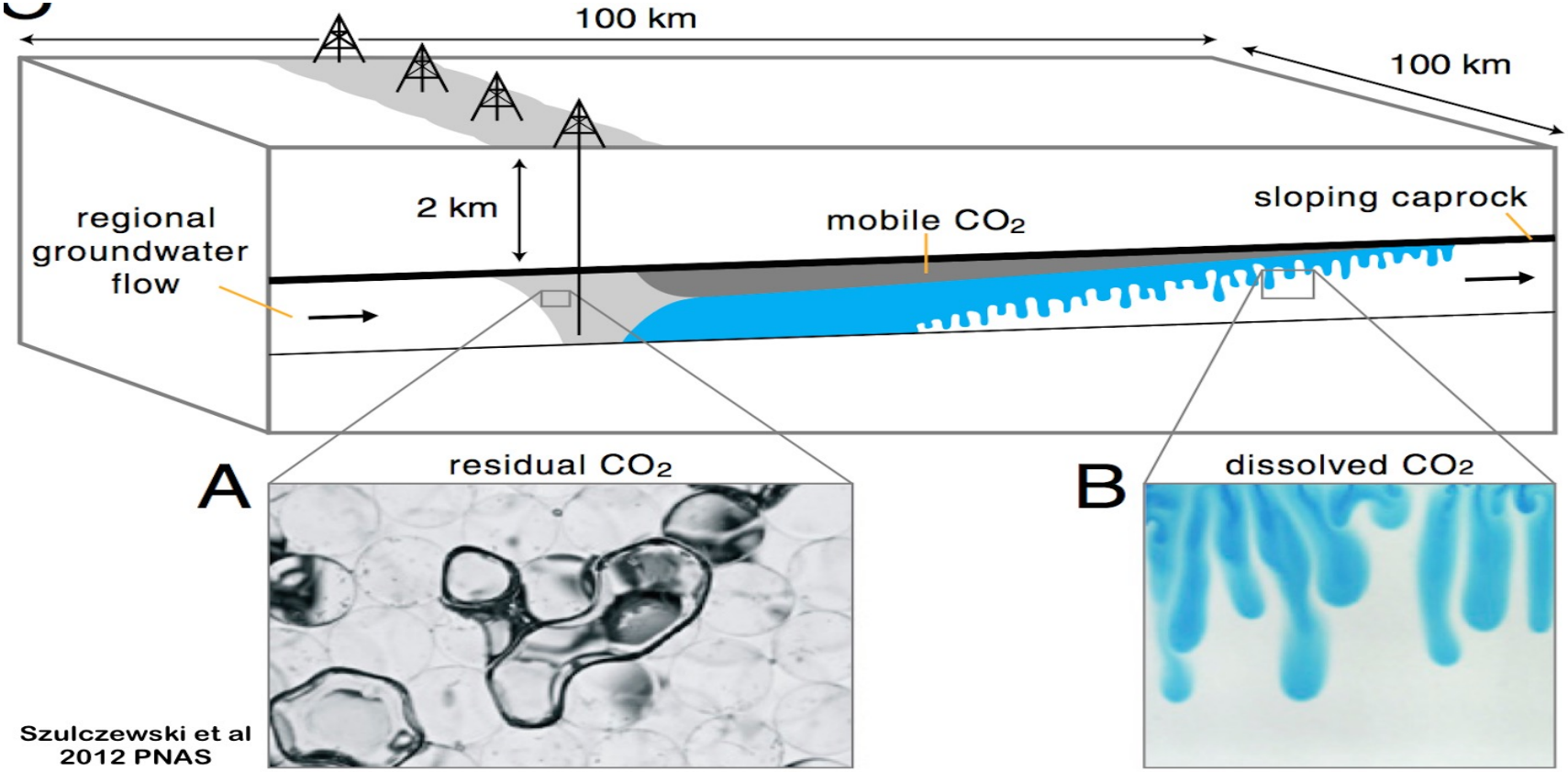
Regulation: Monitoring Geological storage CO2



10^{12} size scale, very small to very large

Good prediction needed from small, to mid, to large for prediction

Science: Laboratory measurement and process. Theory maths, Field calibration

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Fast cycle nature & slow cycle geology

Cheap capture, short storage

Higher cost capture, long storage

Small farm landscape Normandy = England 1920, good capture, unreliable storage

- Both hedgerows and the cliffs of Dover are examples of natural carbon sinks
- However, they are vastly different in terms of permanence
- Does it make sense to value them equivalently in terms of their services as a carbon sink?

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MONITORING

Hazards and risks

real or over regulated ?

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Theoretical hazards geological storage very low probability, self sealing

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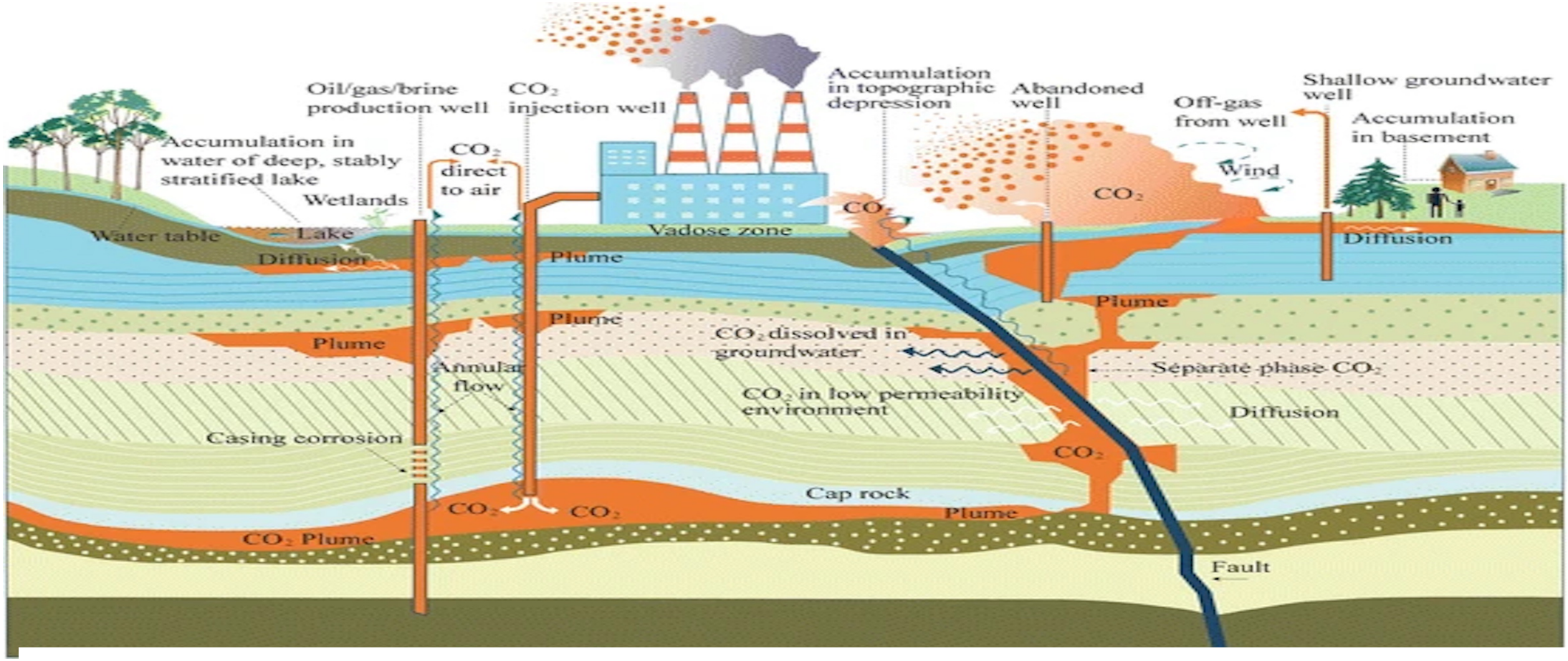

