aspentech

Brochure

Subsurface Science & Engineering Solutions for Carbon Storage

Overview

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.

AspenTech® provides a comprehensive suite of digital solutions for CCUS, supporting every stage of the process—from CO_2 capture and transportation to utilization and long-term geologic storage (Figure 1). These digital technologies play a critical role in reducing both the cost and energy demands associated with large-scale carbon capture, while also minimizing risks and uncertainties to ensure a reliable and safe approach for the long-term containment of CO_2.

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

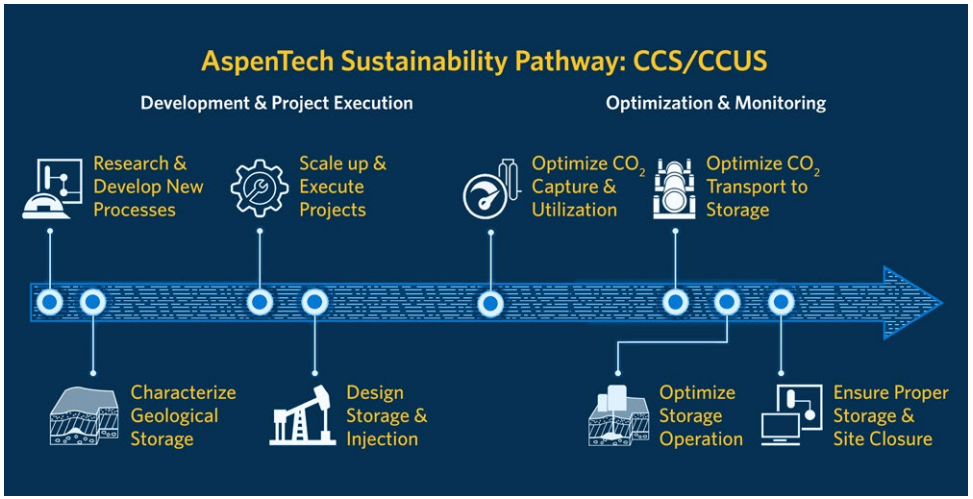

Figure 1: AspenTech's sustainability pathway for CCUS, encompassing both the surface and subsurface.

> **"We have heavily used AspenTech to optimize our technologies. Digital and AI are key to dramatically driving down the costs of carbon capture technology."**
>
> **—Bill Gross, CEO, Carbon Capture & IdeaLab**

AspenTech Subsurface Science & Engineering (SSE) solutions facilitate the selection of carbon sequestration sites, evaluate geological risks, optimize injection conditions to maximize project value, and monitor CO_2 movements in the subsurface through efficient data analysis and integration.

Through its comprehensive Subsurface Science & Engineering suite of software, AspenTech provides the technology needed to ensure the success of carbon storage projects throughout their lifetime, from site screening and selection to storage monitoring (Figure 2). This technology allows decision-makers and other key stakeholders to:

