Carbon Management Fact Sheet

California's ambitious climate goals require both significant reductions in greenhouse gas emissions and the growth of carbon management solutions including carbon capture and sequestration (CCS) and carbon dioxide removal (CDR). These solutions prevent industrial carbon dioxide (CO_2) from entering the atmosphere or remove existing CO_2 directly from the air. CCS and CDR are identified by the International Panel on Climate Change (IPCC),[i] the International Energy Agency,[ii] and the California Scoping Plan[iii] as essential for decarbonizing industry and fighting climate change.

How It Works

These projects are a system of integrated engineering solutions that consist of three main steps:

1. Capture
2. Transport
3. Storage

1. Capture

Carbon can be removed from the atmosphere and stored using nature-based solutions, such as storage in trees. It can also be removed mechanically using technologies that capture CO_2 from a point source before it enters the atmosphere or directly from the air.

Nature-Based Solutions

- **Urban Forests and Forest Health:** Expanding tree canopies and urban parks, and forest restoration and conservation are strategies that allow trees to capture and store carbon.
- **Soil Health:** Regenerative agriculture practices, including composting and biochar, cover crops, and low-till farming, can support soil carbon sequestration.
- **Ecosystem Restoration:** Restoring coastal salt marshes and wetlands create important carbon sinks.

Point-Source Capture Technologies

- **Industrial Source Separation:** Can be used at industrial facilities where CO_2 concentrations are high. This includes ethanol plants, hydrogen plants, petroleum refineries, cement kilns, and power plants. The technology also filters out pollutants like particulate matter, sulfur, and nitrogen oxides, helping improve local air quality. While the chemical process can create secondary vapors like ammonia, operators can trap those vapors using specialized air washers, filters, and longer-lasting capture fluids.

- **Bioenergy:** Generates energy from biomass while capturing related CO_2. The process is called Bioenergy with Carbon Capture and Storage, or BECCS when combined with permanent underground storage.

Direct Air Capture (DAC)

- **Atmospheric Extraction:** Extracts CO_2 directly from the air where concentrations are extremely low. It uses solid chemical filters or liquid chemical solutions to trap the gas and release it when heated. This method requires more energy and costs more because the concentration is low.

2. Transport

After capture, CO_2 is transported to storage sites. Pipelines are currently the safest, most cost-effective, and scalable way to transport large continuous volumes of CO_2. Ships, trains, and trucks may also be used in specific circumstances.

CO_2 Pipelines

- CO_2 is typically transported through pipelines as supercritical fluid with a liquid-like density and gas-like fluidity, allowing large volumes to move efficiently.
- CO_2 pipelines are a mature, commercial technology with over 50 years of operating history. More than 5,000 miles of dedicated CO_2 pipelines are currently operating in the United States, accounting for approximately 85% of global pipeline mileage.[iv,v]
- Historically built to transport naturally occurring CO_2 to mature oil fields for Enhanced Oil Recovery (EOR) in Texas, pipelines are now rapidly expanding into dedicated multi-user networks for permanent deep carbon storage.

Trucks, Trains, Ships

- Transporting CO_2 as a high-density liquid via trains, trucks, or ships is more volume-efficient over long distances, but transporting this way takes a lot of energy because the CO_2 must be cooled to about −50 °C. As a result, this method works best for temporary, smaller shipments, and has operational challenges and higher costs than pipelines.

3. Storage

Storage involves injecting CO_2 deep underground into permeable rock layers capped by thick, solid rock layers to keep it trapped. At depths below 2,600 feet, the temperature and pressure keep the CO_2 dense, similar to oil.

In California, suitable formations in the San Joaquin and Sacramento Basins are typically 5,500 to 8,500 feet deep. This is much deeper than groundwater aquifers that are typically less than 500 feet below ground.

Underground storage options include:

- **Deep Saline Aquifers:** Deep, saltwater-filled sandstone or limestone formations offer the vastest storage capacity worldwide. These aquifers are not useable for human consumption.
- **Depleted Oil & Gas Reservoirs:** These rock formations have proven structural integrity because they successfully trapped oil and natural gas for millions of years. That same empty space created when those resources were extracted can now be used for storage.

