Reservoir simulators are essential for assessing, developing, optimizing and monitoring CO₂ storage and CO₂-EOR operations. A simulator provides important key characteristics of the reservoir, such as storage potentials, pressure build-ups, optimized injection and/or production strategies, well-placements and CO₂ migration paths. For robust decision making, multiple simulations are typically done. This is both to explore optimal solutions by varying strategies, and by using several reservoir models to account for the uncertainty inherent in the reservoir models. Hence, robustness and speed of the simulation tools are essential. In this paper, we demonstrate our open reservoir simulator on several real North Sea field examples with success.

To enhance the economically viability of CO₂ sequestration, it is of interest to study the potential of combining it with Enhanced Oil Recovery (EOR). Large parts of the initial infrastructure cost can then be paid for by the increase in oil recovery. When the potential for oil recovery is reached, the CO₂ injection can continue as a pure storage project. Injecting CO₂ in mature oil fields reduces the risk of leakage, as the reservoirs provide natural traps for fluids or gases lighter than water. Moreover, oil companies are often committed to properly sealing off the reservoir through plugging of wells. While CO₂-EOR has successfully been implemented on-shore, it has proven challenging to get the necessary investment off-shore. Traditionally, demonstrating good economics through reservoir simulation has been a key enabler for investments off-shore.

Our aim is to develop a simulator tailored to the application of CO₂ storage in combination with EOR. The simulator needs to account for the complex interaction of CO₂ and hydrocarbons, and at the same time be applicable to field models. Most available simulators that can handle CO₂ injection in mature oil fields are either commercial, with little flexibility with respect to tailored modelling, or cannot handle the complexity of oil and gas fields. As a remedy, we provide an open and flexible simulator that handles the needed complexity both in terms of physics and performance.

This work presents an extended black-oil simulator where the migration of the CO₂ component is modelled using an additional equation, and the miscibility of CO₂ and hydrocarbons is approximated using the Todd-Longstaff model. This extended black-oil model is more computationally efficient than a full compositional approach, allowing for comprehensive uncertainty analysis and optimization studies, where multiple realizations are warranted. In addition, extending the black-oil model enables direct use of the simulator for CO₂-EOR studies on most existing reservoir models, avoiding the need to convert the model to a compositional formulation first. The simulator itself is designed as a drop-in replacement for commercial simulators, enabling direct studies of CO₂-EOR in existing oil company work-flows using standard commercial tools both for post- and pre-processing. In short, all
steps have been taken to make the reservoir simulator an enabler for CO$_2$-EOR in cases where reservoir simulation forms an important part of the decision basis.

The simulator is implemented as part of the Open Porous Media (OPM) initiative. OPM aims at providing a common platform for developing open-source simulation tools for porous media applications. The open development model allows for testing alternative and more advanced fluid models, for instance for the mixing of CO$_2$ and hydrocarbons on real field case models. The capability of the simulator is demonstrated on several field case examples, including the Smeaheia case, where the Norwegian government plans a full-scale CCS demonstration.