EMERSON™

Software Solutions for Carbon Storage

Emerson E&P Software for Carbon Capture

A Key Technology for Mitigating Global Climate Change

Carbon Capture Utilization and Storage (CCUS) has the potential to play a key role in reducing emissions from the hardest-to-abate industry sectors. Its ability to prevent carbon dioxide emissions at the source and permanently store the captured CO_2 in the subsurface makes it an essential part of the solution.

Storing carbon in a geological formation involves key technical challenges, including assessing geologic reservoirs, and estimating storage capacity, injectivity, containment for the permanent and safe storage of CO_2, and demonstrating the reliability and conformance of the process.

Emerson E&P Software provides the technology needed to ensure the success of carbon storage projects throughout their lifetime. Our comprehensive suite of subsurface software provides technologies to:

- Accurately evaluate storage capacity
- Assess and preserve storage containment integrity
- Optimize injection capabilities
- Increase subsurface predictability
- Demonstrate regulatory conformance

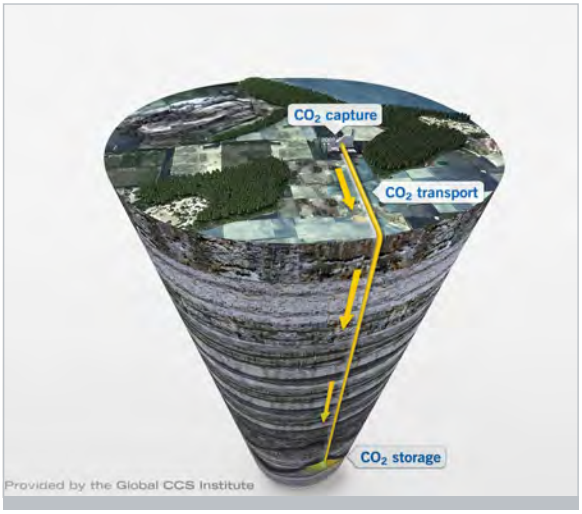
Storage Capacity

The reliable estimate of CO_2 storage capacity is of upmost importance to increase a carbon storage project's chance of economic success.

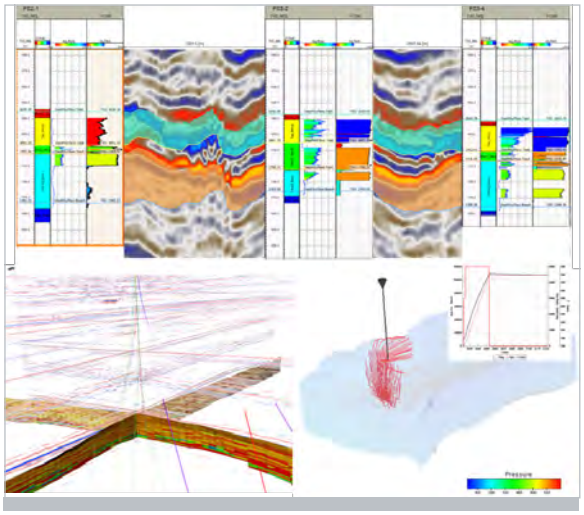
Characterization of the storage reservoir enables operators to de-risk the storage capacity assessment and determine if the reservoir is adequate to permanently store CO_2.

The first step in the characterization study is to collect all available data. For a depleted field, well, seismic and production data are usually available. For a saline aquifer, data might be scarcer. The Emerson software portfolio provide geoscientists with a full range of reservoir characterization and modeling solutions that help assess heterogeneities and build geologically realistic models regardless of the amount of data available.

The Geolog solution suite for petrophysics analysis provides tools to perform the standard deterministic interpretation and calculation of porosity, permeability and lithology logs. The SeisEarth quantitative seismic interpretation tool offers the level of integration,



▲ The carbon capture and storage process. *Source: Global CCS Institute*



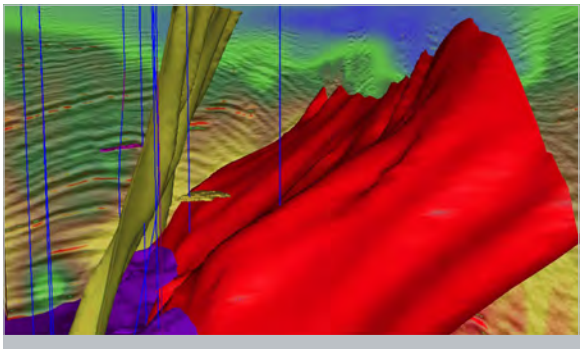
▲ Static and dynamic modeling to support the evaluation of storage capacity.

qualification and analysis needed by geoscientists to confidently use seismic amplitudes to identify quality storage sites, clearly delineate storage reservoirs, and characterize reservoir properties. Emerson's geomodeling solution provides the technology to build 3D models that deliver an accurate picture of the storage complex, capturing rock property trends and heterogeneities. The flexibility of the Emerson geomodeling solution allows geoscientists to not only integrate well and seismic information when available, but also to integrate conceptual knowledge.

