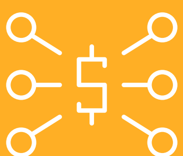
Managing Carbon Capture and Storage (CCS) Risk

A Methodical Framework for Proactive Risk Management

Carbon capture and storage (CCS) is a promising approach for controlling carbon emissions from fossil fuel power plants and other large emitters. To make the strategy viable, adopters must take a proactive approach to risk management and mitigation.

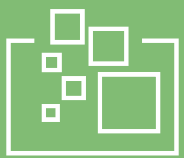
Carbon Capture and Storage and Risk

Managing risk is a fundamental element of any carbon capture and storage project. CCS risk—including technical, economic and regulatory risk—arises from the fundamental nature of these large infrastructure projects. CCS involves:



Large capital investments, with significant capital outlay required up front.

Long time horizons, often extending for decades from initial planning to final closure.



Technical complexity, with technologies at various stages of maturity and many interdependent components.

Multiple stakeholders, including regulators, investors, carbon markets and community members.

Before implementing a CCS project, adopters need to have a clear understanding of all the types of risk involved and a proactive strategy for managing these risks. Risk must be managed across the entire process: capture, transport and storage. CCS risk can be successfully managed at each stage through strategic and proactive approaches to risk mitigation, including cross-chain risk management, schedule and budget integration, and system design integration.

Types of CCS Risk.

	Policy & Stakeholder	Economic	Technical
Overall	• Government incentives/tax credits • Policy stability • Regulatory uncertainty • Stakeholder engagement/ acceptance	• High capital and operational costs • Borrowing costs • Insurance costs • Revenue/incentive stability • Cost inflation	• Technology maturity • Expertise • Project execution • Safety
Capture	• Emissions mandates	• Carbon price/market dynamics • High capital cost	• Capture technology selection • Energy penalty of capture
Transport	• Pipeline permitting • Right-of-way	• Volume aggregation	• Pipeline leaks • Truck/rail spills
Storage	• Well permitting • Pore space ownership/access	• Long-term liability • Payment model complexity/ uncertainty?	• Site suitability/ geology • Well construction • Injection safety • Plume migration/ leakage of stored CO_2 • Groundwater contamination • Induced seismic activity

Risk vs. Uncertainty

Risk management for CCS must consider both risk and uncertainty.

- Uncertainty is the RANGE of possible outcomes.
- Risk is the PROBABILITY of an adverse outcome.

Battelle's CCS risk management approach addresses both.

- We can reduce uncertainty by implementing thorough technical evaluations and advanced modeling methods to better define possible outcomes.
- Overall risk can be managed using a variety of mitigation strategies that minimize the probability of adverse outcomes.

Three Essential Tactics for De-Risking CCS

While there are many inherent risks in CCS projects, there are a number of tactics that can be employed to de-risk the process. An integrated and methodical approach to risk can reduce uncertainty, provide a clearer picture of the risk profile, and improve outcomes for CCS projects.

Tactic 1: Cross-Chain Risk Management

Capture, transport and storage are highly interdependent. It is important to look at risk across the whole CCS value chain and understand how decisions made at one stage impact risk across all stages. Consider public outreach and stakeholder engagement: a cross-chain approach to engaging public officials, emergency responders, landowners, and communities can ensure consistent messaging and enhance stakeholder buy-in across the capture, transport and storage value chain.

Often, there are technical or economic tradeoffs with risk decisions at each stage. Understanding these tradeoffs and developing an integrated and consistent approach to risk management will help companies make better de-risking decisions. For example, an emitter/developer may find it desirable to seek technical/financial partners with specific expertise to share the risk of a CCS project or to be part of a CCS hub (a network or consortium of carbon emitters) that provides access to alternate offtake contracts (e.g., selling CO_2 for industrial uses or retaining responsibility for CO_2 storage). However, this introduces new complexities into the project, including different criteria and risk tolerance. This, in turn, increases part-chain failure risks, in which failure or underperformance in one part of the CCS value chain jeopardizes the entire project.

Tactic 2: Project Schedule and Budget Integration

CCS project developers must look at the schedule and budget across the entire value chain, from capture and transport to injection, storage and long-term site management. Unplanned delays at one stage of the project due to budget shortfalls or permitting issues can cause a ripple effect. For instance, if the transport component is delayed due to pipeline right-of-way issues or the storage component is delayed by Class VI well permitting, it can impact the economic viability of the overall project. Some things to keep in mind:

- Setting clear milestones and aligning development schedules for each stage of the process to avoid bottlenecks will help to ensure a smooth implementation of the project.
- Budget integration may reduce overall project costs, for example by consolidating service providers across the components.
- Hiring an overall project manager with single-point accountability to oversee the integration of different components can reduce the risk of unexpected delays and disruptions.

