Energy Geosciences
EARTH & ENVIRONMENTAL SCIENCES AREA

Geologic Carbon Sequestration

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What Is Geologic Carbon Sequestration?

Geologic Carbon Sequestration in A Nutshell

What is Geologic Carbon Sequestration?

- Geologic carbon sequestration is defined as the placement of pressurized CO_2 into a deep subsurface reservoir so that it will remain safely and permanently stored.

How Much CO_2 May be Sequestered Underground to Help Mitigate Climate Change?

- Studies suggest that a few gigatons (billion tons) of CO_2 per year would have to be sequestered worldwide to support climate mitigation measures. (2023 GHG emissions: 53 billion metric tons of carbon dioxide equivalent, $GtCO_2e$).
- These estimates comprise CO_2 removed from the atmosphere (Direct Air Capture) as well as CO_2 captured from major emissions sources prior to release into the atmosphere (e.g., energy sector; hard-to-decarbonize industrial processes).

What Are the Properties of CO_2 Deep Underground?

- When injected deep underground (> 800 meters down to several thousand meters), the CO_2 is almost as dense as water, thus allowing for storage of much greater volumes of CO_2 than at the surface.

What Keeps the Buoyant CO_2 from Migrating Back Up Towards the Surface?

- The injected CO_2 is trapped in suitable storage reservoirs through multiple storage mechanisms.
- Most important in the short term is the geology (structural trapping): Impermeable rock layers and other features within and above the storage formation act as seals, preventing CO_2 from moving out of the storage formation.
- Over long timescales, CO_2 reacts with the formation rocks and becomes a solid mineral (mineral trapping).

Is Geologic Carbon Sequestration Already Done?

- Yes, in addition to many pilot and demonstration studies, there are several industrial-scale projects worldwide. Some of these have been operating for years if not decades.
- Many more large projects are in construction or in development/planning stages.

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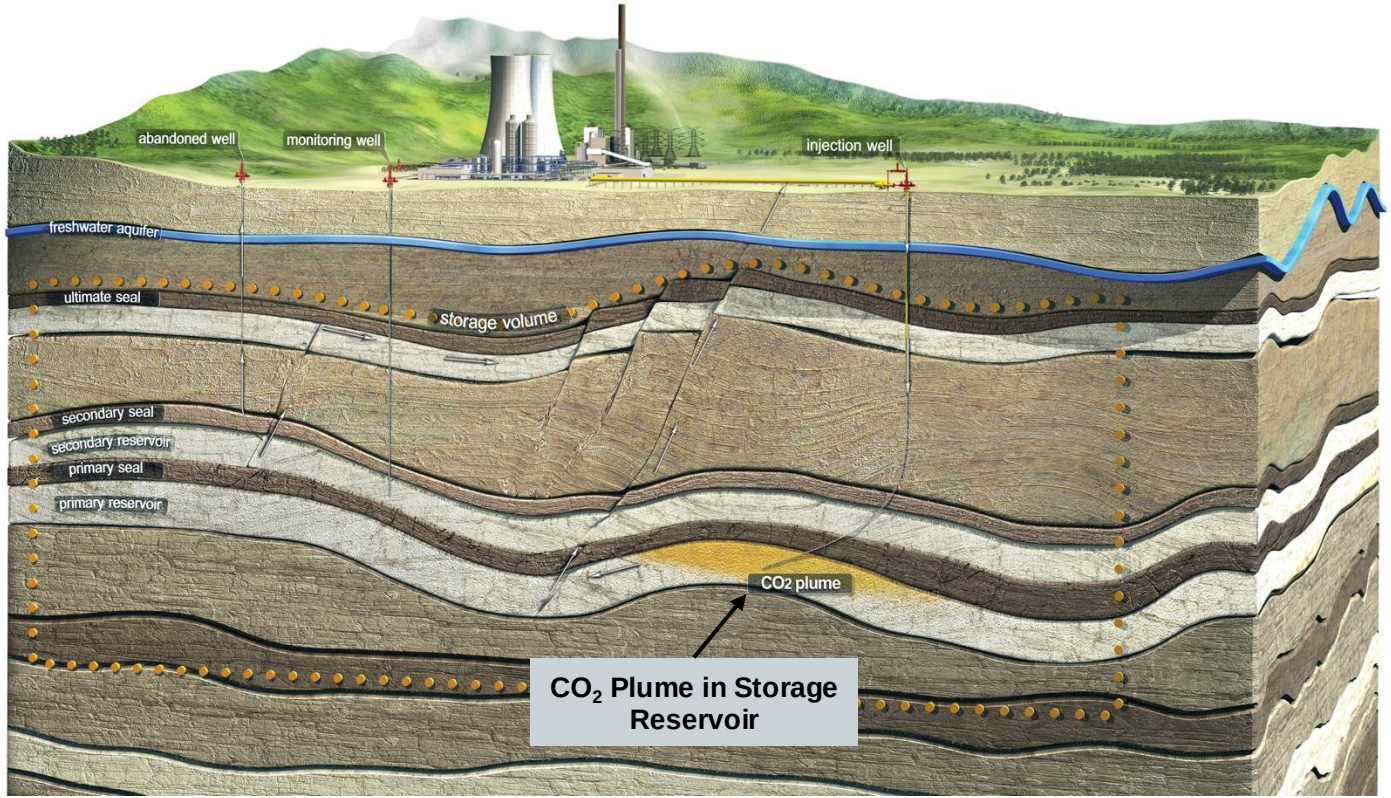
Geologic Carbon Sequestration: Injecting CO_2 into a Deep Permeable Reservoir with Overlying Seals