Emerson 3D geological models can be used directly for site specific or regional storage capacity evaluation in saline aquifers and depleted oil and gas fields. The model can also be exported to a dynamic simulator for a more accurate estimation of storage capacity.

In the case of storage in a depleted field, calibrating the models to historical production data is the starting point for a reliable estimation of the porous rock volume available to store the injected CO_2. Tempest™ ENABLE includes a state-of-the-art history matching tool. By taking into account all engineering data and tolerances concurrently, Tempest ENABLE intelligently drives the simulator through hundreds of realizations and greatly accelerates the history-matching process. The ensemble of calibrated models can then be used as input to simulations, in order to forecast the CO_2 flow in the storage reservoir and provide a range of actual storage capacity.

Tempest MORE is a modern, full-field, black oil and compositional reservoir flow simulator. It enables engineers to estimate storage capacity through dynamic modeling. Optimized for running large models in parallel, engineers benefit from fast and robust simulations, including a wide range of engineering features for solving carbon injection and storage challenges and predicting CO_2 flow in the subsurface.



▲ Predicted pore pressure co-rendered with seismic and interpretation data. The growth fault in red and the interpreted higher angle fault in yellow appear to form pressure bound.

Storage Containment

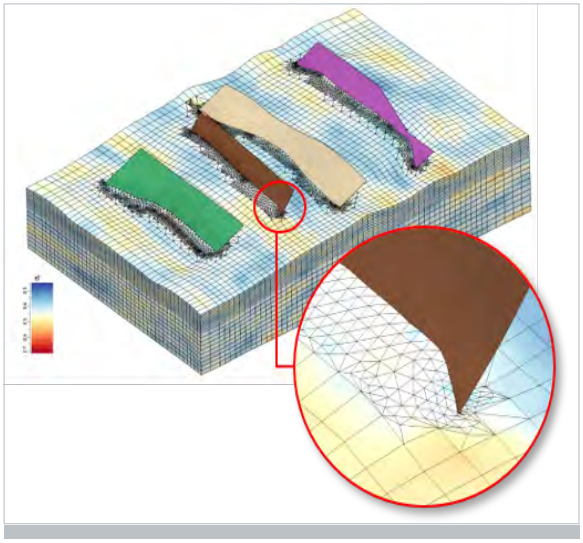
Leakage of CO_2 along faults, wells or due to fracturing can undermine the value of geological carbon storage. Therefore, a reliable assessment of long-term storage containment integrity is a critical component of business decisions regarding site selection and development.

To help geoscientists and engineers gain confidence in their assessment of storage containment, Emerson's comprehensive suite of software solutions provides the technology that will enable them to:

- Gain a good understanding of the seal quality
- Identify discontinuities in the subsurface
- Evaluate the fault sealing potential
- Assess the stress field
- Determine the maximum injection pressure
- Monitor the well integrity

With its broad range of modules, Geolog provides tools for analyzing capillary pressure and assessing the long-term integrity of the caprock unit, identifying critically-stressed fractures and fault families in the current stress field to mitigate geomechanical risks, and monitoring well integrity to eliminate potential leak pathways.

Integrated solutions for high-resolution seismic velocity model determination, seismic inversion, geologic modeling, petrophysical analysis, and visualization enable the creation of a defensible pore pressure prediction model and the estimation of fracture pressure. Understanding pressure limits allows an informed injection strategy design.



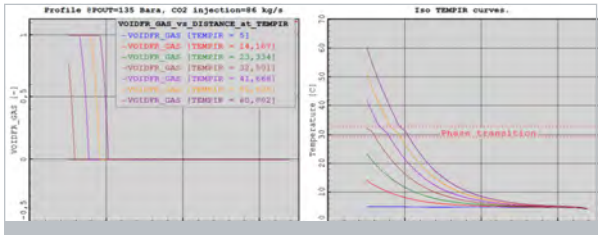
▲ 3D mechanical hybrid grid including hexahedral and tetrahedral elements to perfectly capture faults and fine-scale heterogeneities impacting the storage complex geomechanical behavior.