Many risks of unplanned migration can be imagined, Legacy wells are most real. Monitoring gives early warning

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Sleipner commercial CO2 storage since 1996

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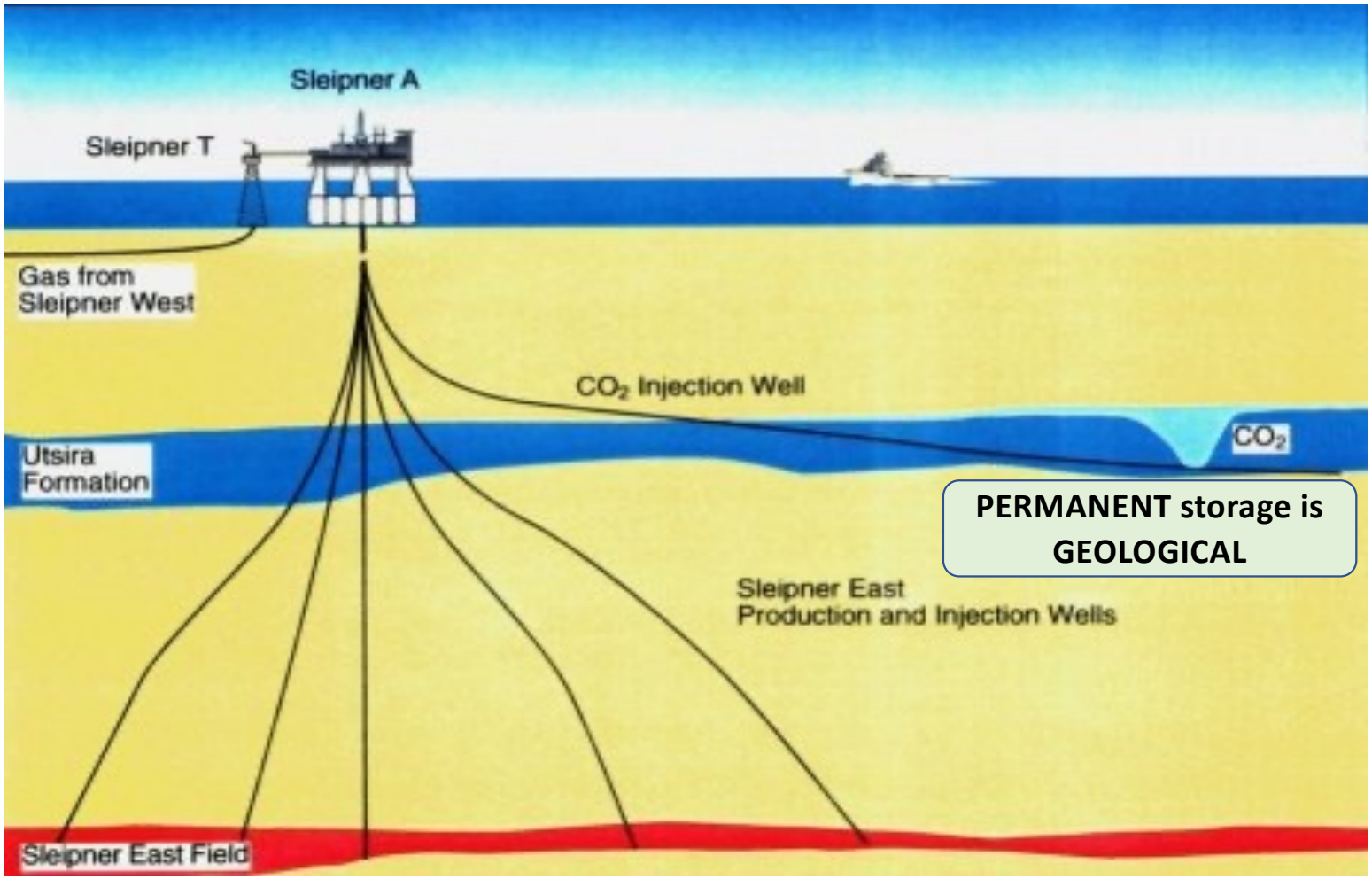
Since 1996 CO2 produced from the Sleipner field, has been separated offshore, and 1MtCO2/yr injected safely



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Sleipner - location & seismic reflection resolution

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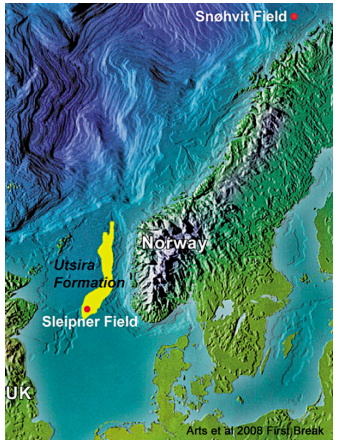

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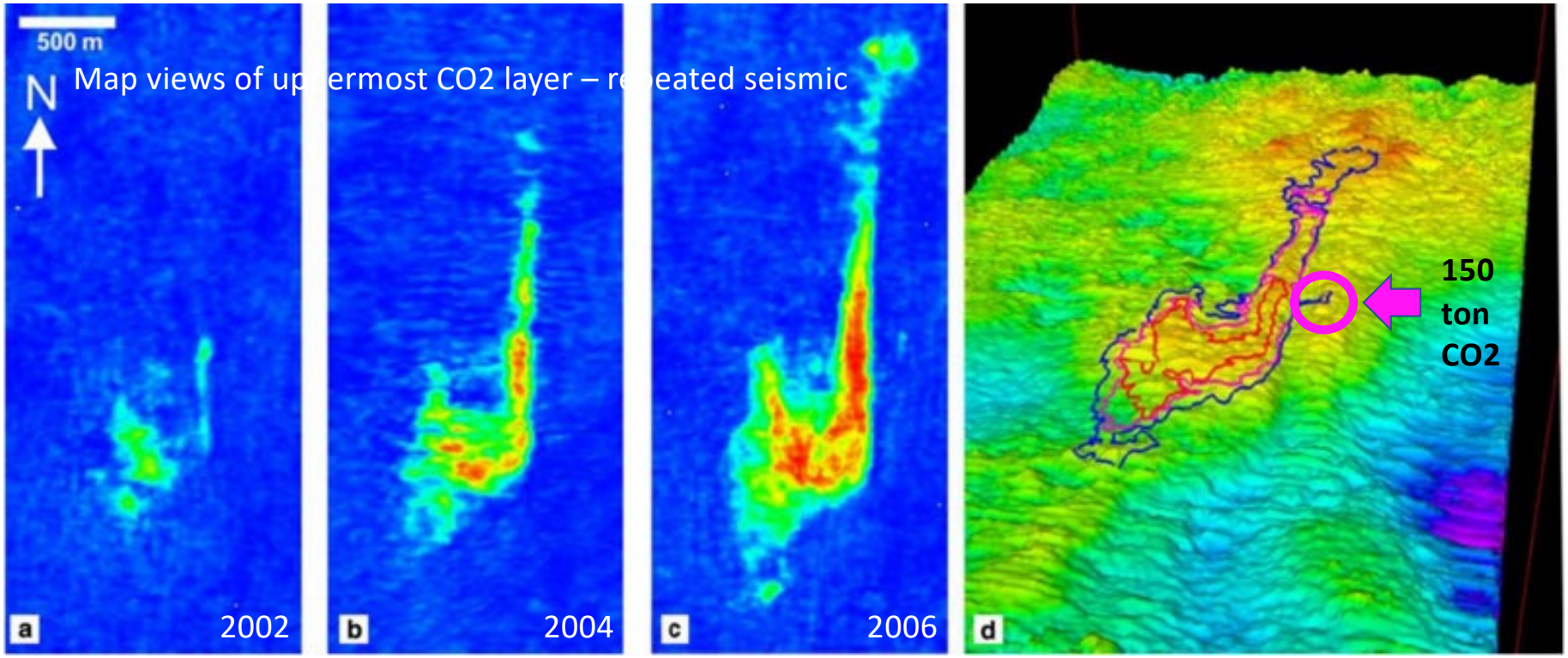

