Underground CO_2 Storage with Water Production

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Outline

- General issues related to CO_2 storage with water production
- Example simulations
- Conclusions

Present status of CO_2 storage with water production

- The option of and the implications of water production is deserves more attention
- Not mentioned in EU directive
- Not yet widely considered as possible integral part of the CCS value chain
- However, a number of publications on the topic the last years

Underground storage of CO_2
Basic issues

- **Capacity, ”sufficient *space*”**
- **Injectivity, ”*getting it in*”**
- **Trapping, ”*keeping it there*”**
- **Monitoring and remediation, ”*watching what happens and fixing irregularities*”**

Water production relates to all these issues

Why?

- **Capacity**:

  At same average aquifer pressure increase, additional reservoir volume stored CO_2 equals volume brine extracted.

- **Injectivity**:

  Aquifer pressure relief by water production increases injectivity for given tubing head pressure.

- **Trapping**:

  Less pressure build up, less risk for leakage through faults, fractures, and wells.

- **Monitoring and remediation**:

  Production wells are also monitoring wells. Leaks: More possibilities for redirection of fluids and capillary trapping

When not to produce water

- Sufficiently large permeable aquifer with no neighbour projects competing for pore space, and with no risk for affecting neighbouring groundwater resources,
- There exists other cheaper natural supply of water.
- Difficult to handle produced water (salinity, toxic brine solvents)

Water as a resource

- Thermoelectric power generation need cooling
- Capture, in particular plants retrofitted for capture, needs significant additional cooling
- In arid areas; desalination of produced water for irrigation, drinking water (desalination of sea water <1$ per m^3).
- Water for industrial processes
- Reduced risk for storage project, improved public acceptance and improved business opportunities

Why CCS in arid areas?

- Indeed, no use for capture if no qualified storage site exists

- Build power plant and capture facillities at storage site?

  - *Less need for pipelines from capture to storage site*
  - *Job opportunities at storage site means improved local public acceptance!*

Water production can be a necessary integrated part of the CCS process. Need for reliable water production and handling.

CCS value chain and risk

- Petrophysical properties vary widely from aquifer to aquifer, and certainly the **storage performance** is by far the **largest uncertainty** in the CCS value chain.

- The option, or possibility of water production to reduce risk could be important for the decision to go ahead or not for a CCS project.

- Including water production in a CCS project could possibly also impact future liability issues in case of leakage.