Multiple Seals Between Deep CO_2 Injection Reservoir

> 800 m to several thousand m

Burj Khalifa (828 m)

Sedimentary rocks with alternating permeable and impermeable layers

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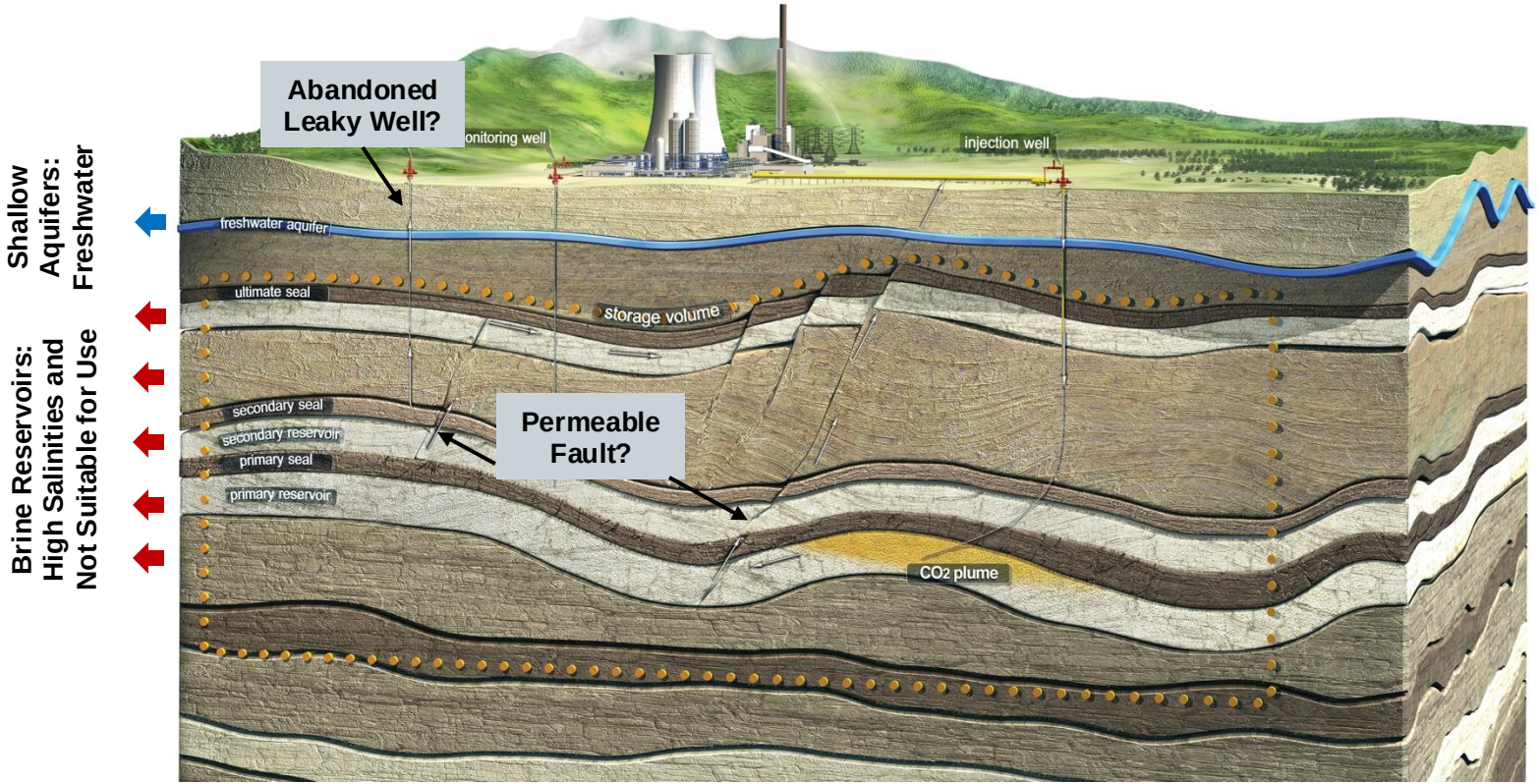

