Siting and Monitoring CO_2 Storage Projects

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Well Selected and Managed Sites Are the Key to Safe and Secure Storage

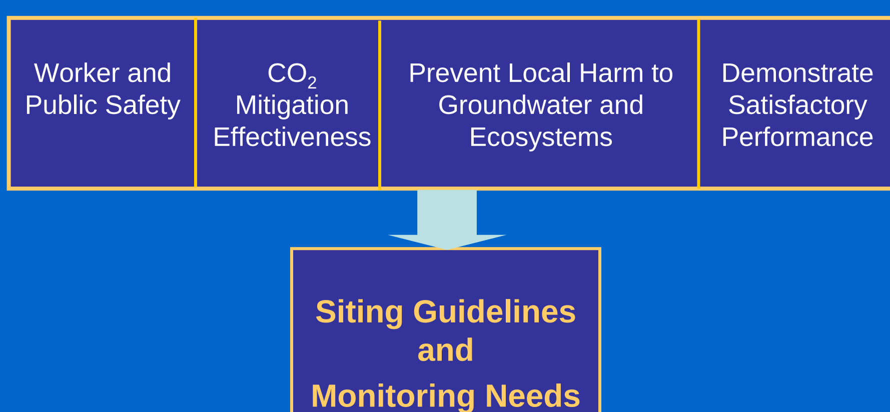
" With appropriate site selection informed by available subsurface information, a monitoring program to detect problems, a regulatory system, and the appropriate use of remediation methods to stop or control CO_2 releases if they arise, the local health, safety and environment risks of geological storage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

IPCC Special Report on CO_2 Capture and Storage (2006)

Key Messages (for now)

- Lots of experience siting injection projects
  - Natural gas storage
  - Oil-field brines
  - Liquid and hazardous waste
  - Regulatory framework is in place
  - Modifications can address CO_2 storage specific issues
- Performance specifications regarding CO_2 mitigation need to be developed
- Monitoring methods for CO_2 storage projects are available
  - Adapt existing methods
  - Protocols for storage projects should be developed
  - Technological innovation will improve spatial and temporal resolution
- We need approaches to facilitate early site selections to gain more experience with geological storage
  - "Learning by doing"
  - We have the tools to start

Goals for Geological Storage of CO_2



What criteria would be used to judge whether or not a site is acceptable?

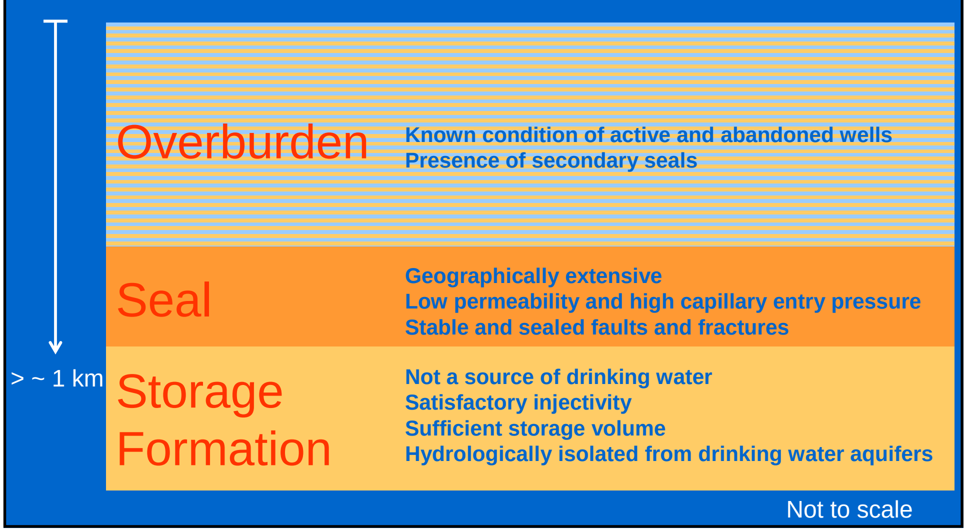
Local environmental impacts

No harm to drinking water	x
No harm to terrestrial or aquatic ecosystems	x
Other?	?

CO_2 mitigation effectiveness

Retention rates of > x%/1000 years	?
Leakage rates of < y%/year	?
Other?	?

Some Attributes of an Effective Storage Sites in Oil, Gas and Saline Formations



Experience Siting Injection Projects

- Underground injection control program
  - Class I, II, III, IV and V program
- Natural gas storage experience most relevant
  - Buoyant compared to water
  - Aquifer gas storage
- New issues
  - Large scale of projects
  - Geographic location
  - Reactivity of CO_2 with well sealing materials

