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What geological CO_2 storage quality is required?

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Motivation for study

- CO_2 capture and geological storage (CCS) may become one of a few major technologies to mitigate greenhouse gas emissions. (Transition phase to carbon-free technologies.)
- Not one but many measures and technologies required to meet stringent climate policy targets
- Background for developing rules for storage site selection and “good management”, and possibly to determine the “optimal” level of storage
- Quality important for public trust

Objective

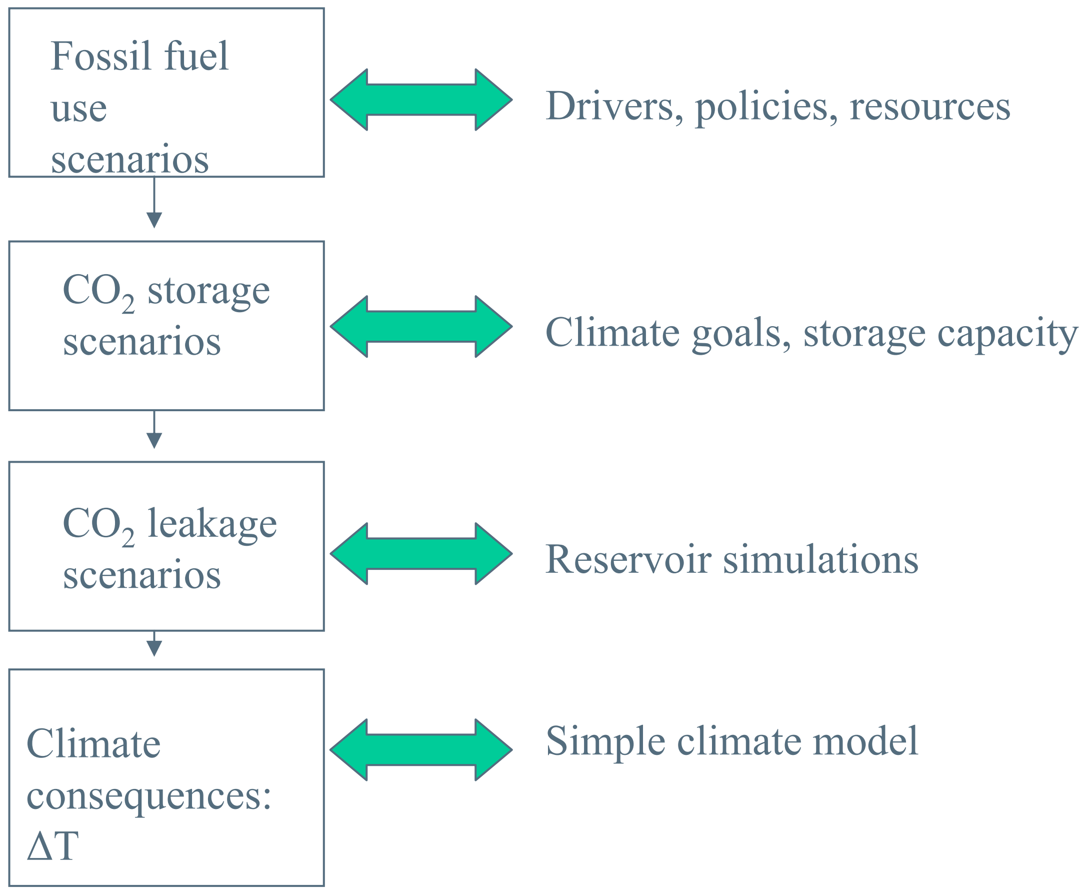
- Explore quality requirements of large scale geological storage of CO_2
- Quality defined as retention time of stored CO_2 (average storage time)
- Must be consistent with defined climate policy targets – maximum warming by year 2100:
  * 2 °C (EU and Norway)
  * 2.5°C
  * 3 °C

