

CO2 storage risk and liability for CCS



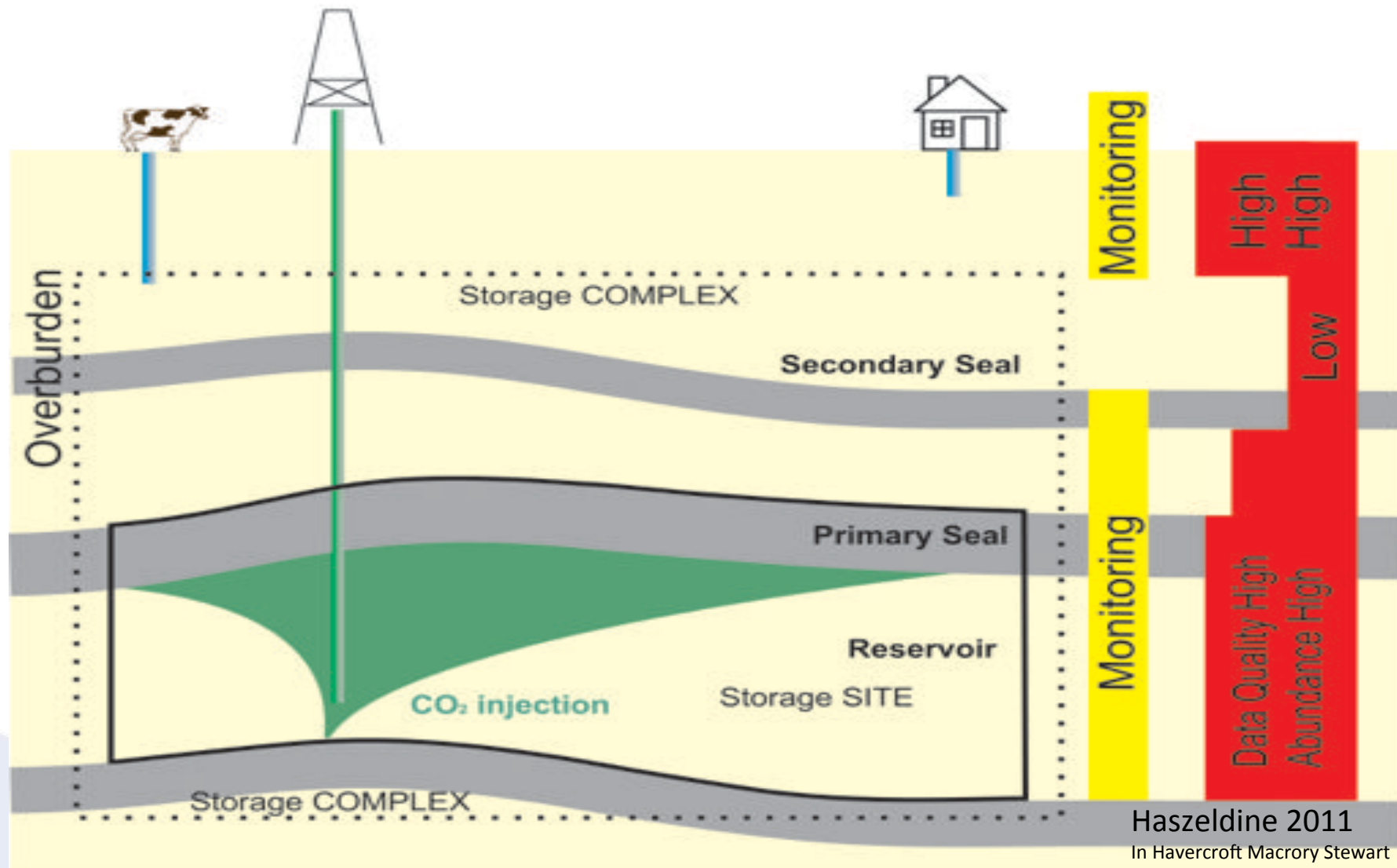
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Paris 20 April 2015

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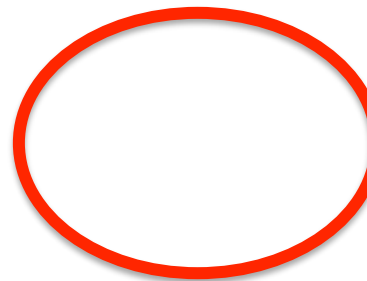
Perception, and conceptual images





Perception:
What does CCS
look like ?

