CCS Technology Options

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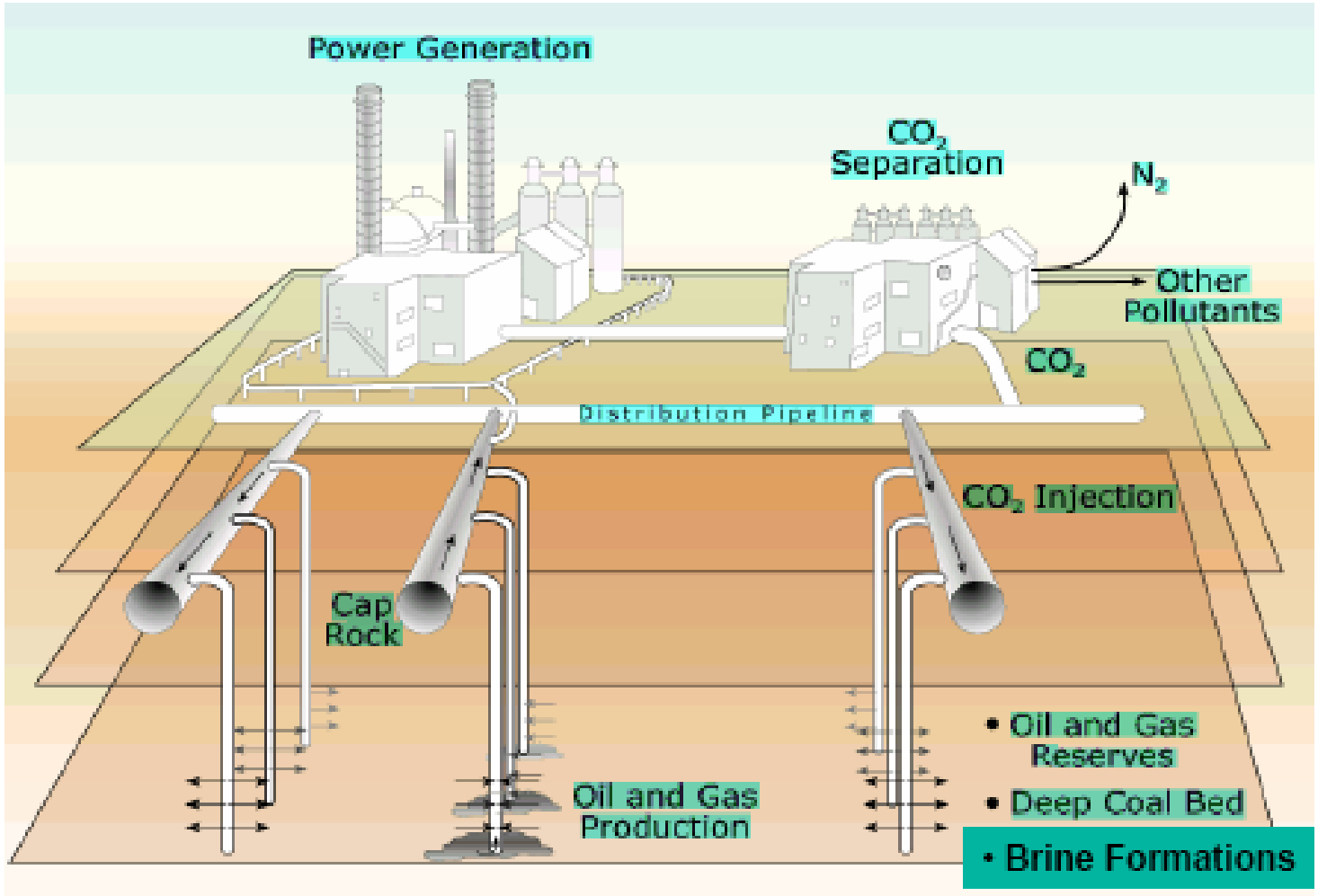
Geologic Sequestration Involves Capture, Compression and Injection



Primary Storage Options

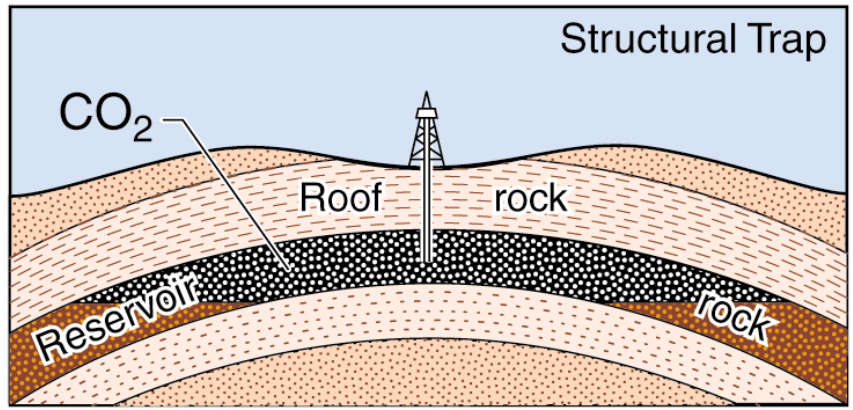
- **Oil and gas reservoirs**
  - Storage with Enhanced Oil Recovery (EOR), Enhanced Gas Recovery (EGR)
  - Storage only
- **Deep, unminable coal beds**
  - Storage with Enhanced Coal Bed Methane (ECBM) recovery
- **Saline formations**
  - Storage only