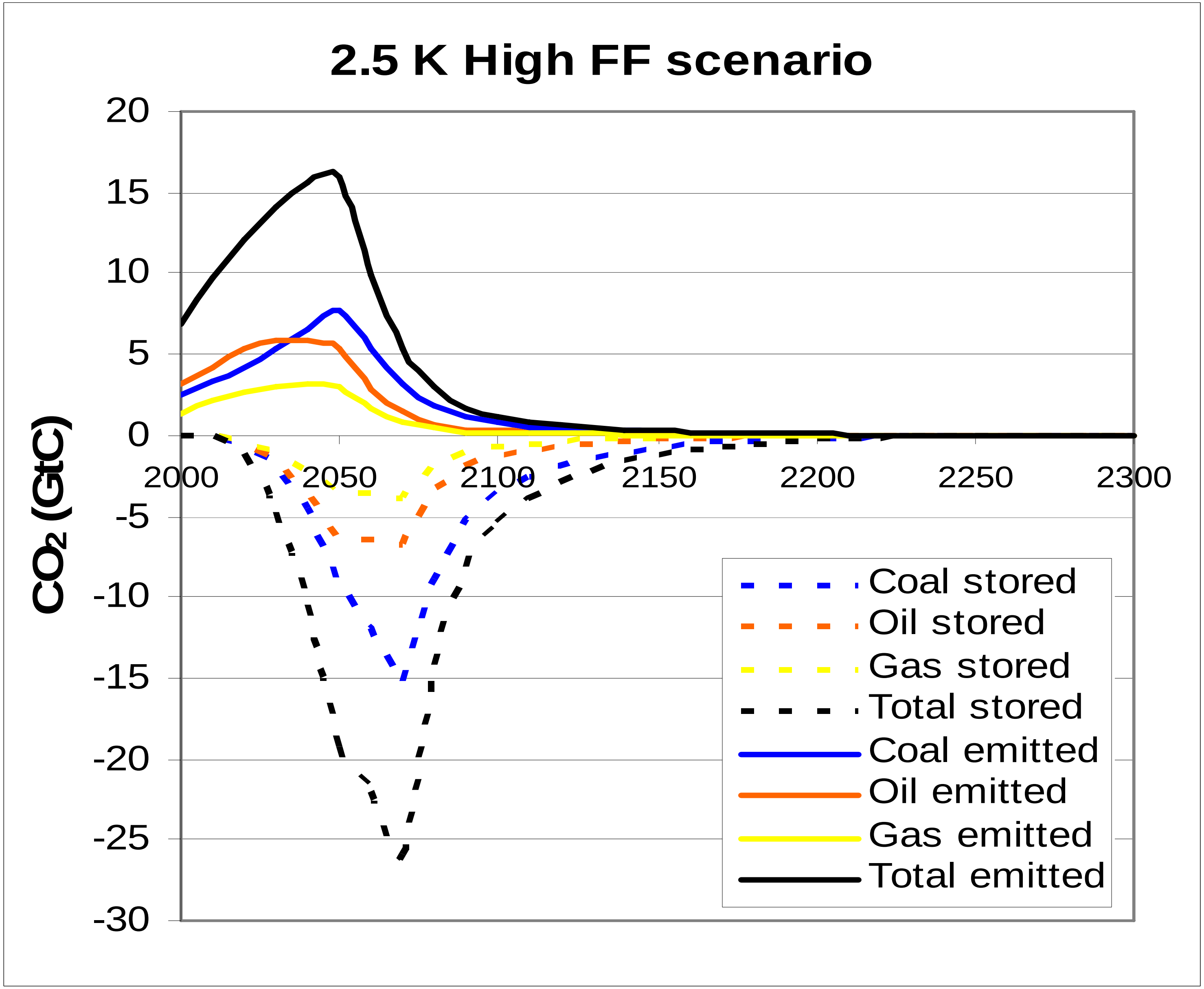
Research question: Is CCS a good global warming mitigation measure? – What storage quality is required?

