Monitoring, Mitigation, and Verification (MMV) in Geological Sequestration Scenarios, Technical Advances and Economic Constraints

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Where MMV is Needed

Power Plants

- Separate CO_2- S, NOx, Metal
  Scrubbers, Membranes

- Leak Testing – Pipes
  Monitors (CO_2, S, N, T)

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Pipelines

- <u>Leak Testing</u>
  Monitors (gas, biology)
- <u>Pipe Integrity</u>
  Sensors inside pipe
  (nanotechnology, acoustics)

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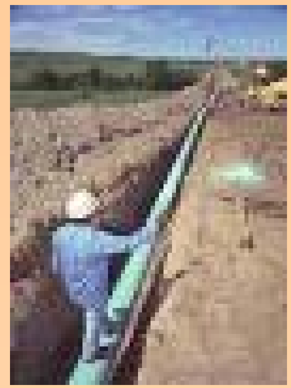
Pipelines



• Leak Testing
Monitors (gas, biology)

• Pipe Integrity
Sensors inside pipe
(nanotechnology, acoustics)

Reservoirs

• Leak Testing
Monitors (gas, H_2O, biology)

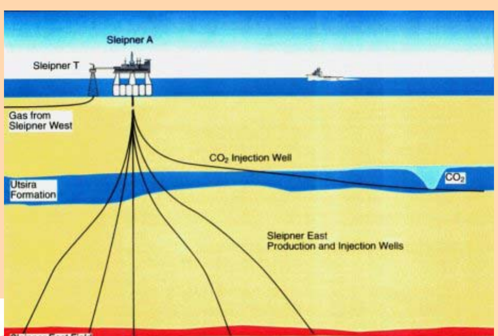
• Reservoir Integrity
CO_2 movement
Faulting, cementing

Purpose of Monitoring in Geological Reservoirs

- Determine effectiveness of CO_2 storage
  - safety (public, environment)
  - economics (carbon credits, infrastructure)
- Determine impacts on reservoir
  - chemical/physical changes
  - CO_2 movements, calibrate models
  - remediation
- Settle legal disputes
  - storage/seepage scenarios
  - impacts to other reservoirs

Reservoirs – EOR, coal beds, aquifers

- Spatial set-up of MMV- subsurface, surface, local, satellite
- Timeline of measurements -Baseline, operation, closure
- Safety/regulations set-up – workers/public, environment, mitigation
- Economic constraints – tech costs and sampling designs



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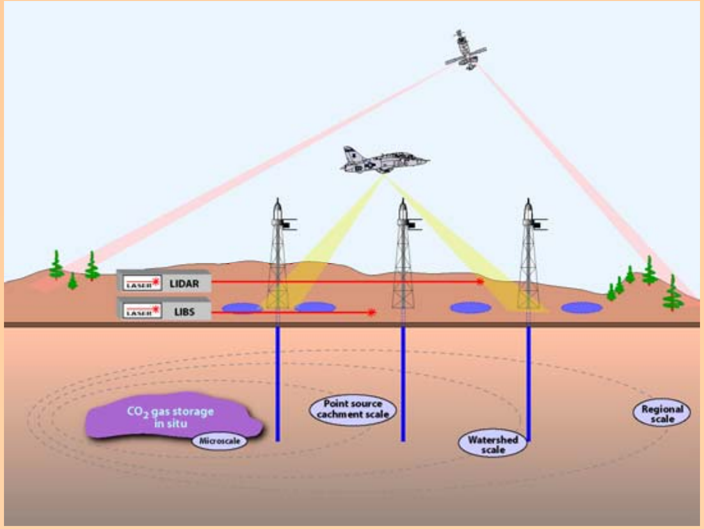
Spatial Analyses and Technologies



- <u>Satellite</u> = Vegetation (NDVI), [CO_2], geology
- <u>Regional</u> = [CO_2], H_2S, Rn, EM
- <u>Local</u> = Eddy Flux, LIDAR, Tracers
- <u>Surface</u> = Chamber, Tracers, LIBS, Vegetation, microbes, soil gas/water composition
- <u>Wells</u> = injection/production rate, temperature, pressure (wellhead, formation, casing, annulus) wire line (gamma, neutron, resistivity)
- <u>Subsurface</u> = Groundwater, Ground Deformation, Seismics (Passive, 4D, X-well, Micro), gravity, Tracers, tilt, EM