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

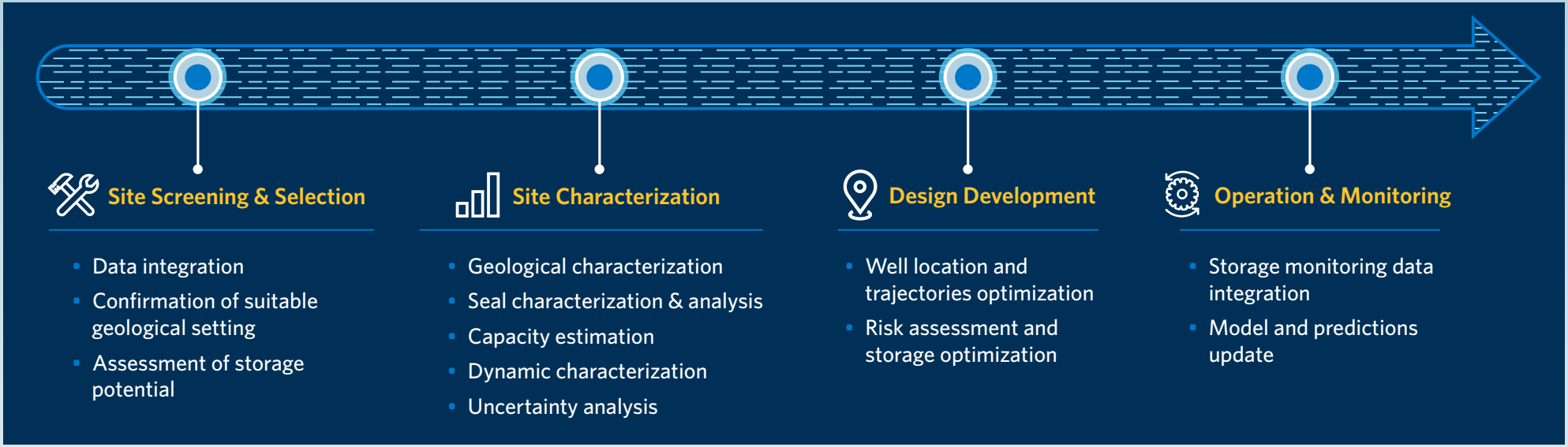

Figure 2: Subsurface studies throughout a carbon storage project lifecycle.

Accelerating Time-to-Results With Machine Learning and Workflow Automation

AspenTech Subsurface Science & Engineering solutions combine the power of Industrial AI with unparalleled domain expertise to support the development of scalable carbon storage solutions. These well established technologies enable geoscientists to create repeatable and automated subsurface workflows using machine learning, to meet the demand for speed and scale while ensuring the robustness of carbon storage studies.

Designed for easy automation, AspenTech SSE solutions allow geoscientists and engineers to focus more on analyzing results and less on data interpretation and model updates. They also support efficient sensitivity and uncertainty analyses.

Accurate Storage Capacity Evaluation

The reliable estimation of CO_2 storage capacity is of utmost importance to increase a carbon storage project's chance of economic success and ensure project viability. Accurate characterization of the storage reservoir is paramount to de-risking the storage capacity assessment and determining if the reservoir is adequate to permanently store CO_2.

The first step in a characterization study is gathering all available data. Well, seismic and production data are usually available for a depleted field, whereas data for a saline aquifer may be more limited. Regardless of data availability, AspenTech offers tools that ensure data accuracy, enhance collaboration and provide deeper insights into carbon storage studies. These solutions include a collaborative database that facilitates real-time data access, advanced interoperability for seamless collection and integration of diverse data types, and sophisticated analytical tools for efficient data analysis. Additionally, automatic quality checks

help identify and resolve data inconsistencies, ensuring a reliable foundation for successful carbon storage studies.

An end-to-end solution for analysis and optimization

AspenTech's Subsurface Science & Engineering suite, covering every stage in the workflow, from seismic processing and imaging to production, provides 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 (Figure 3).

The **Aspen Geolog**® family of products for petrophysics analysis enables the deterministic interpretation and calculation of porosity, permeability and lithology logs.

The **Aspen SeisEarth**® quantitative seismic interpretation solution offers the level of integration, qualification and analysis needed by geoscientists to confidently use seismic amplitudes to identify quality storage sites, clearly delineate storage reservoirs and characterize reservoir properties.

AspenTech geological modeling solutions (**Aspen RMS**® and **Aspen SKUA**®) enable the creation of 3D models that deliver an accurate representation of the storage complex, capturing rock property trends and heterogeneities in the reservoir, overburden and downburden. The flexibility of these tools allows geoscientists to integrate well and seismic information when available, while also including conceptual knowledge where data is limited.

The geological model can be used directly for both site-specific and regional storage capacity evaluations. AspenTech's geologic modeling solutions include a unique storage capacity calculation tool that computes the theoretical structural and stratigraphic storage capacity of saline aquifers using an accurate 3D representation of the storage site.

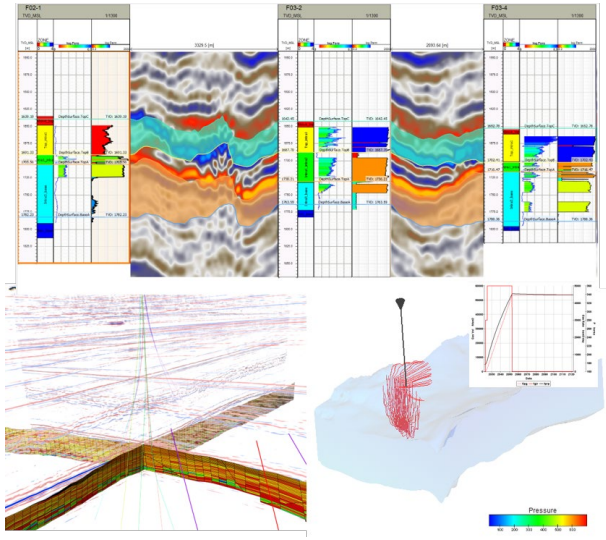

Figure 3. Static and dynamic modeling to support the evaluation of storage capacity.