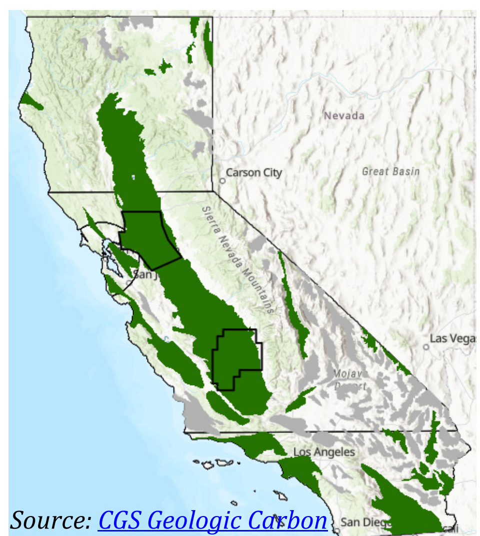
After injection, CO_2 is locked into the rock by four trapping mechanisms:

1. Structural trapping: A physical barrier under impermeable caprock layer(s)
2. Residual trapping: CO_2 trapped in tiny rock pores
3. Solubility trapping: CO_2 dissolving in formation fluid
4. Mineral trapping: CO_2 reacting to form solid carbonate rock

As a result of these trapping mechanisms, storage security increases over time.

Underground Storage Potential in California

California possesses substantial potential for permanent carbon storage, primarily within the deep basins of the Central Valley. It is estimated that California's total storage capacity is 150 to 500 gigatons of carbon[vi] – enough to store centuries worth of state industrial emissions.



Source: [CGS Geologic Carbon Sequestration Data Portal]

Key California Storage Basins

- **Sacramento Basin:** Extensive saline aquifers and depleted gas fields near industrial facilities in Northern California.
- **San Joaquin Basin:** High-capacity area with thick sandstone formations and robust shale caprocks.
- **Ventura, Los Angeles Basins & Salton Trough:** Regional capacity in southern coastal and inland basins.

Technological Maturity

As of October 2025, there were 77 operational CCS plants in the world,[vii] and 19 operating in the United States.[viii]

Status of CCS Technology Development

- **Ethanol plant capture equipment**: Commercially available.
- **Cement/steel plant capture equipment:** Under demonstration as part of active commercial-scale pilot projects.
- **Direct air capture**: A few commercial-scale projects globally, but high energy and costs remain a deployment and scaling challenge.
- **CO_2 pipelines:** Technology is very mature, with thousands of miles already in place across the U.S.[ix]
- **Geologic storage:** In existence for over 50 years in saline aquifers and depleted oil and gas fields in the U.S. as part of enhanced oil recovery operations and for over 20 years as part of climate mitigation with no oil extraction.[x]

Health, Safety, and Environmental Risks

CCS is based on standard industrial chemical and oilfield processes. However, it also has specific operational risks that require strict engineering, monitoring, and regulatory requirements and oversight.

Potential Risk	Potential Impact	Characterization
Pipeline Rupture / Leak	Localized CO_2 dispersion, potential asphyxiation at high concentrations	Failure rates for CO_2 pipelines and those carrying oil and gas are both very low. However, CO_2 is transported at high pressure and is heavier than air, meaning it can displace oxygen and act as an asphyxiant at high concentrations. Generally, small leaks do not present this risk, but large ruptures can. [xi] From 1994 to 2021, leaks accounted for 48 percent of CO_2 pipeline incidents while ruptures accounted for 3 percent.[xii] Siting decisions, continuous monitoring, and rigorous pipeline engineering can help avoid pipeline leaks.
Induced Seismicity	Microseismic activity triggered by fluid pressure changes along faults	The injection of CO_2 in the subsurface may change stresses on existing faults leading to induced earthquakes and potential leakage. Documented seismic events have been small and are considered microseismic events when non-damaging and not felt by humans. The IEAGHG reviewed 36 CO_2 storage sites,[xiii] 19 of the projects undertook seismic monitoring, 10 detected some microseismicity attributed to injection, with only one known "felt" earthquake to date (Mw 4.4, Cogdell, Texas).[xiv] Continuous monitoring in conjunction with a project-specific traffic light system protocol guides mitigation actions, with the goal of detecting microseismicity and taking operational actions before larger events occur.
Groundwater Contamination	CO_2 acidification of shallow drinking aquifers,	For CO_2 acidification to occur, injected CO_2 must move up through faults or fractures, unsealed legacy wells, or compromised caprock into shallow aquifers. Many of the same engineering solutions used to protect drinking water from oil and gas production are effective at