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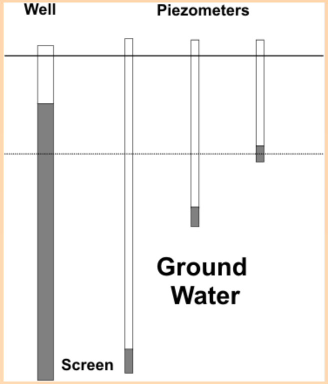
Temporal Scales Needed to be Monitored

Daily

Injection well monitor
(T, P, CO_2, flow)

Weekly

Eddy Covariance
(T, flow, CO_2)



Groundwater (DIC)

Year-Multiyear

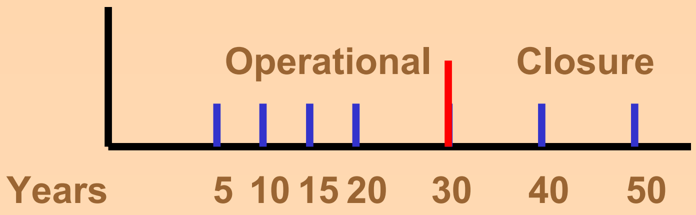
Satellite-15 m resolution
(CO_2, vegetation index)

Rock/cement weathering

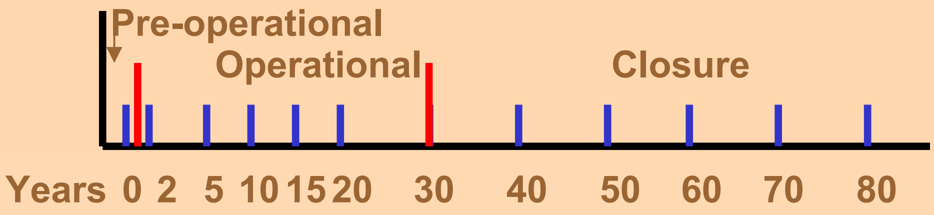
Timeline for Monitoring at Varying Sites

- Baseline Measurements = seismic, groundwater, atmospheric CO_2, tracers, vegetation type, microbes, soil gas/water composition
- Operation = well logs, seismics (4D-frequency below), groundwater (comp., pH), [CO_2] and isotopes (regional, local, surface), vegetation
- Closure = periodic checks of seismics, groundwater, [CO_2], pressure

Proposed frequency of geophysical measurement (Larry Myer LBNL)



EOR



Saline Formations

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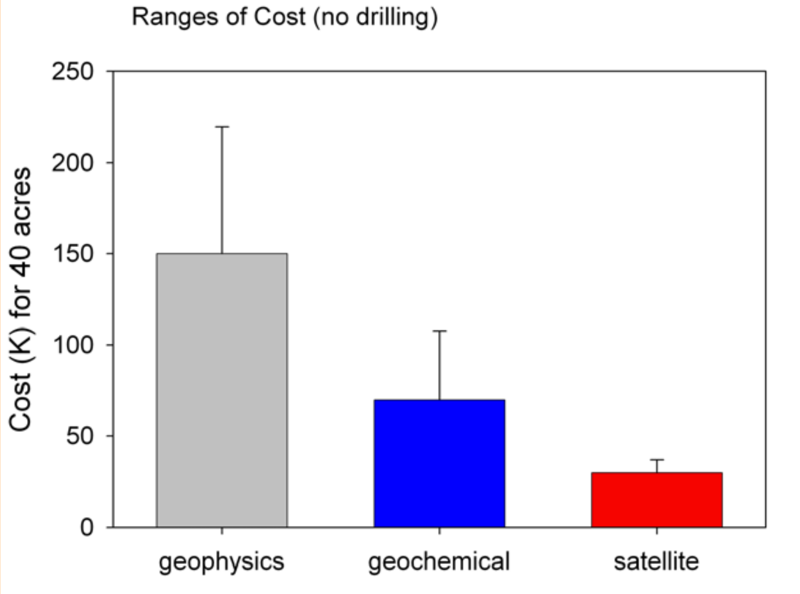
Safety and Regulations in Place

- <u>Worker/public</u>: EPA standards, controls, safety locks, emergency response
- <u>Risk assessment/mitigation</u>: Potential hazards (geologic, public), emergency response
- <u>Outreach efforts</u>: townships, company, local/state governments