Tactic 3: System Design Integration

System design integration involves creating an overall system that is flexible, resilient and compliant. A system design approach is used to reduce technical risk, ensure smooth operations, and minimize delays, downtime or safety events. Consideration must be given to:

- Compliance with environmental regulations, safety standards and tax credit requirements.
- Upstream and downstream consequences of technical decisions made at each stage of the process. System design integration impacts CCS decisions upstream, midstream and downstream. Design parameters for CO_2 (e.g., purity, temperature, pressure) must be consistent and suitable across the value chain.
- The capture system must be designed to ensure that the CO_2 meets purity and pressure requirements for pipeline transport and injection. Excess moisture and impurities can require design mitigation against corrosion or performance failure.
- The selection of storage sites can be influenced by geology, pipeline accessibility, regulatory environment, opportunities to aggregate CO_2 volumes, and other technical factors. Assessing the technical tradeoffs requires a keen understanding of the different components and their drivers.

Building in operational redundancies and flexibility at each stage may be necessary to enable the system to accommodate unexpected challenges, new requirements or emerging opportunities. For example, injection facilities should be designed for flexibility to accommodate future CO_2 volumes or well workover. It is also advisable to acquire subsurface data that allows for a range of project outcomes, including corrective actions.

Key Concepts:

Cross-Chain Risk Management

- Assess and understand the interdependencies within the CCS value chain components
- Identify and analyze technical and economic tradeoffs to mitigate risks across the chain
- Develop strategies to manage counterparty risk and risks associated with the integration of capture, transport, and storage

Project Schedule and Budget Integration

- Construct a comprehensive project timeline that aligns with budget constraints
- Optimize capital expenditure through strategic planning and phasing of project elements
- Sequence critical data acquisition and design milestones to streamline project development
- Prioritize permitting activities to ensure project progression without delays

System Design Integration

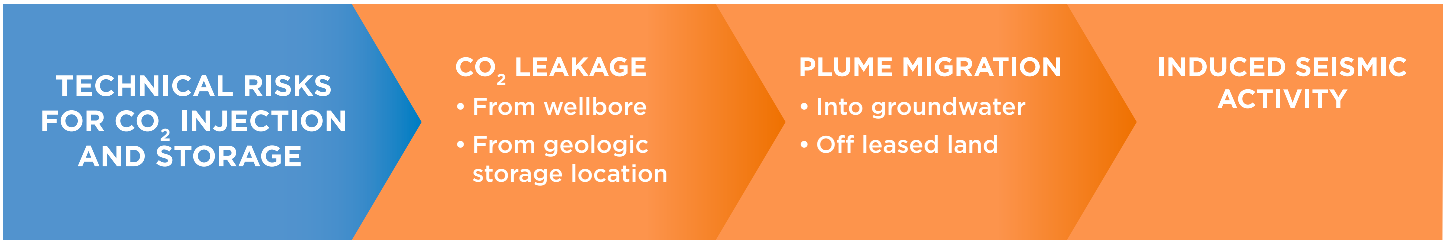
- Design the CCS system with flexibility to handle operational variances and unexpected events
- Incorporate redundancy to reduce the risk of system failures and downtime
- Maintain consistency across the system to ensure smooth operations
- Implement measures to ensure tax credit eligibility and minimize recapture risk