Burj Khalifa (828 m)

Potential Pathways for CO_2 or Brine to Escape from Primary Storage Reservoir

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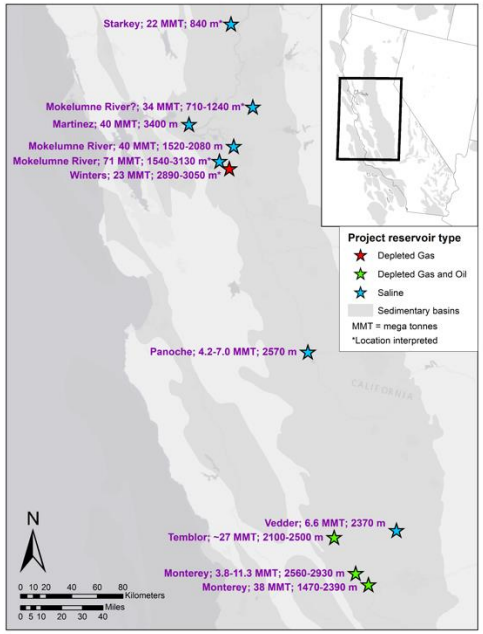
Status and Outlook of Carbon Capture/Removal and Geologic Sequestration

Geologic Sequestration Projects in Regulatory Review (10/2023)

