Building an Enhanced Oil Recovery Culture to Maximise Asset Value

Marco Rotondi
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Building an Enhanced Oil Recovery Culture - Agenda

1. Introduction
2. EOR Challenges & Solutions
   2.1 EOR Time to Market
   2.2 EOR Costs
   2.3 EOR Mindset
4. eni Successful Case Histories
5. Conclusions
Meeting Future Production Demand

Enhanced Oil Recovery

- Miscible Gas Injection & WAG
- Thermal Methods
- Chemical Injection
- Microbial Methods & Others

Source: IEA World Energy Outlook 2012
EOR Projects Time to Market

Faster Deployments

- **Screening Phase**
- **Y1**
  - **Lab Analyses & Simulation**
  - **Y3**
    - **Pilot Test @ well scale**
  - **Y4**
    - **Interwell Pilot Test**
  - **Y5**
    - **Full Field Implementation**

- **Y6-8**

- **EOROG™**
- **IPSE**
- **in-house EOR labs**
- **APA for EOR**
- **Streamlines**
- **High Resolution Simulator**
- **Log-inj-log**
- **SWCTT**
- **WA SWCTT (Jan 2014)**
- **NA SWCTT (Aug 2014)**
- **NA SWCTT (Jan 2014)**
- **NA Polymer Plant (2014)**
- **NA Polymer Plant (2015)**

- **Standard procedures**
- **Strategic contracts**
- **Monitoring best practices**

- **From a sequential to a quicker parallel approach**
**Screening Tool for Optimal EOR Techniques & Analogues**

**In house tool for quick screening phase and EOR analogues evaluation**

1. Algorithm searches for analogues within EOR database

2. Optimal EOR Techniques

3. List of references

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2) SPE-174315 – “A New Bayesian Approach for Analogs Evaluation in Advanced EOR Screening” – EUROPEC, June 2015
Understanding & Reproducing EOR Mechanisms

“Study the past if you would divine the future”

1. Production Data Analysis for EOR
   - Methane Bank

2. Material Balance
   - Streamlines
     - Optimizing Waterflood

3. Streamlines

4. 3D simulation
   - Core Scale
     - Eclipse Stars UTChem
   - Well Scale (SWCTT)
   - Sector & Full Field Scale
     - Low Salinity
     - Sea water

Optimizing Waterflood

Janus Bifrons
Faster & More Accurate EOR Simulations

Deployment of a high resolution simulator for full field simulation

**Standard Case Study**
- Low permeability oil reservoir
- Coarse grid: 139x122x56, 200k active cells
- 46 Horizontal wells and LGR to simulate horizontal wells + hydraulic fractures

**Pushing the limits**
- Combining HPC2 hardware (30,000 cores, 6000 GPUs) and new simulator to run larger models and capture geological complexity avoiding upscaling

- **Outstanding results in terms of simulation time**

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3) SPE175633 “Advances in Sim. Tech. for High-Resolution Models: Achievements & Opp. For Improvement”– SPE RCSC Sept. 2015
Reducing EOR Costs

- EOR generally perceived as expensive, but comparable production costs to other oil resource exploitation

- Finding & development costs even lower if projected to 2035

- Keep an eye on emerging techniques

- Low Salinity & ‘Smart’ Water

- Considering existing surface facilities & infrastructures and seek for opportunities!

Sources: Resources to Reserves, IEA – 2013
World Energy Investment, IEA – 2014
EOR...

- is still wrongly perceived as a "reservoir or lab" subject while requires a fully multidisciplinary approach
- is still considered a technological frontier: "We have always done like this..."
- should not be exclusive to mature fields
- requires a strong top management support and long term vision / continuity

EOR Challenges

Changing the Mindset – A new EOR ‘Culture’

Start

Reorganization and reinforced EOR team

Growing of a new generation of EOR professionals to generate new ideas and support future EOR implementations

Internal guidelines & external collaborations

EOR know-how dissemination (WS, webinars, lectures, papers, etc.)
Many valuable studies and lab tests, very few field applications
More time spent to understand “how it works” rather than “if it works in the field”
A more pragmatic approach was needed to promote EOR applications within the Company
Reorganising and rationalising EOR initiatives and R&D portfolio
EOR Systematic Screening & Opportunity Evaluation

**EOR Action Plan**

**High Level Screening**

- eni Portfolio Screening
  - Viscosity (cP @RC)
  - Depth (ft)
  - Oil field

**Low Level Screening**

- Field by field opportunity evaluation (analogues)

**Optimal EOR Techniques**

- (Strategy revision)

**Evaluation of additional unconstrained EOR resources & RF**

**Additional EOR oil**

**eni Field**

- Current Dev: MGI + RI
- Permeability: 200 mD
- Depth: 8760 ft
- Viscosity: 105 °F
- Temperature: 185 °F
- Initial Pressure: 3500 psia
- OOIP: RF @ 2014

**Analog Field**

- Current Dev: WAG
- Permeability: 243 mD
- Depth: 9840 ft
- Viscosity: 207 °F
- Temperature: 207 °F
- Initial Pressure: 3632 psia
- OOIP: RF @ 2014

**Short term opportunity implementations**

- (quick deployment of mature techniques at low cost)

**Mid term opportunity implementations**

- (building internal competences)
eni EOR Projects

More than 20 new EOR initiatives launched...