Seismic reflection surveys have been acquired for the Sleipner field condensate production – these accidently include the Sleipner storage site. Repeat differences **detection is excellent - 150 tonnes CO2**. Lateral migration 1m/day. Buoyant CO2 fills uppermost reservoir topography. Also measure **PRESSURE**

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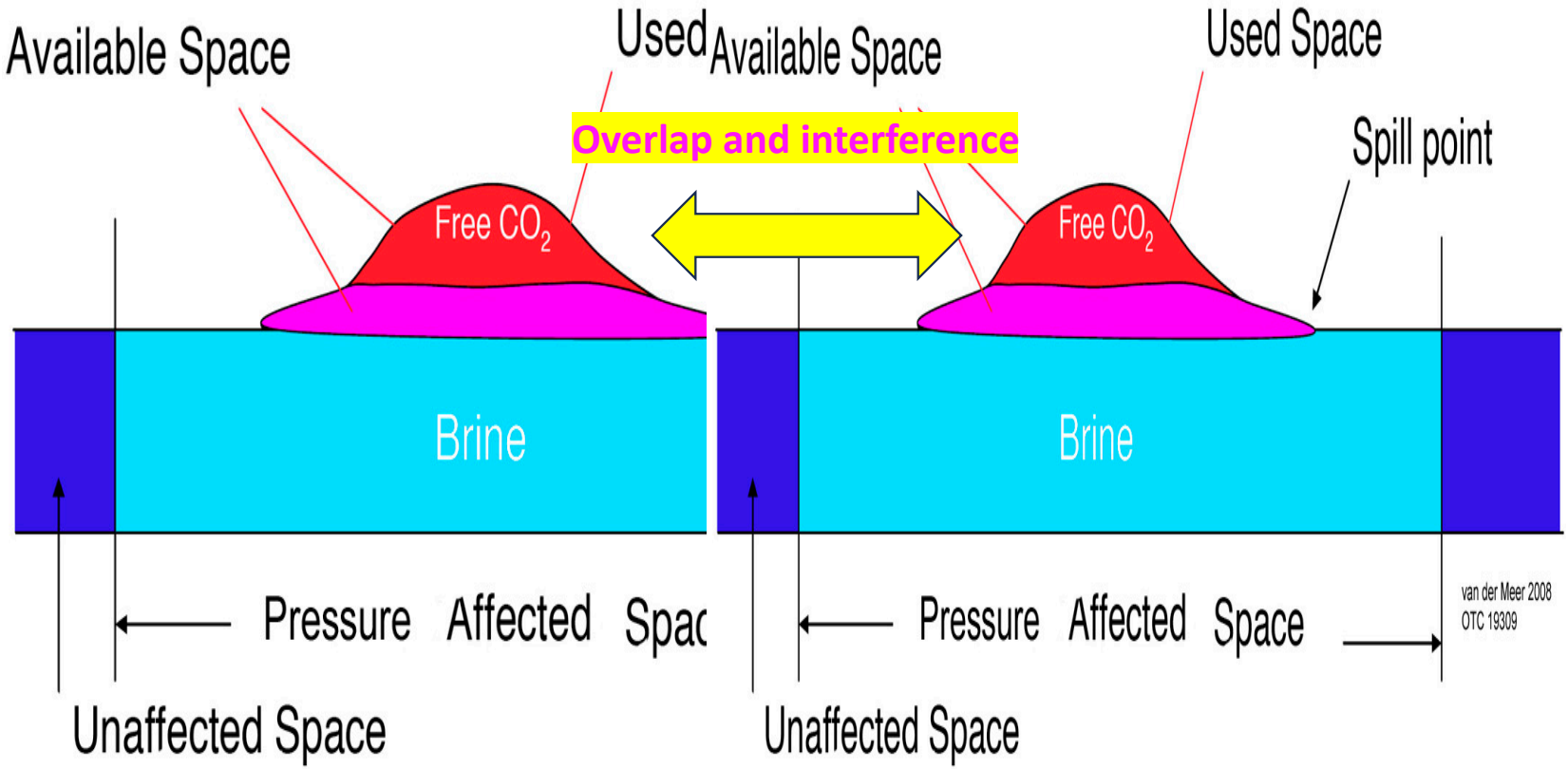
Pressure extends much further than CO2 – decreases ability of 2nd store to inject