"I previously used Aspen Geolog in the hydrocarbon exploration and production industry, where the system's ease of use and powerful Python scripting capabilities significantly contributed to the workflow efficiency. I found that Aspen Geolog easily makes the transition to Carbon Storage."

—Adam Haeker, Director of Geoscience, Milestone Carbon

MILESTONE ENVIRONMENTAL SERVICES

The geological model can be exported to a dynamic simulator for a more accurate estimation of storage capacity. For storage in a depleted field, calibrating the models with historical production data is the starting point for a reliable estimation of the porous rock volume available to store the injected CO_2. **Aspen Tempest® ENABLE** technology includes a state-of-the-art history matching tool. By considering all engineering data and tolerances concurrently, Aspen 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, to forecast the CO_2 flow in the storage reservoir and provide a range of storage capacity.

Aspen 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.

Storage Containment

Carbon dioxide leakage along faults or wells or due to fracturing can compromise the effectiveness of geological carbon storage. Therefore, a reliable assessment of long-term storage containment integrity is crucial for informed business decisions regarding site selection and development.

AspenTech's comprehensive Subsurface Science & Engineering solutions provide digital technology to help geoscientists and engineers gain confidence in their assessment of storage containment, while also enabling 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, Aspen Geolog supports the analysis of capillary pressure and the assessment of the caprock unit's long-term integrity. They help to identify critically stressed fractures and fault families in the current stress field to mitigate geomechanical risks, while also 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 (Figure 4). Understanding pressure limits is crucial to developing an informed injection strategy design.

The **Aspen EarthStudy 360**® full-azimuth imaging solution is designed to take full advantage of rich-azimuth seismic acquisitions. Aspen EarthStudy 360 delivers unique discontinuity images and allows the recovery of 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.

AspenTech geological modeling and reservoir engineering solutions connect to geomechanical simulators to predict the behavior of the subsurface when injecting and storing CO_2 underground. AspenTech geological modeling solutions offer a superior 3D gridding technology to ensure the generation of optimal finite element meshes that fully capture current and future reservoir geomechanical behavior (Figure 5).

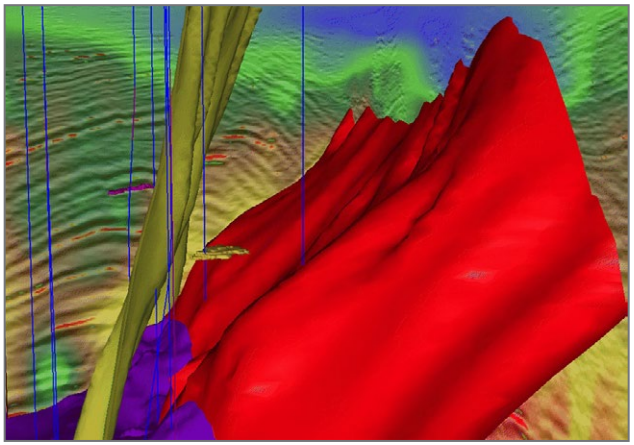

Figure 4. Predicted pore pressure co-rendered with seismic and interpretation data. A higher-pressure zone appears to be bound by the yellow and red faults.

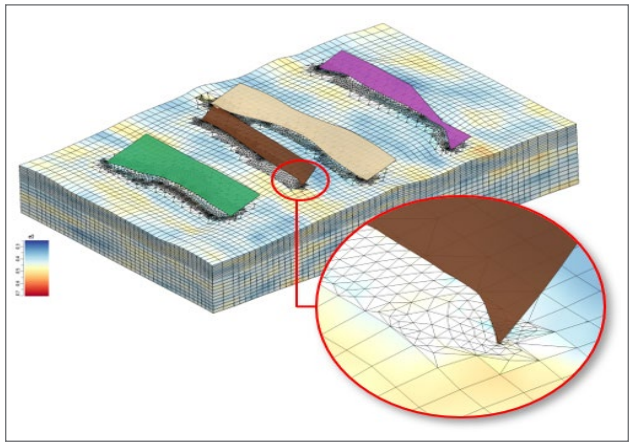

Figure 5. 3D mechanical hybrid grid including hexahedral and tetrahedral elements to perfectly capture faults and fine-scale heterogeneities impacting the storage complex geomechanical behavior.