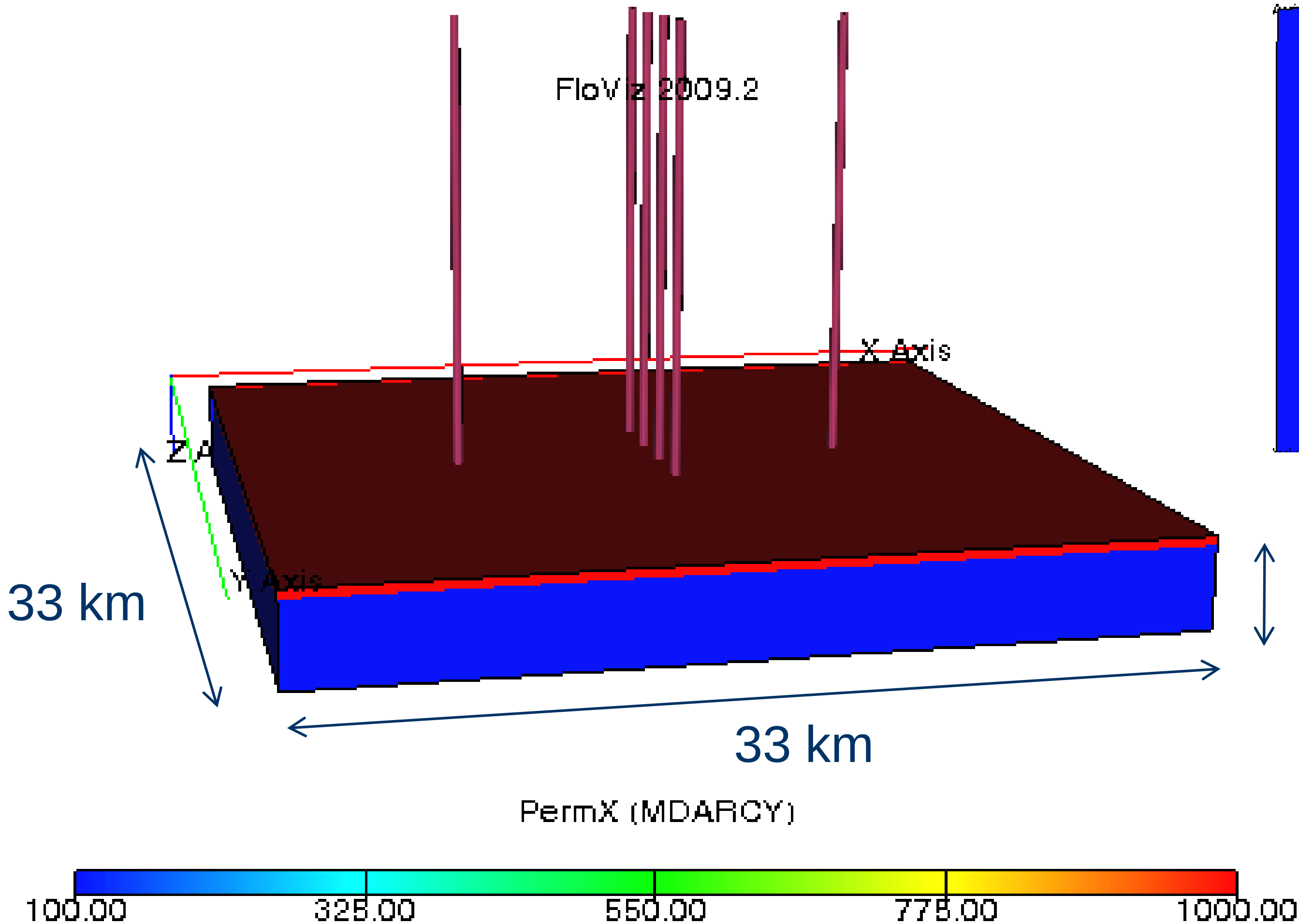
- The option of future water production is considerably more flexible onshore than offshore.

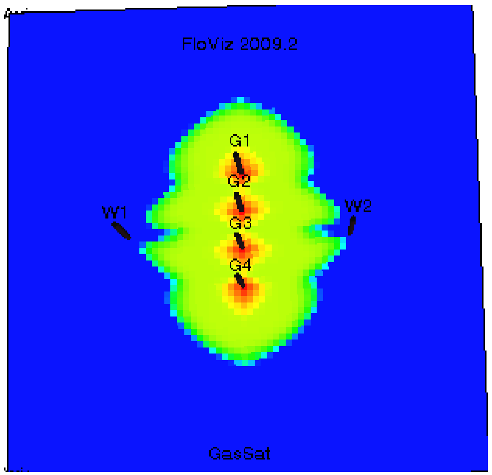
- Very large uncertainties related to optimal water production strategy, gas brakthrough, pressure communication, wait and see…?

Simple example

- 800MW coal power plant with CCS, storing approximately 6Mt/y for 30 years.
- Underground storage unit with no flow boundary conditions
- Size of storage unit chosen to ”critical size”
- Storage unit has a high permeable top layer below the cap rock.
- Maximal injection pressure set to 73% of lithostatic pressure
- Maximal water handling capacity 4Mm^3/y
- 4 central vertical injectors, two flanked water producers