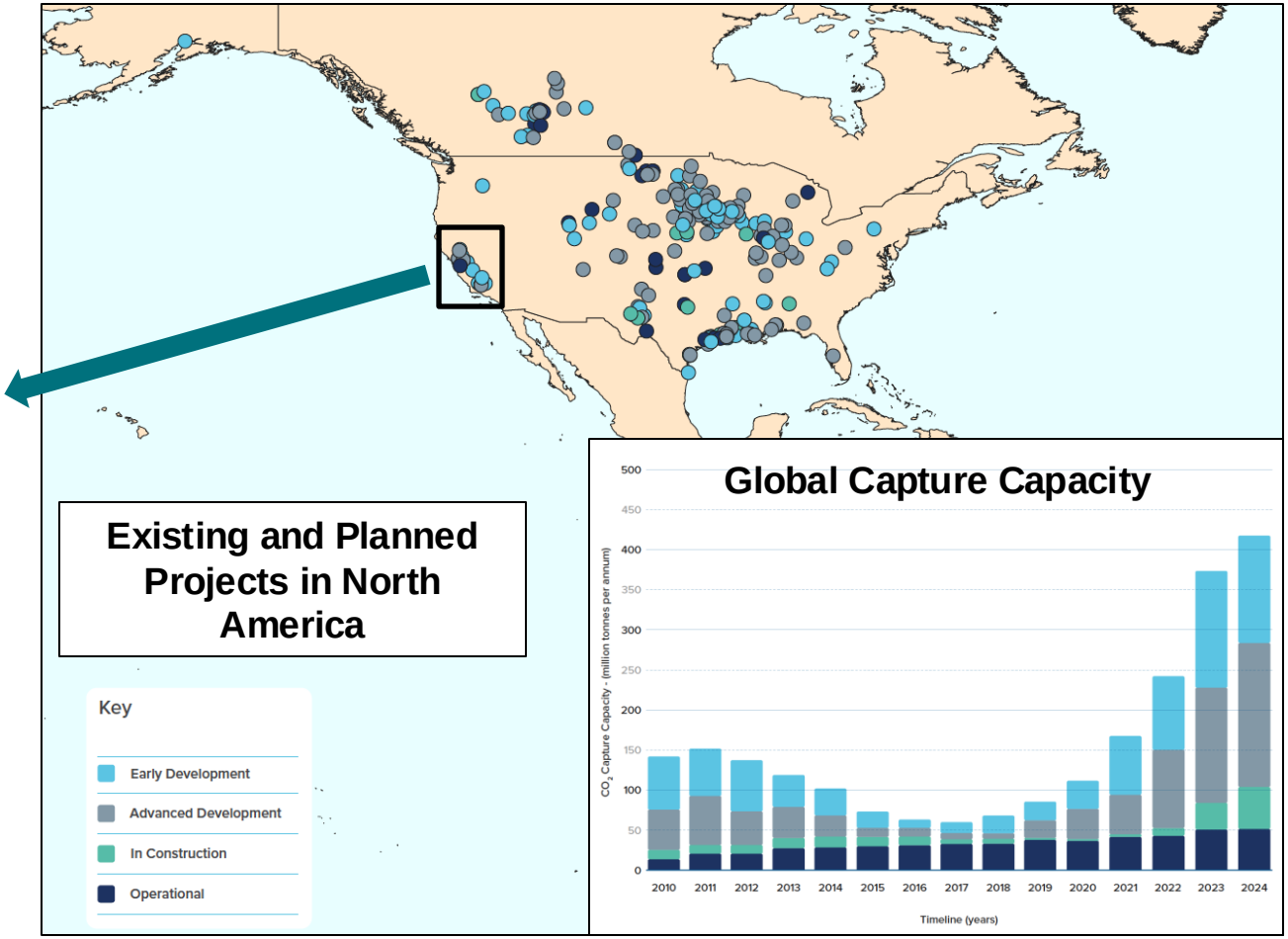


Saline Formations: Saline formations are porous formations filled with brine, or salty water, and span large volumes deep underground.

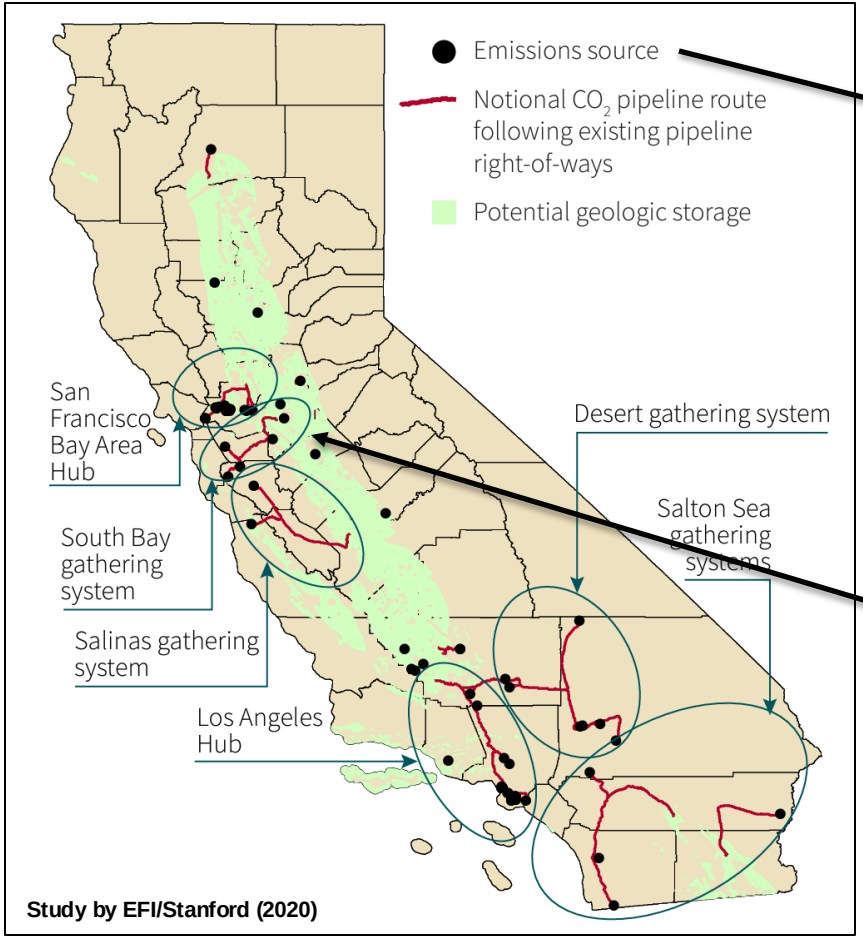
Depleted Oil or Gas Reservoirs: Once the oil and natural gas has been extracted from an underground formation, it leaves a pore volume that can be readily filled with CO_2.