Economic Issues in Geological MMV

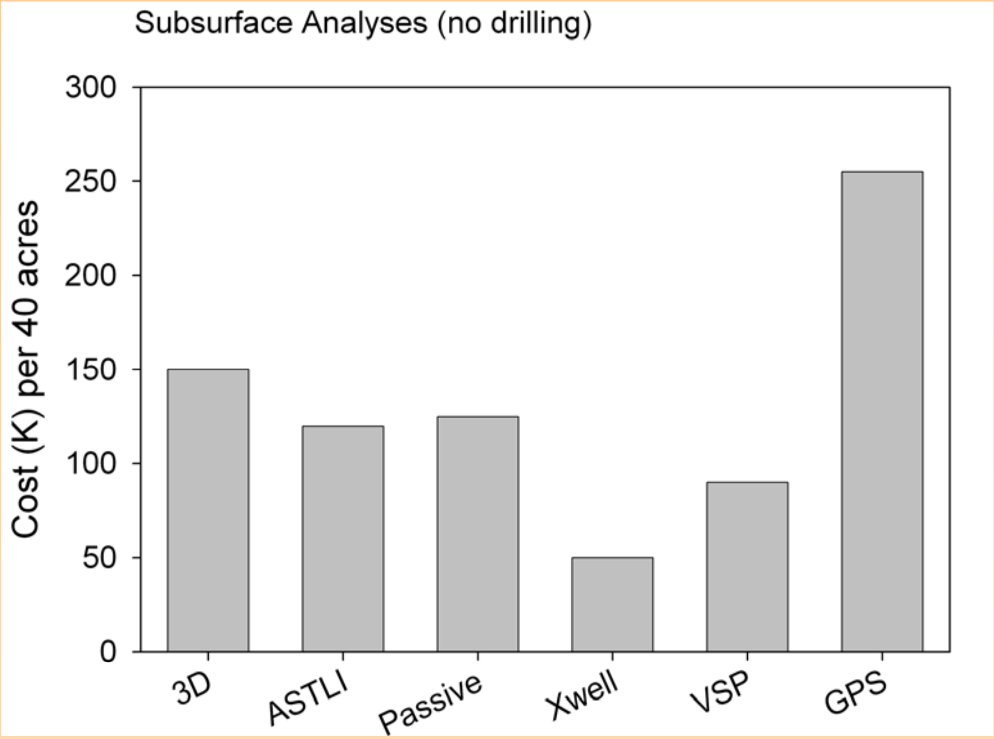


- Technological costs
  - geophysics, geochemical, sattelite
- Sampling designs (network arrays)
  - temporal and spatial
  - regulatory constraints

Costs taken from contractors, universities, labs, web

Geophysical Costs - Technologies

- Costs = equipment, collection, analyses
  1 time costs for 40 acres
  No drilling of new wells