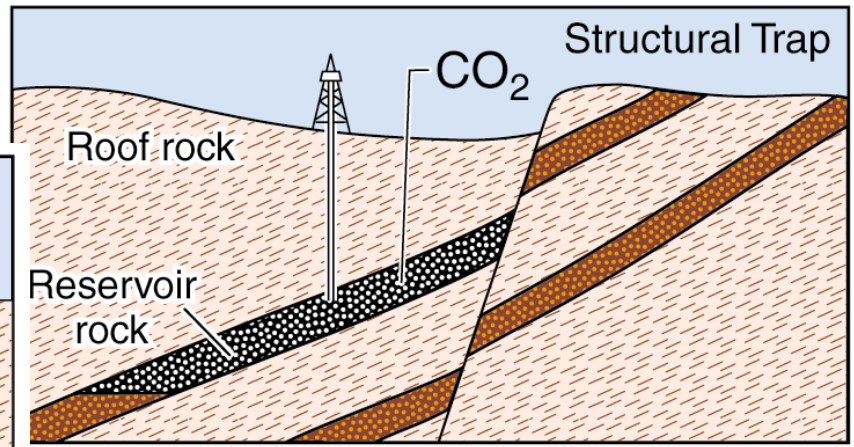
Oil and Gas Reservoirs are the Early Storage Targets

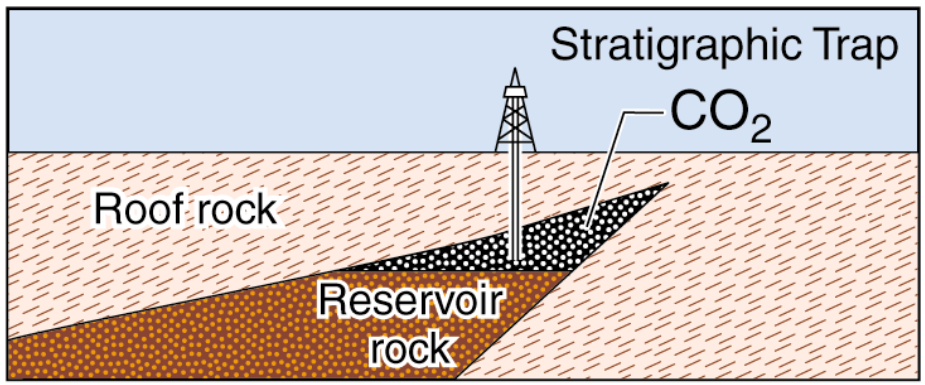
- Reservoirs are broadly distributed
- Reservoir seals are inherent
- Reservoir characteristics well defined
- Decades of relevant technological experience
- Depressurization provides storage capacity
- EOR, EGR provide cost off-sets
- Storage capacity likely too small in long term
- Abandoned wells need to be addressed

Typical Hydrodynamic Traps for Oil and Gas Reservoirs

- Oil, methane, carbon dioxide all buoyant fluids
- Seals provided by low permeability cap rock or faults