Status 2024*

*Global Status of CCS 2025 Report, Global CCS Institute (2024)

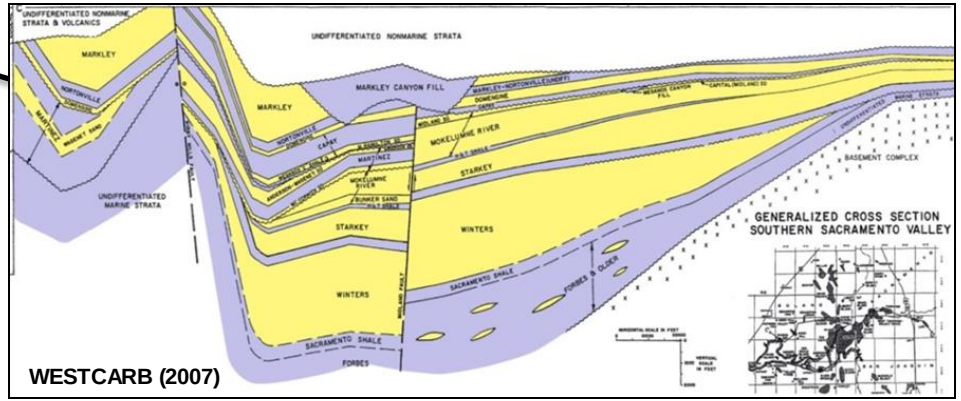


Geologic Carbon Sequestration in California – Where?



