CO_2 Sequestration Options for California

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Outline

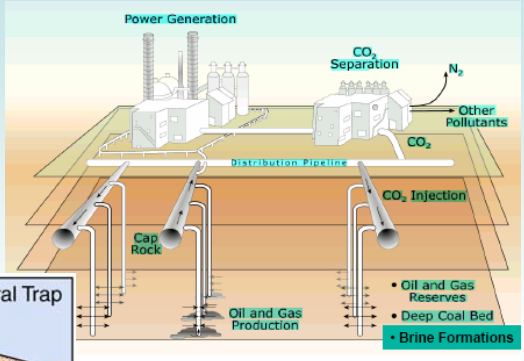
- Geologic sequestration
  - Technology description
  - Risks, costs, monitoring
- WESTCARB
  - Results for California
  - Phase II pilot studies

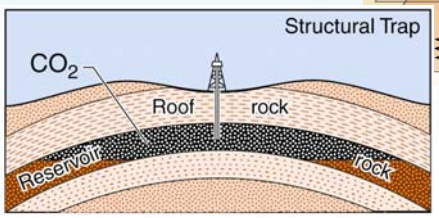
Terrestrial and Geologic Sequestration Are Both Options

- Terrestrial: Sequestration of carbon by natural processes in forests, plants, and soil; CO_2 source independent
- Geologic: Sequestration of CO_2 in deep saline formations, oil and gas reservoirs and coal-beds; requires industrial processes to capture at source and transport via pipeline
- Technology for both options is available and being implemented

Geologic Storage Mechanisms

- Physical, hydrodynamic, trapping
- Dissolution
- Phase trapping
- Mineralization
- Surface adsorption



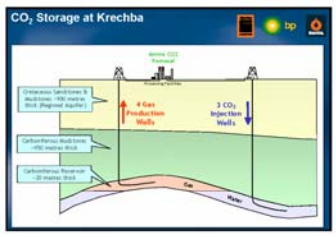


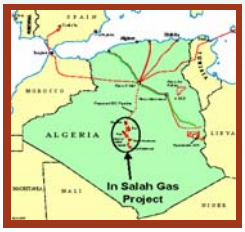
Primary Storage Options

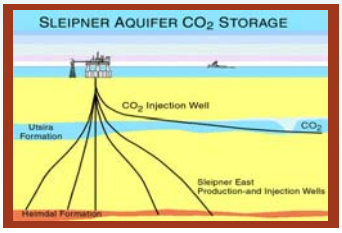
- Oil and gas reservoirs
  - Storage with Enhanced Oil Recovery (EOR), Enhanced Gas Recovery (EGR)
  - Storage only
- Deep, unminable coal beds
  - Storage with Enhanced Coal Bed Methane (ECBM) recovery
- Saline formations
  - Storage only

Geologic Sequestration Is Already Under Way

- Statoil injects $1x10^6$ tons per year at Sleipner
- BP to inject $0.8x10^6$ tons per year at In Salah
- EnCana EOR project with CO_2 storage in the Weyburn field







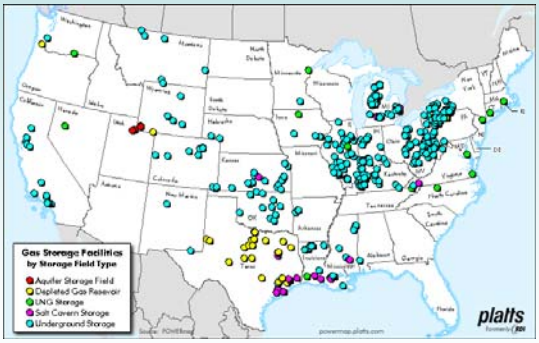
International Consensus on Geologic Sequestration Issues Provided by IPCC Report

- Availability of sinks, capacity
- Technology readiness
- Costs
- Risks
- Monitoring
- Remediation

" 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

Many Lines of Evidence Indicate Storage Can Be Safe and Secure

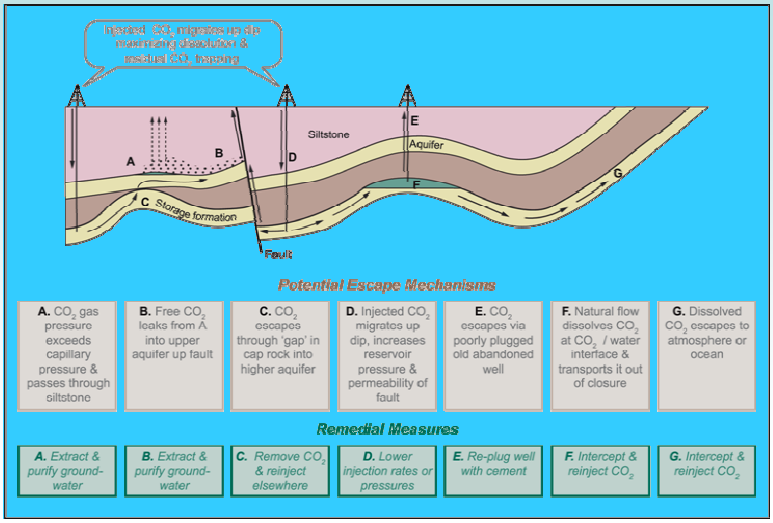
- Natural analogues
  - Oil and gas
  - CO_2 formations
- Industrial analogues
  - Natural gas storage
  - CO_2 EOR
  - Liquid waste disposal
- Monitoring existing projects
  - Sleipner
  - Weyburn