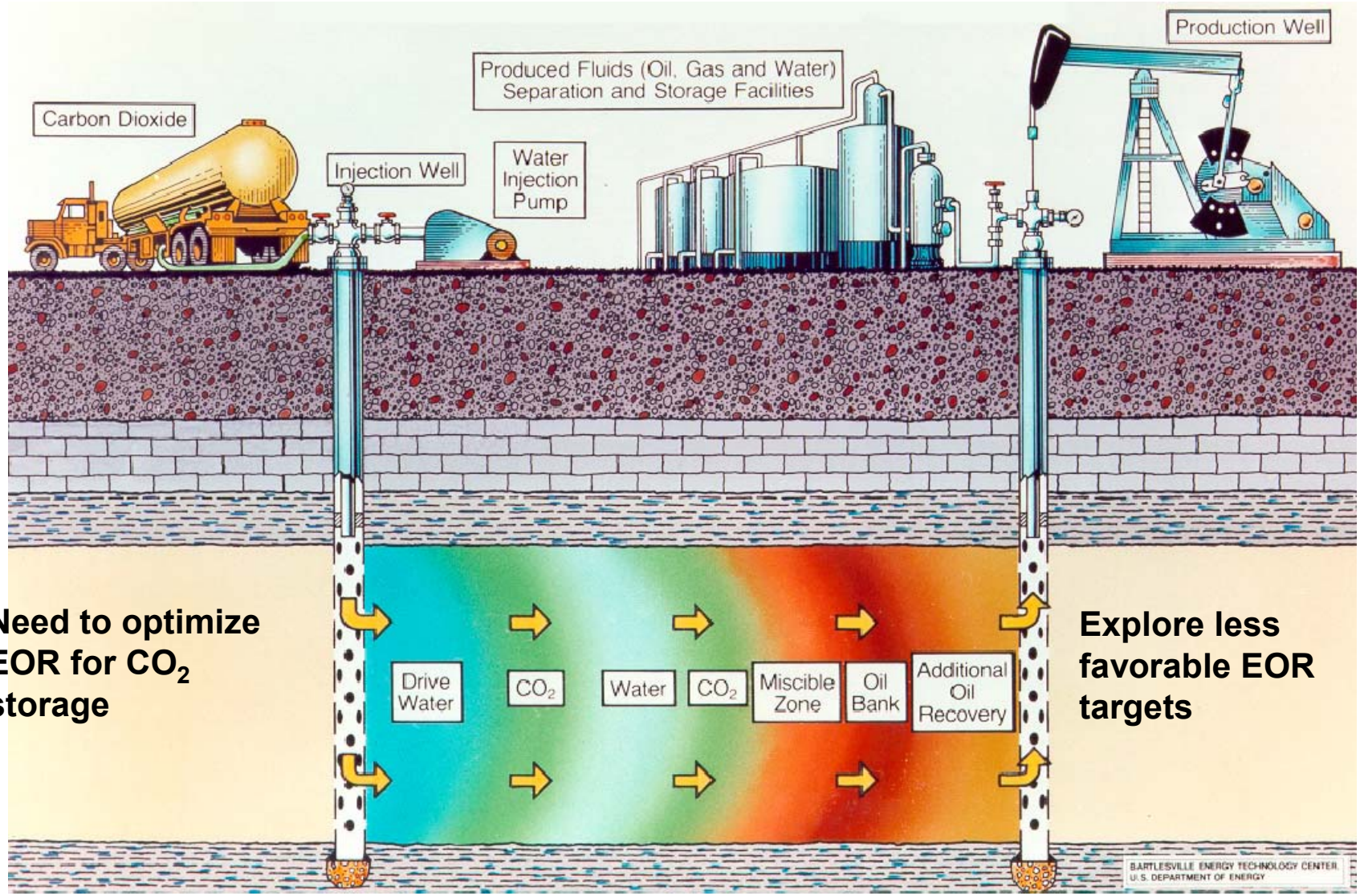






Source: W Gunter, ARC

CO_2 EOR is a Commercial Technology

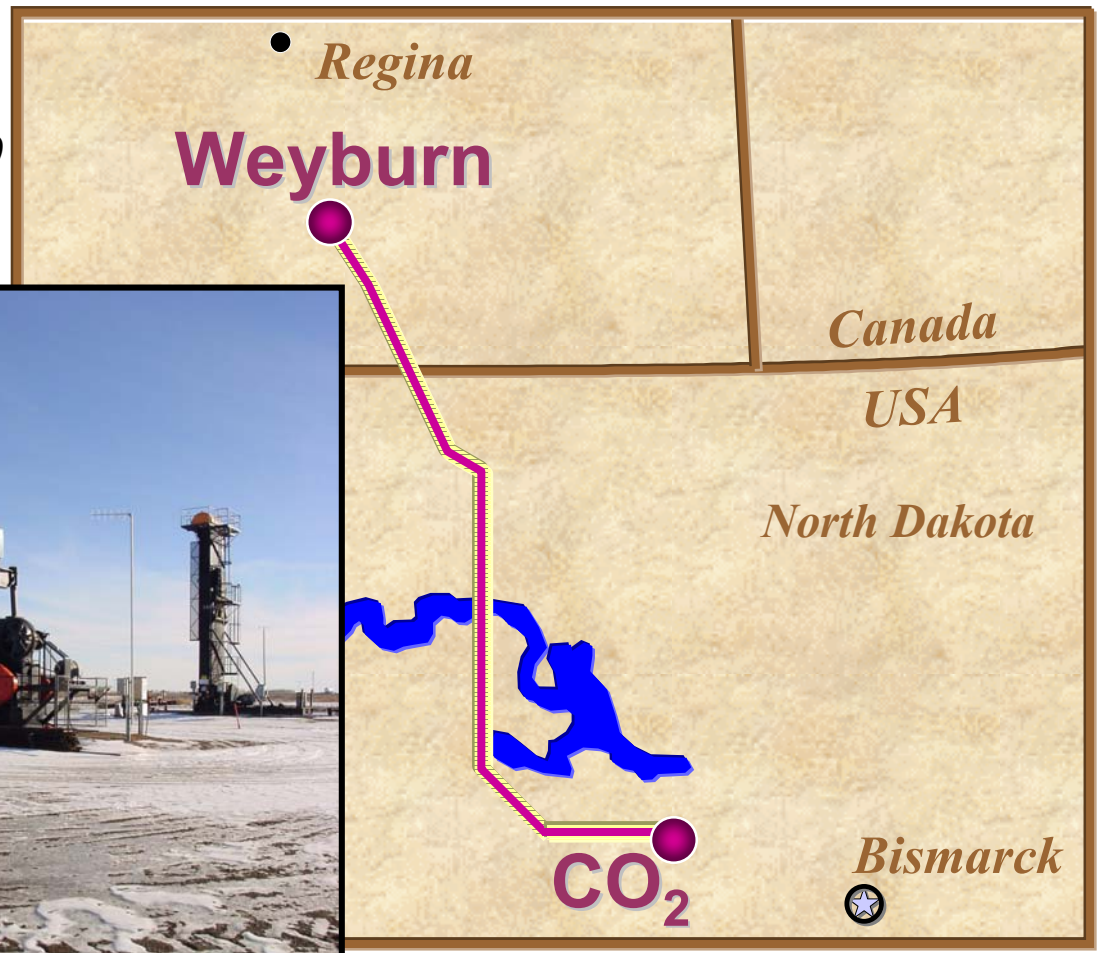