Storage compartment, ”critical size” for a 800MW coal power plant with capture

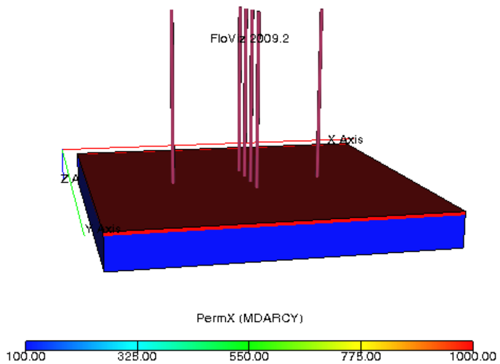




Aquifer properties

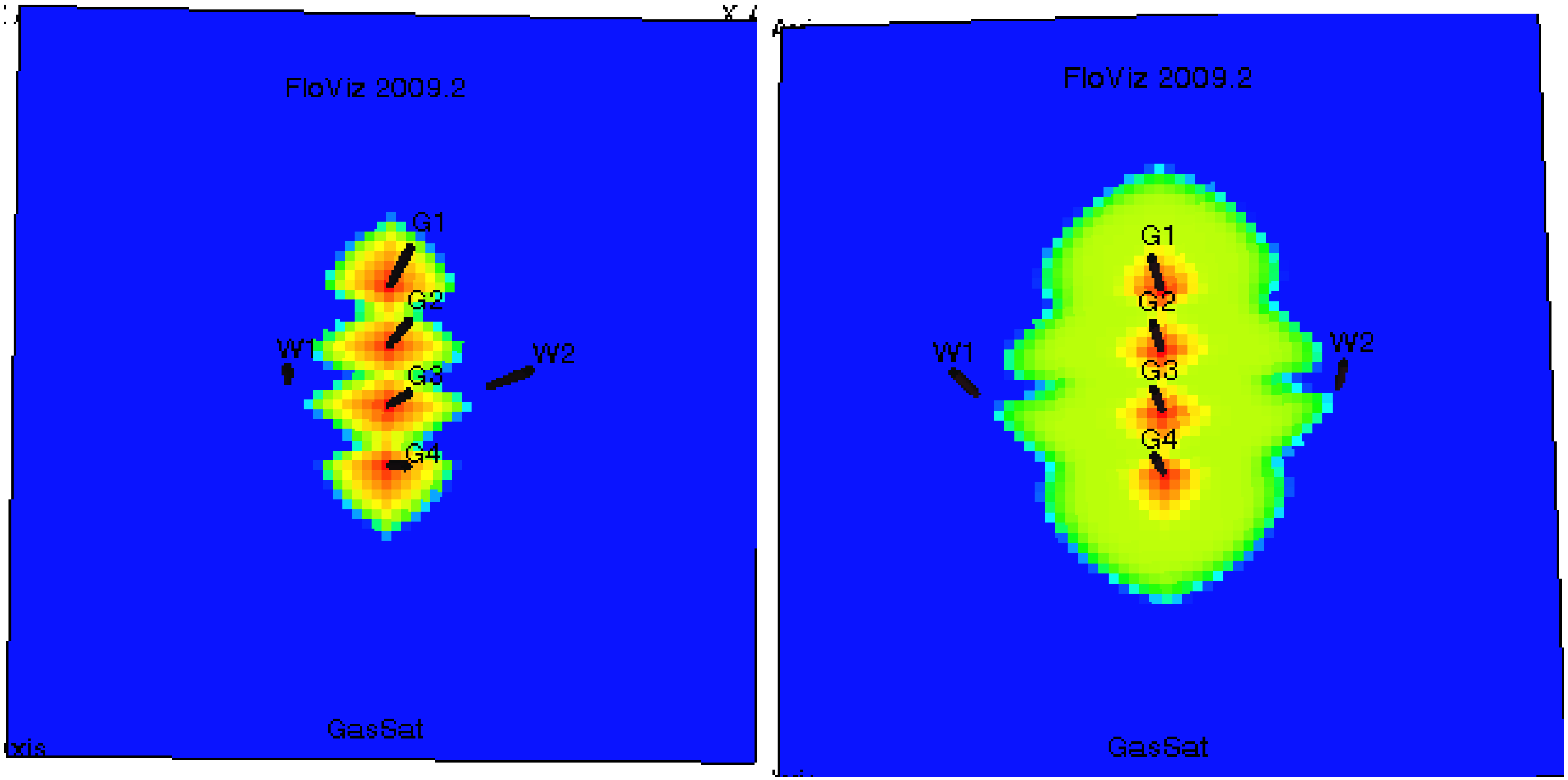
- Depth to aquifer: 1100m
- Compartment: 33km x 33 km x 100m
- Porosity: 0.2
- Thief zone: 10 m thick layer at top, 1000mD
- Below, 90m of aquifer, 100mD
- Total compressibility: cT = 1e-4 1/bar
- Initial aquifer pressure: 110 Bar
- 80% of lithostatic pressure: 220 Bars
- No-flow boundary conditions
- Eclipse grid blocks 440m x 440m x 10m (75x75x10)

