

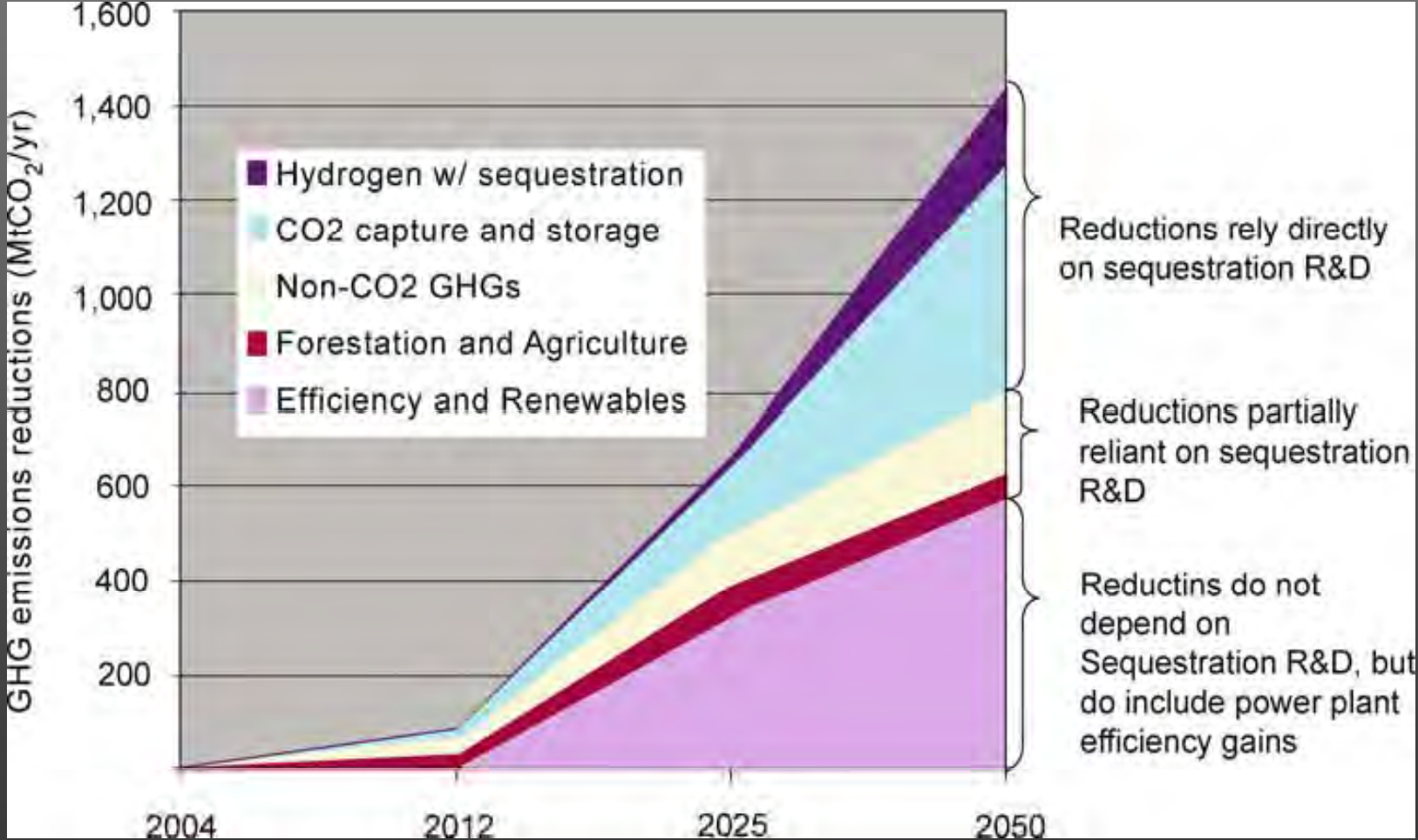
Possible Impacts of Carbon Sequestration and Storage Enhancement Techniques on Ground Water Resources

