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

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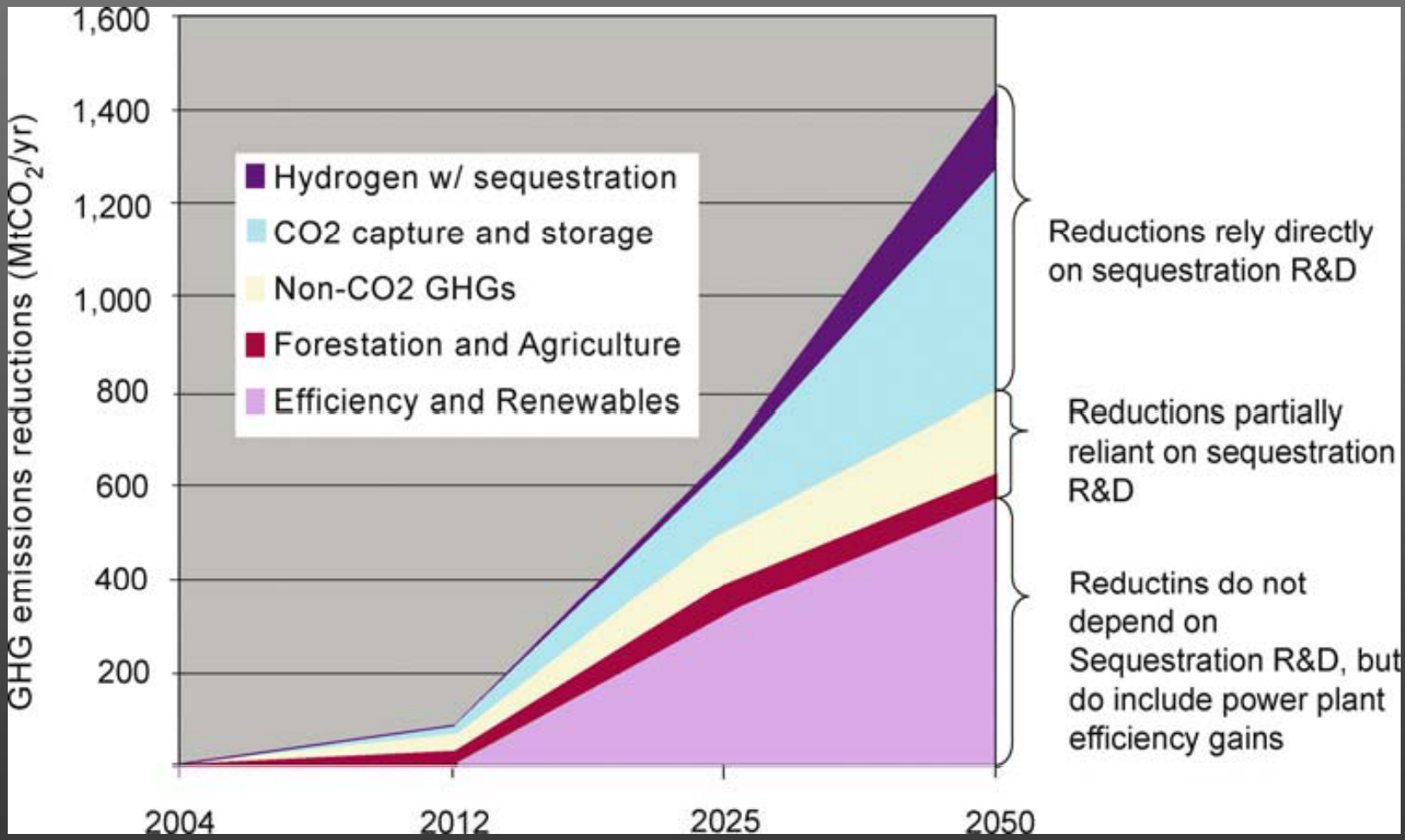
Contribution to GHG Emission Reductions