Well properties

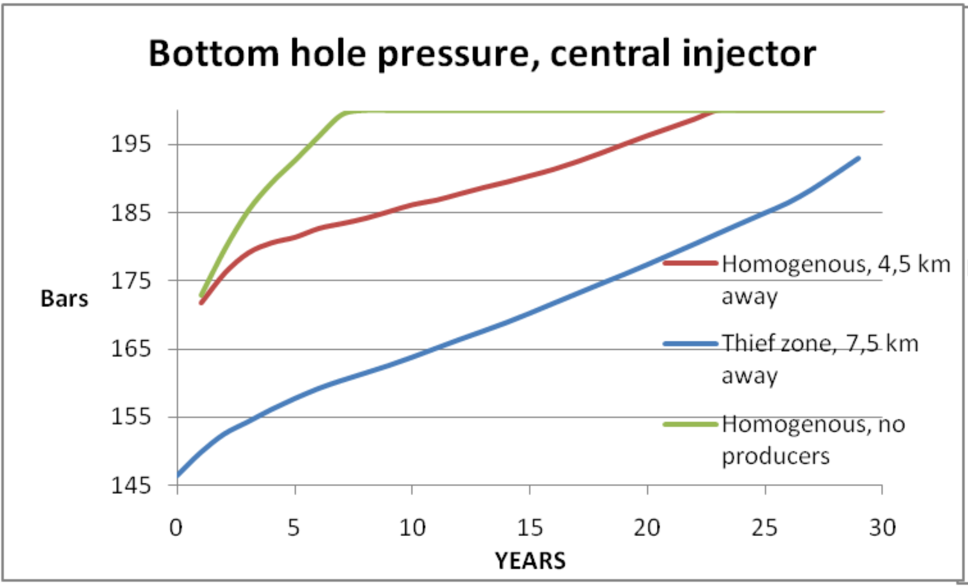


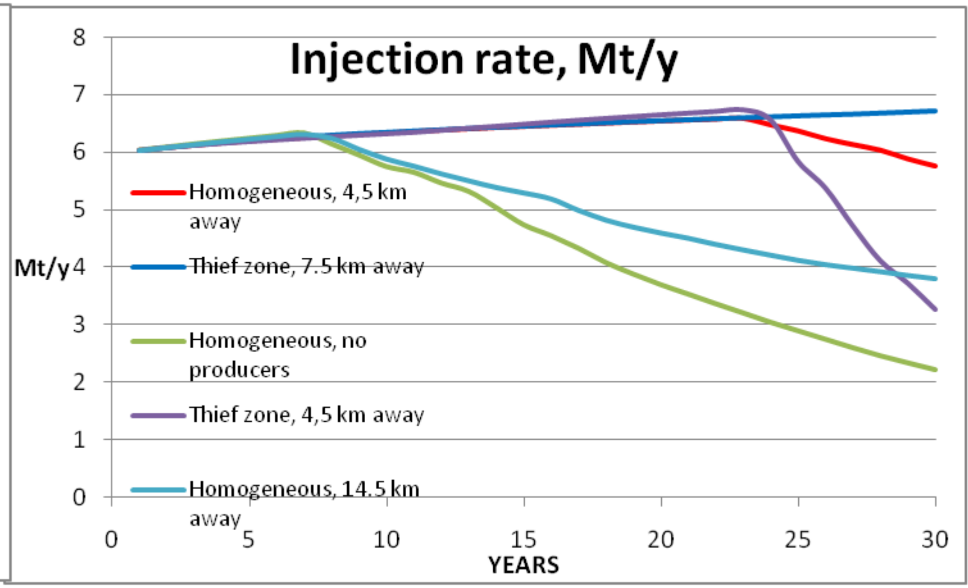
- 4 central vertical injectors.
- 2 vertical producers, distance to injectors vary from 4.5km to 14.5km.
- Well radius 0.05m, perforated in whole interval.
- Injectors controlled by rate, each 1.5Mt/y.
- Maximum bottom hole pressure 200Bars.
- Water producers controlled by bottom hole pressure, but with rate constraint.
- Water producer shuts in at gas breakthrough
- Well stream 20°C, pBH = 145 Bars ⟹ pTH = 55 Bars,
  pBH = 200 Bars ⟹ pTH = 95 Bars