Need to optimize EOR for CO_2 storage

Explore less favorable EOR targets

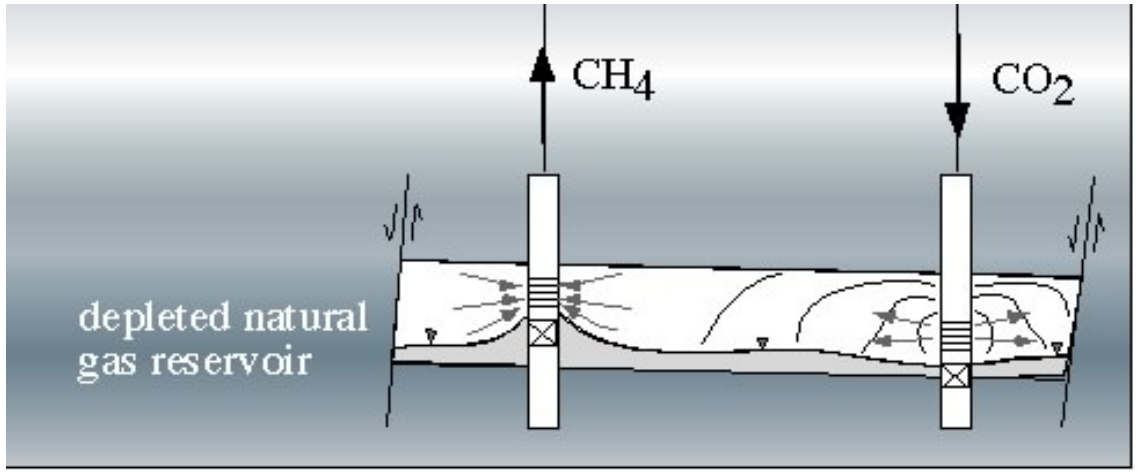
CO_2 Storage with EOR is Underway at Weyburn

