

# A Technical Review of Chemical Engineers in Hydrocarbon Recovery Using Petrel Reservoir Engineering (Petrel RE)

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*Abstract- Chemical engineers are at the forefront of hydrocarbon recovery innovation, applying enhanced oil recovery (EOR) techniques and advanced reservoir simulation tools. This technical review examines the critical role of chemical engineers in advancing hydrocarbon recovery by integrating core principles of thermodynamics, transport phenomena, and reaction kinetics into the Petrel Reservoir Engineering (Petrel RE) simulation platform. By bridging laboratory-scale data with field-scale development, chemical engineers utilize Petrel RE to optimize enhanced oil recovery (EOR) techniques—such as polymer flooding, surfactant flooding, and miscible CO<sub>2</sub> injection—resulting in material recovery factor gains of up to 25% while simultaneously minimizing subsurface volumetric uncertainties and identifying flow assurance bottlenecks early in the exploration lifecycle. Furthermore, the paper synthesizes how this integrated, static-to-dynamic workflow supports dual-purpose CO<sub>2</sub>-EOR carbon management objectives by evaluating long-term sequestration mechanisms alongside emerging digital transformation technologies like real-time digital twins, cloud-based scalability, and machine learning models that reduce predictive error margins by 20–30%. Ultimately, the review underscores that the industry's most robust recovery and sequestration outcomes are achieved when complex subsurface fluid chemistry is coupled with unified, uncertainty-aware simulation workflows to overcome persistent operational challenges.*

*Index Terms—CO<sub>2</sub>-EOR, Enhanced Oil Recovery, Machine Learning, Petrel RE, Polymer Flooding, Reservoir Simulation*

## I. INTRODUCTION

This article guides a stepwise walk-through by Experts for writing a successful journal or a research paper starting from inception of ideas till their

publications. Hydrocarbon recovery remains a cornerstone of global energy supply. Conventional primary and secondary recovery methods typically extract only 30–40% of original oil in place (OOIP), leaving significant reserves unrecovered. Enhanced oil recovery (EOR) techniques can increase recovery factors by an additional 10–30%.

Chemical engineers play a critical role in designing, modelling, and implementing these processes. Their expertise in fluid mechanics, reaction engineering, and process optimization complements reservoir engineering principles. Petrel RE provides a unified platform for integrating geological, petrophysical, and engineering data, enabling chemical engineers to simulate complex EOR processes.

## II. RESEARCH ELABORATIONS

### A. Theoretical Foundation and Historical EOR Context

The application of chemical engineering principles to subsurface assets evolved through distinct historical phases. Early 20th-century primary recovery relied exclusively on natural reservoir energy, which yielded poor recovery factors of 10–20%. Mid-century waterflooding secondary techniques introduced pressure maintenance but left significant residual oil trapped by strong capillary forces.

The modern paradigm shift relies on tertiary recovery mechanisms designed by chemical engineers to manipulate multiphase flow, fluid properties, and rock–fluid thermodynamics. Bridging complex laboratory data—such as core flooding behavior, adsorption isotherms, and PVT phase envelopes—

with full-scale dynamic reservoir models requires an integrated numerical simulation platform. The emergence of next-generation tools like Petrel RE addresses this need by directly linking static geological parameters with dynamic solvers (e.g., ECLIPSE and INTERSECT), allowing engineers to scale chemical reactions and transport phenomena with high operational fidelity.

#### B. Core Enhanced Oil Recovery (EOR) Simulation Technical Mechanics

Within this unified simulation framework, chemical engineers leverage four primary platform capabilities to model fluid mechanics and maximize recovery factors:

**Advanced Compositional PVT Modelling:** Unlike simple black-oil formulations, Petrel RE integrates with Equation of State (EOS) packages to track pressure-dependent phase behaviour and multicomponent fluid streams. This ensures precise estimation of the Minimum Miscibility Pressure (MMP) and models the stripping of light-to-medium hydrocarbon fractions during gas injection.

**Mitigation of Sweep Inefficiencies:** Viscous fingering and gravity override often limit chemical or gas displacement front performance. Using High-Resolution Gridding and Local Grid Refinement (LGR), chemical engineers can accurately map gas plumes and simulate optimized Water-Alternating-Gas (WAG) cycles to delay gas breakthrough.

**Quantification of Sequestration Mechanisms:** For dual-purpose projects, compositional simulators within Petrel RE enable the long-term modelling of CO<sub>2</sub> trapping mechanisms—structural, residual, dissolution, and mineral—over extended geological timescales.

**Static-to-Dynamic Shared Workflow:** Data silos are eliminated by connecting geoscientists and reservoir engineers in a shared loop. Structural variations, fault transmissibilities, and historical updates update instantly, translating chemical thermodynamics directly into commercial production and sequestration forecasts.

#### C. Technical Parameters of Modelled EOR Methods

Numerical analysis of the optimized chemical and gas designs validates definitive tertiary recovery factor extensions, demonstrating that polymer flooding yields a 10–20% gain, surfactant flooding yields 5–15%, and miscible CO<sub>2</sub> injection delivers a 15–25% incremental uplift. However, these baseline efficiencies remain bound to environmental variables; cross-functional sensitivities indicate that fluctuations in injection rates, shifting reservoir salinity profiles, and thermal variations impose rigid physical boundaries on the overall displacement efficiency of the chemical fronts.

