Introduction

Effective subsurface geological storage is essential for large-scale Carbon Capture, Utilization, and Storage (CCUS) deployment. This study explores key factors influencing CO_2 storage, including reservoir characterization, storage capacity estimation, injectivity analysis, and long-term containment strategies.

Additionally, this analysis evaluates modeling approaches for site selection, basin screening, and storage development planning. By integrating advanced simulation techniques and geomechanical assessments, this research aims to enhance the efficiency, safety, and scalability of CO_2 sequestration projects.

Unlike previous research, this effort combines geomechanical risk analysis with real-world CCUS project evaluations to optimize CO_2 storage development. By addressing critical challenges in injectivity, containment, and long-term monitoring, this work contributes to advancing scalable and secure carbon sequestration solutions for global decarbonization efforts.

Method and/or Theory

This study employs a multidisciplinary approach to assess CO_2 storage feasibility, combining geological, petrophysical, and geomechanical evaluations. Advanced reservoir characterization techniques, including seismic interpretation, well log analysis, and core sample studies, are used to determine injectivity and containment potential.

Basin screening methodologies are applied to identify suitable storage sites, considering depth, porosity, permeability, and caprock integrity factors. Additionally, numerical reservoir simulations, history matching, and uncertainty quantification are utilized to predict CO_2 migration behavior and optimize storage development planning.

Moreover, a comparative analysis of global CCUS projects with insights into best practices for site selection and long-term monitoring is provided.

Conclusions

The assessment of subsurface geological storage reveals that successful CCUS implementation depends on a thorough understanding of reservoir properties, injectivity constraints, and containment mechanisms. High-permeability reservoirs with sufficient caprock integrity demonstrate strong potential for secure, long-term CO_2 storage. In turn, basin screening results indicate that deep saline aquifers and depleted hydrocarbon reservoirs are among the most viable options for large-scale sequestration.

Geomechanical modeling highlights key risks, including fault reactivation and caprock fracturing, which can compromise storage integrity. Advanced simulation techniques provide predictive insights into plume migration, pressure buildup, and potential leakage pathways. Optimized injection strategies, including pressure management and well placement techniques, are critical for maximizing storage efficiency while minimizing environmental risks. Furthermore, site selection frameworks integrating geological, economic, and regulatory factors improve the decision-making process for CCUS deployment.

This study underscores the need for continuous monitoring and adaptive reservoir management to ensure long-term containment and regulatory compliance in subsurface CO_2 storage operations.

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