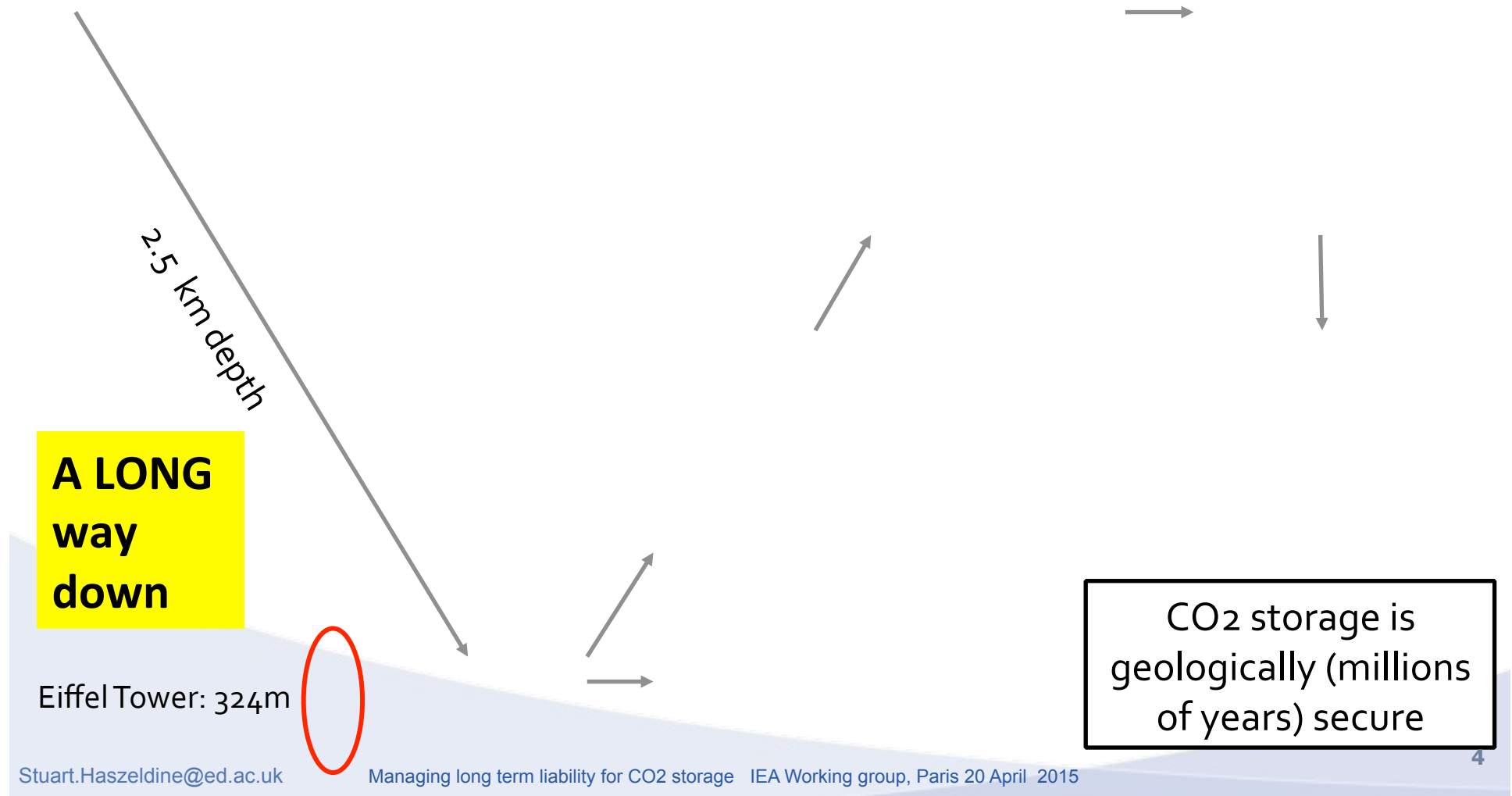
expensive
FINANCE



uncertain
RISK

Cartoon suitable for illustrating the pathways and process. But false proximity = **RISK**