Injectivity Optimization

Optimizing injection efficiency is essential for delivering the CO_2 at a sufficient rate to ensure the success of a carbon storage project. To support this, **Aspen METTE**® provides flow assurance and optimization tools for the efficient design and operation of the injection system by performing both dynamic and steady-state analysis of well and flow lines (Figure 6). Efficiency can be further improved by simulating multiple scenarios to assess the limits of the injection system. Aspen METTE enables the simulation of the entire CO_2 injection network, from topside to the storage reservoir, providing a deep understanding of the system and helping to mitigate operational risks.

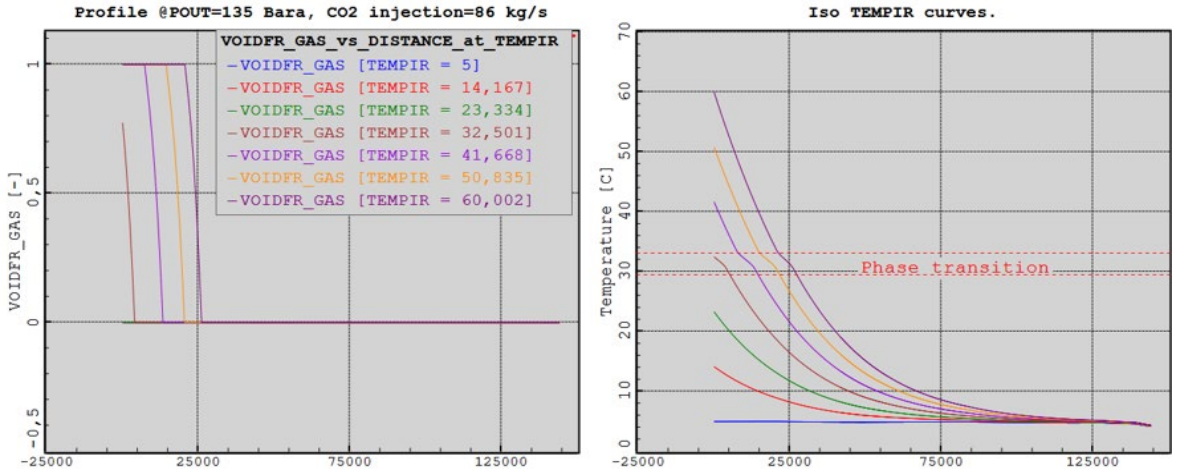

Figure 6. Flow performance calculations in Aspen METTE for a 144 km CO_2 pipeline. Left: Void fraction of CO_2. Right: Profiles for different injection temperatures.

Risk Assessment and Mitigation

Subsurface predictability is a critical goal for mitigating risks and optimizing the execution of carbon storage projects. This can be achieved through a comprehensive uncertainty analysis and integration procedure. Petrophysical, geophysical, geological and engineering uncertainties contribute to variations in storage capacity, containment and injection performance.

The AspenTech SSE portfolio includes tools to assess data and interpretation uncertainties throughout the modeling process, accounting for uncertainties in velocity models, horizons and fault locations while maintaining the geological consistency of the 3D model. This approach enables the evaluation of how structural uncertainties impact gross rock volume, storage capacity and fault seals.

The uncertainty solution also includes **Aspen Big Loop™**, an application-agnostic ecosystem that facilitates automated, reproducible and auditable workflows. By connecting the geologic modeling and reservoir engineering solutions, Aspen Big Loop carries quantified uncertainties and their dependencies from one step of the flow to the next, resulting in reliable probabilistic predictions for storage capacity and performance.

"With a well-proven solution and a broad set of technolgies prefectly tailored to our needs, Aspen SKUA emerged as the best fit for carbon storage modelling and analysis. The built-in workflows have streamlined our processes, allowing me to rapidly and efficiently build a variety of probabilistic models. Aspen SKUA's seamless integration with other software packages makes cooperation with other groups within the organization a breeze."

—Chris Kedzior, Subsurface Advisor, Carbon Alpha

Carbon Alpha

Monitoring CO_2 Storage Projects

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

The Aspen SeisEarth seismic interpretation suite incorporates 4D seismic analysis to check the reliability and repeatability of time-lapsed surveys (Figure 7). 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.

The 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, Aspen Big Loop offers the ability 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.