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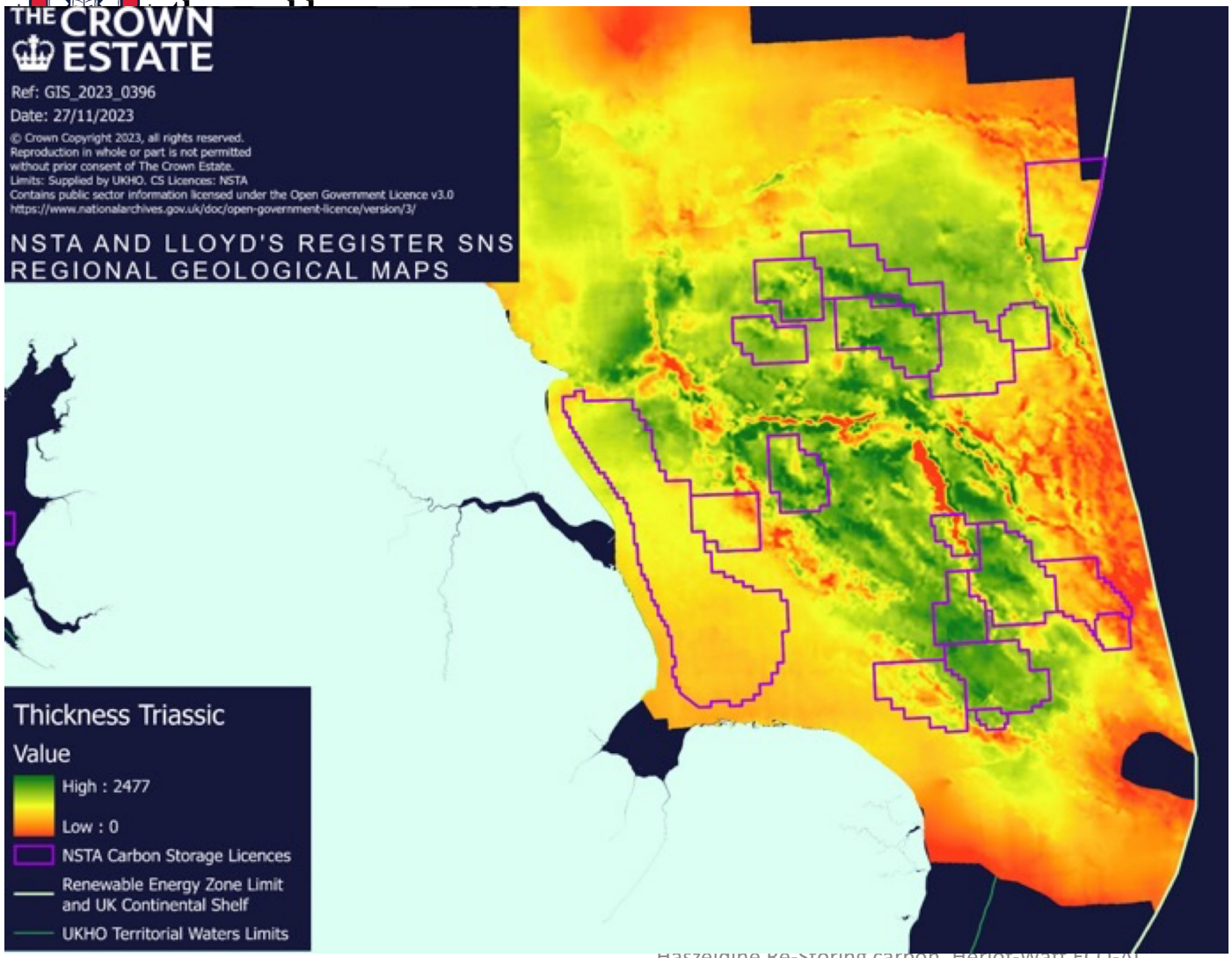

UK Bunter sandstone licenses join together – pressure overlap

How will licensing adjust storage capacity? First developer can use all the wide "pressure space" and second developer, overlapping will inherit much less than maximum capacity

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QUEST, commercial storage north Alberta, 2015

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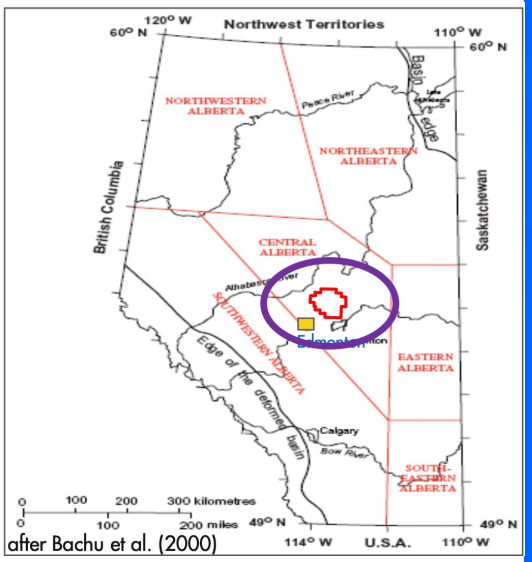
Alberta provincial government CAN$ 745M. And Federal Govt CAN$ 120M funding. Successful storage operation on land since 2015. 1.1 Mt CO2/yr to 2040, using 3 injection boreholes

Operating at lower cost and higher capture performance and reliability than originally designed.

Monitor : pressure, temperature, groundwater chemistry

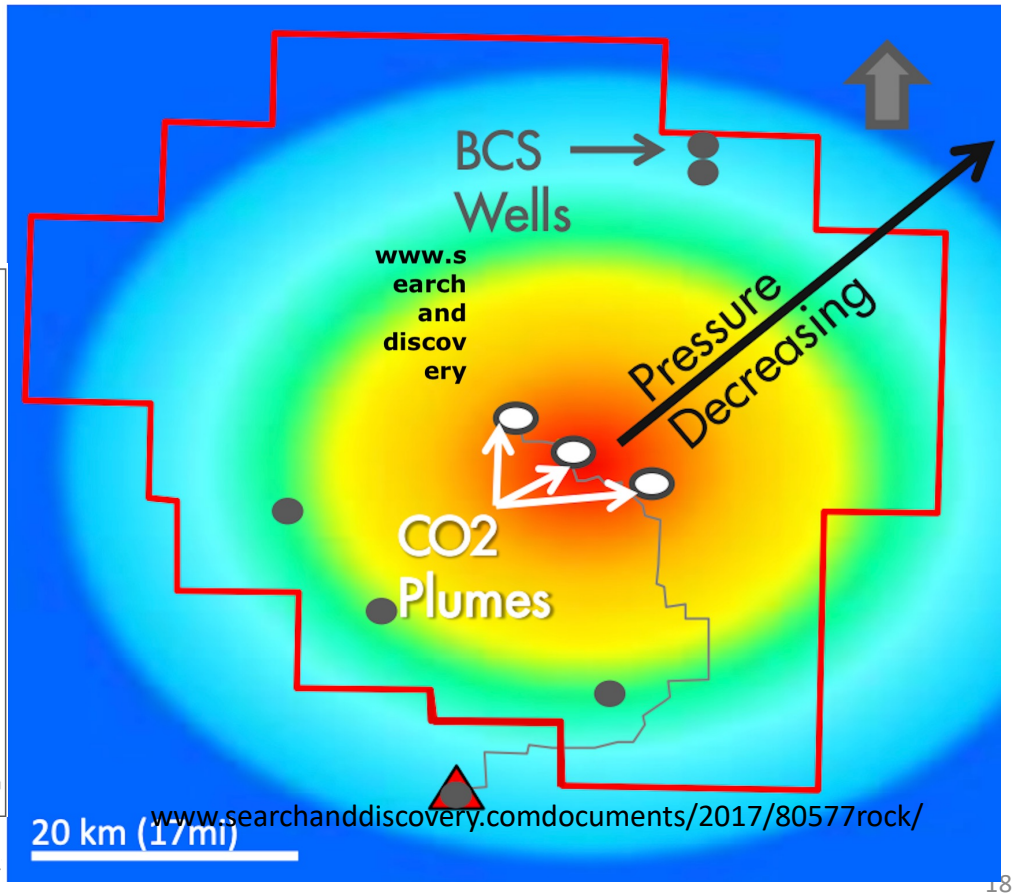
Now unlocked confidence to encourage tens CCS project proposals in Alberta

Pressure increase extends much further than physical CO2



after Bachu et al. (2000)