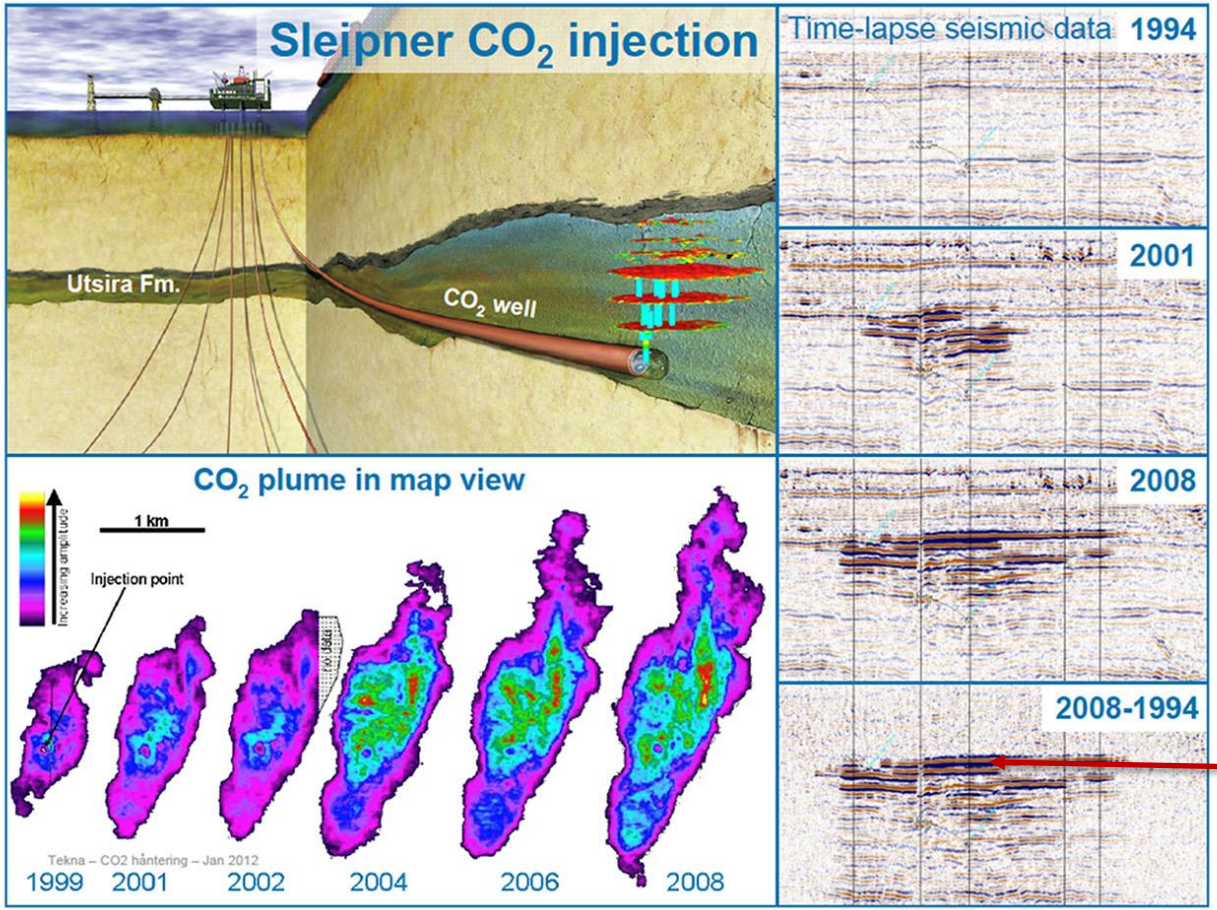
CO_2 Captured From Major Emissions Sources Needs to Be Transported to Suitable Geology

Central Valley: Deep Regional Sediments With Multiple Seals



Industrial-Scale Sequestration Has Been Done Since 1996 (Example)

The Sleipner CCS Project of the Coast of Norway has since 1996 Injected and Safely Stored about 1 Million Tons of CO_2 Per Year



Time-Lapse Tomographic Monitoring of CO_2 Plume in Storage Reservoir (Plan View)

Time-Lapse Tomographic Monitoring of CO_2 Plume in Storage Reservoir (Cross-Section)

Top of the Storage Reservoir

Image courtesy of Equinor ASA

Risks and Guardrails: CO_2 Leakage and Induced Seismicity

EPA's Class VI Regulations

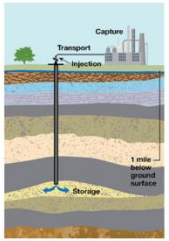
Class VI – Wells used for Geologic Sequestration of Carbon Dioxide

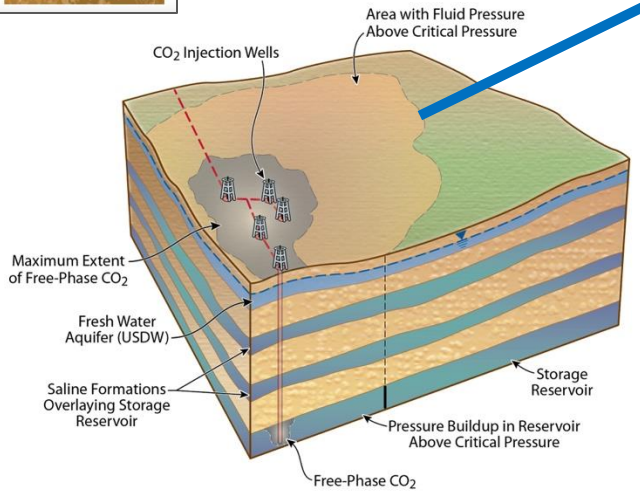
On this page:

