California Energy Commission

Geologic Carbon Sequestration Strategies for California
(The Assembly Bill 1925 Report to the Legislature)

Presented by
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at the
IEPR Staff Workshop on
Commercial-scale Geologic Carbon Sequestration
Sacramento, CA
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What are the components of geologic Carbon Capture and Storage (CCS)?

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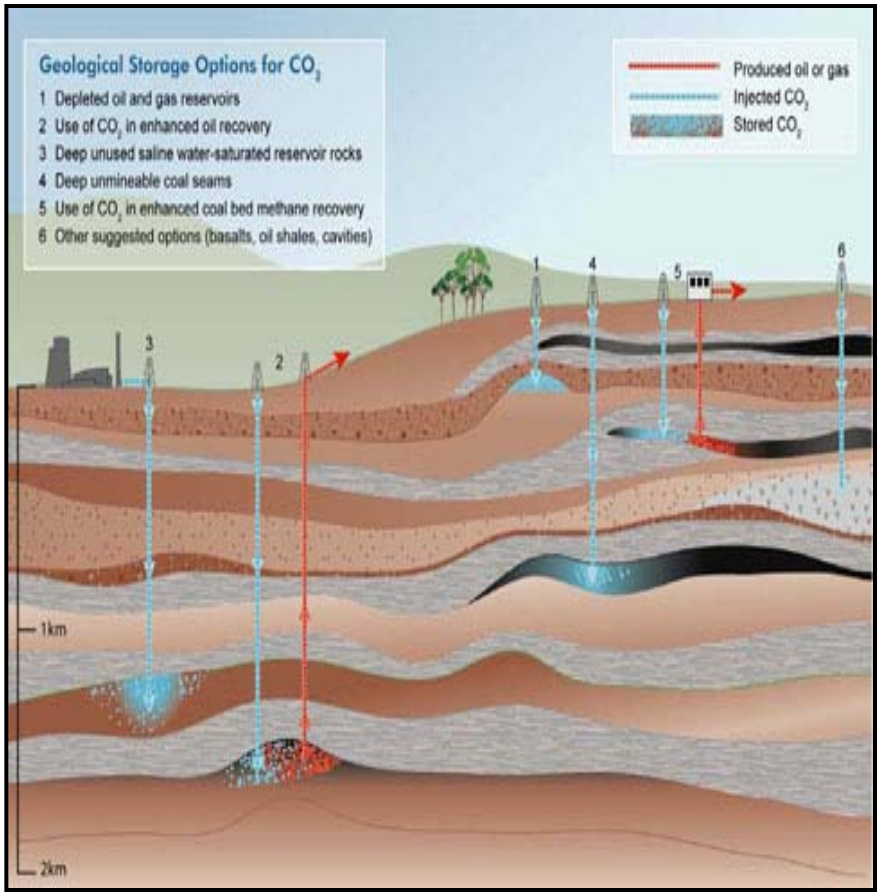

"Special Report on CCS", IPCC 2005

- CO_2 is "captured" out of emissions from a power plant or industrial facility (a point source)
- The separated CO_2 is transported to a storage site
- CO_2 is injected as a supercritical (liquid-like) fluid for storage in deep geological formations:
  - Saline Formations
  - Depleted Oil & Gas fields
  - Unmineable Coal Seams

The intent of AB 1925 and California CCS issues

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AB 1925 required the Energy Commission, with the Dept of Conservation, to prepare a report containing:

> "recommendations for how the state can develop parameters to accelerate the adoption of cost-effective geologic sequestration strategies for the long-term management of industrial carbon dioxide"

- How much geological potential for CCS does California have and the types and locations of major CO_2 point sources?
  - Imported electricity from coal plants provides 20-30 % of electricity and accounts for about half of inventoried GHG emissions from the power sector
  - Largest point sources in-state are natural gas power plants, cement plants and refineries
- How well is California positioned to move forward?
  - Technical readiness
  - Regulatory and statutory readiness
  - Risks and risk management
  - Economic considerations
  - Potentially favorable early opportunities
  - Further work

Screening of sedimentary basins in California

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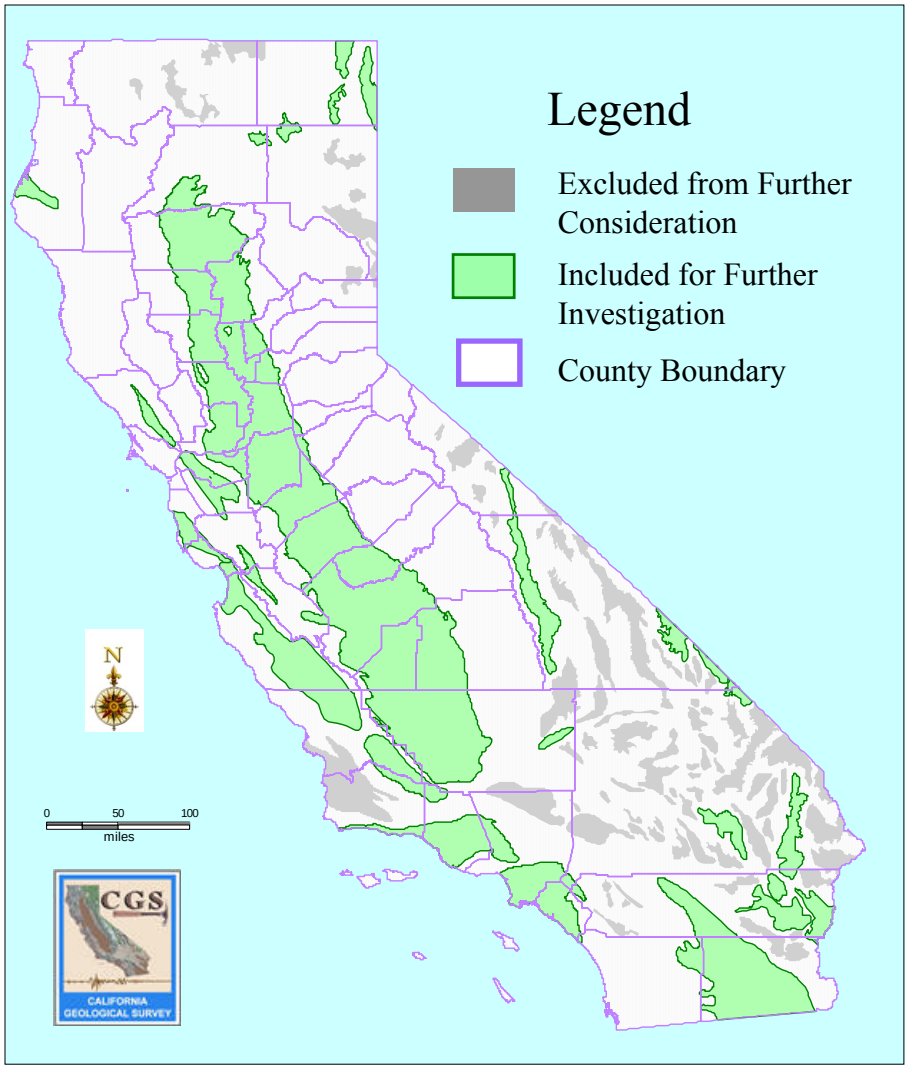
- 104 basins were screened
- 77 basins were eliminated from further consideration due to:
  - Lack of porous & permeable formations
  - Lack of suitable seals
  - Sediment thickness < 800 meters
  - Being within parklands, tribal lands, or military installations
- 27 basins met the initial screening criteria (>38,000 square miles)
  - Most promising are Sacramento, San Joaquin, Ventura, Los Angeles, and Eel River basins
  - Storage estimates using NETL (2007) methodology for 10 largest basins = 75-300 Gt CO_2