Schematic: CO_2 Plumes and Area of Elevated Pressure



www.searchanddiscovery.comdocuments/2017/80577rock/

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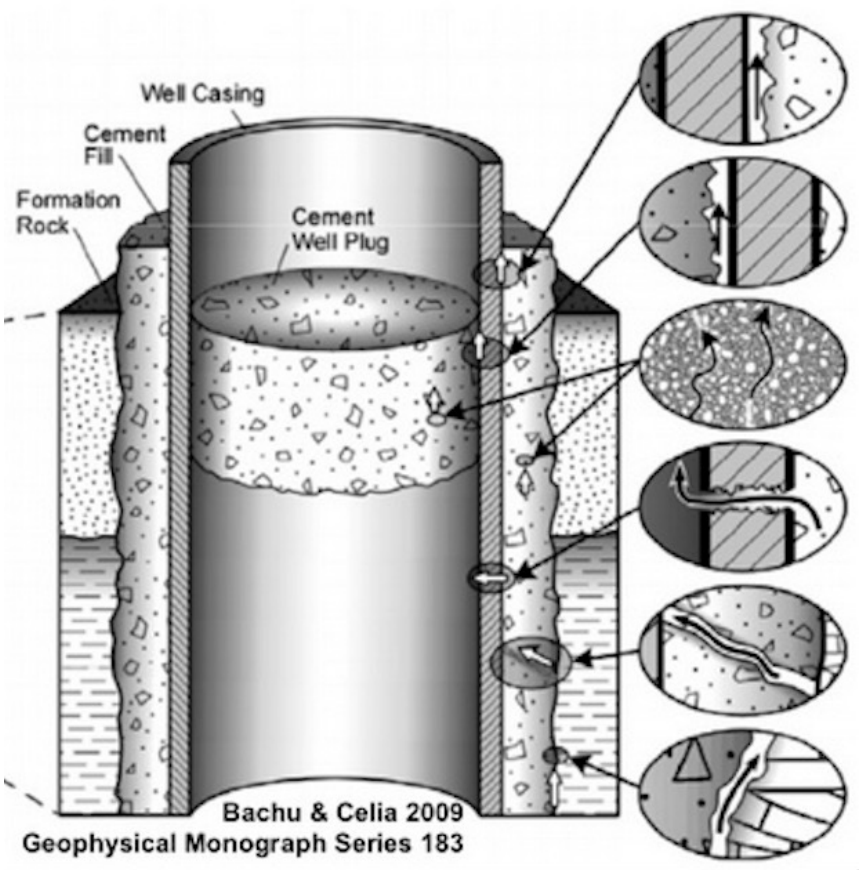
Borehole leakage – cement seal



Potential pathways for borehole leakage

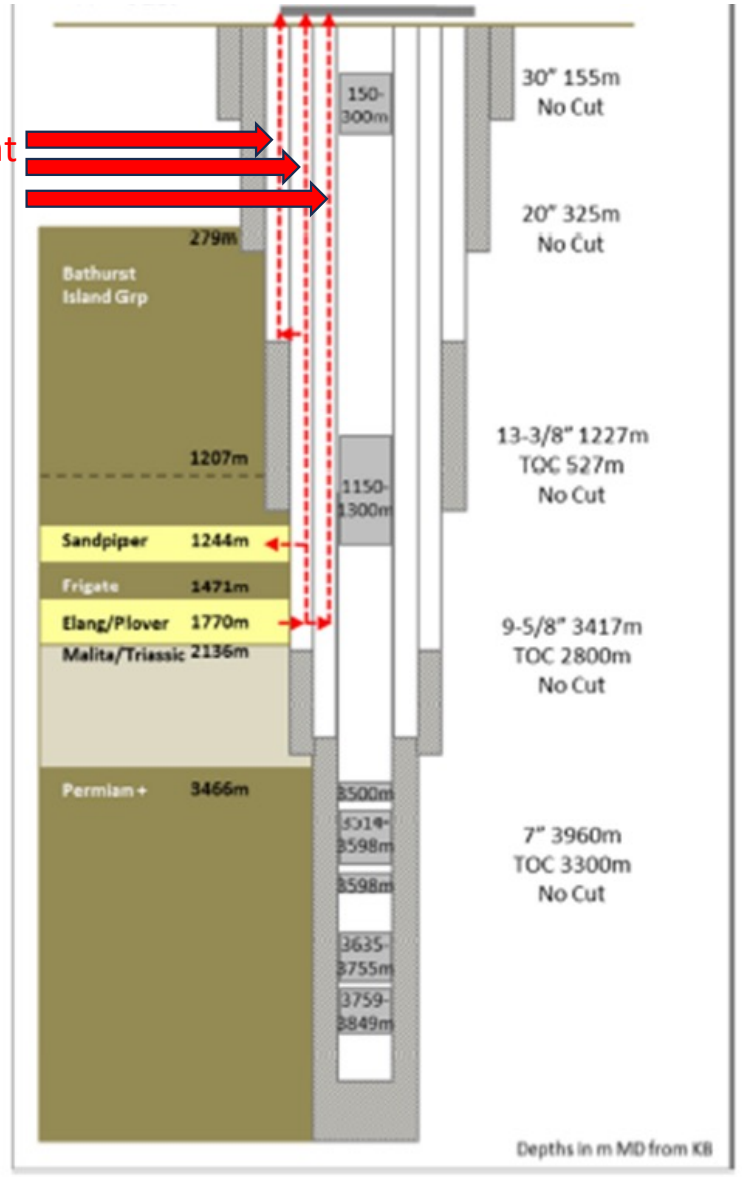
Alberta Basin

West Canada

Missing cement seal around casing

Exploration borehole not well cemented for abandonment

Bonaparte Basin NW Australia.



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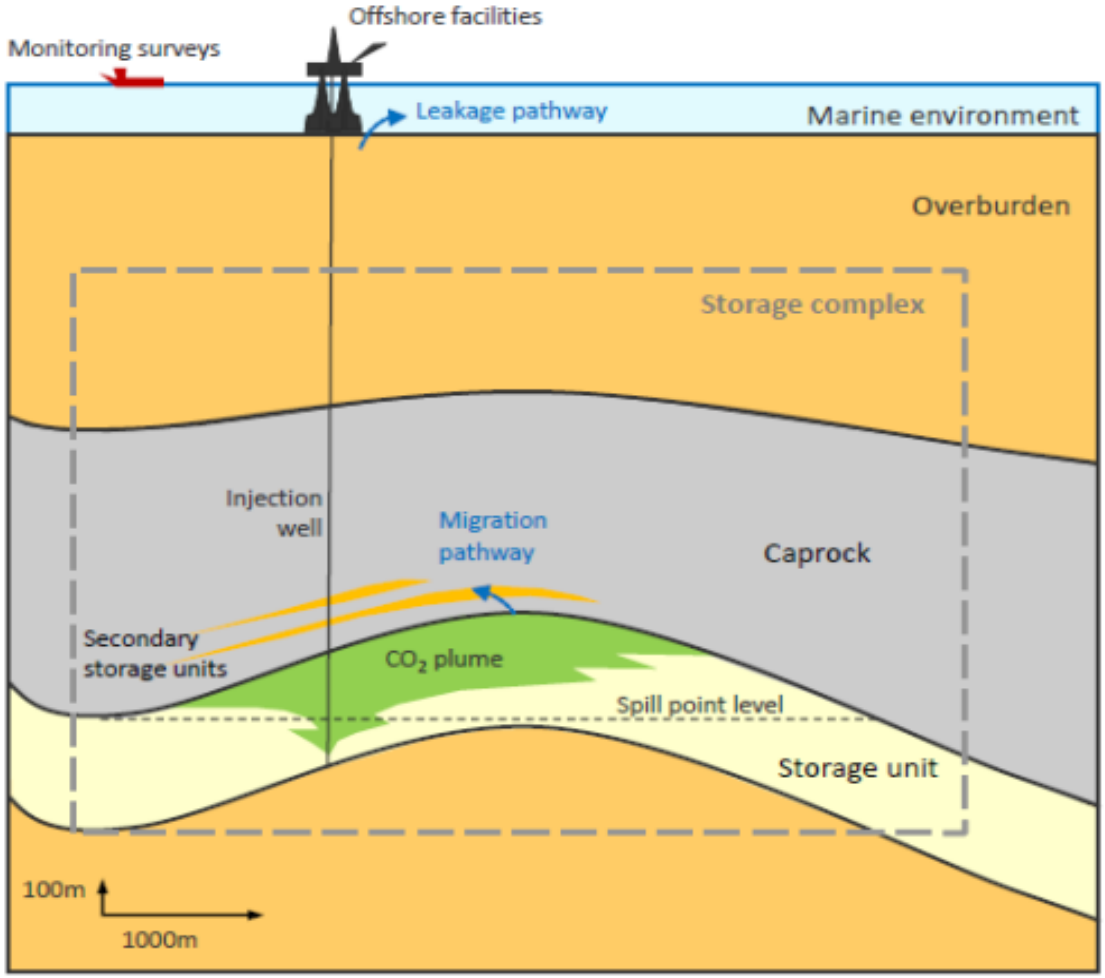
Legal storage complex (Europe)

