Unconventional resources: Challenges & Opportunities. The role of EOR

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Unconventional Resources

- Conventional resources: small volumes, easy to develop
- Unconventional resources: large volumes, difficult to develop

Source: repsol.com
Unconventional Resources

Non−conventional Crudes ~7 Trillons Barrels in Place
Source: IEA World Energy Outlook 2006

1. Proved conventional oil reserves are approximately 1/3 of the non-conventional oil reserves.
2. Established recoverable heavy oil and bitumen resources are about 716 Billion barrels.
3. Most of heavy and extra heavy crude oil reservoirs are in Canada (Alberta’s Oil Sands) and Venezuela (Orinoco Belt).
4. Unconventional resources are harder to recover and more expensive to develop.
5. Require new, highly energy intensive production techniques to deal with their inaccessible placements or unusual compositions.
6. Are highly dependent on economics and on the oil price (many projects require a minimum of 80US$/bbl to make a 10% ROI).
Enhanced Oil Recovery (EOR)

1. EOR
   - Primary and secondary recovery targets mobile oil
   - EOR targets in mobile oil

2. EOR current status
   - Low world oil production due to EOR (~3.5% of daily production)
   - Majority: thermal methods (Canada, Venezuela) (around 2/3)
     - CO2-EOR, HC injection and chemical EOR (around 1/3)
     - Others: marginal

3. EOR challenges
   - Projects are complex, technology-heavy and require considerable CAPEX and financial risks (high injectant costs)
   - Long lead time

4. EOR advantages
   - Oil already found → no exploration risk
   - Main surface facilities already in the field
   - Markets available
   - Increased value of a company assets

The potential recovery factor that can be achieved with EOR is high!!!
**Unconventional resources + EOR**

**Unconventional resources**
To transform these resources into reserves, new technologies must be developed
- To increase \( k/\mu \) ratio
  - \( k \) is usually increased by fracking
  - \( \mu \) is usually decreased by heat
- Rock wettability alteration (e.g. low salinity water)

**EOR potential**
EOR application in unconventional oil resources is the next frontier of technology development

![Diagram showing permeability and viscosity with EOR target and oil types](chart.png)

Source: BP, Harris Cander (2012)

**Big EOR potential to unlock unconventional resources!!!!**
Unconventional resources + EOR

Heavy Oils
Some examples

Bitumen in carbonate
Challenging development plan in and extra-heavy oil
Offshore, deep water
In-Situ Upgrading

**Carabobo**: huge amount of Extra Heavy Oil [34.5 billion bbl]
- Very challenging FDP [400,000 bbl/d]
- High heterogeneity
- Regional aquifer
- Relative high P & depth reservoir
- High NG demand to generate steam
- Several pilot tests in OOB, no commercial

**Grosmont**: largest bitumen carbonate formation worldwide [318 billion bbl], onshore, shallow, high So
Commercial technology not available
- Very high oil viscosity
- Low energy
- High heterogeneity
- Oil-wet, majority of oil is in the matrix
- Poor containment of injected fluids
Technology Challenges in Heavy Oil

Some examples

Bitumen in Carbonate
Challenging development plan in and extra-heavy oil
Offshore, deep water

In-Situ Upgrading

Offshore, deep water:
- 2000m, low T, high P
- Flow assurance big challenge
- New or adapted technology is required
  - no steam process feasible (high depth)
  - surface facilities limitations

In-Situ Upgrading:
- Inside Reservoir HO converted into synthetic crude oil
- Bring the Surface Refinery into the Reservoir
  - Production of higher quality oil
  - Feasibility for oil transport by pipeline
  - Reduction in the requirements of water & natural gas, and GHG emissions
- 5-10 years of R&D before executing the first pilot

Now

Future
R&D in EOR for heavy oil

Wettability alteration in Heavy Oil

- Novel functional Polymers
- Improved water flooding (for thin reservoirs)
- Surfactants for extreme reservoirs condition
R&D in EOR for heavy oil