- We make no assumptions about any specific regulatory frameworks for site selection and management in these calculations

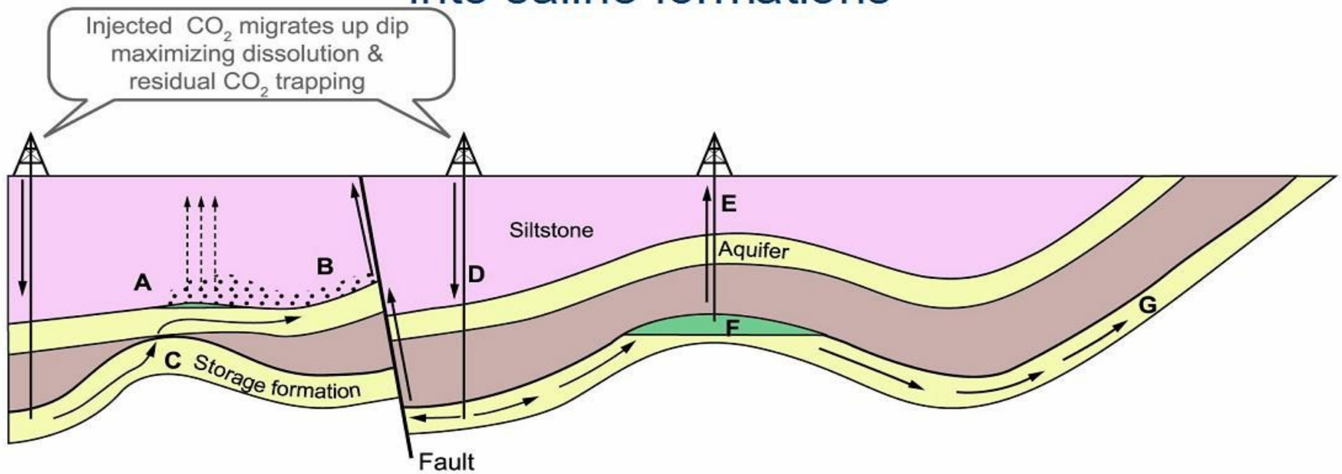
Required quality of geological CO_2 storage:

Experimental set up




2.5 K High FF scenario
CO2 (GtC)
20
15
10
5
0
-5
-10
-15
-20
-25
-30
2000
2050
2100
2150
2200
2250
2300
Coal stored
Oil stored
Gas stored
Total stored
Coal emitted
Oil emitted
Gas emitted
Total emitted

Potential leakage routes and remediation techniques for CO2 injected into saline formations



Potential Escape Mechanisms

A. CO_2 gas pressure exceeds capillary pressure & passes through siltstone	**B.** Free CO_2 leaks from A into upper aquifer up fault	**C.** CO_2 escapes through 'gap' in cap rock into higher aquifer	**D.** Injected CO_2 migrates up dip, increases reservoir pressure & permeability of fault	**E.** CO_2 escapes via poorly plugged old abandoned well	**F.** Natural flow dissolves CO_2 at CO_2 / water interface & transports it out of closure	**G.** Dissolved CO_2 escapes to atmosphere or ocean

Remedial Measures

***A.** Extract & purify ground-water*	***B.** Extract & purify ground-water*	***C.** Remove CO_2 & reinject elsewhere*	***D.** Lower injection rates or pressures*	***E.** Re-plug well with cement*	***F.** Intercept & reinject CO_2*	***G.** Intercept & reinject CO_2*