2009 GWPC Water/Energy Sustainability Symposium

D.L. 'West' Marrin
Water Sciences & Insights
www.watersciences.org

Contribution to GHG Emission Reductions

from J. Lityanski et al., 2006 *Climate Change*

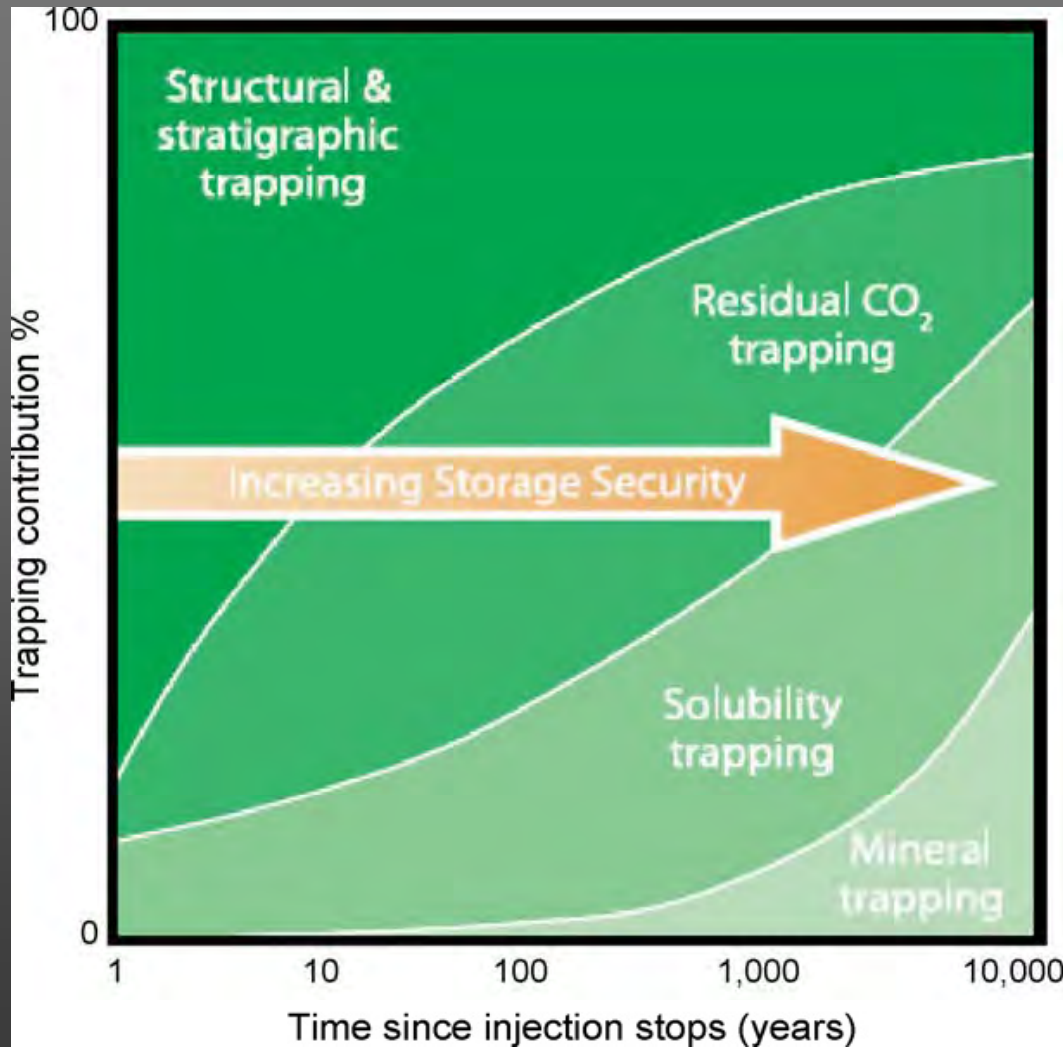


Carbon Capture Technologies



- ✓ Sorbents on stacks of oil- or coal-burning power plants uptake other gases (H_2S , NO_x , SO_x)
- ✓ Reduced efficiency in electricity production and use of fossil fuels to collect and handle CO_2
- ✓ Solvents, membranes, cryogenics, enzymes, and combustion to improve or eliminate capture
- ✓ Transfer to ocean basins, saline aquifers, or abandoned petroleum reservoirs

Processes Contributing to Sequestration



from IPCC Report, 2005

How much CO₂ reaches shallow soil horizons or the atmosphere?