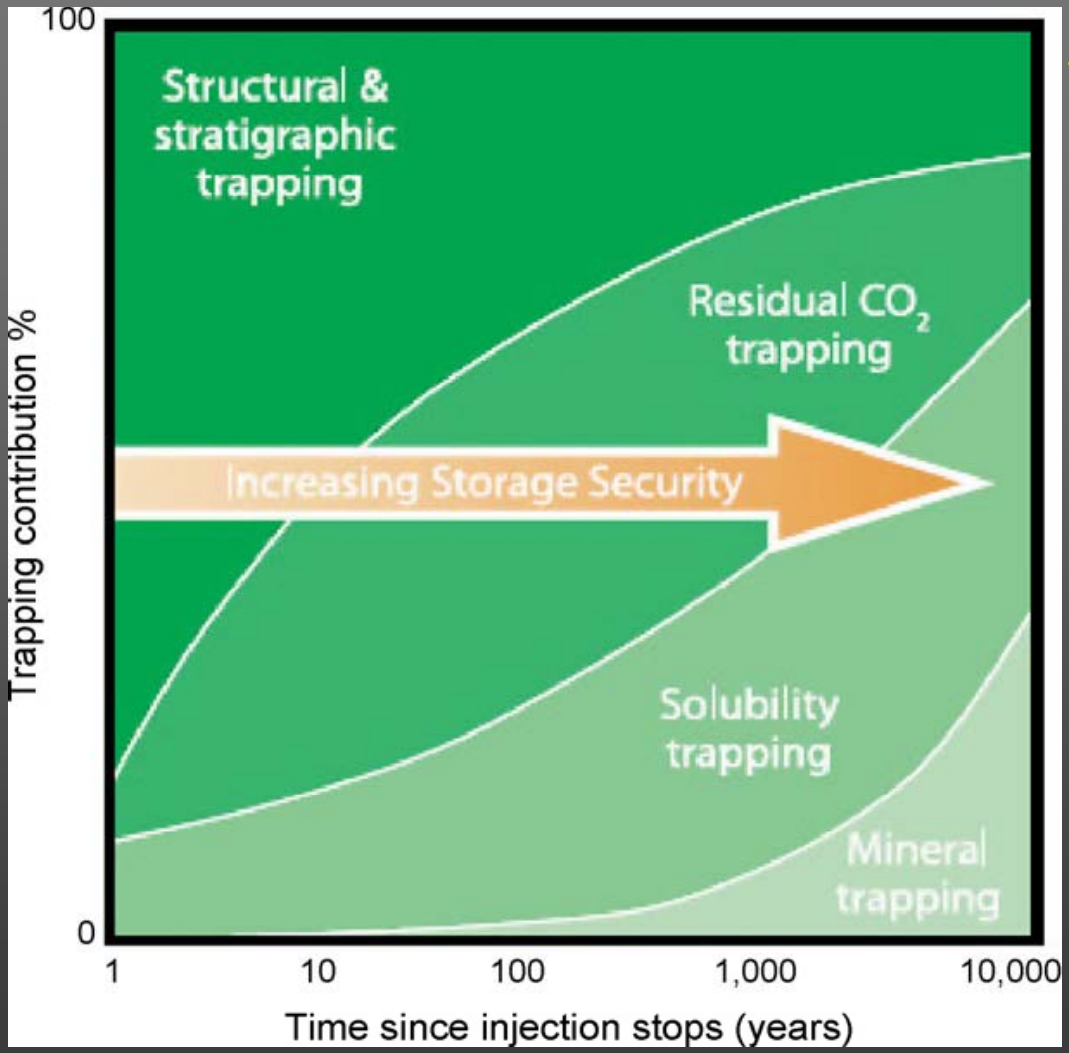
from J. Lityanski et al., 2006 *Climate Change*