Gas saturation, 30 years, for optimal injector to producer well spacing Homgeneous vrs. Thief zone



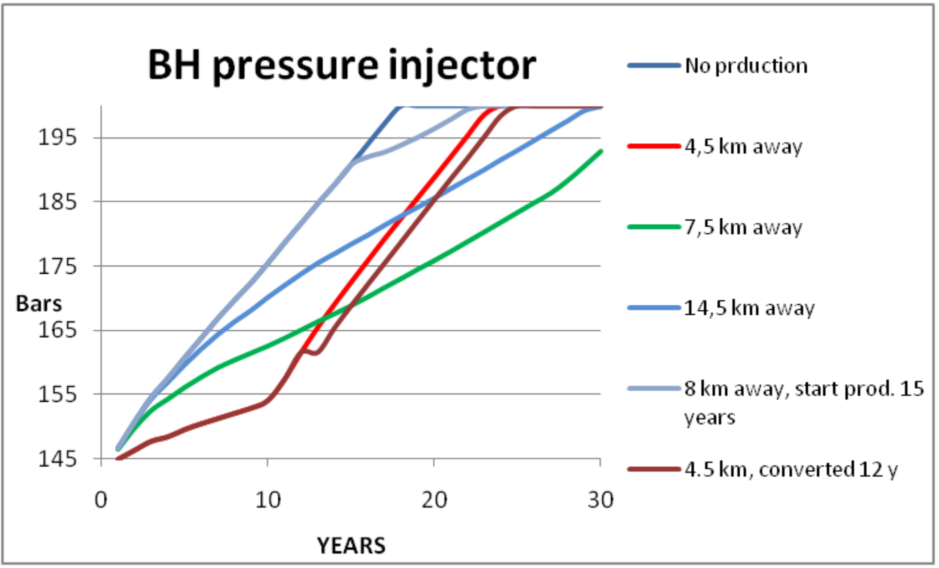
Homogeneous versus thief zone

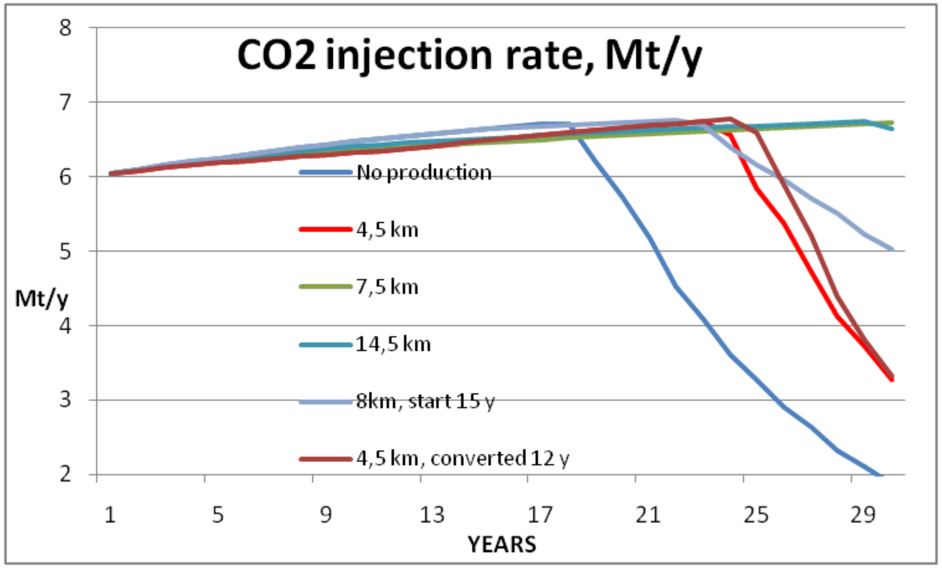




- 4.5km optimal for homogenous, 7.5 km optimal for thief zone
- Closing of water producers more critical than low permeability for injection rate
- Producers should not be placed too far away