1-2Mt/year 2000

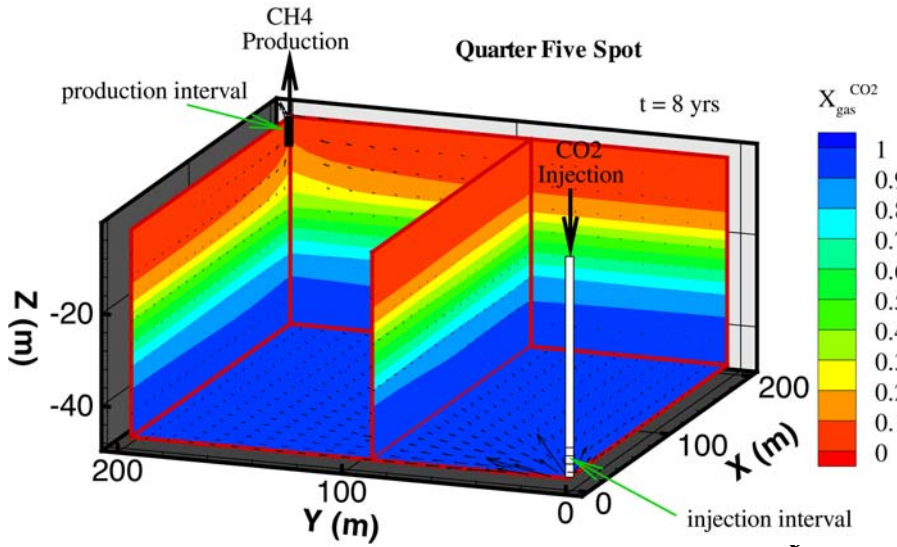


An additional 70 – 80 CO_2 EOR projects world wide

CO_2 EGR has Potential

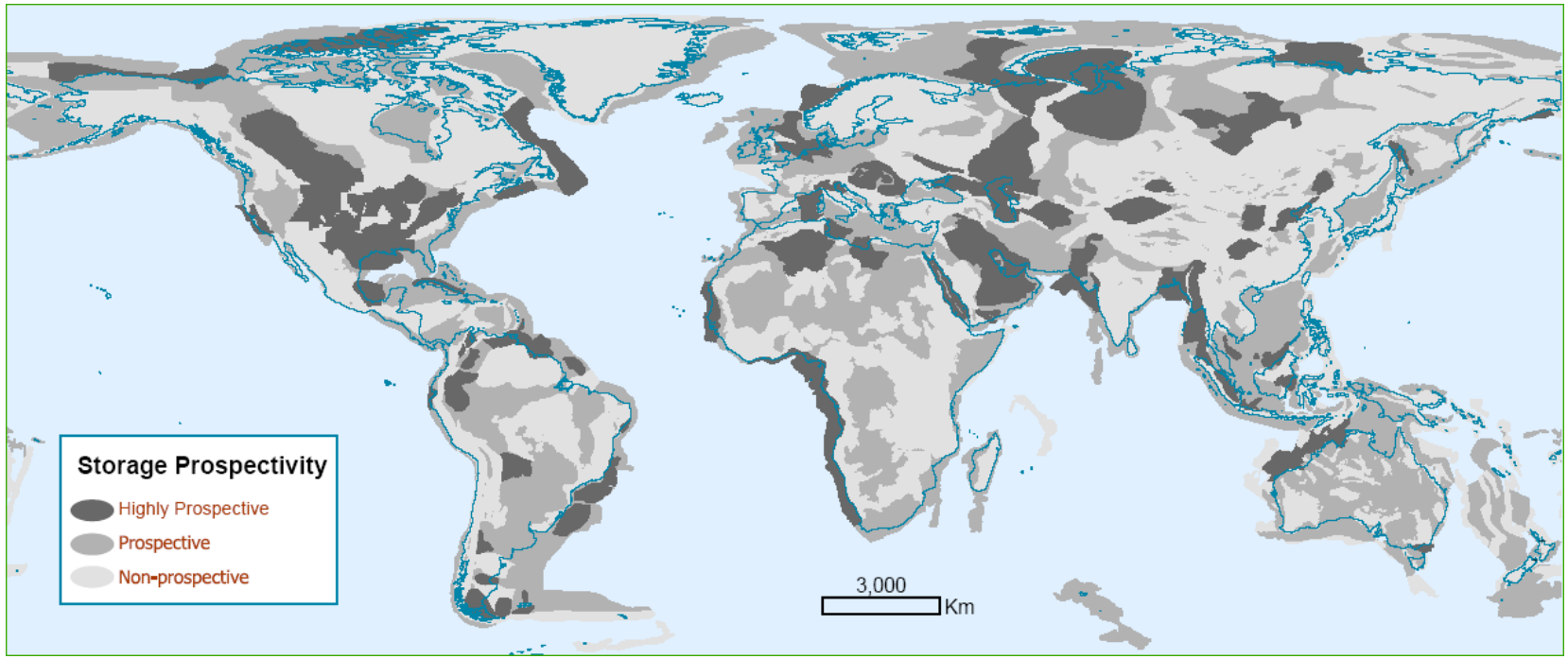


- Technology is untested
- CO_2 has favorable density and viscosity



Source: C Oldenburg, LBNL

Prospective Saline Formation Storage Broadly Distributed

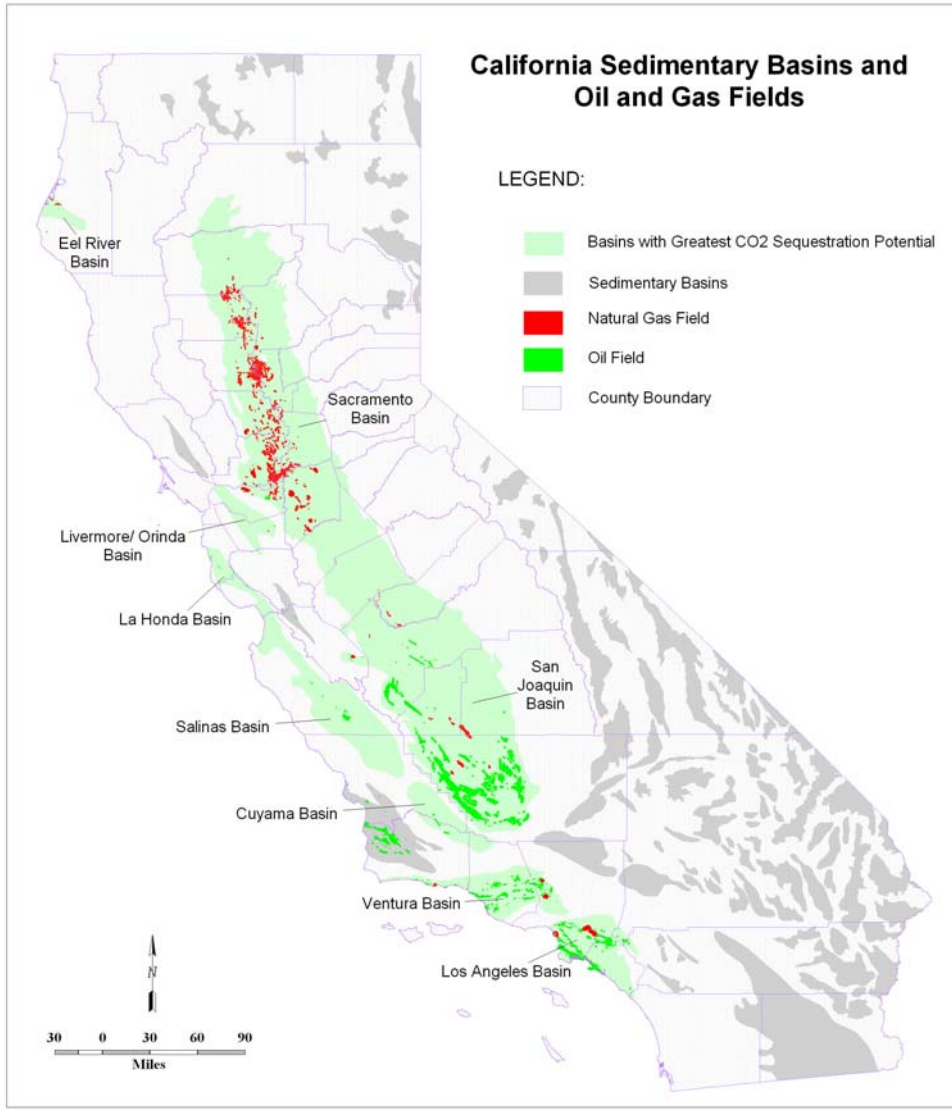


From Bradshaw and Dance 2005

"It is likely that the technical potential for geological storage is sufficient to cover the high end of the economic potential range (2200 $GtCO_2$), but for specific regions, this may not be true." IPCC, 2005

Saline Formations Include Oil, Gas Reservoirs as Subset

