Synergy of CO$_2$ storage and oil recovery in different geological formations: case study in the Baltic Sea

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Abstract

CO$_2$ geological storage (CGS) is an efficient tool to mitigate climate change and to continue use of fossil fuels for energy production. Renewable energy is becoming more popular to reduce impact of human activity on the Earth. However, oil is still the most profitable energy source and will remain the same in the future. Taking into account the development of CGS and profit of oil production, the combining Enhanced Oil Recovery (EOR) technology in the depleted oil reservoirs with CGS (CO$_2$-EOR) is well-known commercial practice and has been already successfully implemented during last decades. Use of CO$_2$ offers an attractive opportunity to increase effectively oil production in the depleted oil reservoirs. CO$_2$-EOR ensures permanent storage of large quantities of CO$_2$ underground (EOR+) reaching the goals to reduce the greenhouse gas effect on the Earth’s atmosphere, achieving win-win situation [1]. Nevertheless, when using underground oil recovery usually has the highest priority and can cause a conflict of interest with other underground uses. Such a case in the Baltic Sea Region was studied for the first time.

The E6 offshore structure was found by seismic exploration and explored in 1984 by one well E6-1 (depth 1068 m), located 37 km from coast of Latvia [2, 3]. The structure was estimated as prospective for oil in 10.5 m thick oil-bearing reservoir layer of the Saldus Formation in the Upper Ordovician Porkuni Stage. The fractured-porous reservoir is represented by carbonate rocks with average porosity 18% and gas permeability up to 39 mD. Oil flow was 2.7 m$^3$ per 24 hours [4]. Oil shows were found in the sandstones of the Cambrian Series 3 Deimena Formation and in the Devonian rocks. The E6 structure was licensed to the Odin oil company in 2008 for oil exploration and production.

The Deimena Formation (53 m thick reservoir sandstones) in the E6 structure, located 135.5 m lower under the oil reservoir of Saldus Formation. It is covered by Lower Ordovician clayey primary cap rock and additionally covered by Ordovician and Silurian (in total 266 m thick) clayey carbonate rocks and Devonian siliciclastic and carbonate rocks [2, 3]. According to [5], fault system within the structure has led to the migration of hydrocarbons from the Cambrian reservoir to the upper Ordovician reservoir. The E6 structure was estimated as the most prospective for CO$_2$ storage in the Deimena Formation sandstones offshore Latvia [2, 3].

In our study we are discussing possibility of CGS in the Cambrian Deimena Formation and CO$_2$-EOR from the Upper Ordovician Saldus Formation. During exploration, the inflow of light oil was insignificant due to low pressure in the reservoir. Injection of CO$_2$ into the oil reservoir will significantly increase pressure and consequently oil extraction. CO$_2$-EOR method has been already tested for the Cambrian Deimena Formation ROZ (residual oil zone) in the Baltic Sea Region by the oil company. Two pilot injections have been made into Lithuanian onshore oil fields (about 2 km depth) for EOR-CCS in 2013, investigating potential of CO$_2$ to be used for EOR. The results
showed that one tonne of produced CO₂ could produce one tonne of oil from Cambrian reservoir [6]. Testing of CO₂-EOR in Ordovician reservoir has not been done yet.

Planning the simultaneous use of the underground at different depths could be made in synergy, supporting profit from EOR and thus reducing the overall costs. This synergy will save resources on infrastructure and logistics and presenting win-win situation, storage of large amount of CO₂ and extracting of oil. Taking into account large area of the oil-bearing structure, we assumed it prospective for EOR+ that means large hypothetical potential for permanent storage of CO₂ in the future depleted oil field. Considering that the field is not yet depleted, it is possible to start simultaneous drilling of injection well for CO₂ storage into Deimena Formation and oil production well into Saldus Formation.

The risk of CO₂ leakage from the Deimena Formation due to uncertainties of the fault system considered as profit for EOR+ in the Upper Ordovician Formation. Fault integrity risk assessment study should be made to prevent possible CO₂ leakage from the oil reservoir via fault system. In case of zero or very low vertical migration of CO₂ out of the Deimana Formation, the CO₂ injection could be made into the third well, which could be drilled after depleting of the Saldus Formation.

Two possible scenarios are proposed to be considered for common use of the E6 structure: a) two wells and possible leakage through the faults out of the Deimena Formation, and b) three wells and “no leakage” scenario. The surplus of the (a) scenario is a common injection well, while the surplus of the (b) scenario is more oil produced than for conventional CO₂-EOR. Surplus for both scenarios is increased CO₂ storage capacity. For economic modelling of these scenarios the estimated by the license owner oil reserves of the E6 structure, 362 MMBO (million barrels of oil) equivalent at the maximum closure of 585 km², will be used.

In the present study, for the first time, the prospects of synergy of CGS and CO₂-EOR/EOR+ in different geological formations in the same storage site were discussed. Profits of the synergy and possible risks were analysed for two possible scenarios. All available data from the E6 offshore structure including detailed description of the oil-bearing Upper Ordovician Formation, 3-D models, results of the petrophysical alteration effect on the rocks of storage reservoir induced by CO₂ and incorporated into the numerical seismic modelling were analysed together in this study [7, 8, 9]. Case study presented in this research, as the first of this type in the study area, can be an example and has an importance for further studies in the field of common use of the underground, when CGS and CO₂-EOR/EOR+ can meet in different storage formations of one geological structure. Implementation of the proposed scenarios will permit to clarify the history of oil migration within the E6 structure and will make input into geological history of the study area.

References