Understanding Technical Risk for Carbon Storage

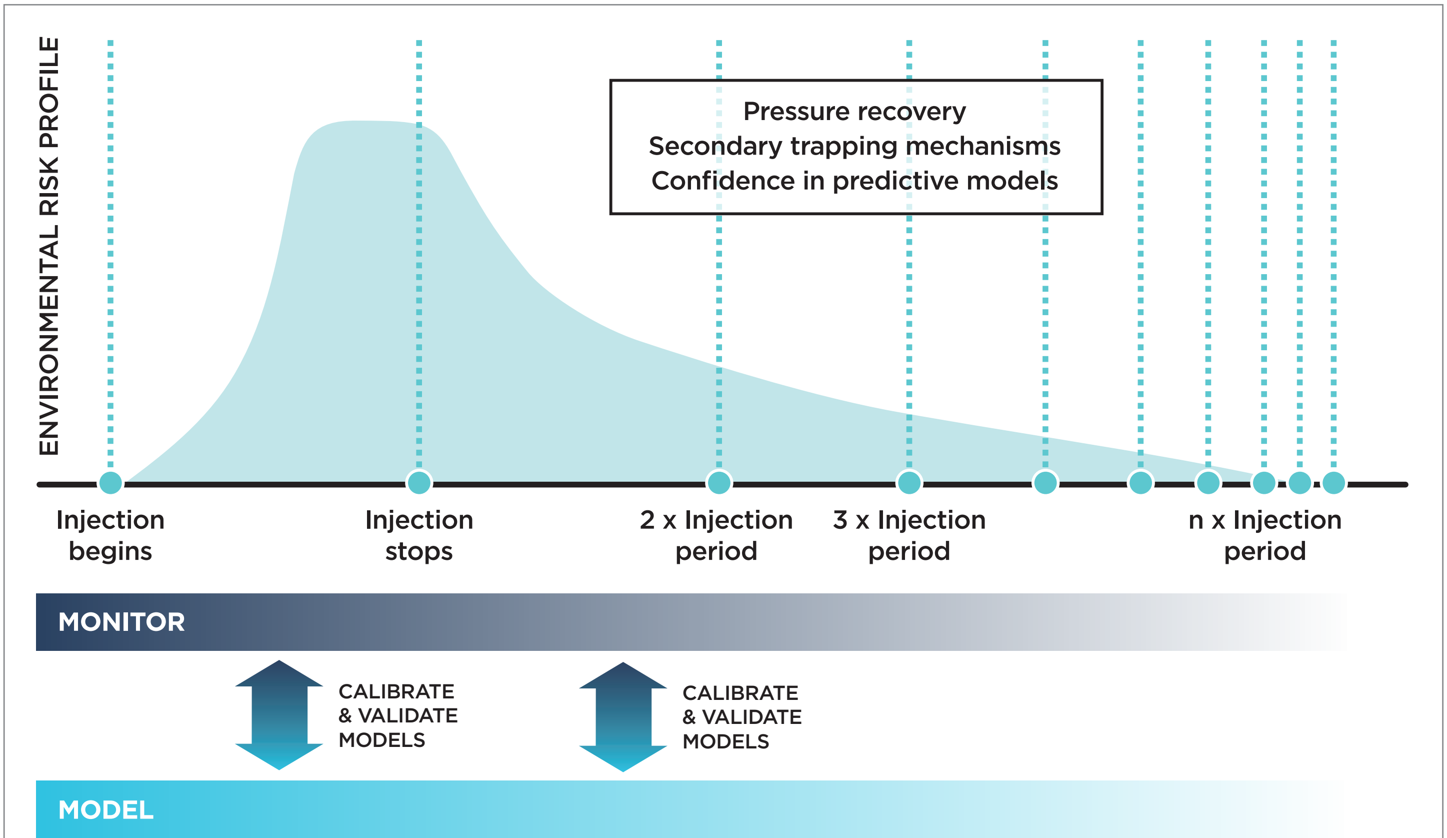
While it is important to be aware of all aspects of risk for CCS, discussion of risk often centers around technical risks during the injection and storage phase of the process. This is the stage with the highest technical risk and uncertainty and the part of the value chain least understood by non-oil & gas developers. In addition, the injection and storage phase is characterized by:

- High stakes, with the potential for risks to human health and the environment in the event of CO_2 leakage.
- High visibility and public perception of risk, which make this phase (along with pipelines for transportation) more likely to generate community stakeholder concerns.
- Long time horizons for residual risk, potentially years or decades after injection.

However, it is important to remember that saline aquifer storage is mature and well-understood, especially within the oil & gas industry. CO_2 gas injection now has a decades-long track record in the U.S. and internationally, including both pure storage projects and the use of CO_2 for enhanced oil recovery (EOR). While it is impossible to completely eliminate technical risk, developers can minimize it with appropriate de-risking strategies and compliance with all regulatory, permitting and Monitoring, Reporting and Verification (MRV) requirements.



The risk profile generally peaks in the early years post-injection and stabilizes as CO_2 dissolves and equalizes with the reservoir.

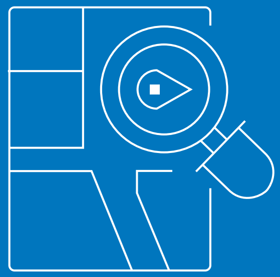


*Model reproduced from Global CCS Institute, Carbon Neutrality: Scenarios for Deep Decarbonization, August 2019

De-Risking CO_2 Injection and Storage

Technical risk for a CCS project must be assessed prior to injection in order to identify the highest risk elements and implement measures to mitigate them. This requires a high degree of technical expertise and experience, including:

- Subsurface geology and geophysics
- Wellbore drilling and injection technologies and methods
- Monitoring technologies
- Modeling and data analysis
- Program management and operations

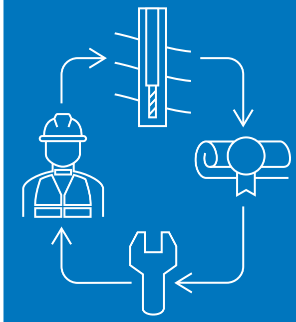


Site Selection

Site selection lays the foundation for a successful CCS project. Typically, carbon is injected into a deep saline aquifer or a depleted oil & gas field. Advanced modeling methods (such as Static Earth Modeling and Numerical Reservoir Simulations) are used to evaluate the storage capacity, stability and containment reliability of the formation. These models provide a detailed picture of the subsurface and predict how CO_2 will behave once injected, including the potential for plume migration. They are also used to determine safe injection rates and maximum storage potential.