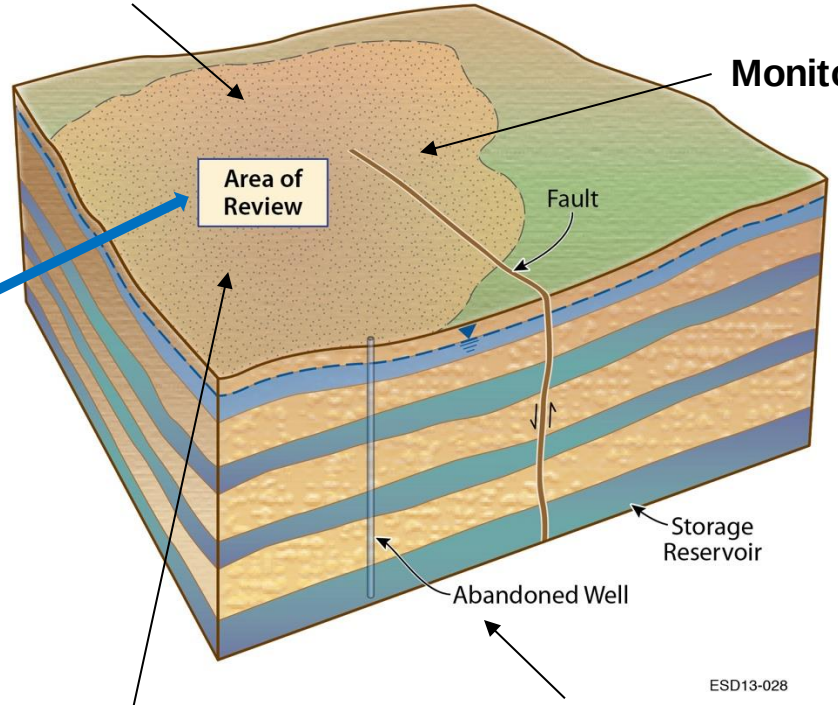
What is a Class VI well?

Class VI wells are used to inject carbon dioxide (CO_2) into deep rock formations. This long-term underground storage is called geologic sequestration (GS). Geologic sequestration, as part of carbon capture and storage (CCS), is a technology that can be used to reduce CO_2 emissions to the atmosphere and mitigate climate change.

Possible sources of CO_2 for GS include CO_2 captured from point source emissions, such as from an industrial facility (e.g., steel and cement production) or energy production (e.g., ethanol, hydrogen production, or power plants), as well as CO_2 captured directly from the atmosphere.