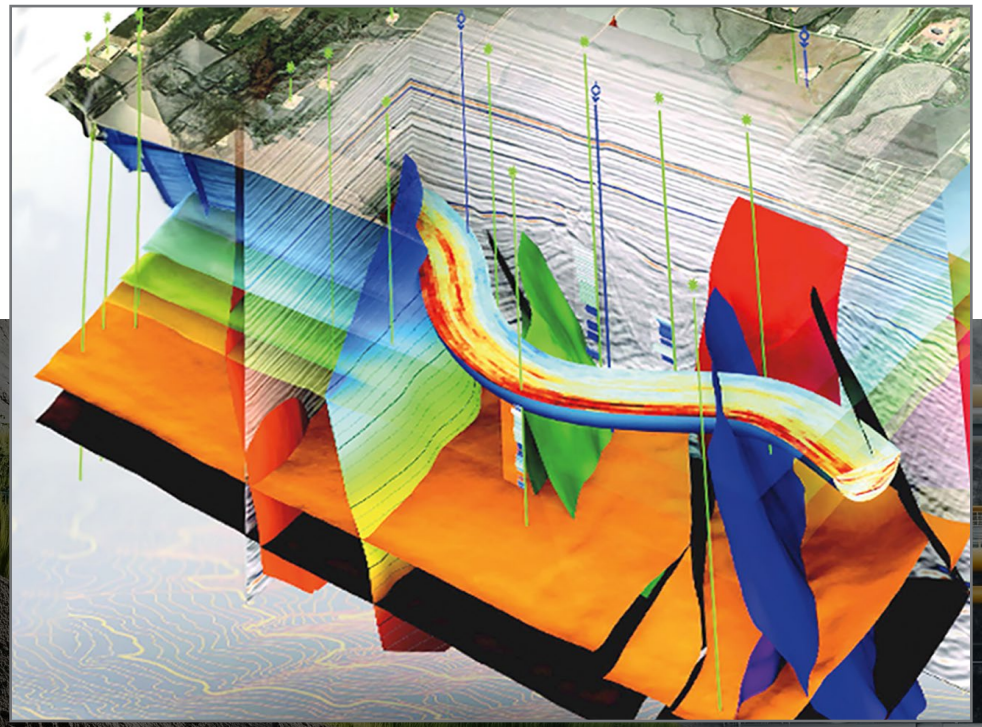

Figure 7. RGB with lit opacity view of the extent of the Sleipner CO_2 plume in 2006, highlighting seismic spectral characteristics and geometry. Data supplied by the Sleipner Group: Equinor Energy AS (operator), ExxonMobil Exploration and Production Norway AS, LOTOS Exploration and Production Norge AS and KUFPEC Norway AS.

Summary

AspenTech's Subsurface Science & Engineering solutions for carbon capture and storage (CCS) ensure data accuracy, enhance collaboration and optimize processes across the entire CCS lifecycle—from site selection to storage monitoring. By addressing key technical challenges such as storage capacity evaluation, containment integrity and injectivity optimization, AspenTech enables the efficient and safe execution of CCS projects, ensuring regulatory compliance and accelerating commercialization.

With a comprehensive portfolio that spans both above- and below-surface solutions, AspenTech offers critical digital technologies that support customers as they address their subsurface and surface challenges throughout the CCS journey.

Your Partner for Optimizing CCS and Accelerating Sustainability Initiatives

These AspenTech SSE digital software solutions are already playing a valuable role in CCS activities around the globe.

- **Aspen Echos/Aspen GeoDepth/Aspen EarthStudy:** Generate high-definition quality images from vintage and new seismic to evaluate storage site conditions.
- **Aspen SeisEarth:** Locate, delineate and characterize the storage site from seismic data. Monitor CO_2 sequestration location and state over time using 4D Seismic.
- **Aspen Geolog:** Characterize subsurface formations, analyze rock properties and fluid geochemistry to confirm suitability.
- **Aspen RMS/Aspen SKUA:** Create a 3D model of the storage site to confirm storage capacity & containment, and define development plan.
- **Aspen Tempest:** Simulate flow of CO_2 in the subsurface to confirm trapping mechanisms and assess uncertainties to ensure long-term containment.
- **Aspen METTE:** Simulate injection of CO_2 in pipeline and wells to ensure continuous flow from surface to subsurface.
- **AspenTech Subsurface Intelligence:** Estimate available formation volume for CO_2 storage.

About Aspen Technology

Aspen Technology, now part of Emerson, is a global software leader helping industries at the forefront of the world's dual challenge meet the increasing demand for resources from a rapidly growing population in a profitable and sustainable manner. AspenTech solutions address complex environments where it is critical to optimize the asset design, operation and maintenance lifecycle Through our unique combination of deep domain expertise and innovation, customers in asset-intensive industries can run their assets safer, greener, longer and faster to improve their operational excellence.

aspentech.com