SRCCS Figure TS-8

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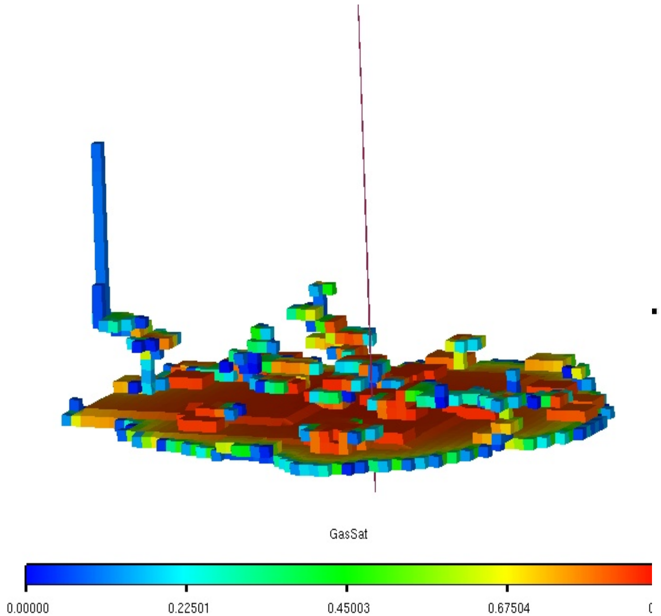
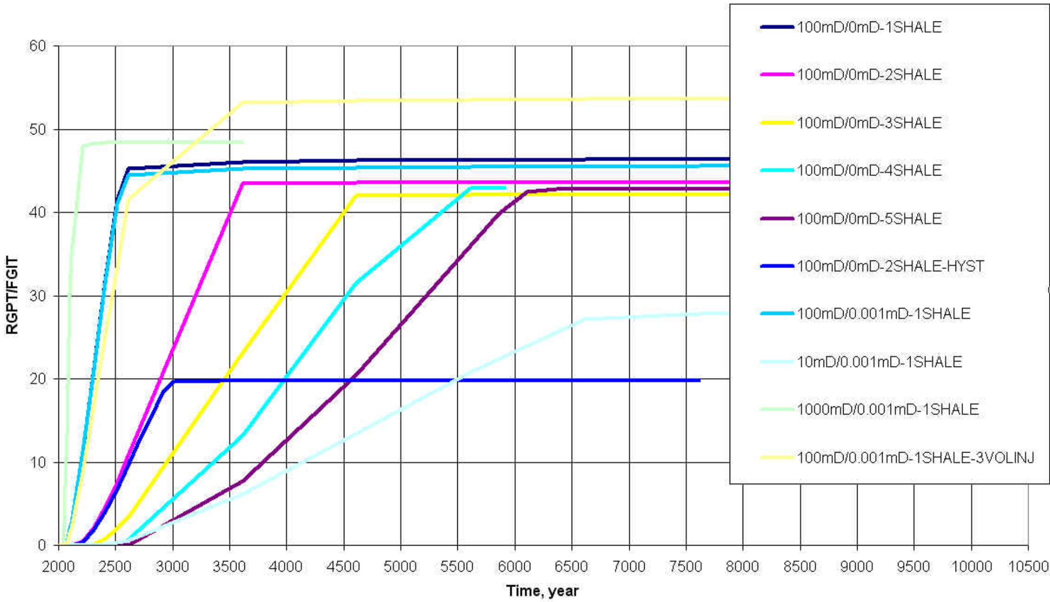
Leakage scenarios for saline formations (aquifers)