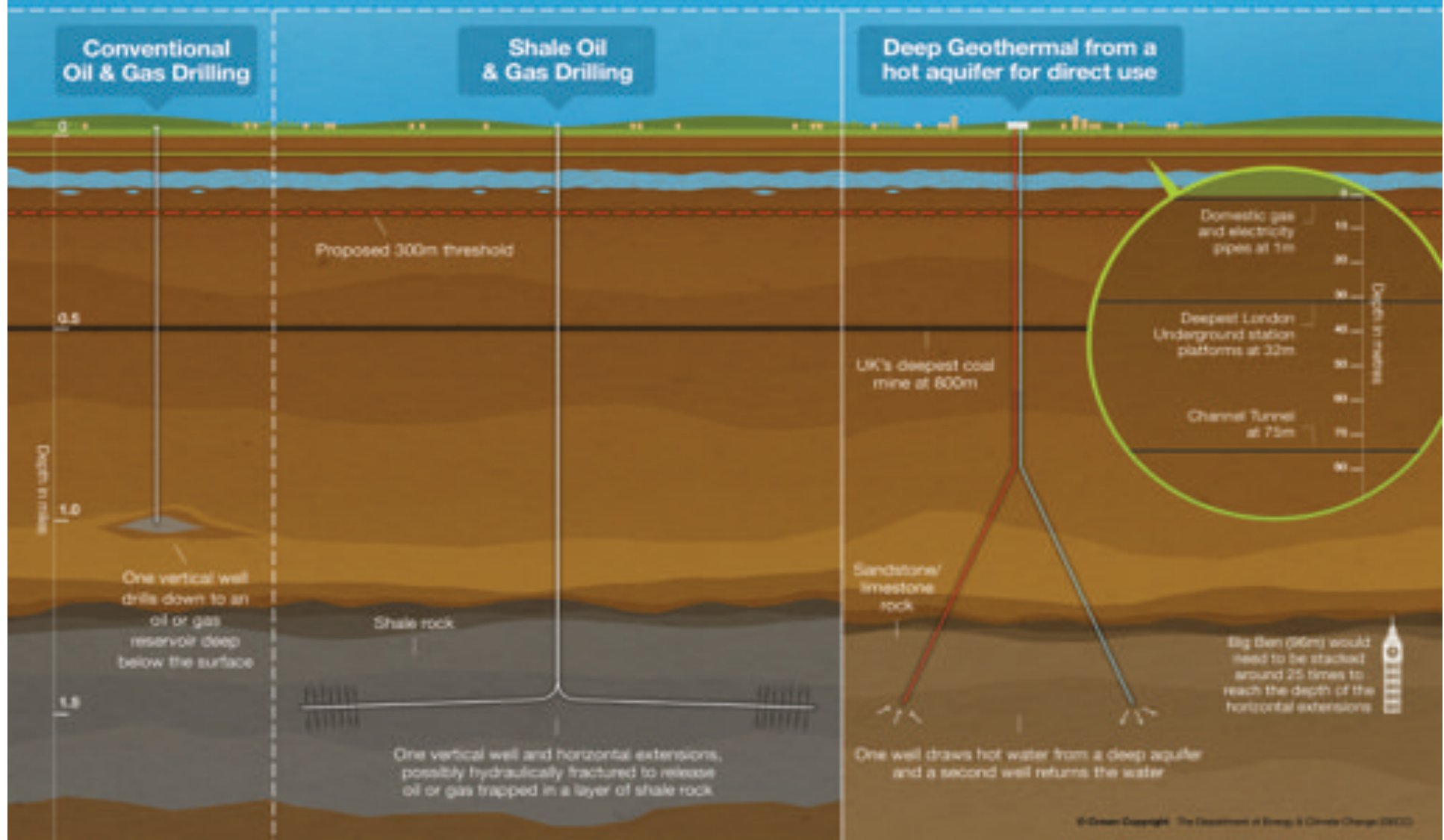
True scale representation: Geological CO₂ storage



Fracking perception

Cartoon suitable for illustrating the pathways and process. But false proximity = **RISK**

What does underground drilling look like?