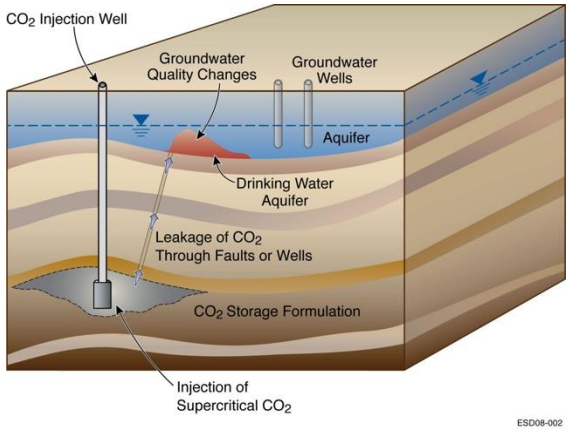




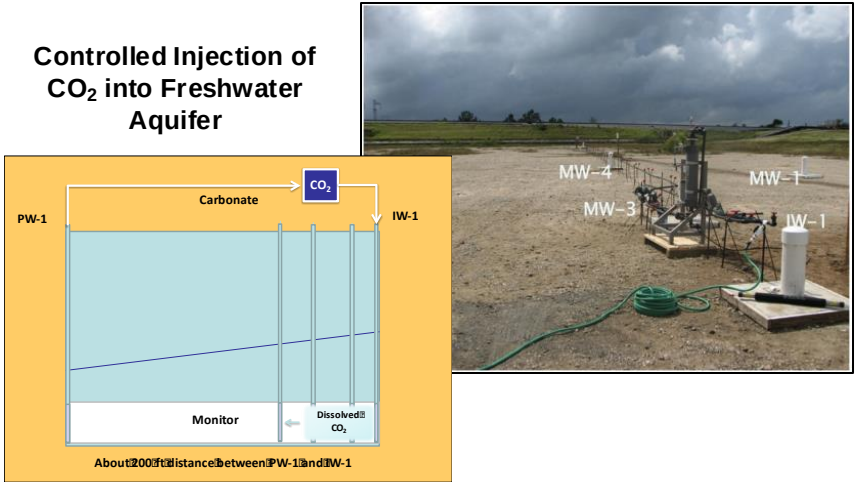


Managing Risk of CO_2 Leakage

Can CO_2 escape from deep sequestration and what would be the impact (e.g., to groundwater)?



Controlled Injection of CO_2 into Freshwater Aquifer



Prior to Project Start

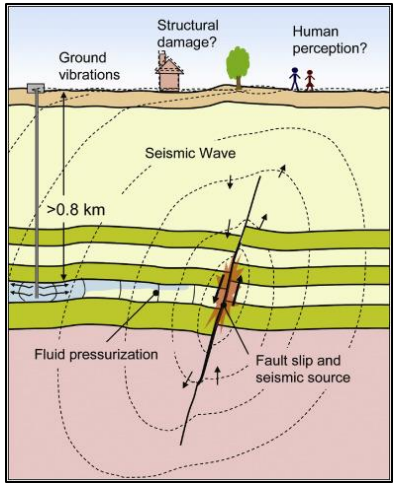
- Finding and Characterizing Potential Leakage Paths
- Corrective Action on Existing Wells If Necessary
- Risk Assessment Studies

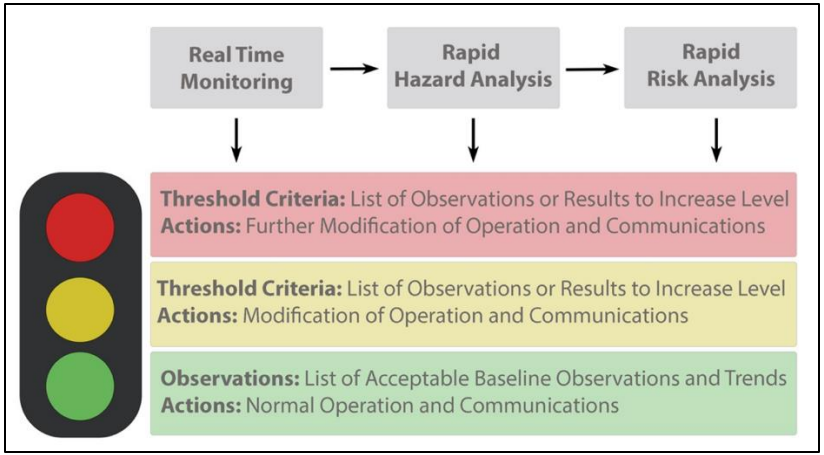
During and After Injection:

- Performance Monitoring in Storage Formation:
  - CO_2 Plume Migration
  - Pressure Buildup
- Assurance Monitoring:
  - Leakage of CO_2 or Pressure Changes in Sediments Above Storage Formation
  - Freshwater Aquifer Impacts
  - CO_2 Leakage at Ground Surface

Managing Induced Seismicity Risk

Can the Injection and Storage of Large Volumes of CO_2 Create Sizeable Earthquakes?





Traffic Light System for Induced Seismicity

Prior to Project Start

- Site Characterization to Detect Faults in Storage Reservoir, Seals, Basement
- Forecasting of Seismic Hazard and Risk Assessment
- Develop Risk Management Plans with Threshold Criteria

During and After Injection:

- Real-Time High-Sensitivity Seismic Monitoring
- Rapid Hazard and Risk Analysis
- Implement Pre-Defined Risk Mitigation Measures If Necessary

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Thank you

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