	leaching trace minerals	reducing the risk of CO_2 acidification of shallow drinking water. These include requirements to plug legacy wells, ensure the geology creates thick or multiple layers of impermeable caprock, design and construct multi-barrier wells, and restrict injection pressure to prevent fracturing of the protective caprock, as well as the US EPA requirements that injection zones sit beneath the lowermost formation containing an underground source of drinking water.[xv]
Surface Storage Leakage	Gradual release of CO_2 back into atmosphere, diminishing climate benefit	This risk can be managed through comprehensive site selection, multi-mechanism trapping, and long-term post-injection monitoring, reporting, and verification. The IPCC estimates that properly selected and managed geological storage sites are very likely to keep over 99% of their stored CO_2 for 100 years, and likely to retain over 99% over 1,000 years.[xvi]

[i] AR6 Synthesis Report: Climate Change 2023 — IPCC.
[ii] Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach – Analysis - IEA.
[iii] 2022 Scoping Plan Documents | California Air Resources Board.
[iv] "10 CO_2 Utilization Infrastructure." National Academies of Sciences, Engineering, and Medicine. 2024. *Carbon Utilization Infrastructure, Markets, and Research and Development: A Final Report*. Washington, DC: The National Academies Press. doi: 10.17226/27732.
[v] IEAGHG, "CO_2 Pipeline Infrastructure", 2013-18, December 2013.
[vi] WESTCARB Regional CCS partnership, an organization led by the California Energy Commission (CEC) and the U.S. Department of Energy (DOE), estimated the CO_2 storage capacity of saline formations in the ten largest basins in California ranged from 150 to 500 gigatons (Gt).
[vii] CCUS In 2025: An End-Of-Year Review.
[viii] Global-Status-of-CCS-2025-report-9-October.pdf.
[ix] Annual Report Mileage for Hazardous Liquid or Carbon Dioxide Systems | PHMSA.
[x] Baker, S. E., Stolaroff, J. K., Peridas, G., Pang, S. H., Goldstein, H. M., Lu, F. Y., ... & Aines, R. D. (2020). *Getting to Neutral: Options for Negative Carbon Emissions in California*. Lawrence Livermore National Laboratory (LLNL-TR-796100).
[xi] Are there risks to transporting carbon dioxide in pipelines? | MIT Climate Portal.
[xii] Vitali, Matteo et. al, "Statistical analysis of incidents on onshore CO_2 pipelines based on PHMSA database." *Journal of Loss Prevention in the Process Industries*, Volume 77, July 2022, doi:10.1016/j.jlp.2022.104799.
[xiii] Hosseini et. al, "Current State of Knowledge Regarding the Risk of Induced Seismicity at CO_2 Storage Projects," IEA Greenhouse Gas R&D Programme Technical Report 2022-02, January 2022.
[xiv] United States Geologic Survey (USGS), Earthquake Hazards Program, "Felt Report," assessed in 2026.
[xv] Federal Regulation Source: 40 CFR § 146.81(d)
[xvi] Metz, B., Davidson, O., de Coninck, H. C., Loos, M., & Meyer, L. A. (Eds.). (2005). *IPCC Special Report on Carbon Dioxide Capture and Storage*. Prepared by Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press.