Government cartoon trying to illustrate **scale = LOW RISK** but clock tower too large ...

Actual data

CCS :

Greatest risk – through boreholes
Operational 1996
Fewer than 20 boreholes pure CCS
One leak In (Salah) – theft of valves

CO2-EOR

Operational 1972
Many thousand boreholes
No reported leaks (?)

CO2 production

Since 1930's
No regulation
Blowouts – Sheep Mountain, Hungary
All closed down simply
Deaths / km pipe 0.3 x hydrocarbon

FRACKING (high volume) :

Greatest risk – through boreholes
Operational 1992
More than 10,000 boreholes USA
100 – 1,000 leaking B/H

Health effects possible

Few enough to need statistical analysis
Huge amplification in media

Poor trust in motives

Poor trust in operational ability
Agreement (USA) by personal payment
Agreement (EU) not achieved

Perception of risk not rooted in numbers, facts make little impact

Shell Peterhead – Goldeneye public engaged

Peterhead :

Extensive dialogue locally

Politicians

Regulators

Interest groups on/off shore

Other businesses

Public(s)

Schools

Slow build of confidence

Listening not just talking

Jobs, jobs, jobs is local +ve

Supply chain & procurement

Confidence in honest operation

Innovation, global quality

Ability to manage the unexpected

A realistic image scale, which enables publics to understand the size, and teases to discover more

By national advertisement, both developer and Government become committed

How to work CCS injection

Example of risk profile

www.Wri.com

Most risk early during operations = oil & gas; State takeover > 3x injection
problem is to fund, determine and guarantee payment 1x - 3x injection

Perception

**A secure and
safe design
With many
observation
sensors**



**Needs skilled
people and
systems to
operate**

**And accidents still
occur**

Induced fractures : In Salah Algeria

**InSar & seismic
detected
anomaly
Closed down**

Snøhvit observation of pressure buildup



**CO2 injection into channel sands below gas reservoir → range of possibility predicted
Pressure rising after 3 months. Borehole treatment. Still rising to limit at 36 months.**

Snohvit : driving properly with Plan B properly

**Plan A fault
compartment : go to
larger Plan B**

Sto

Site and Complex

At Goldeneye storage for Peterhead, to Site is a depleted gas field 3km below sealevel. This is extremely well understood from Shell's operational history of gas extraction

The reservoir (in the Site) will be under-filled

There are 3 rock seals between reservoir and seabed. And a 1,000m thick chalk aquifer, to dissolve and disperse CO₂. These will retain CO₂ within the Complex.

And seabed sediment, to dissolve CO₂

ALL scenarios of leakage have been considered, with mitigation plans.