Monitoring will be a Key Element of Geologic Sequestration Projects

- The oil and gas industry has developed highly sophisticated geophysical technologies which are directly applicable to geologic sequestration
- Additional approaches should, and are, being developed
- Monitoring requirements have not been established, but monitoring over the operational life of a geologic sequestration project using current technology would cost only ~$0.10/ton CO_2

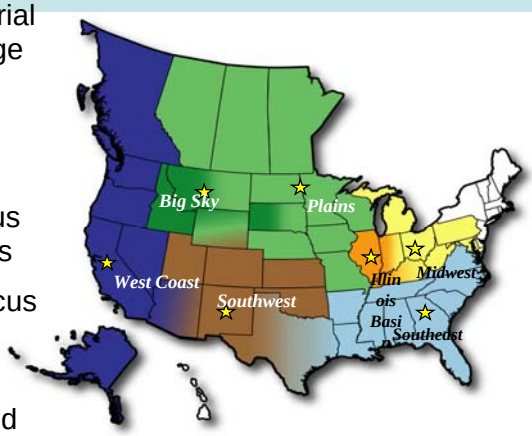
Potential Release Pathways and Remediation Measures



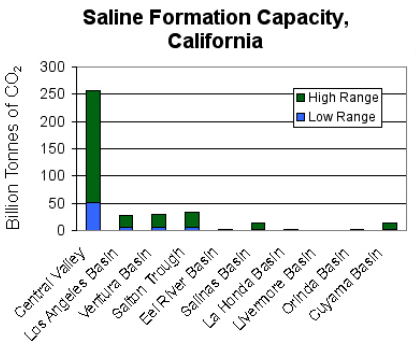
Source: IPCC Special Report on CCS

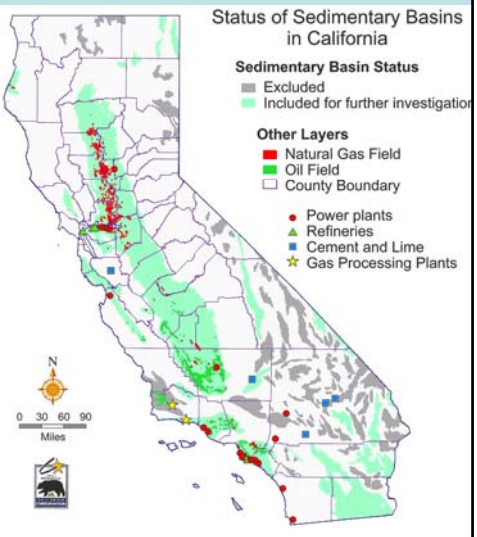
WESTCARB: West Coast Regional Carbon Sequestration Partnership

- Opportunities for terrestrial and geologic CO_2 storage are being evaluated
- Over 70 participating organizations
- Phase I (complete): focus on regional assessments
- Phase II (underway): focus on pilot studies
- Phase III (coming): pre-commercial geologic field test