Study  Pilot  Full field implementation  Gas injection  Thermal EOR  Chemical EOR
- Onshore NA field
- Developed with WI and mGI
- **Already high RF**
- Nearby field produced by means of WAG
- New reservoir model
- **Conversion of existing WIs**
- WAG pilot started in Q2 2013
- Impressive results, additional **URF of 6%**
- Cost per EOR barrel < 0.5 USD/stb

**Improving RF: Never give up!**

*SPE174700, “On the Road to 60% Oil Recovery By Implementing Miscible HC WAG Injection in a NA Field” – SPE EORC, Aug. 2015*
Offshore UK, structurally complex reservoir
Developed with WI (high WC = 91%) & crestal offspec gas disposal
Change of operatorship in April 2014 -> APA, Streamline, New 3D Model
Water injection is inefficient and attic oil bypassed
WAG a feasible solution -> gas from issue to resource

WAG pilot forecasts

- WAG Pilot (conversion of two water injectors) foreseen for Q2/Q3 2015
- Low cost opportunity
- Additional 2% on URF
- Based on pilot results, other 3 water injector wells will be converted to WAG injectors

From study to pilot in 1y time, low cost per EOR barrel
Deepwater iWAG & Foam Assisted WAG
Implementing EOR from Day 1 🌈💡

**Project Overview**
- **Deepwater WA field**
- Production start-up Q1 2015 (2 prod)
- **iWAG start-up Q2 2015** (2 inj)
- Analogue field produced by WAG showed gas BT in 1.6 km away producer in 75 dd
- **FAWAG R&D project launched**

**WAG & FAWAG Forecasts**
- foam assisted WAG
  - Reducing gas mobility in reservoir
  - Increasing sweep efficiency
- WAG + 30% on RF wrt natural depletion
- **FAWAG** less than 1% on additional recovery but – 53% on produced gas

Moving to more complex techniques to maximise RF & mitigate subsurface risks
Maximising Sweep Efficiency in Waterfloodings

Exploiting & combining water conformance, low salinity & chemical EOR techniques

Areal sweep efficiency
Vertical Sweep Efficiency
Microscopic Displacement

Water Conformance
Low Salinity
Polymer Flooding
Surfactant

Screening Phase
Lab Analyses & Simulation
Pilot Test @ well scale
Interwell Pilot Test
Full Field Implementation

- 2 NA Low Salinity Projects
- Alaska Low Sal + Polymer
- ME low salinity
- WA offshore polymer

- Egypt Bright Water
- NA Polymer flooding
- NA Low Salinity + Polymer flooding

1) SPE171794 - "Low Salinity Water Injection: eni's Experience" – ADIPEC, 2014
2) SPE17951 - "SWCTT to Assess Low Salinity Water and Surfactant EOR Processes in West Africa” – IPTC, 2014
3) "Low Salinity Waterflooding for EOR: Stochastic Model Calibration and Uncertainty Quantification” – EAGE IOR 2015
Bright Water Pilot & Field Deployment Results

**Bright Water Deployment**
- Thermally activated polymer that improves waterflooding sweep efficiency by in depth reservoir conformance i.e. plugging thief zones and forcing water to follow new paths
- **Ultra mature field**, 94% WC
- Target bypassed oil (inefficient WI by APA & Streamline analysis)
- **2010**: successful pilot test
- **2013**: extension to 2 water injectors and 7 producers

**Field Results**

**Pilot**

**Extension**

*Graph showing oil rate (Sm3/d) from gen-08 to nov-14.*

--- DCA  
Qoil (Sm3/d)

*SPE154042 – “Thermally Activated Particle Treatment to Improve Sweep Efficiency: Pilot Test Results and Field Scale Application Design in El Borma Field” – IOR Symposium, April 2012*
Bright Water Field Deployment Results

Gain continuing with time, well life extension > 5y, Low treatment costs
Increase in oil production (Well A)

WCT reduction (Well B)

"Polymer Injection: EOR Application in a North African field from Lab Analyses to Project Start-up", OMC 2015
North Africa – Maximising Waterflooding Efficiency

**Maximising Waterflooding Efficiency**

**EOR Case Studies**

**Results**

**Oil Gain +38%**

**BW Results**

1. "History Match and Polymer Injection Optimization in a Mature Field Using the Ensemble Kalman Filter”, EAGE IOR 2013
2. "Chemical EOR project for a Giant NA Field”, OMC 2015

**Q3 2014 – Low Salinity SWCTT**

**Q2 2015 – Dispersed WI + Polymer Pilot**

**Q3 2014 – Low Salinity SWCTT**

**2009 – Peripheral WI**

**2016 – Low Salinity Pilot**

**Combination of different Technologies**

**A Change in Strategy**

**2014 – Low Salinity Pilot**

**2015 – Dispersed WI + Polymer Pilot**

**1985 – Peripheral WI**
Conclusions

- Reducing EOR time to market & costs is feasible
- Take advantage of previous experience
- Be proactive in seeking for opportunities to improve RF (existing infrastructures)
- Still open technical challenges:
  - Going deepwater
  - Carbonates
  - Standard procedures for monitoring phase
- Keep investing in people and technology even in this low oil price scenario
- Promote a more collaborative environment among IOCs, NOCs, SCs and universities