Emerson's full-azimuth imaging solution (EarthStudy 360™) is designed to take full advantage of rich- azimuth seismic acquisitions. EarthStudy 360 delivers unique discontinuity images and allows to recover stresses, fractures, and geomechanical properties from full-azimuth amplitude and residual moveouts. Discontinuities can be interpreted from high-resolution depth images and integrated in a 3D model for a holistic analysis of structural trapping.

Emerson geomodeling and flow simulation solutions can connect to geomechanical simulators to predict the geomechanical behavior of the subsurface when injecting and storing carbon. Emerson offers a superior 3D gridding technology to ensure the generation of optimal finite element meshes that fully capture current and future reservoir geomechanical behavior.

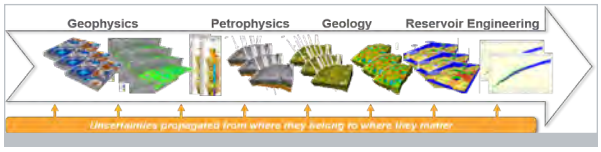
Injectivity

Injection efficiency must be optimized in order to inject the CO_2 at a sufficient rate for a successful carbon storage project.



▲ Flow performance calculations in METTE for a 144 km CO_2 pipeline. Left: Void fraction of CO_2. Right: Profiles for different injection temperatures.

To ensure the successful and safe flow of CO_2 from surface to subsurface, Emerson's flow assurance and optimization solution METTE™ provides tools for the efficient design and operation of the injection system by performing both dynamic and steady state analysis of well and flow lines. The injection can be optimized by envisaging multiple scenarios to assess the limits of the injection system. METTE unlocks the possibility of creating a digital twin of the CO_2 injection network from topside to storage reservoir, providing a deep understanding of the entire injection system and mitigating operational risks.



▲ Big Loop workflow enables propagating uncertainties and assesses overall storage risk throughout the life cycle of a storage complex.

Risk Assessment

Another important goal for mitigating risk and optimizing carbon storage project execution is to increase subsurface predictability. This is done through a thorough uncertainty analysis and integration procedure.

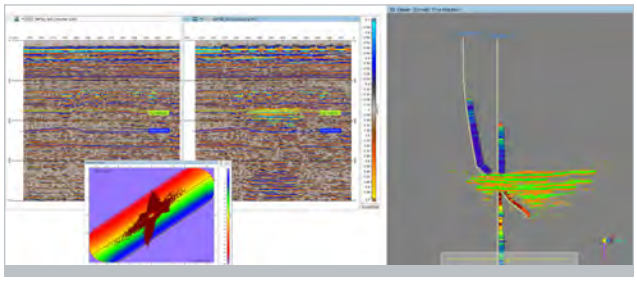
Petrophysical, geophysical, geological, and engineering uncertainties lead to uncertainties in storage capacity, containment and injection performance. All Emerson solutions include tools to assess data and interpretation uncertainties. The Emerson uncertainty offering also includes Big Loop™ - an application-agnostic ecosystem for setting up automated, reproducible, and auditable workflows. These help propagate uncertainties and capture their dependencies, resulting in reliable probabilistic predictions regarding storage capacity and performance.

Monitoring CO_2 Storage Projects

The demonstration of storage process reliability and performance verification are based on tracking the movements, concentration and long-term fate of CO_2 plumes in the subsurface.

Emerson's SeisEarth™ seismic interpretation suite incorporates 4D seismic analysis to check the reliability and repeatability of time lapsed surveys. High-fidelity opacity rendering, RGB blending, and volume math operations allow geoscientists to extract and understand differences in time lapsed seismic volumes and track the movement of CO_2 in the subsurface.

Emerson geomodeling solutions allow geoscientists to integrate monitoring data in automated workflows, in order to easily update models carried forward from the site selection phase. Similarly, as an evergreen workflow, Big Loop provides the capability to update an ensemble of models with the latest monitoring information while calibrating the models to any type of observed data, including 4D seismic. The result is a ready-to-analyze flow model calibrated to multiple geophysical, geologic and injection data, ensuring consistency with the underlying geology and providing a reliable prediction of the fate of the CO_2 plume in the subsurface.



▲ Sleipner 4D seismic analysis to extract and understand the differences between time-lapsed seismic. *Data courtesy of Equinor.*

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