Oil and gas fields are common in basins passing the screening criteria

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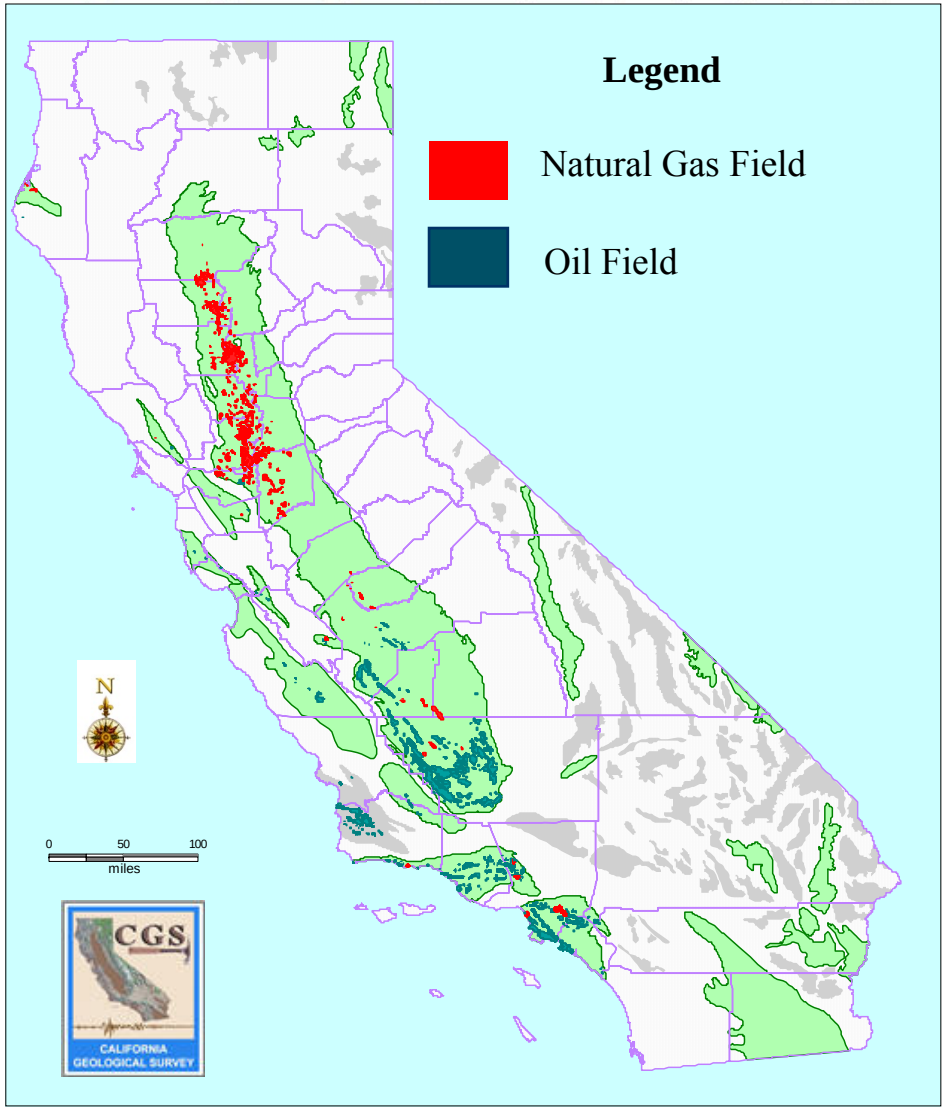
- Depleted oil and gas fields are potentially good sequestration sites
- Capacity estimates are about 5000 $MMTCO_2$
- Presence of oil and gas demonstrates the capability of structures in these basins to sequester buoyant fluids over geologic time scales (millions of years)



The largest in-state point sources are natural gas power plants, cement plants and refineries