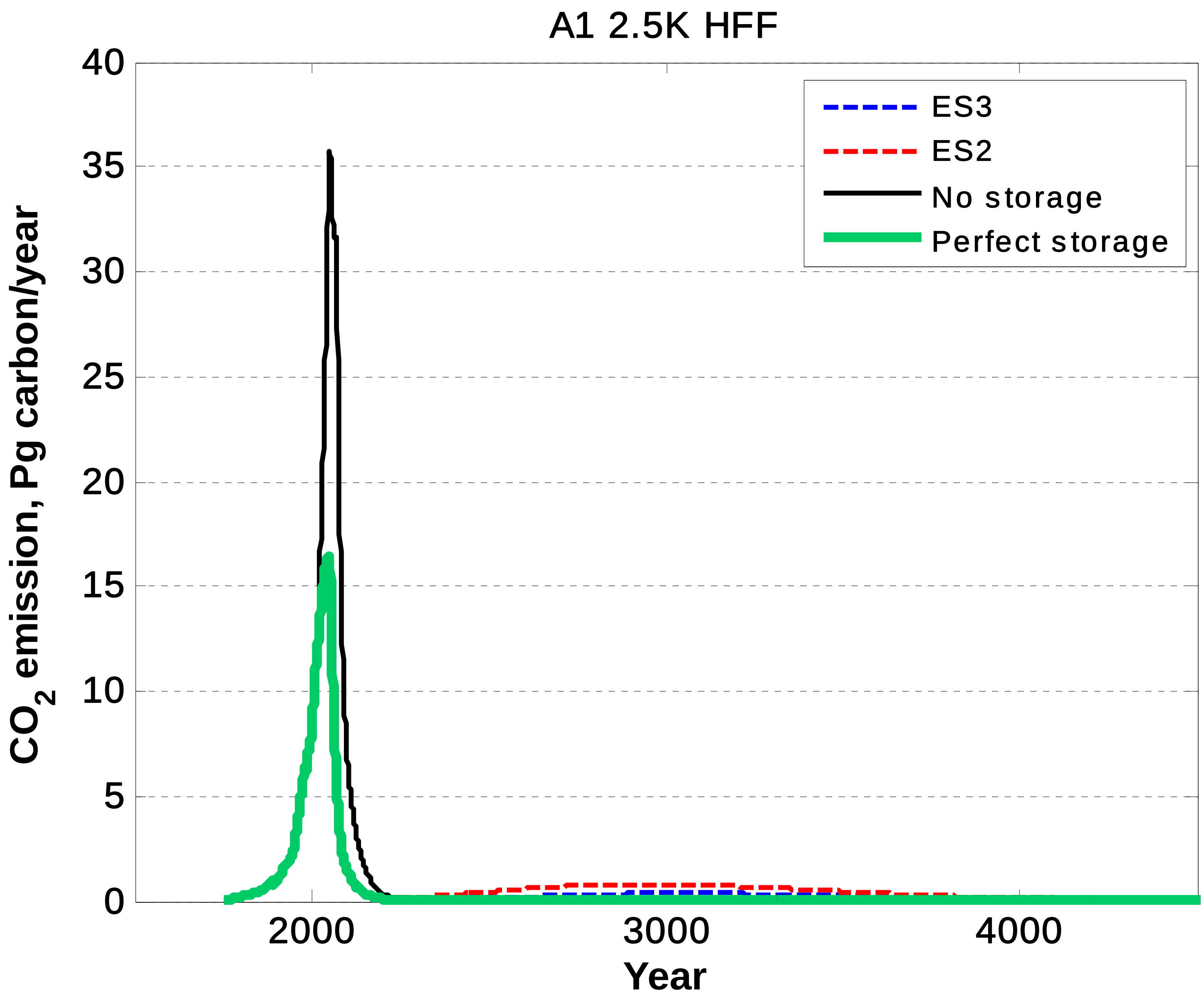
- Long-term reservoir simulations
- Injection into reservoirs of variable quality
- Leakage through fractures
- Percolation through a network of conducting sand bodies embedded in non-conducting shale
- A combination of the two above
- Several combinations of rock permeability, stored volume of CO_2, etc.