Chance of leakage - minimal

North Sea storage: SCCS reports 2009, 2011, 2015

Captain Sandstone Aquifer

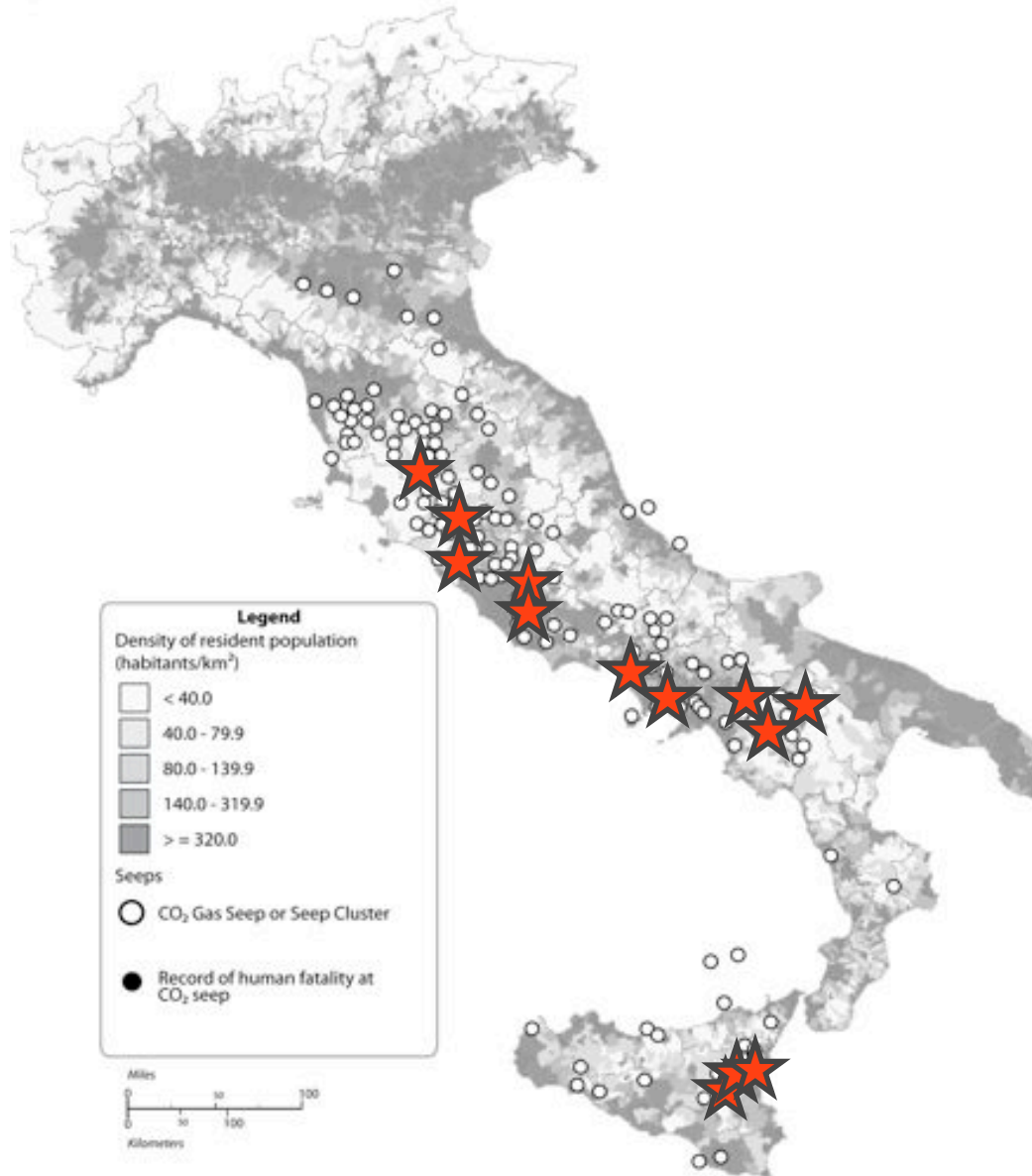
Aquifer mapping, injections
flow simulations, Seabed
siting, costs, jobs

**Identified best regions and
timelines for work**

How significant is
un-anticipated performance, or a leak ?

Cartoon suitable for illustrating the pathways and process. But false proximity = **RISK**

Analogues: Mortality at Italian CO₂ Seeps



★ = human fatality

19 deaths in
50 years.

13 seeps

11 deaths in 20 years
≡ “full” record

If no death year recorded -
assumed > 20 yrs.