- Storage Site = local setting to inject and retain CO2
- Storage Complex = regional setting includes
  - Primary Storage Unit - this is where CO_2 is injected
  - Secondary Storage Units – overlying porous sands to catch leakage
  - Caprock - prevents CO_2 from leakage and can consist of one or multiple layers
- Storage Complex is overlain by the Overburden which buffers potentially leaking CO_2



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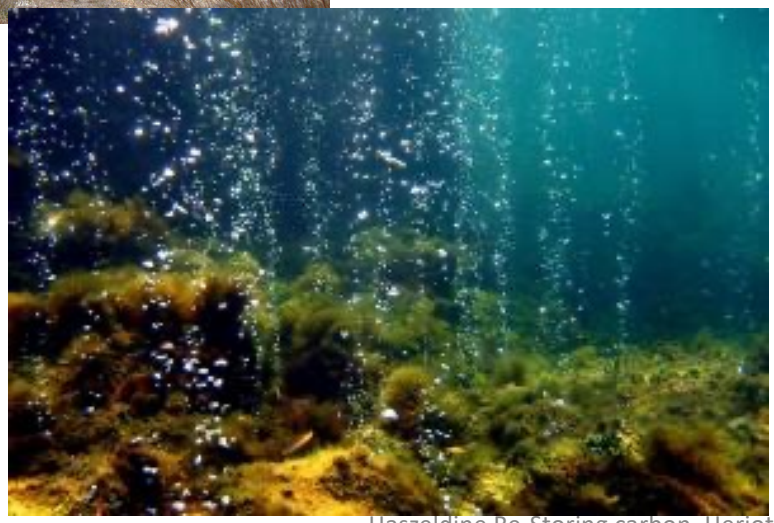
Leaks to surface important?

Mefite, SW Italy 2000yr natural CO2 seep, local dispersion

Tyrrhenian Sea , SW Italy natural volcanic CO2 seep, local dispersion within hours – similar to North Sea models



Industrial 24 inch pipe rupture, 200 barrels CO2, Yazoo Miss 2020. Dispersed to air in tens minutes

CO2 health effects are toxic if >3% air to decrease takeup of oxygen,

and fatal asphyxiation only if CO2 >50% because air is diluted oxygen supply

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Pace of developing storage sites

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Keeling curve measured since 1956
Is carbon abatement winning?

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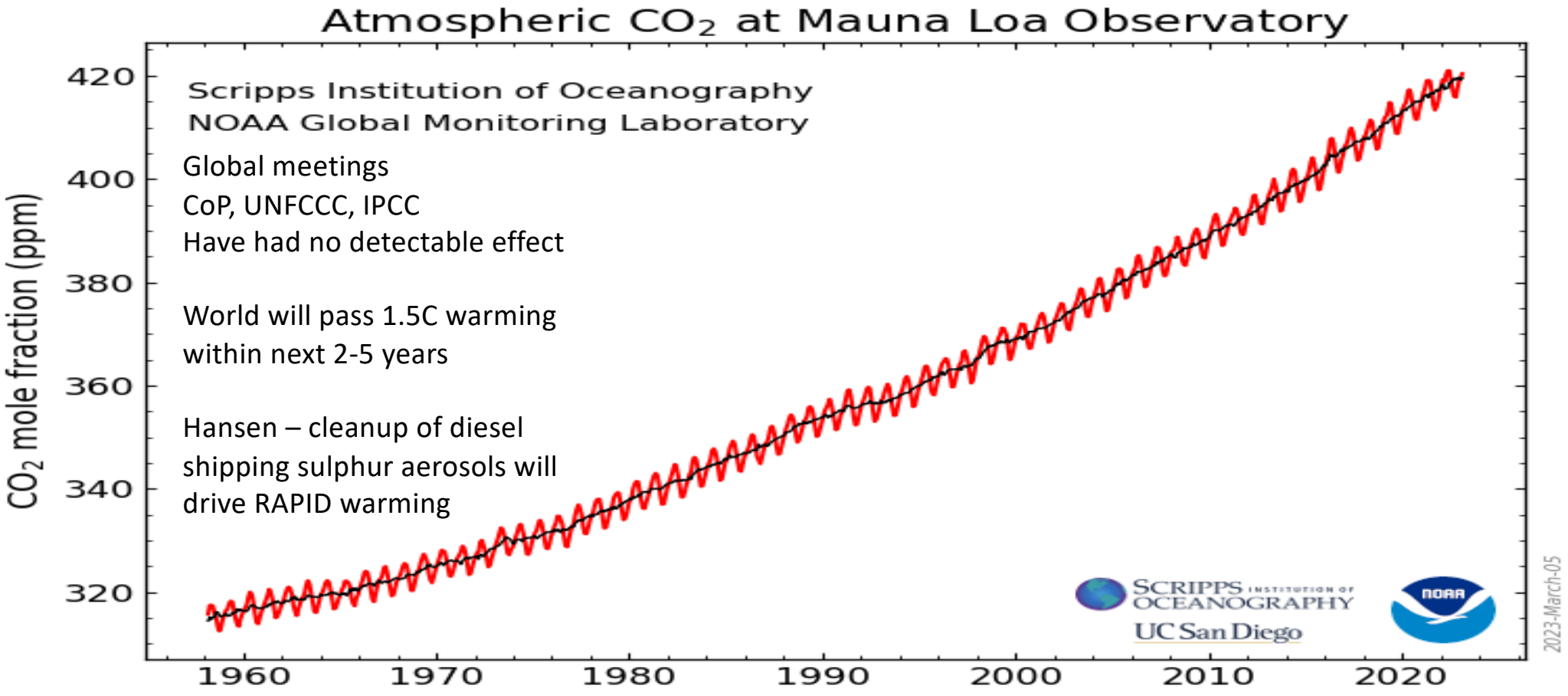

Global meetings
CoP, UNFCCC, IPCC
Have had no detectable effect

World will pass 1.5C warming within next 2-5 years

Hansen – cleanup of diesel shipping sulphur aerosols will drive RAPID warming

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Multi-year UK pathway
Entering the Government Track process