Little CO₂ will ever undergo mineral trapping

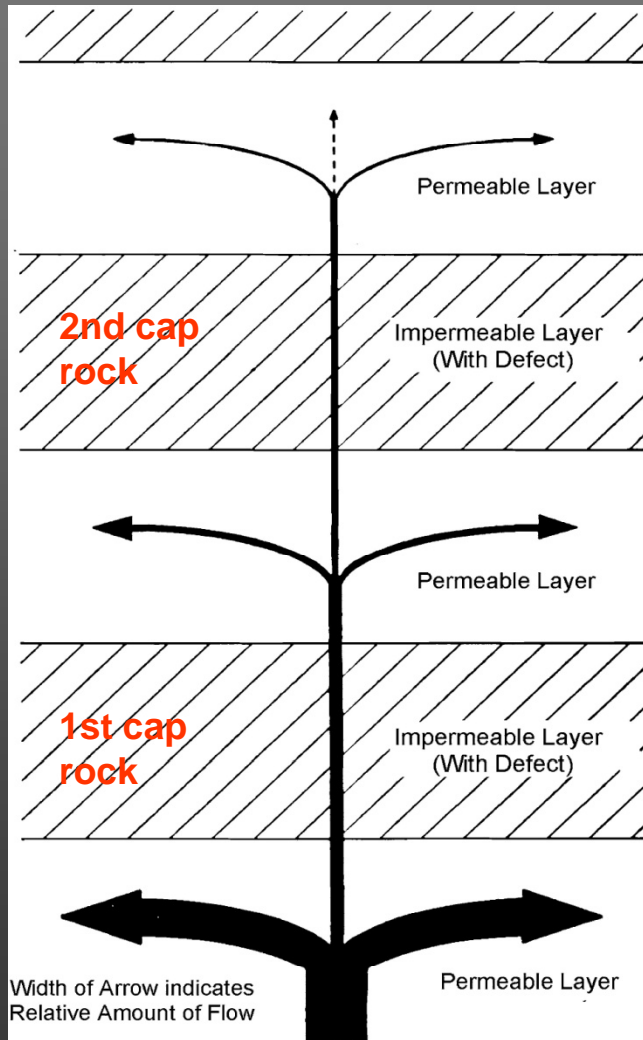
Structural Trapping

(rapid physical/chemical)



- ✓ CO₂ can move through joints, faults, well casings, and higher permeability zones in heterogeneous cap rocks
- ✓ Injection causes media deformation (fractures near well) and pressure effects up to 100 km (forcing brine solutions out of formation)
- ✓ Buoyancy effects will drive CO₂ upward toward either ground surface or shallow potable aquifers
- ✓ Increased CO₂ alters pH and carbonate equilibrium leading to dissolution of metals (adsorbed/mineral), Cl, and SO₄

CO₂ Leakage into Overlying Strata



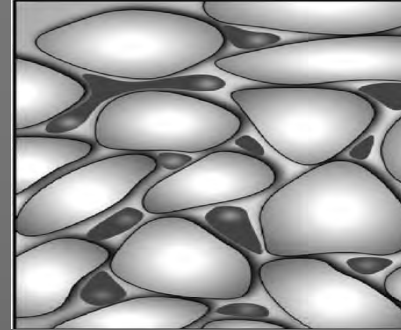
from C. Miller et al., 1986 *Ground Water Monitoring Review*

Poorly constructed water or petroleum wells serve as major CO₂ conduits, as do abandoned borings

Small fractures or heterogeneities in first cap rock are subject to injection stresses, gas pressures, and CO₂-induced dehydration of clays

Gas Trapping and Dissolution

(moderate physical)



- ✓ Interfacial tension between water and CO₂ limits migration of gas or supercritical fluid (multi-phase flow)
- ✓ Usually occurs only after injection has ceased and leading edge of CO₂ plume has passed (hysteresis effect)
- ✓ Water dissolution limited by salinity (2%-7%), pressure, temperature, and surface contact area
- ✓ CO₂ is more soluble in organic phases (oil and coal) and displaces CH₄—a potent GHG and redox determinant

Mineral Trapping

(very slow chemical)



- ✓ Initial pH drop results in mineral dissolution from calcite and iron hydroxides, as well as corrosion of steel casings and solubilization of organics (DOC and HCs)
- ✓ Following injection there is a gradual return to previous levels of Fe, Mn, Zn, Pb, Ca, HCO_3 and pH
- ✓ Estimating bicarbonate buffering is essential to rock-water interactions responsible for sequestration
- ✓ Eventually, CO_2 reacts with silicate minerals to create several types of carbonate rocks (millennial timescales)

Approximate Global Storage Capacities for Carbon Dioxide Emissions

| | Depleted Petroleum Reservoirs | Deep Saline Aquifers | Unmined Coal Seams | Forestation/ Agricultural Soils |
|--|-------------------------------|----------------------|--------------------|------------------------------------|
| Global Capacity (gigatons) | 920 | 400-10,000 | <250 | Scenario dependent |
| Emissions to 2050 (% of total) | 45 | 20-500 | <12 | Short-term solution |

From IEA Greenhouse Gas Reports, 1998-2001

Monoculture Tree Plantations



- ✓ Encourages the cutting of virgin forests and is a detriment to local economies, land uses, and forest biodiversity
- ✓ Contributes to lowering of shallow water tables, as well as salination and acidification of soil pore water
- ✓ Increases vulnerability of both plantation and native trees to disease, parasites, fire, and increased erosion
- ✓ Reduces surface flows and water quality (TDS/DOC) for downstream users—essentially swaps carbon credits for water resources

Agricultural Soil Practices



- ✓ Agricultural soils contribute about 7% of GHG emissions and store carbon for about 20-40 years
- ✓ Encourages use of nitrogen or manure fertilizers and herbicides that impact shallow groundwater tables
- ✓ Limited tillage, permanent cover, and mulch retention reduces erosion and influences infiltration (SOC vs. DOC)
- ✓ Selecting for soil organisms, wastewater irrigation, and use of "biochar" have competing effects on water quality

Carbon Storage and Water Resources

- Field trials have yielded results not predicted by modeling (e.g., mobilization of organics and higher vertical permeabilities).
- Only a fraction of CO₂ is fully sequestered—is it enough to reverse climate effects on the global water cycle?
- Are the water resource threats posed by these technologies worth the variable gains in carbon storage? And over what timescales?