Underground Natural Gas Storage

20 to 30 Mt/yr are injected for CO_2-EOR

The Effort Needed to Assess a Storage Site Varies By Formation Type

	Oil	Gas	Saline
Overburden	Known condition of active and abandoned wells Presence of secondary seals	Known condition of active and abandoned wells Presence of secondary seals	Known condition of active and abandoned wells Presence of secondary seals
Seal	Geographically extensive Low permeability and high capillary entry pressure Stable and sealed faults	Geographically extensive Low permeability and high capillary entry pressure Stable and sealed faults	Geographically extensive Low permeability and high capillary entry pressure Stable and sealed faults
Storage Formation	Satisfactory injectivity Sufficient storage volume Hydrologically isolated from drinking water aquifers	Satisfactory injectivity Sufficient storage volume Hydrologically isolated from drinking water aquifers	Satisfactory injectivity Sufficient storage volume Hydrologically isolated from drinking water aquifers

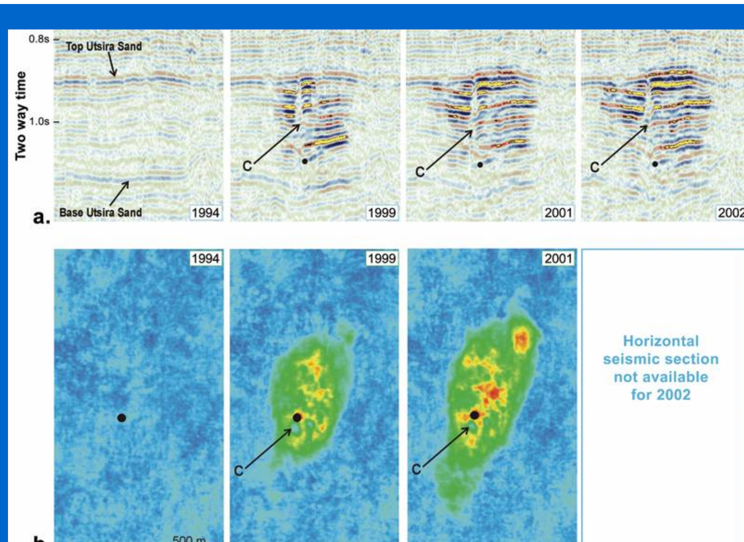
More Effort — Less Effort

Not to scale

Monitoring Methods

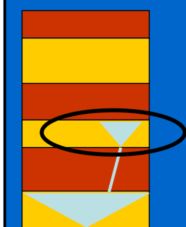
- Well maintenance and operations
  - Detect well or cement degradation
  - Avoid overpressuring the formation
- Plume tracking and leakage monitoring
  - Seismic
  - Gravity
  - Land surface deformation
  - Electromagnetic
- Surface seepage detection methods

Examples: Seismic Data Collected at Sleipner

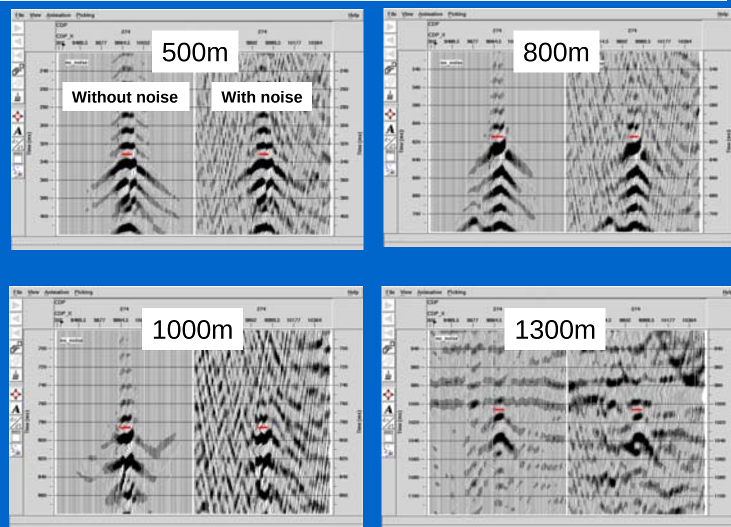


Time-lapse 2-D Surface Seismic: Simulation

Conceptual Model



1000 tonne accumulation



Surface Monitoring for Seepage Detection and Inventory Verification

- Point atmospheric CO_2 concentration
- Eddy covariance
- Flux accumulation chamber
- Open path optical techniques
  - Surface based, plane, satellite
- Soil gas and vadose zone monitoring
- Fluid and gas phase tracers

Flux Chamber

Courtesy of Jennifer Lewicki, LBNL

Detection Limits

- Are they sufficiently sensitive for monitoring leakage of CO_2 from storage projects?
  - Seismic imaging
    - Promising if secondary accumulations occur
  - Pressure monitoring
    - Best suited for monitoring known vulnerabilities
  - Surface fluxes
    - Distinguishing background variability from leakage signal is the key
    - Leaks confined to 10% or less of the footprint of the plume should be easy to detect
    - Anthropogenic background may be more challenging than natural ecosystem fluxes

"Learning By Doing"

- Gain more experience in geological storage of CO_2 by doing industrial scale projects (> 1 Mt/year)
- Facilitate early site selections by a flexible yet protective approach
- Streamline multi-jurisdictional permitting
  - Air, climate, groundwater, ecosystems
- Employ robust monitoring programs to maximize learning
- Gain confidence by openness and transparency

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