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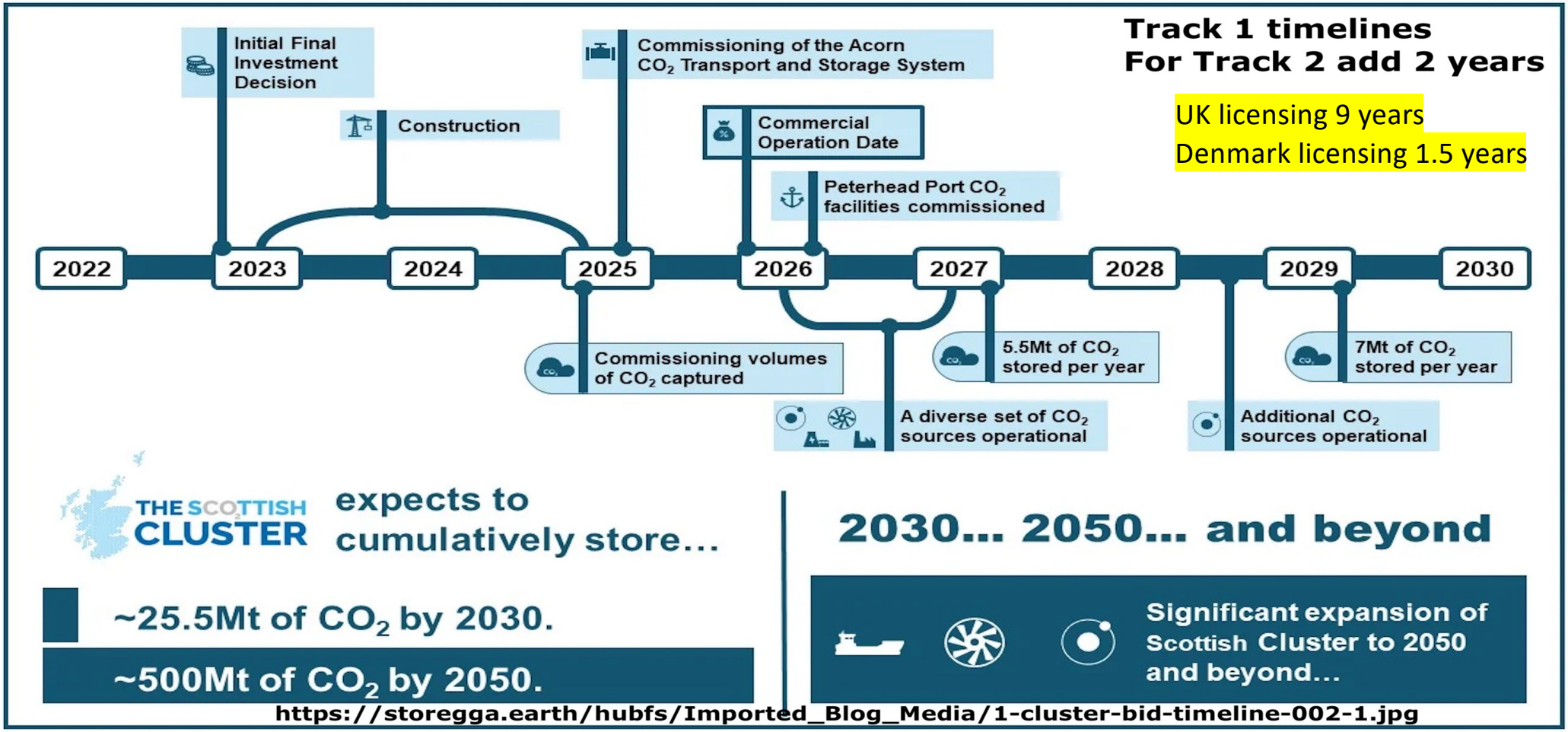
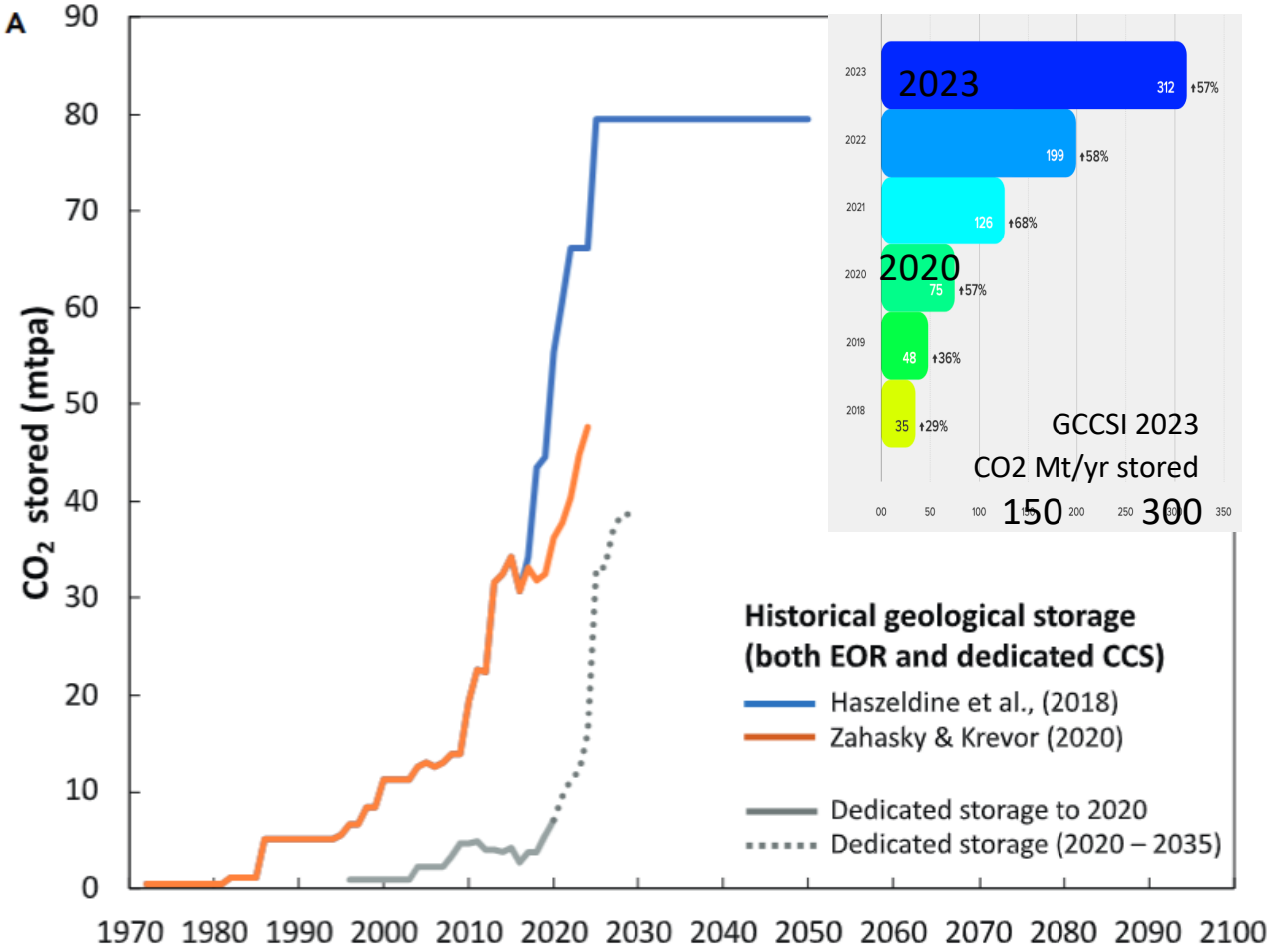