- Oil and gas reservoirs are local hydrocarbon accumulations in sedimentary basins
- Data from oil and gas reservoirs pertinent to surrounding saline formation
- Much technology is directly transferable



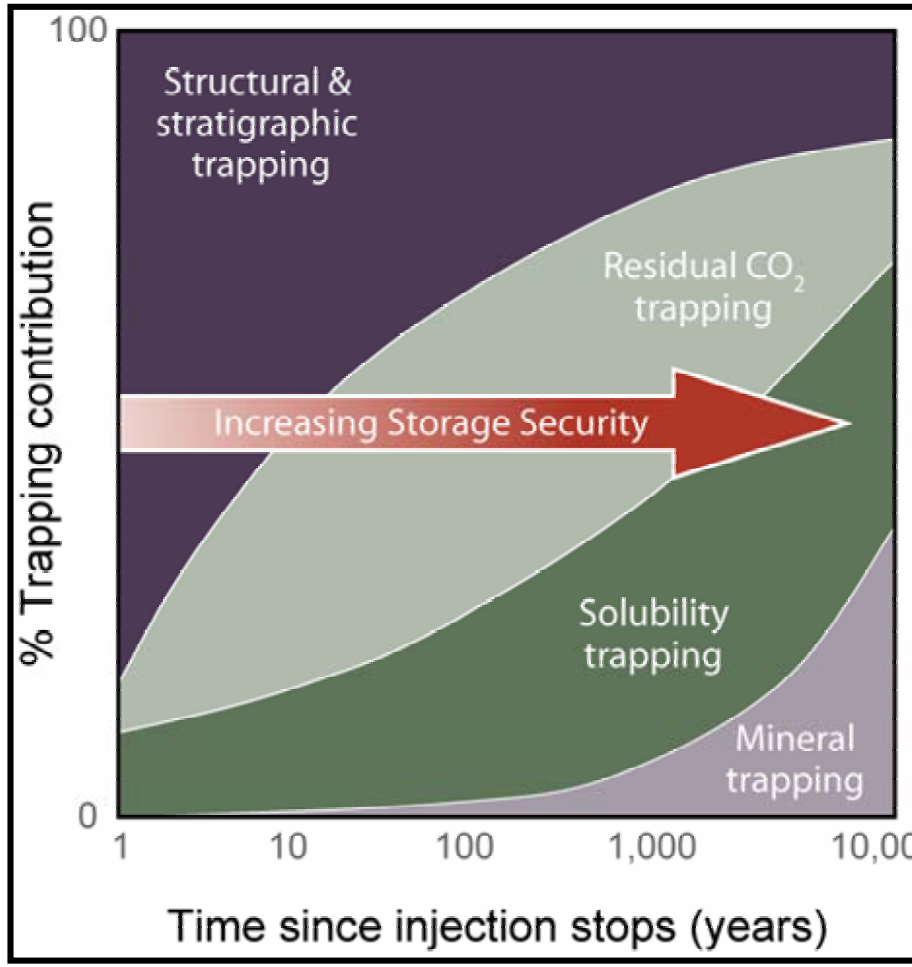
Saline Formations Will Become the Primary Storage Opportunity

- Site characterization needed to define trap, seal and reservoir characteristics
- Monitoring will be key in assessing performance and demonstrating storage security
- Relevant technological experience is available for site selection, management, monitoring and remediation, if necessary
- No cost off-sets yet identified; subsurface component of CCS, including monitoring, about 10% to 20% of total project costs