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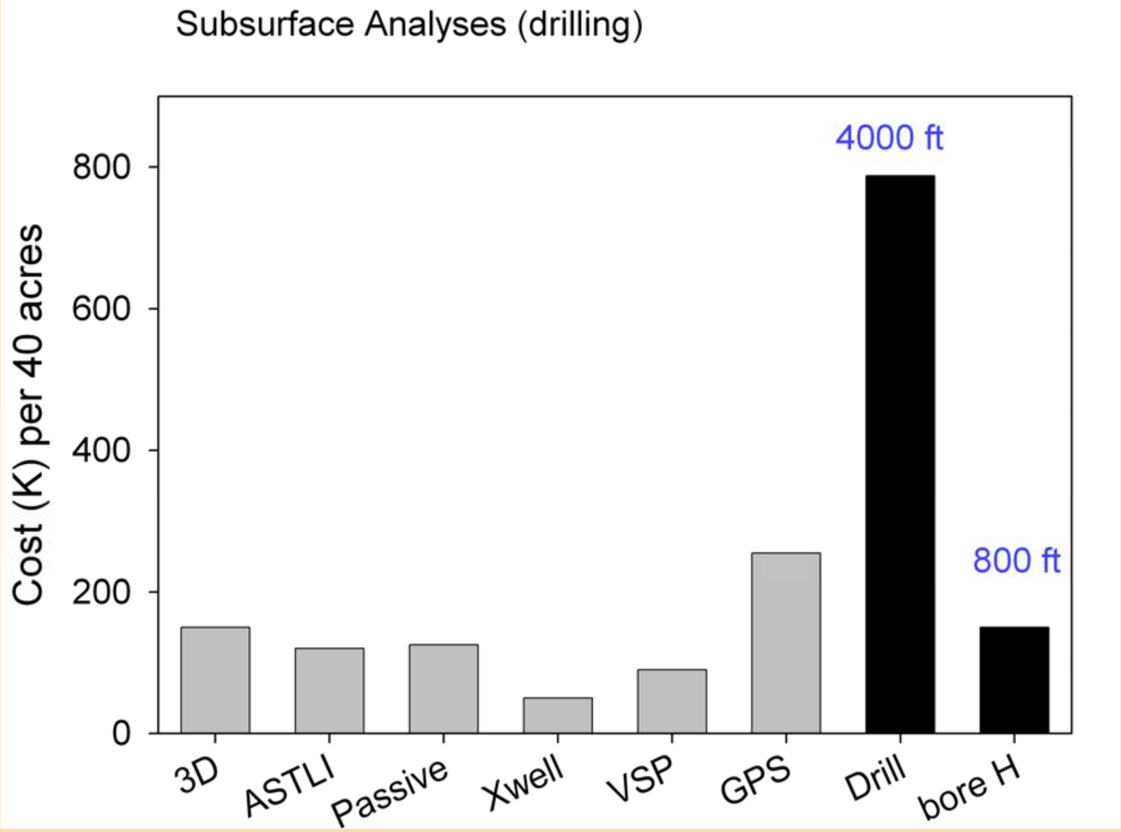
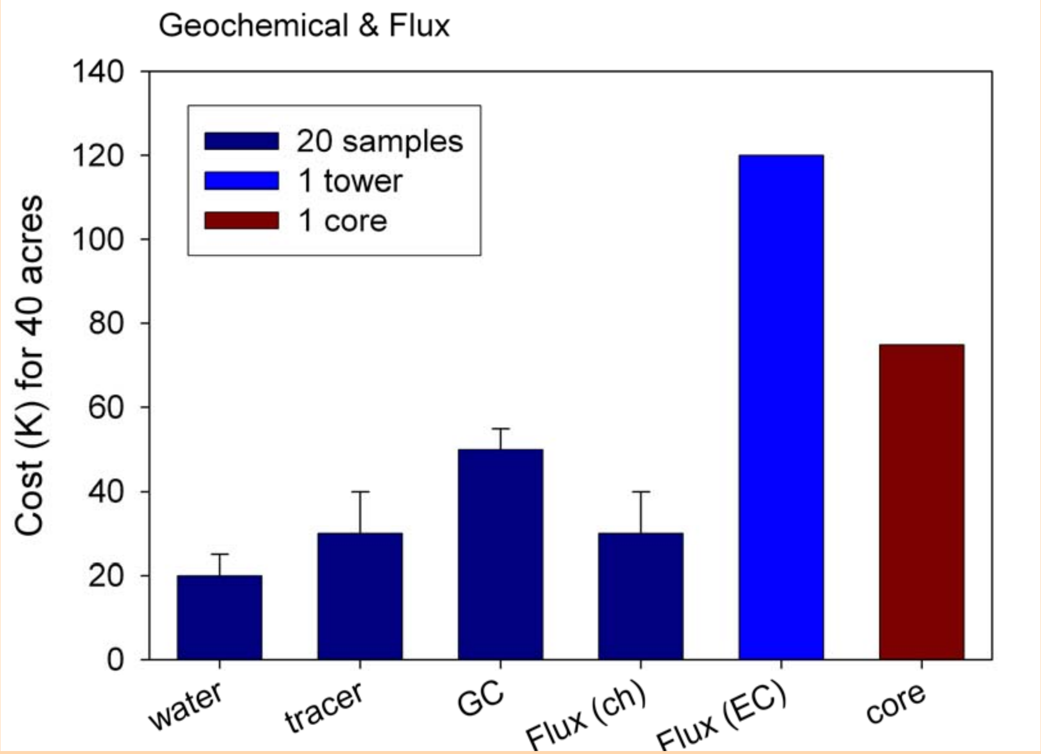
Geophysical Costs - Technologies



- Cost = Drilling (1 hole)

Geochemical Costs - Technologies



- Costs = analyses (lab)
  analyses + equipment (field)

Costs taken from contractors, universities, labs, web

Tailored Approach to Monitoring Site

- Reservoir type and history – Geology, well location, data archives,
  Land ownership (permitting)
  Infrastructure, risks/safety

- Economics – Dictate MMV technologies, sampling strategies

- Technology Overlap – Geophysics, couple tests with similar equipment

Conclusions & Future Directions

Conclusions:

- MMV – Power plants, pipelines, reservoirs
- MMV – Spatial and temporal scales
- Economics – Dictate technology & sampling
- Tailored approach used per reservoir

Future Directions

- Economic modeling: Needed for MMV
  Help with sampling designs
  Help with risk/safety evaluations