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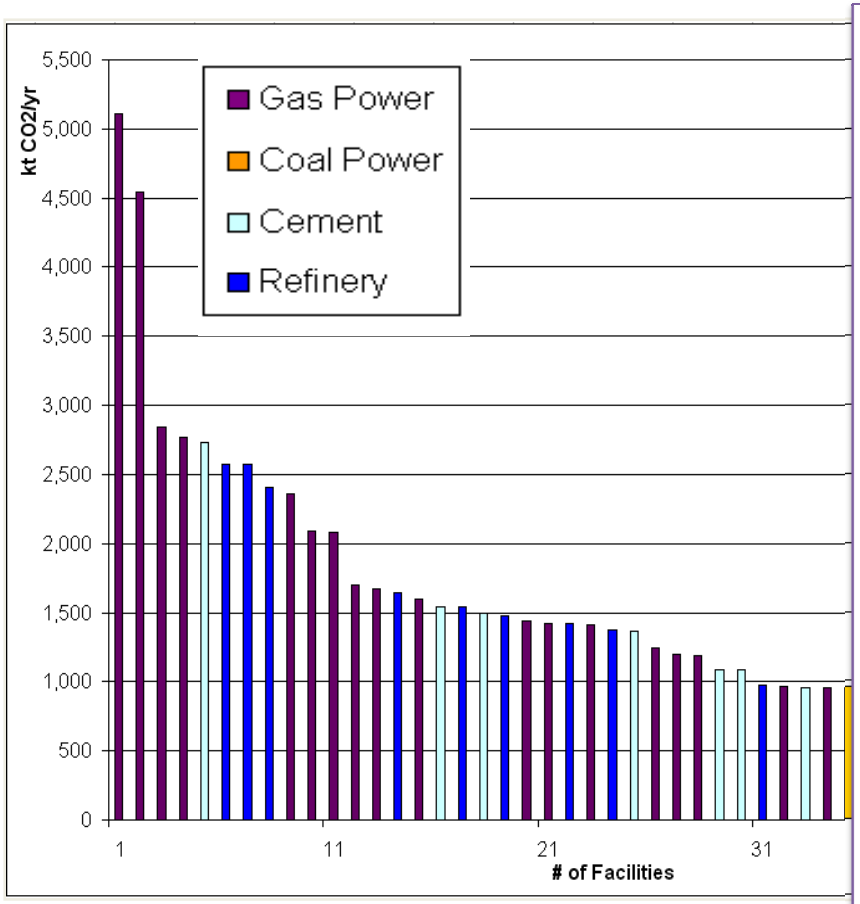

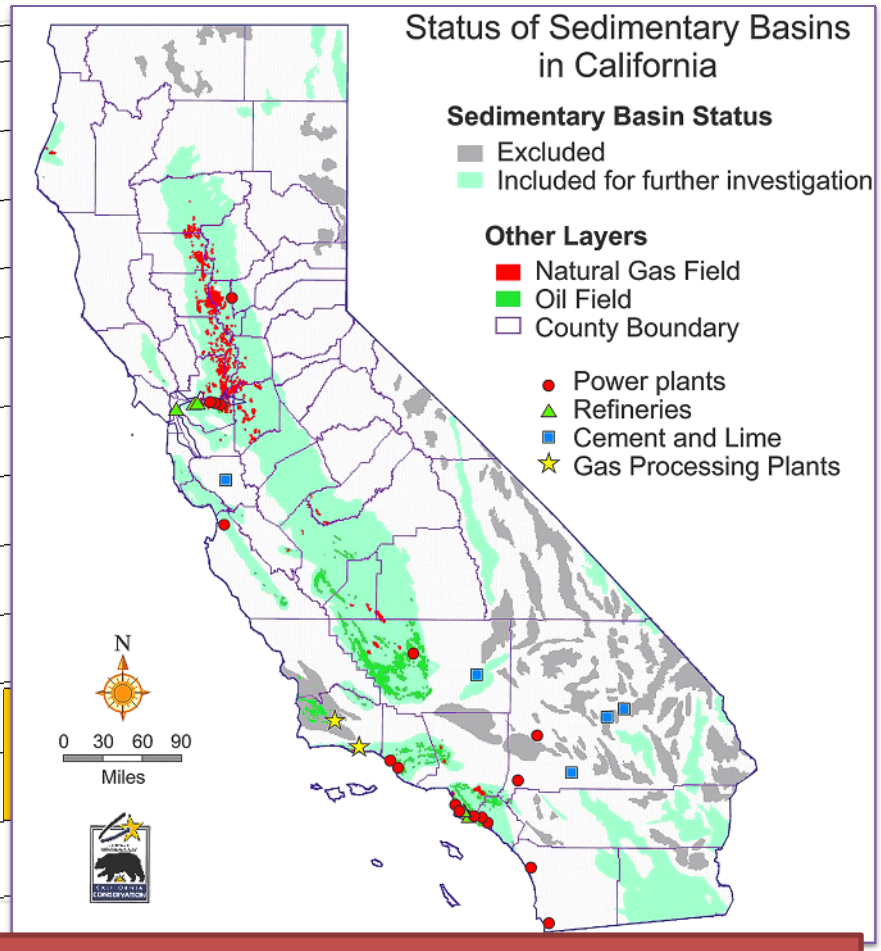

90% are within 50 km of a potential sequestration site

However, how to best implement CCS for California is a regional issue

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- Electricity imports into California
  - 22-32 % of electricity used
  - 39-57 % of GHG emissions
- Transportation fuels are exported to neighboring states—
  - 100% of Nevada's
  - 60% of Arizona's
  - 35% of Oregon's
- Does the carbon flow with the energy?
  - Inventory
  - Credits; cap-and-trade
  - Actual
- How does each state meet its individual carbon emissions goals in this context?