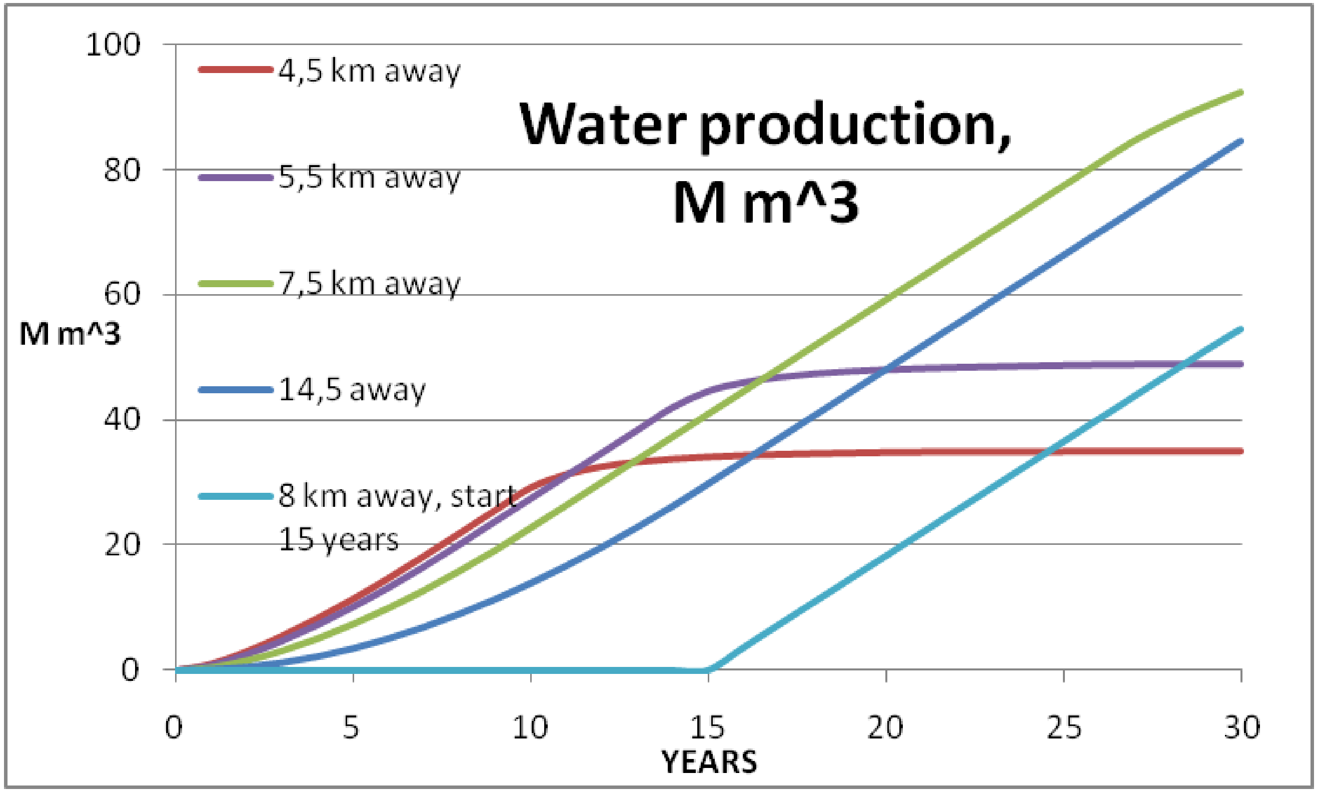
Bottom hole pressure and injection rate, thief zone model





- Storage unit too small without water production
- Gas breakthrough can be a problem
- Distant water producers can be fine for capacity, not so much for injectivity
- Delayed water production requirers more production wells
- Conversion of production wells marginally effective

Thief zone, total water produced



- Water production volume is of order 50% of subsurface injected CO_2 when water is produced throughout the whole project
- Limit water production rate by placing producers further away, tradeoff

Conclusions

- Water production as a possible integral part of the CCS value chain derserves attention
- Water production as risk reducer can be important for business decisions
- Produced water can be a resource
- Water production relates to numerous CCS issues
- A water producer is also an observation well
- Improved flexibility in pressure/injection management

- And finally… it's good news for streamline simulation!