The injection site must have the appropriate geology for injection and storage and meet requirements for temperature, pressure, salinity, porosity and permeability. A suitable injection site features:

- A deep formation (typically at least 800 meters/2600 feet below the surface) with porosity and permeability suitable for CO_2 injection.
- An impermeable caprock layer that acts as a top seal for the injected carbon.
- Minimal risk of potential pathways (e.g., faults) for CO_2 leakage to the surface or into groundwater.

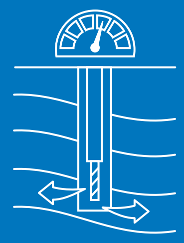


Wellbore Drilling and Maintenance

U.S. EPA Class VI permits have rigorous requirements for well design to ensure safety and minimize risks of CO_2 leakage through the wellbore. If drilling a new well, it must comply with all regulations, safety standards and known best practices for CCS injection wells. If the project will utilize an existing oil & gas well, it must be compliant with all requirements for CO_2 injection and storage. A thorough assessment of the well's condition, including its structural integrity and the suitability of existing materials for CO_2 exposure, is essential.

Down-hole monitoring and data collection are used in this phase to verify the storage capacity of the formation, determine safe and efficient injection rates, and ensure the safety and stability of the wellbore. Data collection methods may include:

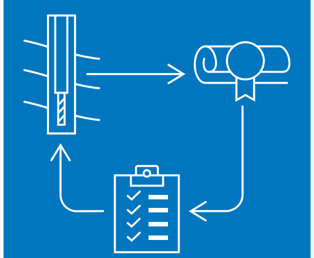
- Wireline logging
- Core rock sampling
- Stratigraphic well testing



Injection Phase

During the injection phase of CCS projects, specialized sensors and logging tools are used to monitor the injection process and ensure the safe and efficient introduction of CO_2 into the formation. These tools allow real-time measurement of injection rates and conditions and monitor the integrity of the wellbore for damage or leakage.

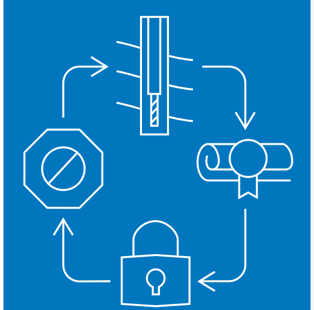
- Injection temperatures and pressures are monitored to ensure that CO_2 is maintained in a supercritical state to optimize storage space and minimize the risk of leakage.
- Various tools and sensors are used to map the movement of the CO_2 plume within the reservoir.
- Downhole monitoring tools are used to detect any integrity breaches in the wellbore casing or sealant.



Monitoring, Reporting and Verification (MRV)

The MRV phase is critical for complying with regulatory standards and qualifying for tax incentives or credits associated with carbon sequestration. It encompasses a comprehensive suite of activities designed to ensure the project's environmental integrity and operational safety over its lifetime. This includes:

- Continuous monitoring of the injected CO_2's behavior within the storage formation.
- Verification of CO_2 storage volumes through direct measurements and indirect indicators.
- Reporting of monitoring results and verification findings to regulatory bodies in a timely and transparent manner.



Site Closure

At the end of a project's active life, the site closure phase involves several critical steps to ensure the long-term safety and stability of the CO_2 storage. These include:

- Capping off the well.
- Confirming the integrity of the cap to ensure CO_2 does not leak from the wellbore.
- Long-term monitoring of plume migration.
- Updates of migration models using monitoring data to verify that CO_2 remains securely contained within the target formation.

Battelle: Your Partner in CCS Risk Management

Battelle offers unparalleled expertise in Carbon Capture and Storage (CCS) risk management. Our goal is to help you navigate potential risks and implement mitigation strategies that reduce uncertainty, ensure safety and compliance, and optimize outcomes. We use an integrated and strategic risk management process, focusing on the entire CCS value chain to ensure your project's success.

COUNT ON US FOR:

25+ years of CO_2 storage experience, with **75+** successful CCS projects worldwide.

Comprehensive services for carbon injection and storage, including project management, permitting, construction, operations, and Monitoring, Reporting and Verification (MRV).

Extensive knowledge in subsurface geology, geophysics, and reservoir modeling for accurate site characterization.

Contact Battelle today to explore tailored risk management strategies for your CCS project.

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