SB 1368 and economics suggested a CCS focus on imported coal-generated power

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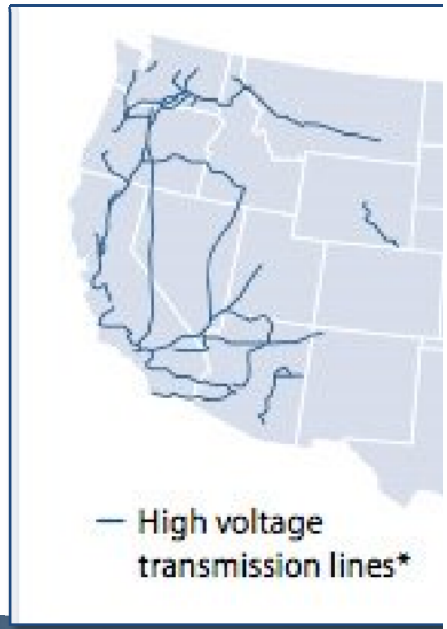
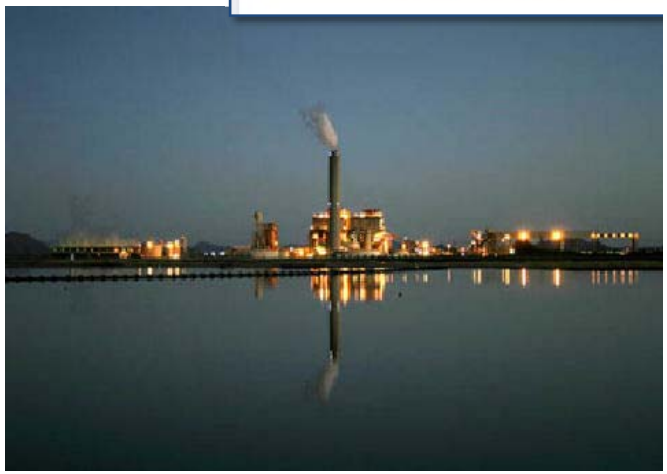
- Imported power generates more than half of power sector emissions (60 out of about 107 MMT CO_2/yr)
- SB 1368 sets an emission standard (defined at 1100 lbs CO_2/MWh) and prohibits long-term baseload power purchase agreements emissions above the standard
- Addition of CCS is the most likely way to meet SB1368 standard, but IEPR (2007) concluded that commercial-scale demonstration is key to developing investor confidence, and CCS on out-of-state coal plants is unlikely to be available to meet 2020 AB32 goals.





However, that opinion is now being re-examined given recent federal policy momentum and in-state petroleum coke-fueled commercial projects like that of Hydrogen Energy

Early economic opportunities in alternative fuels and chemicals

- Ethanol/biorefineries
  - Only a few large plants currently in California, but more are planned
  - About 2500 metric tons CO_2/million gallons of ethanol produced
  - Emissions are essentially pure CO_2 so separation costs are avoided
  - Provides net-negative GHG emissions reductions
- Syngas/pet-coke hydrogen
  - CO_2 capture integrates into pre-combustion process

Opportunities for enhanced oil recovery using captured CO_2

- 80% of emissions sources are within 50 km of a potential EOR site
- EOR operations recycle CO_2, but result in 30-60% of injected volumes left underground
- EOR improves CCS project economics by valuing carbon
- CO_2-EOR has potential to recover up to 5 billion barrels of additional oil*
- CO_2 demand potential for EOR could result in storage of up to 1 billion tons stored*

*U.S. Department of Energy/Advanced Resources International (2005) Basin Oriented Strategies for CO_2 Enhanced Oil Recovery: Onshore California Oil Basins

Deploying CCS projects depends on economics and technical and statutory readiness

Components of technical readiness

- Capture technologies and transportation
- Surface issues for plant and well siting
- Subsurface elements
  - Risk management
  - Site characterization and certification
  - Monitoring and verification
  - Remediation and mitigation

CO_2 pipelines are a mature technology; California lacks infrastructure

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- Regulatory framework exists– Office of the State Fire Marshal
- Over 3000 miles of CO_2 pipeline in the U.S. delivering over 10 Tcf of gas
- Experienced workforce exists
- No serious injuries or deaths associated with CO_2 pipelines
- Mature safety technology: (automatic block valve closure, spacing regulated by USDOT, telemetry for 24-hour real-time monitoring)
- FutureGen environmental risk assessment identified most significant hazard as pipeline leakage, not subsurface leakage

Established methods for facility siting must consider issues raised by CCS

Comments from Energy Commission's Siting, Transmission and Environmental Protection Division:

- Addition of CCS to new or existing power plants has potential effects on regulatory frameworks – such as CEQA and Warren-Alquist – for siting of new plants or retrofitting existing facilities.

- The Energy Commission will likely be the CEQA lead agency for CCS associated with power plants: this aspect should be included in any follow-up studies done in preparation for the (AB 1925) 2010 report.

Subsurface technical readiness relies on mature technologies and experience with analogs

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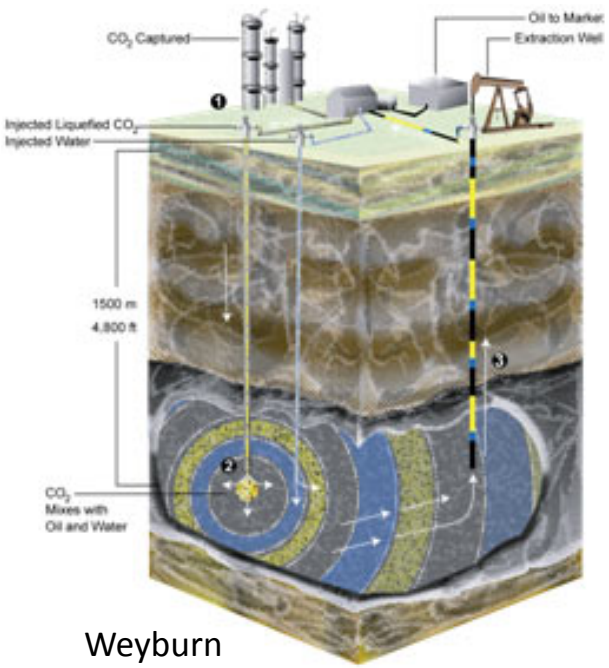
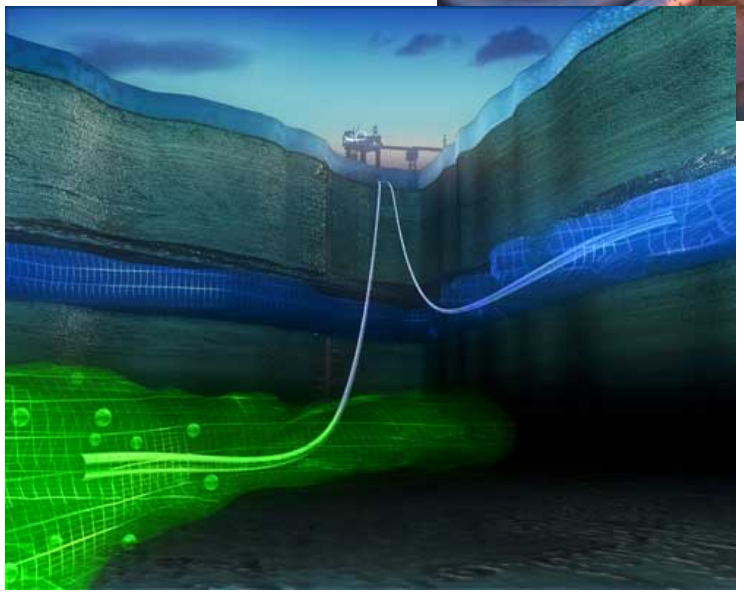


