Placing saline reservoir storage developments - the importance of getting started early

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\section*{Abstract}

Finding suitable storage sites and securing industry participation in geological storage of carbon dioxide (CO\textsubscript{2}) is critical to the successful development of every integrated carbon dioxide capture and storage (CCS) project, although there is often poor understanding by stakeholders of the process, time, costs, and business risks involved in the assessment and development of geological storage sites, especially for saline reservoirs. A systematic stage process, methodology and work programme for the storage life cycle is presented. A major consideration for saline reservoirs is the requirement for new exploration and appraisal activities at the site identification and characterisation stages to prove sites in a practical sense. This may involve seismic reprocessing, 2D/3D seismic acquisition and drilling new wells, coring and injection tests. The amount of time required from initial screening to the project investment decision could take more than ten years for some sites depending on data availability, the status of licensing and regulatory frameworks and the pace of stakeholder approvals. The costs may also be substantial with expenditure up to millions of dollars. CO\textsubscript{2} capture and transportation investments will need to progress in parallel, but it will be prudent for a geological storage site to be proven with high confidence prior to the implementation of pipeline or system. A significant risk is that a viable site may not be confirmed by such site assessment work and the entire CCS chain development could be put at risk. This is analogous to exploration and appraisal risk for oil and gas exploration. Although the quantification of storage exploration risk has not yet been calibrated, there are examples from ongoing geological storage activities where site characterization activities have not yielded positive results that meet the anticipated outcomes of earlier screening studies. Providing storage solutions for CCS deployment and capture by major emitters is widely described as a new business opportunity for potential investors. New business models for geological storage will need to be developed providing remuneration for the storage provider from CCS value chains, commensurate with the additional risk involved. A number of technical, business, policy and regulatory risks impact the risk/reward balance and attractiveness of geological storage and a business opportunity. These include the uncertain and long term nature of monitoring obligations and carbon policies, uncertainties around long-term liabilities, exploration risk in saline reservoirs and potentially low returns. These considerations provide further justification for developing policies for CO\textsubscript{2} storage. Because of the potentially extended timescales, it is essential to get an early start on saline reservoir storage opportunities and for the risks to be appropriately addressed by policymakers and by carbon emitters who require storage services.

\section*{Introduction}

The overall project goals, the generalised scope of saline storage and the time required in a storage project are presented for each stage in Figure 1, together with the major milestones. Storage activities such as site characterisation, selection, and monitoring plans are progressed in conjunction in generating regulatory frameworks are incorporated, along with drilling and seismic activities. Through the successive stages the technical objective is to reduce or better quantify geological uncertainty and risk associated with the prospectivity assessment of the storage site capacity, injectivity, containment and integrity. A major consideration for saline reservoirs is the requirement for new exploration and appraisal activities to address the technical and environmental objectives for site characterisation and

\section*{Figure 1: Stage Gate Framework for Storage activities in Saline Reservoirs}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{StageGateFramework.png}
\caption{Stage Gate Framework for Storage activities in Saline Reservoirs}
\end{figure}

\section*{Illustration of Graduated Levels of Requirements for a CO\textsubscript{2} Storage Ready Plant}

\begin{table}
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Component} & \textbf{CCS Ready Level 1} & \textbf{CCS Ready Level 2} & \textbf{CCS Ready Level 3} \\
\hline
Storage Site Selection & \textbullet \ Modernize documentation & \textbullet \ Collect and evaluate data & \textbullet \ Develop and implement site assessment approach & \textbullet \ Implement site assessment approach \\
\hline
Verifying Site-specific Capacity and Integrity of Storage Site & \textbullet \ Conduct site assessment & \textbullet \ Conduct site assessment & \textbullet \ Conduct site assessment & \textbullet \ Conduct site assessment \\
\hline
Design of Storage Facility & \textbullet \ Review existing design & \textbullet \ Review existing design & \textbullet \ Review existing design & \textbullet \ Review existing design \\
\hline
Cost Estimates for Storage Facility & \textbullet \ Develop detailed cost estimates & \textbullet \ Develop detailed cost estimates & \textbullet \ Develop detailed cost estimates & \textbullet \ Develop detailed cost estimates \\
\hline
Conflicting Uses and Rights & \textbullet \ Identify potential conflicts & \textbullet \ Identify potential conflicts & \textbullet \ Identify potential conflicts & \textbullet \ Identify potential conflicts \\
\hline
Environmental, Safety, and Other Approvals for Storage Facility & \textbullet \ Develop and implement site assessment approach & \textbullet \ Implement site assessment approach & \textbullet \ Implement site assessment approach & \textbullet \ Implement site assessment approach \\
\hline
Site Specific Analysis & \textbullet \ Review existing design & \textbullet \ Review existing design & \textbullet \ Review existing design & \textbullet \ Review existing design \\
\hline
\end{tabular}
\end{table}

\section*{Conclusions}

The systematic framework for storage activities presented in this paper can be used to improve understanding of the work programme, project stages, time, costs and business risks involved in geological storage site assessment and development. The initial stages of screening activity for saline reservoirs, both of which will generally be satisfied at Level 1 of exploration and appraisal permitting, may take between 1.5 and 5 years. Once permitting and licensing regimes for saline reservoirs are in place and exploration permits are awarded, a further 3 - 8 years may be required ahead of project appraisal and storage permitting. Exploration and appraisal activities are likely to be required for most saline reservoir CO\textsubscript{2} storage opportunities due to the limited data and geological understanding after initial screening. The storage aspects of CCS Ready are of particular importance due to the long timeframe and necessary investment in geological assessments. In summary, in the current policy environment developing storage sites may be an uncertain, long time consuming, costly and risky business opportunity. If CCS is to be deployed at industrial scale to mitigate climate change, these limitations will need to be rapidly resolved by policy makers and so provide industry with the appropriate incentives to proceed. Delay in implementing these policies and incentives will hamper the development of a commercial storage industry, further putting CCS technology development at risk.

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\section*{Future Work}

Further work is required to fully integrate with and to proceed in step with capture and transportation.