Major Geologic Storage Opportunities in California

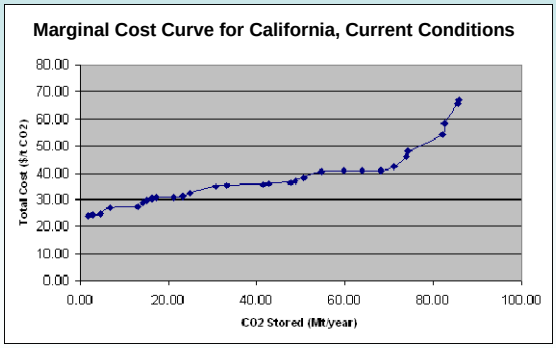




Gas reservoir capacity: 1.7Gt
Oil reservoir capacity: 3.6Gt

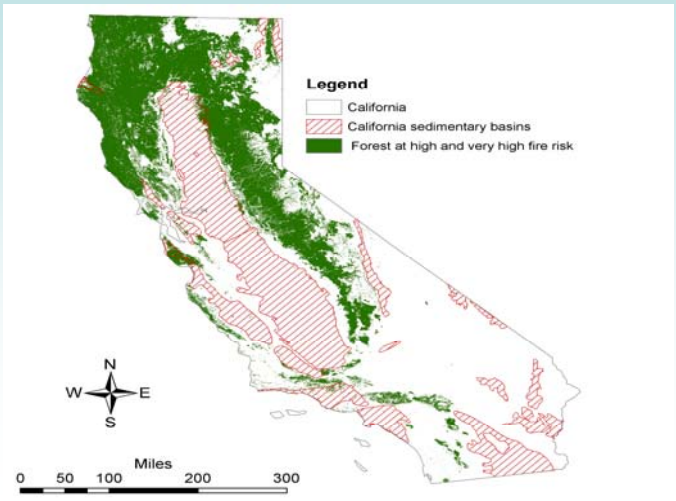
Supply Curves for Geologic Storage Improve Cost Estimates

- CO_2 source characterization
- Capture cost estimation (about 80% of total cost)
- CO_2 storage capacity estimation
- Transportation cost estimation
- Source-sink matching



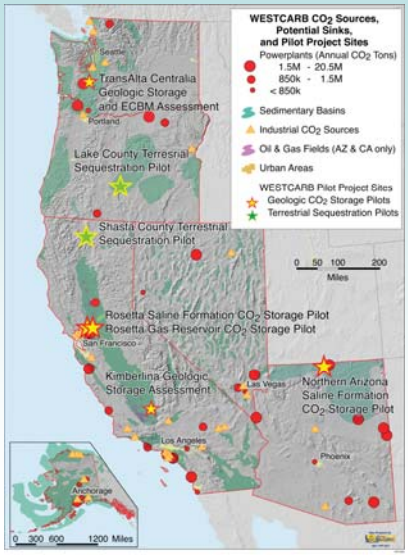
Matching sources to sinks
(From H. Herzog, MIT)

Linking Terrestrial and Geologic Sequestration

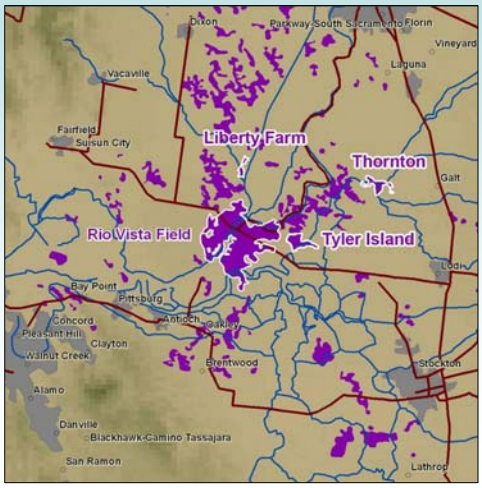


Pilots Planned in Arizona, California, Oregon, and Washington

- Pilots are representative of best sequestration options, unique technologies and approaches, in region
- Pilots involve site-specific focus for
  - Testing technologies
  - Assessing capacity
  - Defining costs
  - Assessing leakage risks
  - Gauging public acceptance
  - Testing regulatory requirements
  - Validating monitoring methods



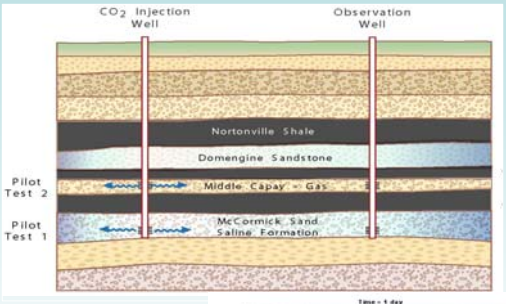
Rosetta Resources CO_2 Storage Pilot

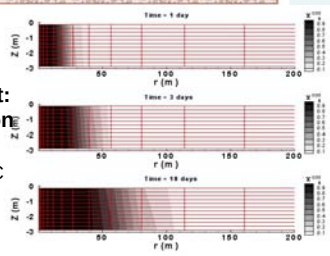


- Lead industrial partner: Rosetta Resources
- Validate sequestration potential of California Central Valley sediments
- Test CO_2 Storage Enhanced Gas Recovery
- Inject about 2000 tons at about 3400ft depth
- Focus on monitoring

Pilot Involves One Injection and One Observation Well

- Assess seal integrity, spatial extent of CO_2, storage capacity, injectivity
- Study mixing and CH_4 displacement in gas reservoir
- Measurements include downhole P and T, fluid sampling, wireline logging, vertical seismic profiling and crosswell seismic, and shallow groundwater and surface CO_2 sensors





Above: schematic cross-section; right: computer simulation of CO_2 in gas reservoir (R Trautz, C Oldenburg, LBNL)

Summary

- The technological tools needed to carry out large scale CO_2 sequestration are available
- There are major opportunities in California for geologic (and terrestrial) sequestration
- Field work in WESTCARB Phase II pilots expected to commence soon
- Results are proving timely for CA policy on GHG mitigation