Stochastic estimate of CO₂ storage resources in depleted reservoirs

Alejandro Rodríguez-Martínez, Ghislain Pujol, Clémence Manhes, Euro García, Luc Van Gastel, Nicolas Agenet*, Sylvain Thibeau

*TotalEnergies, CSTJF, Avenue Larribau, 64000 Pau, France

Abstract

A workflow to estimate CO₂ storage resources under reservoir and surface uncertainties is presented and applied to the Aramis CCS project located offshore the Netherlands. It consists in injecting a CO₂ rich stream transported in liquid phase into deep, highly depleted, gas reservoirs, up to a maximum storage pressure, ensuring a safe and permanent storage. This project exploits the opportunity to use existing infrastructures for new low carbon perspectives in the context of global energy transition.

The significant hydrostatic pressure provided by the liquid CO₂ column in the wells is to be confronted to a low post-production reservoir pressure. For this reason, well completions were designed to maintain CO₂ in liquid phase down to the perforations. However, Joule-Thompson effects are expected near wellbore once the dense CO₂ vaporizes, impacting the well injectivity. Different types of innovative completions have been designed providing narrow injection envelopes bounded by the transport pressure constraints. Wells fitted with such constraining completions are to be combined in order to match the prefixed target injection rate under increasing reservoir pressures. Simulations modelling this system, need to decide what combination of wells to use at each time step to overcome a larger range of operational conditions. Such automated decision-making process is not implemented in any commercial or in-house reservoir simulator. Therefore, a full Integrate Asset Model (IAM) was built, from surface facilities to reservoirs, able to select well combinations capable to meet the injection target rate at any timestep.

Reservoir and injectivity uncertainties had to be captured to obtain probabilistic estimates of CO₂ storage resources distribution. Exploring such a vast field of combined uncertainties is a bulk task requiring very simplified reservoir models, with low computation time, to be included into the IAM. The profiles generated would be the results of specific choices made by the IAM during simulations according to realizations within the uncertainty field and surface constraints.

An innovative iterative workflow was devised to produce MBal (IPM – Petroleum Expert) models able of mimicking near wellbore re-pressurization of each injection well and average reservoir pressure commonly simulated with 3D reservoir models. The global reservoir pressure gradient was segmented over two region types: the main reservoir and the near well bore volumes. The main reservoir volume pressure, assumed to comply with material balance independently of CO₂ specificities, is introduced in the MBal model with a principal tank tuned to capture both the asymptotic and second order variation of the average pressure. Additionally, the evolution of the near wellbore volumes pressure, which is affected by temperature changes and induced mechanisms, required

* Corresponding author. E-mail address: nicolas.agenet@totalenergies.com
to define distinct secondary tanks. Three MBal models were built, per reservoir, to match the pressure behavior of representative P10/P50/P90 models, that were derived from the uncertainty analysis conducted on historical production data history match of the 3D models. Then, the link between near wellbore area and bottom hole flowing pressure was represented by IPR tables introduced in the IAM. Injectivity uncertainties linked to CO₂ phase changes were captured in P10/P50/P90 IPR tables constructed from representative sector-model thermal simulations of each near wellbore region.

These MBal models were then coupled to the IAM to run the base case scenario with the implemented field management system operating the overall injection process accordingly the targeted flow rate while honoring the surface constraints.

Few iterations through 3D models, MBal and IAM, were done to reach robust model matching of both well bottom hole and reservoir pressures for different well combinations and flow rate scenario.

Once the MBal models were validated, representative realizations covering the full domain of subsurface uncertainty were generated thanks to an experimental design. The obvious advantage of this workflow was to run in automated mode a considerable number of simulations in a reduced amount of time and the collection of relevant data for statistical analysis and correlation investigations.

This approach helped to demonstrate the robustness of the injection strategy, embedded in the field management system of the IAM, by including the different uncertainties related to well performances and geosciences. The field management system is optimizing each well operating schedule and rate, accordingly to surface and subsurface constraints, satisfying a field mass target injection rate. The impact of subsurface uncertainties is reduced resulting into a high level of confidence for the CO₂ storage resources with distinct well injection profiles.

**Keywords:** CCS, Depleted gas field; CO₂ storage resources; Integrated Asset Modelling; Reservoir uncertainties; Field Management