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

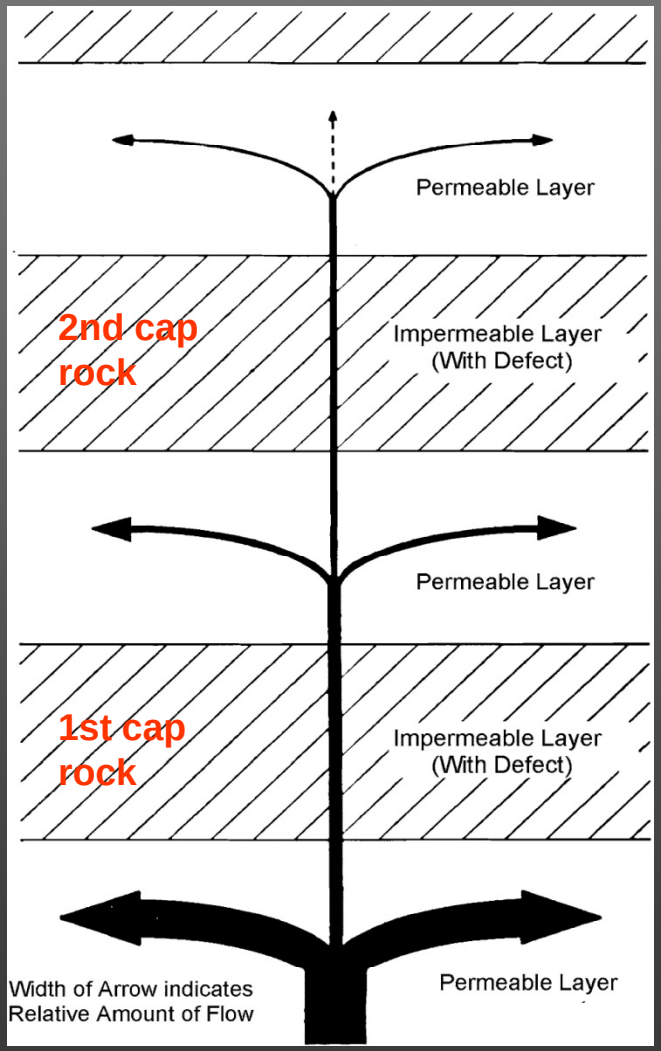
How much CO_2 reaches shallow soil horizons or the atmosphere?

Little CO_2 will ever undergo mineral trapping

Structural Trapping
(rapid physical/chemical)

- ✓ CO_2 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 CO_2 upward toward either ground surface or shallow potable aquifers
- ✓ Increased CO_2 alters pH and carbonate equilibrium leading to dissolution of metals (adsorbed/mineral), Cl, and SO_4

CO_2 Leakage into Overlying Strata



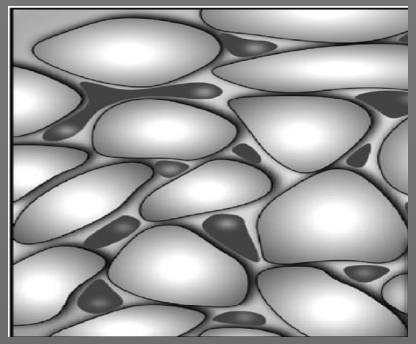
from C. Miller et al., 1986 *Ground Water Monitoring Review*

Poorly constructed water or petroleum wells serve as major CO_2 conduits, as do abandoned borings

Small fractures or heterogeneties in first cap rock are subject to injection stresses, gas pressures, and CO_2-induced dehydration of clays

Gas Trapping and Dissolution

(moderate physical)



- ✓ Interfacial tension between water and CO_2 limits migration of gas or supercritical fluid (multi-phase flow)
- ✓ Usually occurs only after injection has ceased and leading edge of CO_2 plume has passed (hysteresis effect)
- ✓ Water dissolution limited by salinity (2%-7%), pressure, temperature, and surface contact area
- ✓ CO_2 is more soluble in organic phases (oil and coal) and displaces CH_4—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

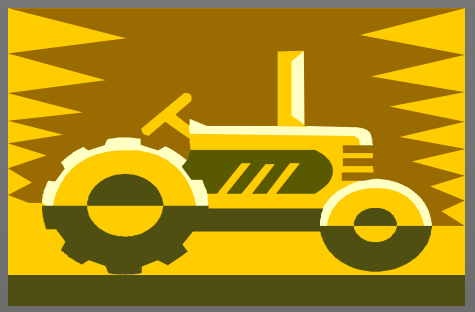
	Depleted Petroleum Reservoirs	Deep Saline Aquifers	Unmined Coal Seams	Forestation/ Agricultural Soils
Global Capacity (gigatons)	920	400-10,000	<250	Scenario dependent
Emissions to 2050 (% of total)	45	20-500	<12	Short-term solution

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 CO_2 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?