Leakage through a percolation network

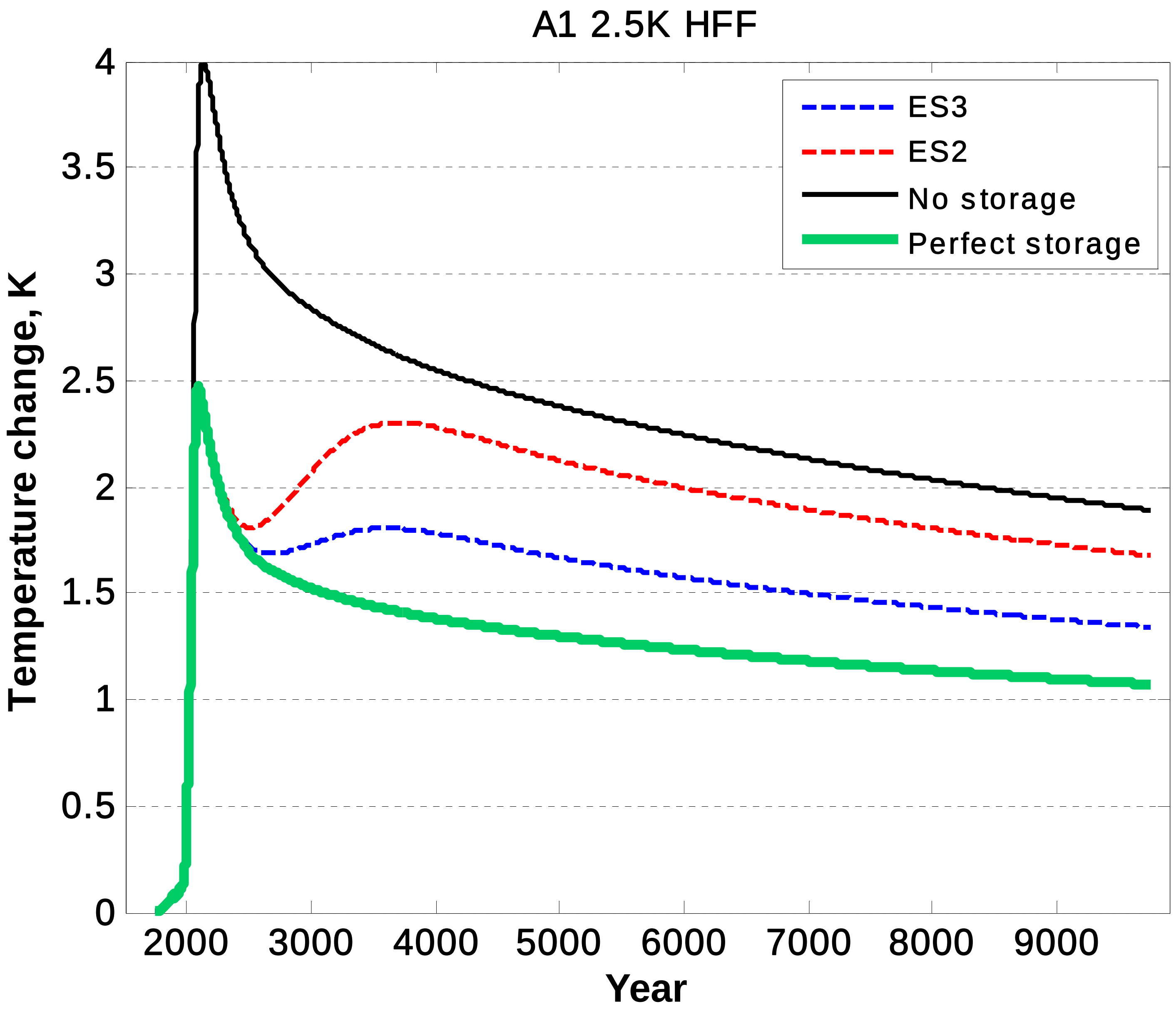
Even if the conducting network of sand bodies eventually allows the CO_2 to escape to the surface (right) the retention allows a lot of the CO_2 to dissolve while some CO_2 is permanently trapped as free gas (escape curves right).







A1 2.5K HFF
40
35
30
25
20
15
10
5
0
CO_2 emission, Pg carbon/year
2000
3000
4000
Year
ES3
ES2
No storage
Perfect storage


A1 2.5K HFF
ES3
ES2
No storage
Perfect storage
Temperature change, K
0
0.5
1
1.5
2
2.5
3
3.5
4
2000
3000
4000
5000
6000
7000
8000
9000
Year

Preliminary findings

Large-scale geological storage of CO_2 can have a significant mitigating effect on man-made global warming, even when storage is not permanent

A relative strict climate target, for example, is feasible with high fossil fuel use if balanced with a high storage rate

In case of a high level of storage, long-term leakage from sites can be non-marginal and lead to a temperature increase over a couple of millennia

- Into the future there can be efficient ways of handling long-term leakage, such as biomass in combination with CCS
- Leakages can to some extent be controlled by good site selection and management, but the former may become more difficult with a very high level of storage