CO_2 Storage in Saline Formations is Underway

Summary of Trapping Mechanisms

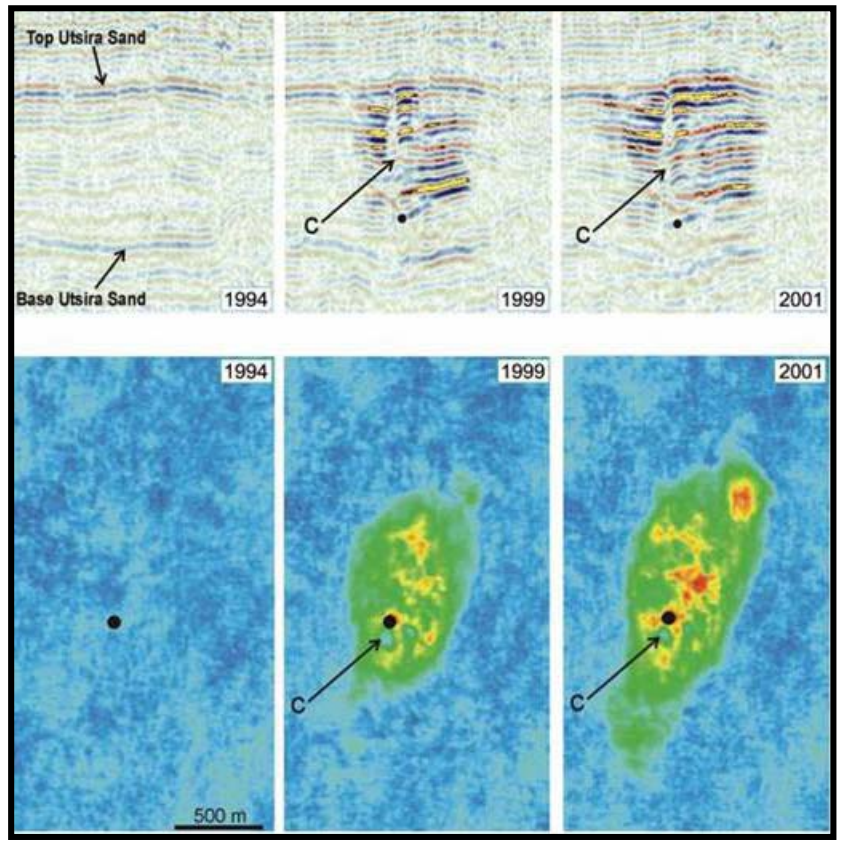
- Structural and stratigraphic trapping beneath caprock
- Capillary trapping (residual CO_2 trapping) in storage formation
- Geochemical trapping
  - Solubility trapping
  - Mineral trapping



Source: S Benson, LBNL

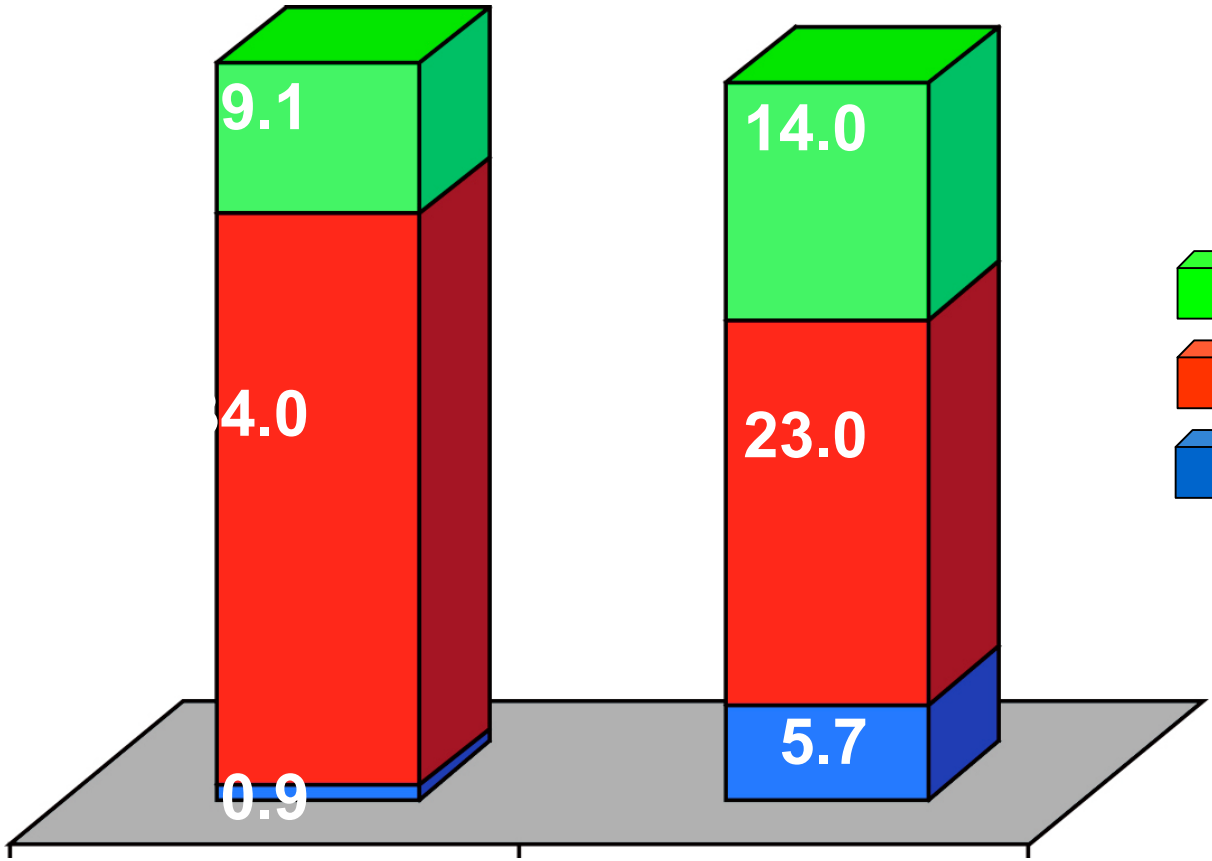
A Substantial Portfolio of Monitoring Techniques are Available