Weyburn

Many analogs

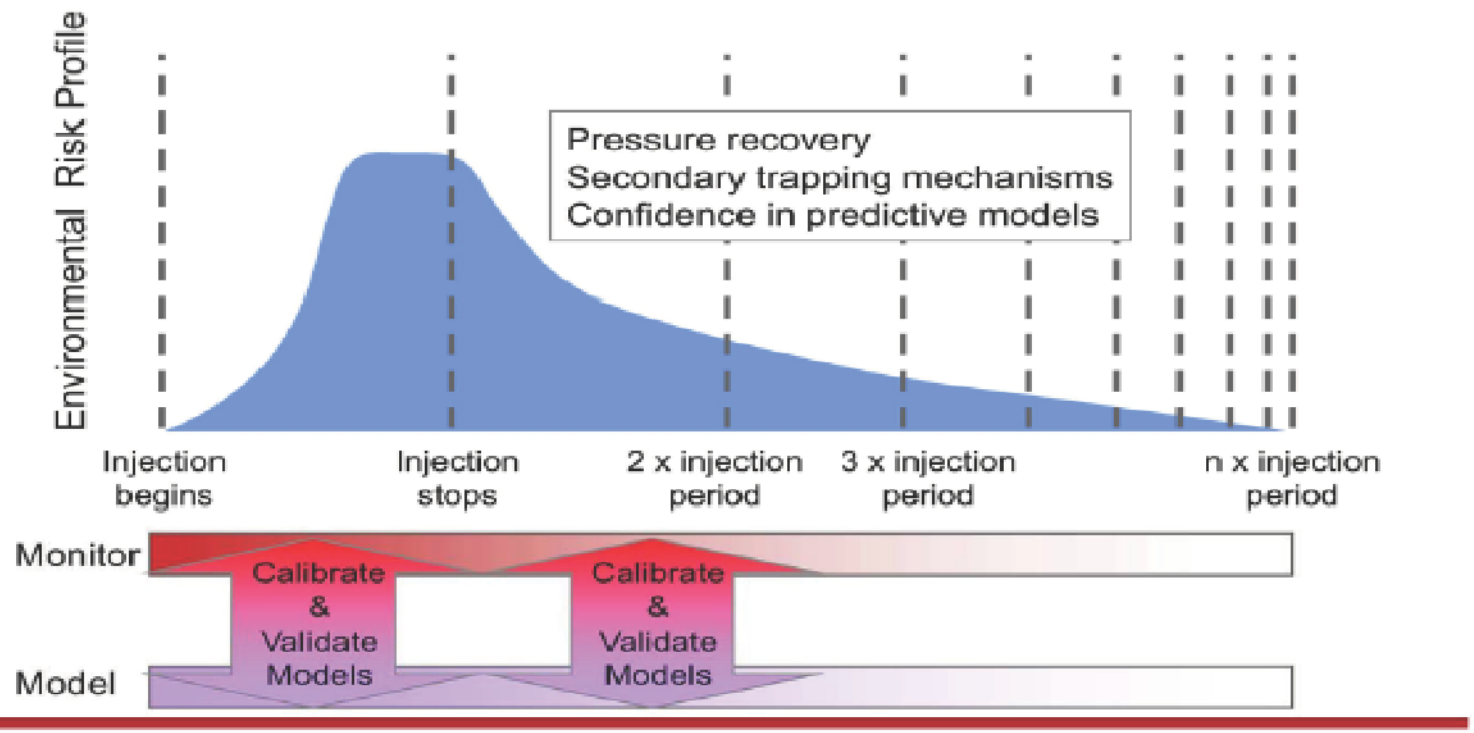
- Natural CO_2 reservoirs
- CO_2 storage through EOR
- Natural gas storage
- CCS pilots and early commercial projects

Sleipner



Oil and gas industry has highly developed subsurface characterization technologies and provides relevant knowledge and experience

Technical risk levels out during injection and then declines over time



From Patton, Zurich, 2008.

The key to risk management is assuring that site characterization and monitoring data give confidence in predictive modeling of reservoir performance

Risk perception and awareness of CCS technology will strongly affect rates of adoption

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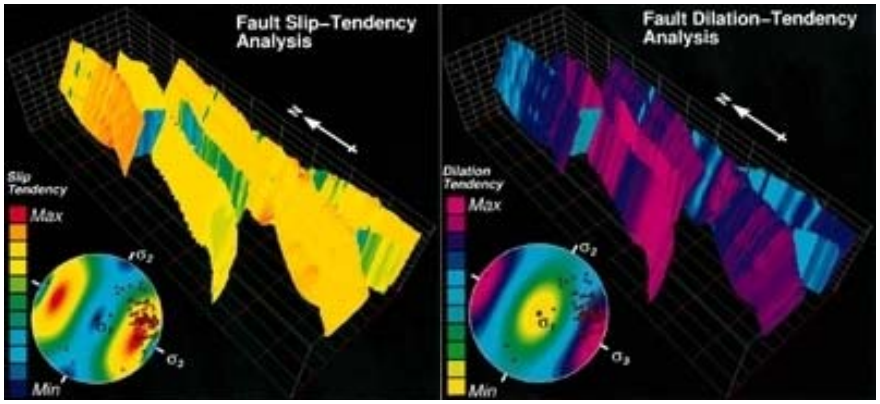
- Surveys show public's greatest concerns are
  - Harm or damage to people, the environment, or property by leakage of CO_2
  - Accountability/stewardship over long time scales

