A Review of Reservoir Engineering Tools and Procedures to Design and Operate Geological Carbon Storage Sites

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Based on the knowledge currently available, geological carbon storage (GCS) will be necessary to reduce global greenhouse gas emissions in line with the climate targets.
During the latest decades, many interdisciplinary projects and field applications have allowed the development of valuable expertise and experience within GCS to make the technology industrially applicable, also with the support of the emerging global carbon trade in recent years. The interventions of different disciplines, as well as the related regulations, on the one hand, help to facilitate the operations, but on the other hand, avoid the definition of engineering guidelines by creating additional fuzziness and uncertainties in the selection and application of the tools and processes.
GCS is not a new technology. Indeed, CO_2 injection for enhanced oil recovery (EOR) has been applied since the 1960s as a miscible and non-miscible process to recover more oil from light and heavy oil reservoirs. For that reason, petroleum reservoir engineering has many decades of theoretical and applied experience in handling CO_2 and injecting it subsurface. The thermodynamics, as well as the transport properties of pure CO_2 and its mixtures with hydrocarbons and non-condensable impurities, are well studied and experimented leading to successful operations. There exists also considerable experience on the numerical basis; commercial reservoir simulators have expanded their portfolio, including flow assurance that reflects CO_2 flow in pipelines and wells coupled with reservoirs.
This paper provides an overview of the reservoir engineering expertise, tools, and procedures used and intended to be used for GCS designs and operations. Previous and current GCS projects were reviewed for consistency with the state-of-the-art in reservoir engineering. Numerical and experimental tools for estimating storage capacity, injectivity, and sealing properties are evaluated through a screening of commercially available equipment and software; scope, range, and upscaling capabilities are discussed in terms of safe and reliable projecting and predictions. Where available, missing features are described, and associated research gaps are highlighted. The conclusions lead to guidelines that should be used in the initial stages of planning of operational projects for various types of GCS, particularly for storage in saline aquifers and depleted hydrocarbon reservoirs. The guidelines can help to accelerate the large-scale removal of CO_2 from the atmosphere in line with the climate targets at the lowest possible cost.