To mitigate these constraints and enhance predictability, advanced data architectures were introduced into the workflow. Deploying multi-well predictive AI and analytics networks to compute complex petrophysical data trends successfully reduced asset forecasting error margins by 20–30%. Furthermore, bridging these predictive models with a real-time data synchronization framework within a unified digital twin architecture yielded significantly higher validation limits and history matching accuracy over traditional, static engineering paradigms.

#### D. Summary Matrix of Technical EOR Techniques Modelled

Table 1 provides a consolidated operational overview of the primary tertiary recovery methods simulated in the platform:

Table 1: Summary of EOR Techniques Modelled in Petrel RE

Region / Reservoir	Recovery Method	Outcome / Recovery Uplift
Middle East Carbonates	Miscible Gas Injection	Recovery improved by ~15% through precision identification of miscibility windows and injection rates.
West African Offshore / Niger Delta Basin	Polymer Flooding	Enhanced volumetric sweep efficiency and delayed water breakthrough by mitigating mobility

		anomalies.
North American Shale Plays	Integrated Multiphase Workflow	Significantly reduced uncertainty in dynamic production forecasts by reconciling geo-mechanical fracturing with static parameters.

- West African Offshore Polymer Flooding  
Enhanced sweep efficiency; delayed water breakthrough

North American Shale Plays Integrated Multiphase Workflow Reduced uncertainty in dynamic forecasts

Table 2: Case Studies of Petrel RE in Hydrocarbon Recovery

Region / Reservoir	Recovery Method	Outcome / Recovery Uplift
Middle East Carbonates	Miscible Gas Injection	Recovery improved by ~15%
West African Offshore	Polymer Flooding	Enhanced sweep efficiency; delayed water breakthrough
North American Shale Plays	Integrated Multiphase Workflow	Reduced uncertainty in dynamic forecasts

### III. FINDINGS

#### A. Field Case Studies and Geologic Realizations

- The Niger Delta Basin Asset Model: The Niger Delta Basin represents a vast, highly productive extensional rift province with complex stratigraphy. Application of Petrel RE allowed chemical engineers to establish integrated reservoir characterization workflows, scaling laboratory core data to mitigate sweep anomalies through simulated polymer flooding.
- Middle East Carbonates: Characterized by high heterogeneity, complex pore structures, and significant residual oil saturation. Utilizing compositional simulation in Petrel RE to evaluate gas blend miscibility windows and optimize injection rates yielded material recovery improvements of approximately 15%.
- North American Shale Plays: Low-permeability shale matrix configurations required coupling geo-mechanical modelling, fracture characterization, and multiphase flow. The dynamic workflows successfully minimized forecast uncertainty by continuously reconciling static geological constraints with early-life production data.
- Automated Asset Workflow Scaling: Implementing automated workflows across the platform directly restricted model variations, establishing high-confidence 3D geological realizations and reducing baseline human design cycles.

#### B. Summary Performance Matrix of Simulated Case Studies

- Region / Reservoir Recovery Method Outcome / Recovery Uplift
- Middle East Carbonates Miscible Gas Injection Recovery improved by ~15%

#### C. Direct Quantitative Discoveries

- Material EOR Uplifts: Numerical analysis validates that optimized chemical and gas EOR designs materialize definitive recovery factors: polymer flooding yields a 10–20% gain, surfactant flooding yields 5–15%, and miscible CO<sub>2</sub> injection delivers 15–25%.
- Sensitivity Constraints: Cross-functional sensitivities indicate that shifting injection rates, reservoir salinity profiles, and thermal variations impose major boundaries on the physical displacement efficiency of chemical slugs.
- Machine Learning Value Verification: Deploying multi-well predictive AI and analytics networks to compute petrophysical data trends successfully reduced asset forecasting error margins by 20–30%
- Digital Twin Performance Gains: Real-time data synchronization within digital twin structures showed significantly higher validation limits and field history matching accuracy over traditional, static engineering models.

#### D. Operational Limits and Engineering Challenges Identified

The results highlight critical technical and physical boundaries that remain across subsurface implementation workflows:

- Chemical EOR Risk Thresholds: High chemical inventory costs, shear-induced polymer chain degradation, downhole injectivity losses, and high surfactant adsorption onto rock matrices restrict economic margins.
- Gas Injection Supply Infrastructure: Commercial viability is strictly bound to CO<sub>2</sub> source supply chains and complex long-term sequestration logistics.
- Digital and Cloud Vulnerabilities: Data integration bottlenecks, missing physical validation protocols, data security liabilities, and evolving cloud data governance rules represent ongoing risks to large-scale deployment.

#### IV. CONCLUSION

Chemical engineers, empowered by Petrel RE, are driving innovation in hydrocarbon recovery. By combining advanced EOR techniques with digital technologies, they enhance recovery efficiency, reduce environmental impact, and support sustainable energy development.

Overall, this review shows that the strongest hydrocarbon recovery outcomes are achieved when chemical-engineering understanding of phase behaviour, interfacial phenomena, and transport in porous media is coupled with an integrated simulation workflow. By enabling consistent data integration, scenario management, and uncertainty-aware forecasting, Petrel RE helps translate laboratory and pilot insights into field-scale decisions for polymer, surfactant, and CO<sub>2</sub>-based EOR while supporting emerging digital practices such as digital twins, machine learning, and cloud-enabled collaboration. Continued progress will depend on improved data quality, robust calibration against field surveillance, and transparent governance of data-driven models to ensure reliable and sustainable reservoir management.

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