New generation of ISC processes
- Application of horizontal wells
- THAI (Toe to Heel Air Injection)
- THAI-CAPRI Integration In-situ Upgrading employing nano catalyst with In-situ Combustion

Electric Heating of Reservoir
- Electrical methods to avoid introducing any fluid into the reservoir
- Resistive, induction and dielectric heating
- The heat is created in the reservoir as current flows through the connate water
- Applicable where steam injection is not feasible

Akshay Sahni, Mridul Kumar, Richard B. Knapp; “Electromagnetic heating Methods for Heavy oil reservoirs,” SPE 62550; June 2000
R&D in EOR for heavy oil

2016

**Short term applications**
- Primary production
  - CHOPS
  - Foamy oil
- Conventional Steam Injection
  - CSS
  - Steam flooding
  - SAGD
  - Others

**Mid term applications**
- SAGD evolution to steam-solvent processes
- New generation of In situ combustion processes
- New Chemical EOR processes & Chemicals
- Reservoir electrical heating
- MEOR

**Long term applications**
- In situ Catalytic upgrading (Nano Catalysis)
- Totally environmental friendly processes
- *In situ* Refinery
Repsol Approach

EOR KTA (Key Technology Area): To generate new solutions and to provide specialized technology support to transform resources into reserves through Enhanced Oil Recovery processes

SPE-169944-MS
“Application of an Integrated Methodology for Pre-Filtering of EOR Technologies”, SPE Biennial Energy Resources Company, Port of Spain, 2014

María León Carrera, Elena Escobar Álvarez;
SPE-174301-MS “Assessment and Ranking of EOR Strategies for Giant Extra-Heavy Oil Fields”, EAGE-Europec Madrid, 2015
R. Coll; E. Escobar; M. León Carrera; and S. Pérez, Repsol S.A.

SPE-180170-MS “Insight of HASD Technology in an Extra Heavy Oil Field in Comparison to Traditional Thermal EOR Processes”, EAGE-Europec Wien, 2016
S. Perez, E. Escobar, Repsol S.A.
Repsol Approach

EOR Technology Screening

- Analogous Reservoir Identification: What have been done in similar reservoirs?
- Ranking of technologies
- Screening using average properties
- Screening using 3D reservoir model (EOR Plug-in)
- Where, in the field, can you apply EOR? What is the EOR impact in the field?

EOR_PORT: Evaluation of all Repsol reservoirs to identify the potential EOR technologies to be applied and the success factor

Static model + Criteria ➔ Maps of potential application of EOR technologies

Repsol Approach

EOR Laboratory

Integrated with the geological, geomechanics, petrophysics and fluids lab!

Contact angle

Interfacial tension

Rock wettability restoration

Steam injection impact on reservoir rocks

Core flooding for EOR

Rel perm end points at steam injection conditions
Repsol Approach

EOR Numerical Simulation

From lab to field scale:
- Thermal EOR: CSS, SF, SAGD, ISC...
- Gas EOR: CO$_2$, N$_2$, WAG
- Chemical EOR: Polymer, ASP

Types of study:
- Sensitivity analyses
- Production history match
- Optimization of operating conditions
- Uncertainty analyses
- Pilot test design and evaluation

Enhanced Oil Recovery simulation
Huge unconventional oil resources in the world → great potential
EOR recovery technologies will play an important role to develop unconventional oil
There are mature EOR technologies at commercial scale… BUT…
… R&D in EOR is key to increase the potential of current EOR commercial technologies and to develop new processes that allow unlocking inaccessible resources (e.g. tight oil) in a sustainable way (environmentally friendly)

Repsol approach to assess EOR Technologies
- Robust workflow to rank EOR technologies
- Lab facilities to perform internal R&D
- Numerical simulation to analyze efficiently the performance of EOR processes
- Pilot plan design

To develop new EOR technologies allows us to be prepared for the future challenges!