CO_2 storage construction rates, much too slow



Continuous increase in storage rates set to continue until 2030 – all subsidised

Lack of planned projects = high degree of uncertainty after 2030-35

Essential that more projects are proposed and developed rapidly due to the lengthy lead times, and rapid rate of global heating

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Carbon Take Back Obligation

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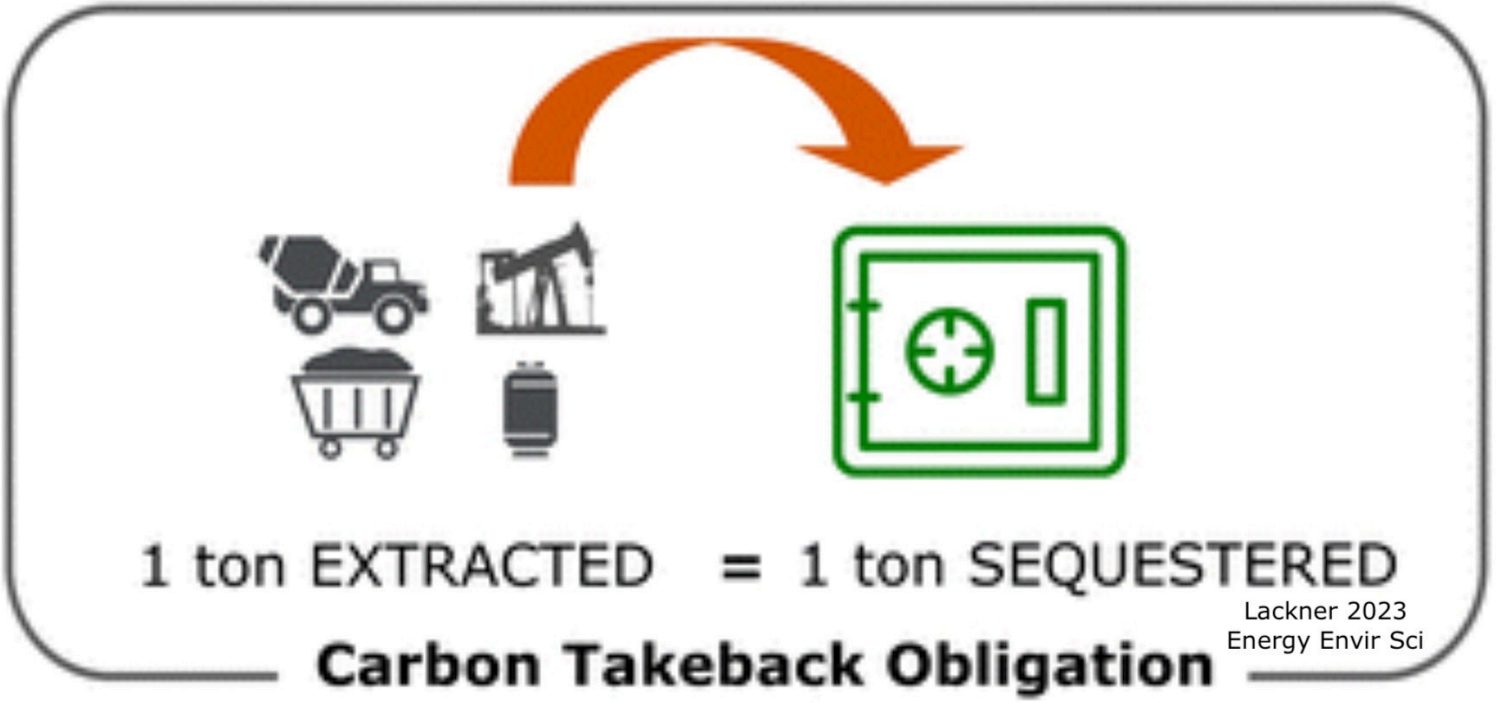
Carbon accounting without Life Cycle Analysis
is possible through the Carbon Takeback Obligation



Lackner 2023
Energy Envir Sci

CO2 capture & storage is operating, safe, resilient, permanent, and low cost

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Mandated storage CTBO could accelerate pace

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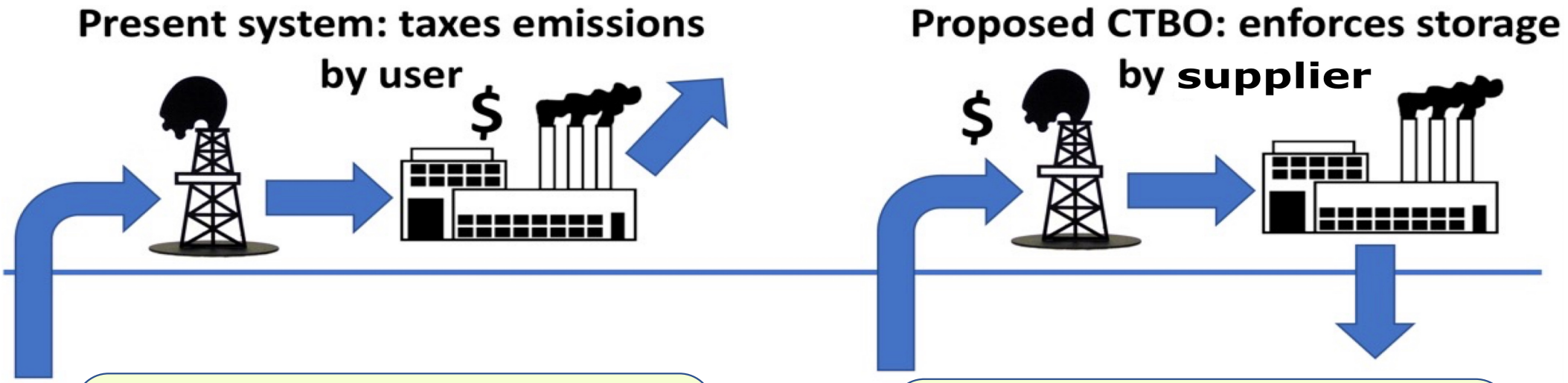
Jenkins et al Joule 2021
https://doi.org/10.1016/j.joule.2021.10.012



Carbon TakeBack Obligation – requires all suppliers of fossil or bio carbon to demonstrate permanent storage of same tonnage

Extended Producer Responsibility compliance market,
Carbon Storage Unit is profitable
Social license to develop oil & gas

Carbon TakeBack Obligation is an <u>enduring policy</u> option for rapid deep decarbonisation
www.sustainable-markets.org

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Summary
Get on with it

- Geological storage of CO2 works
- World is heating faster than CO2 is stored
- Monitoring, remediation – develop solutions not problems
- No subsidy – create a storage market - CTBO

- **Wide and deep expertise exists in subsurface CO2 injection. Storage licenses are being issued in UK, Europe, USA, Canada**
- **Geological storage needed for CCS, BioEnergy CCS, Direct Air Capture CCS and Greenhouse Gas Recovery**
- **Storage of CO2 deep underground, in city-sized sites. CO2 retained by i) impermeable cap rock ii) dissolving in water iii) isolated mini-bubbles after migration, mineral growth**
- **Low cost conformance monitoring needed after closure. Pressure effects temporarily extend much further than CO2**
- **Geological storage is permanent, Nature storage is not**

CO2 capture & storage is operating, safe, resilient, permanent, and low cost

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END