- Seismic and electrical geophysics
- Well logging
- Hydrologic pressure and tracer measurements
- Geochemical sampling
- Remote sensing
- CO_2 sensors
- Surface flux measurements



Time-lapse seismic monitoring results from Sleipner, after Chadwick et al., 2005

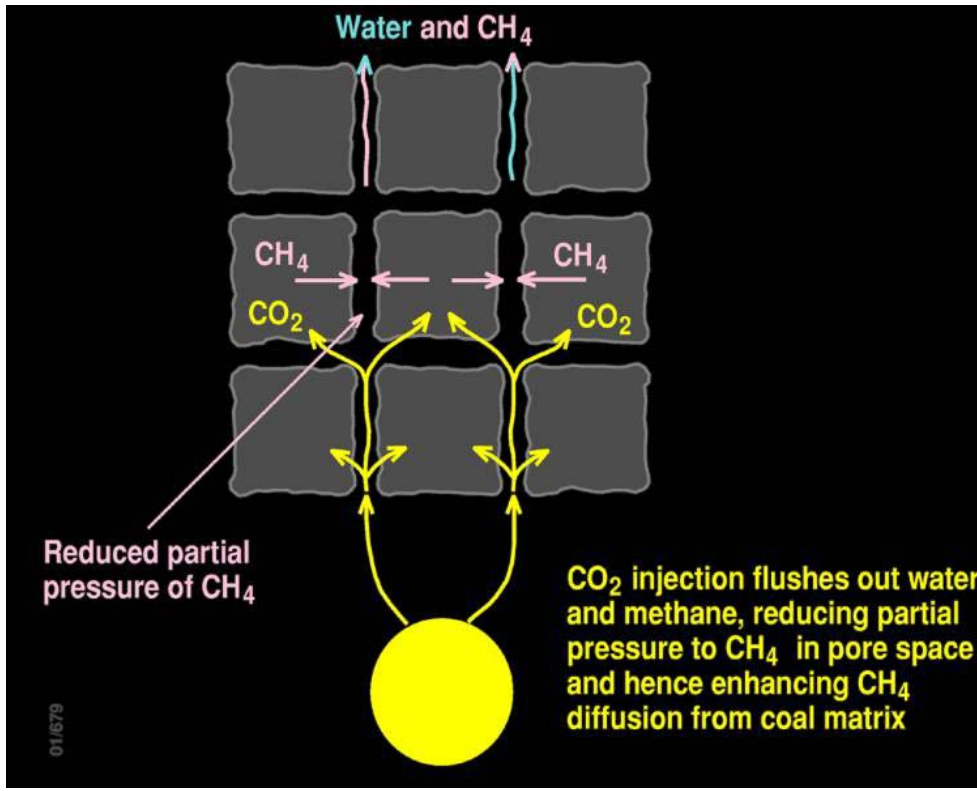
Comparison of Monitoring Costs



Source: Benson et al 2003

Coal Seams May Have Additional Storage Potential

- CO_2 is preferentially adsorbed by coal, displacing CH_4
- Storage capacity small compared to other options
- Uncertain depth to assure no future mining
- Uncertainty about injectivity
- Small scale pilots have been performed



Source: J Bradshaw, Geoscience Australia

Summary

- **Many components are technologically mature**
- **Pilot and demonstration projects are needed to refine costs, gain experience at a regional scale, and gain confidence in the security of geological storage**

" With appropriate site selection informed by available subsurface information, a monitoring program to detect problems, a regulatory system, and the appropriate use of remediation methods to stop or control CO_2 releases if they arise, the local health, safety, and environment risks of geological storage would be comparable to risks of current activities such as natural gas storage, EOR, and deep underground disposal of acid gas." IPCC, 2005