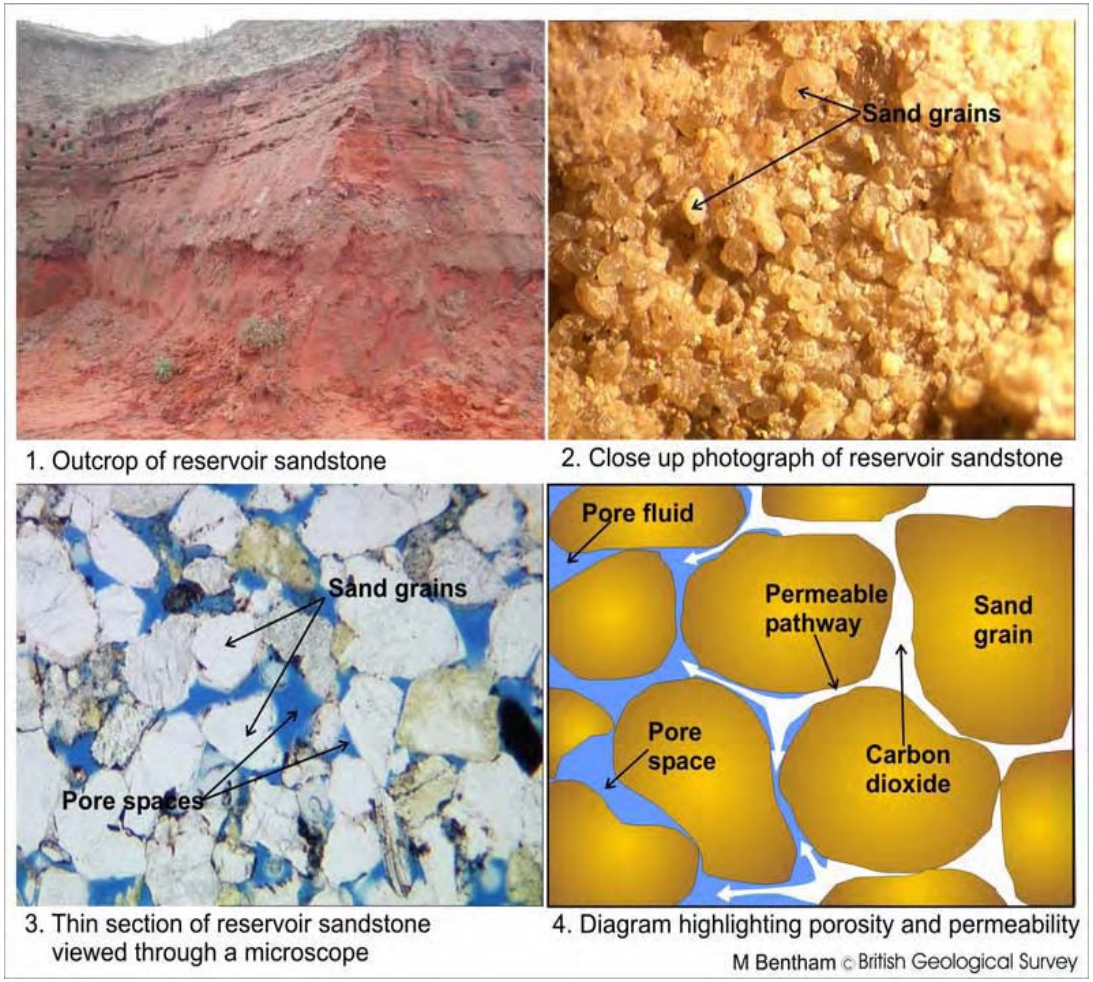
- Other risks
  - Damage from induced seismic or brine migration in saline formations
  - Climate-change risk from cumulative slow leakage of CO_2 to the atmosphere



http://www.swri.org/4org/d20/home/what/subsurf.htm

CO_2 is stored in tiny pockets between rock grains, not in "pools" or "bubbles"

- Reservoir rocks commonly are sandstones with high permeability
- Saline water or brine (from one-third to four times seawater) occupies pore spaces
- CO_2 displaces brine between grains but also dissolves in it and reacts with sand grains



1. Outcrop of reservoir sandstone
2. Close up photograph of reservoir sandstone
3. Thin section of reservoir sandstone viewed through a microscope
4. Diagram highlighting porosity and permeability