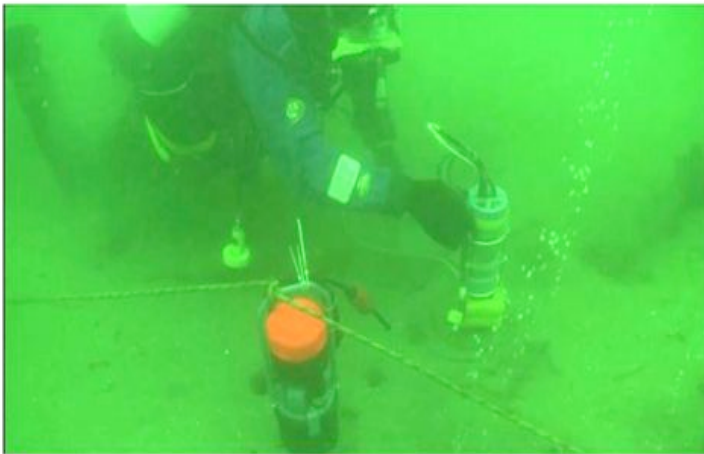
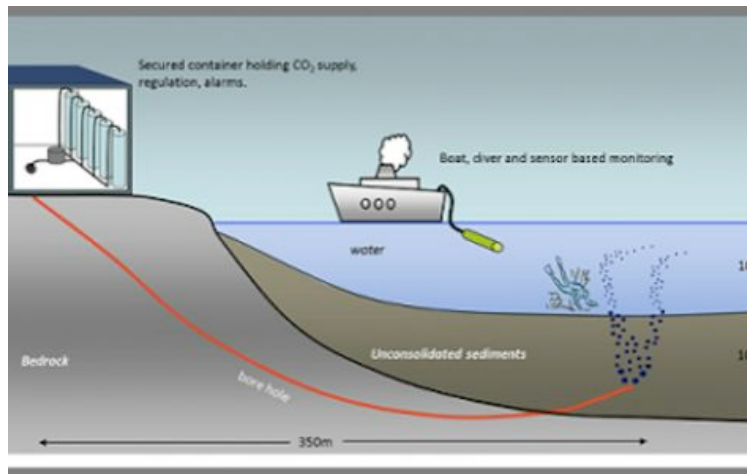
Risk of fatality 2.8×10^{-8}

1: 36,000,000

Roberts Wood Haszeldine PNAS 2011

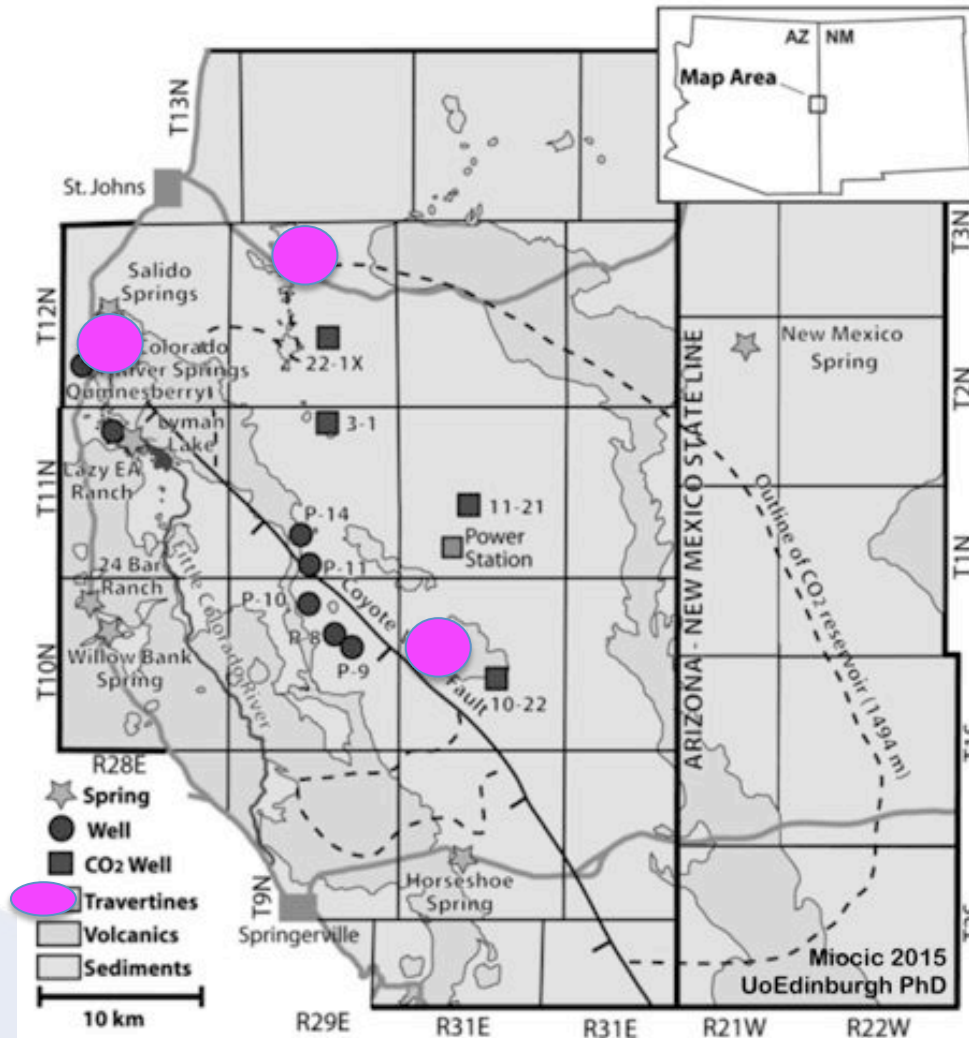
Seabed fractures: QICS in Sco2tland

Blackford 2014 Nature GeoScience



QICS, 4.2 t CO₂ injected into seabed, focused plume fracture flow, and 85% CO₂ retained

Arizona natural structure trap : St Johns



Gilfillan UoE

Age dates of surface travertine 390-50 kyr. ie
>400ky to become empty for 1,000Mt CO2 **SLOW**

Leaks at crest, tip, GWC
Noble gas traces surface to source

Release of CO₂ : Blowout of gas, not liquid



Blowout of CO₂ well 1083m depth Becej Serbia 1969 (near depth of gas/fluid phase change)

Blowout
Nov 1968 to June 1969.
Self-killing by collapse at 300-850m depth

30 shallow monitoring holes

Several 10x more CO₂ released from reservoir, than arrived at surface.
Dissolved into groundwater

Seepage of CO₂ gas continued into the shallower aquifers above the CO₂ reservoir

**Large uncontrolled emission of CO₂.
No deaths. No damage to property.
Monitored, but fixed itself**

Mirecol FP7 2015
Mark Wilkinson UoE

Where does the CO₂ go?

CO₂ fills microscopic pores in sandstone

**4 x trapping mechanisms:
physical, soluble, residual, mineral**

Can injected aquifer CO2 be released ?

Recent Laboratory measures

(Andrew
Bijeljic, Blunt
Int J GHG C
2014)

Carbonates

13 -20%

Sandstones

32 %

CT scan of core shows
residual CO2 in porosity

Compilation of experimental data modes. 61% up to 95% CO2 retained

Summary

- 1) Communication of CO2 geological burial/storage/disposal to publics, and anybody, needs careful content. Cartoon diagrams may mis-inform as well as inform. Facts are not easy to imagine. Images are better
- 2) CCS and Fracking (and any underground operation) are easily confused
- 3) Risk is highest during injection operations. Pressure management is usually balanced against rate of injection. Examples of site management during injection show that hydrocarbon techniques and technology successfully works to enable remediation
- 4) Even if leakage occurs outside the site, and even outside the complex, surface and seabed impacts are minimal. Even at a gas blowout, only small surface damage caused.
- 5) Physics of CO2 residual saturation, dissolution, and dispersion, means that it is **very difficult to remove injected CO2 from the sub-surface**. Leak impacts will be tiny. **Most CO2 will dissolve in the subsurface**. Legal requirements for post closure observation, and cleanup should be based on calculated, not imagined, impacts.

The public impact of risks seems to be very small, needs better quantification