M Bentham © British Geological Survey

A good sequestration reservoir has specific subsurface attributes

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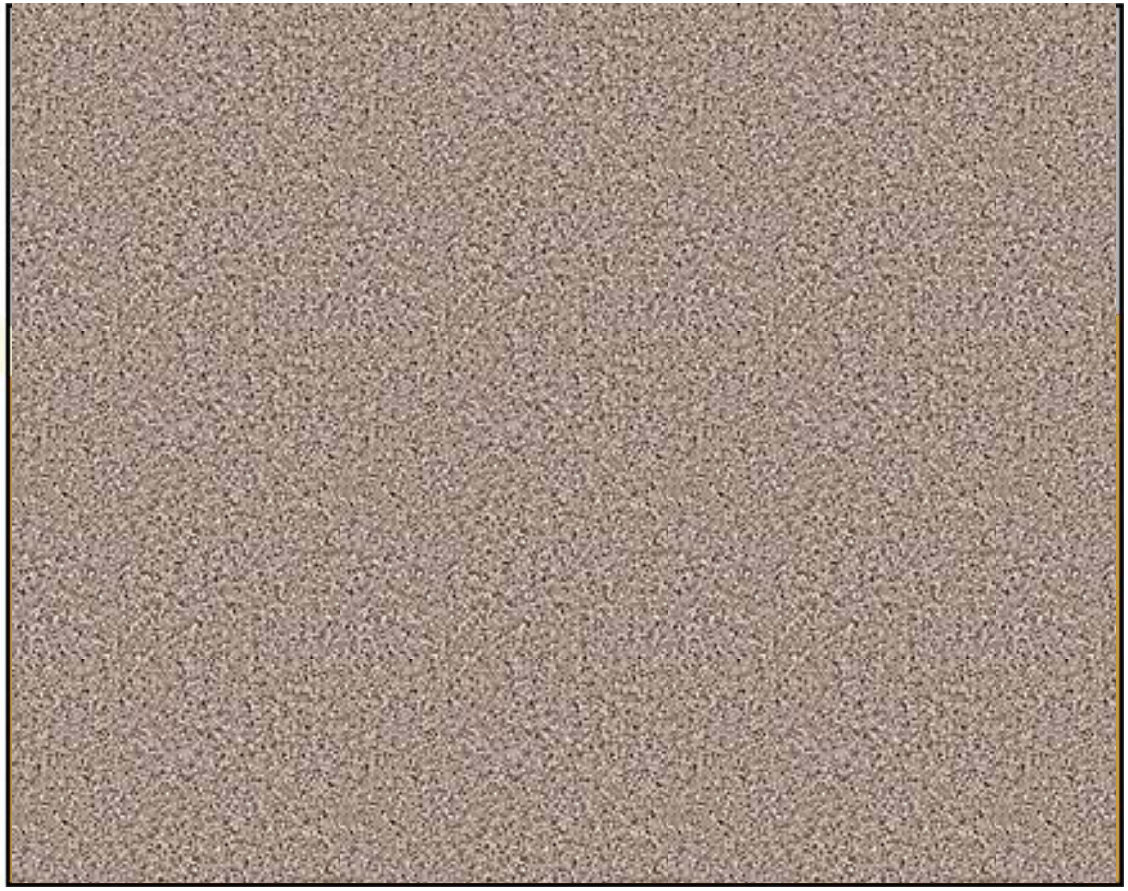
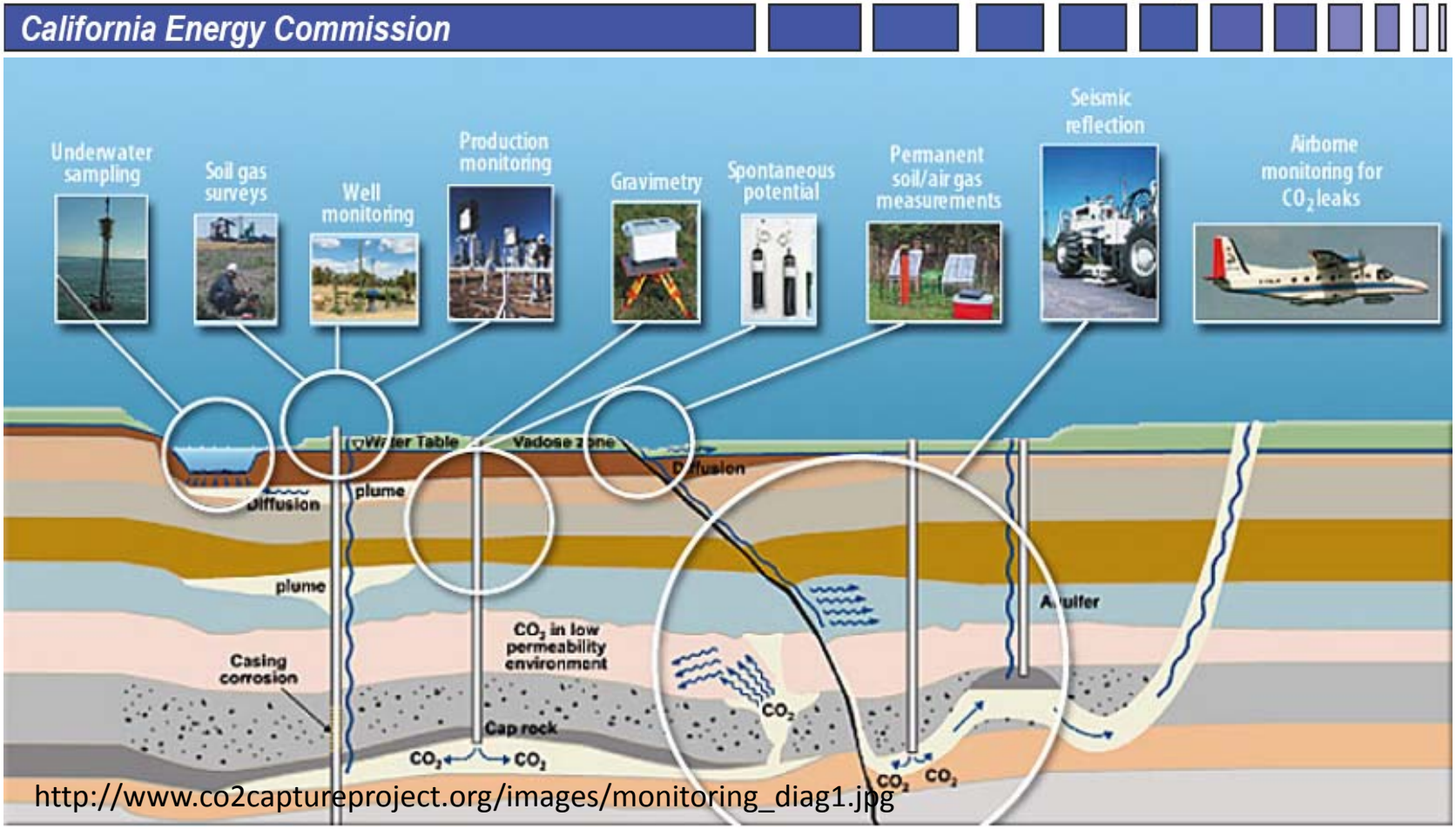
- Injectivity: ability of CO_2 to displace existing subsurface fluids
- Capacity: ability of rock to hold CO_2 as gas, dissolved ions or mineral phases
- Integrity: ability of overlying nonporous rocks to seal reservoir, and no "leaky" orphaned wells or faults



Data collected in site characterization and by monitoring throughout the life of the project must verify reservoir performance.

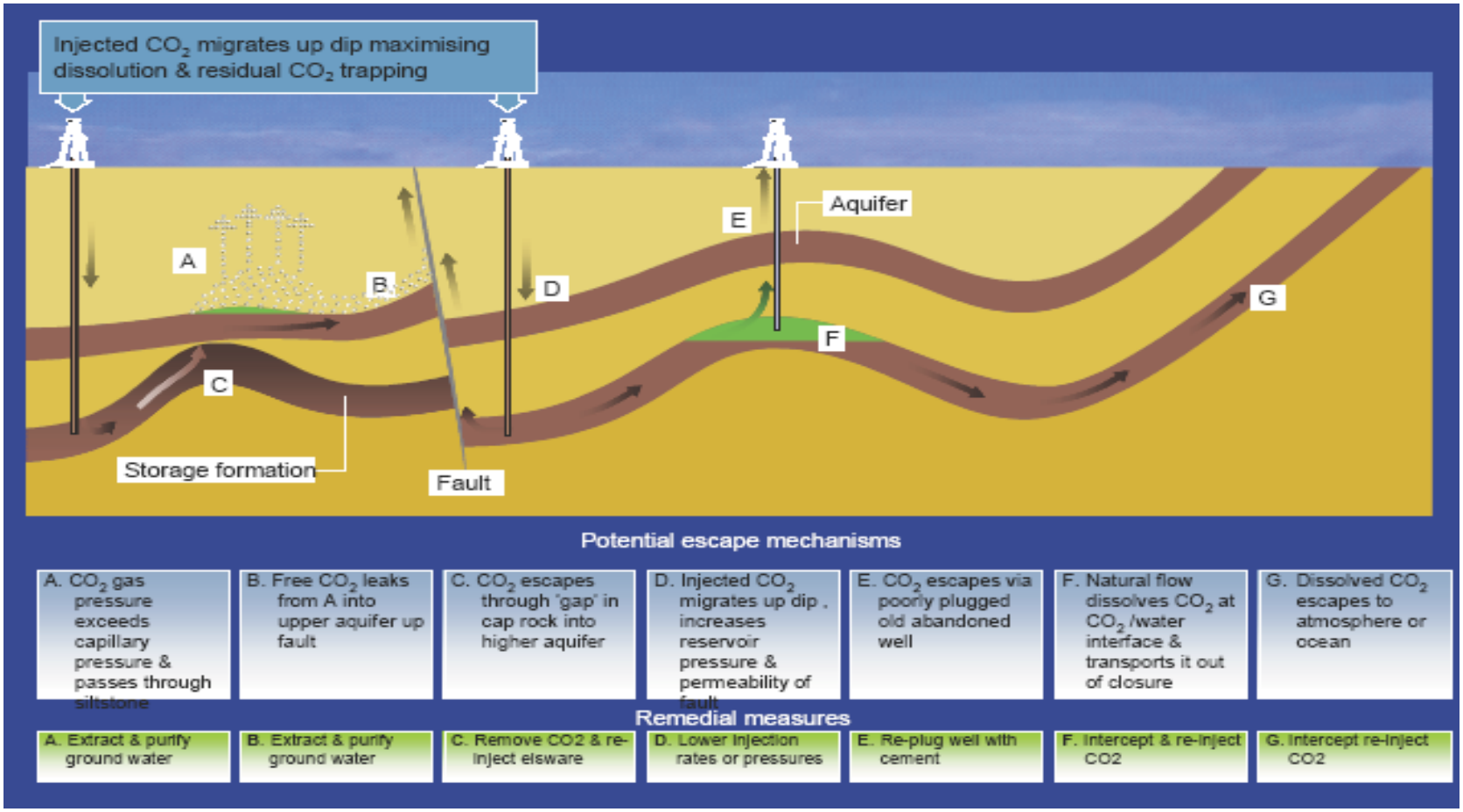
Monitoring must track CO_2 migration, detect leaks, and verify storage



http://www.co2captureproject.org/images/monitoring_diag1.jpg

Density and frequency of monitoring surveys are designed to confidently predict reservoir performance and may decrease as confidence increases over time

Remediation and mitigation addresses what to do in case of a leak



Proper site characterization and monitoring to provide early detection are key to avoiding large acute or chronic leakage

If a large acute leak occurs and reaches the surface, CO_2 must build to high concentrations to cause harm

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Mammoth Mt., CA

magmatic emissions into soils can become fatal to trees and also to humans and animals in low places with stagnant atmospheric conditions

Crystal Geyser, UT

Abandoned exploration well penetrates natural CO_2 reservoir which geysers CO_2 and water without creating harm

Regulatory needs for CCS

- The necessary technology and knowledge exist to inform regulations
- Demonstration and early projects are needed to provide test cases
- Given the differences in emissions sources and sequestration reservoirs, any CCS regulatory framework needs:
  - Flexibility
  - Streamlining
  - Predictability and consistency

Statutory needs for CCS

Given the long-term nature of geologic sequestration, statutory frameworks must:

- Assure long-term stewardship to protect people and the environment (including climate change mitigation)
- Address ambiguities in ownership
- Define liability limits (and how these follow ownership)
- Address issues arising from carbon credits—e.g., when there is value for CO_2

Summary and Conclusions

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- Large geologic potential and large point sources in reasonable proximity with several potential options:
  - Out-of-state power suppliers with coal plants
  - CCS with EOR
  - CCS with ethanol (double carbon reductions)
- CCS is technically ready and similar technical risks have been managed in other industries

- Needs/Next steps
  - Demos and early projects ASAP
  - Enabling regulatory and statutory frameworks for early projects
  - Improving economics of capture
  - Understanding how to develop pipeline infrastructure
  - Understanding effects of CCS on power costs and future energy portfolios for California
  - Identifying ramifications of various regulatory and statutory options
  - Developing appropriate protocols for CCS site selection, operations, and closure