Valorisation du CO$_2$ dans l’amont Pétrolier - EOR CO$_2$ : où va-t-on ?

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Plan

• US C02 EOR Experience
• Future of C02 EOR: challenges and driving factors
• Worldwide perspectives
What is CO2 EOR?

- Injection of CO2 in a reservoir to improve recovery:
  - Improves microscopic displacement efficiency, leading to very low residual oil in swept area
  - Water Alternate Gas processes preferred to improve macroscopic efficiency (limit the extension of unswept area)
  - Typically 5-15% additional recovery
  - Considered economic for oil prices above 80 $/bbl
  - Very dependent upon availability of ‘not so expensive’ CO2 sources
CO2 EOR genesis

- CO2 EOR process well known in the industry, linked with oil price cycles
  - Lab research in 50’s 60’s; pilot tests 70’s
  - Golden age: late 70’s-80’s (high oil price): construction of CO2 pipelines connecting natural CO2 fields and oil fields
  - Collapse: late 80’s. Slow recovery: 90’s – 2000’s with improved oil prices
  - 2010-2030+: a renewed interest associated with the more general industry interest for mature field redevelopment and capture of industrial CO2, global climate issues

- Particularly developed in the USA:
  - USA accounts for 90% of CO2 EOR projects worldwide
  - 50% of CO2 EOR projects worldwide in Permian basin (East Texas)
  - A very modest proportion of world oil production (300 kb/d)
The world's largest industrial CO2 demonstration project, Weyburn:

- 25 000 b/d; 6500 t CO2/d
- 320 miles pipeline
- 40 Mt of CO2 captured from Dakota Gasification Company synfuels plant along the life time of the Project

Weyburn project, Canada

Wikipedia 2014

CO2-EOR US Operations, CO2 sources - 2014

Oil production, 2014
- CO2 -EOR projects: 136
- Oil production, 1,000 b/d: 300

CO2 supplies, 2014
- Number of sources: 17
  - Natural: 5
  - Industrial: 12
- CO2 supply, MMcfd
  - Natural: 2.8
  - Industrial: 0.7

136 Number of CO2-EOR projects
- Natural CO2 source
- Industrial CO2 source
- CO2 pipeline
- CO2 proposed pipeline

Source: Advanced Resources International Inc. based on OGI EOR/Heavy Oil Survey 2014 and other sources
CO2-EOR US Operations, CO2 sources – Beyond 2014…

- Very limited additional natural source of CO2 in US
- US Production increase will mainly rely on new industrial sources of CO2.
Future of CO$_2$ EOR in USA:
DOE’s ambitious long term vision

• DOE plans suggests that potential of oil production by CO2 EOR in the USA is technically evaluated to be 60 Gb at 85 $/b (or >3 Million b/d during 50 years!)

• Main challenge: CO2 availability at affordable cost:
  • CO2 requirements: 20 Gt (average: 1 t CO2=3 b oil): 90 % of CO2 would need to be industrial source (18 Gt)
  • Total CO2 injected in EOR up to now (1970-2010): 0.8 Gt
  • CO2 needs: 400-500 Million t/y; would correspond to CO2 capture from new 70-100 Gw power plants (coal/gas) equipped with capture technology

• Technical bottlenecks:
  • Control of mobility in the reservoir (4 out of 7 DOE funded R&D projects): foam technology
  • Reduce capture cost of industrial CO2 capture by factor 3 (power plants, industrial facilities, in particular hydrogen unit in refining/petrochemicals)
Risk associated with geology: 
Early breakthrough of CO2

High anisotropy

Irregular front

Low anisotropy

Stable front

1

2

3

4 Sg
Risk associated with geology: recovery factors in miscible CO2 injection

Need of a front stabilization strategy: WAG, foams (surfactants)
Effects of foam in controlling CO2 mobility
A strategic R&D topic

Principle: WAG process with water enriched with surfactant => foam created in situ at gas/water interface

Foam acts as a viscous fluid => slower displacement
=> enhanced mobility control

Main challenge: foam stability and robustness at reservoir conditions
=> dedicated foam design for a given field

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CO2 foam EOR: from lab to field application

Robotic platform for formulation

High pressure view cell

In situ X-ray monitoring: gas

Gas front propagation along the core at successive times

In situ X-ray monitoring: foam

CORE

Simulator input

PILOT/FIELD-Scale prediction

Illustration on foam process
PumaFlow™ simulation

WAG
2.00 PV
WAG + foam

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How can « Next Generation » CO2 EOR recover much more oil than current practices

60% improvement in efficiency of CO2 utilization
(4 Bbls/tCO2 vs. 2.5 Bbls/t CO2 with current CO2-EOR technology)

=> Huge opportunity to maximize economics through a combination of:
- thorough reservoir characterization
- Chemically-enhanced mobility control (foam)
- well design optimization
Industrial CO₂ capture cost: a killing factor for CO₂ EOR?

- Estimated cost of capture-storage of industrial source CO₂ with today’s technologies: 100 $/t;
- Estimated cost to make industrial source CO₂ a profitable EOR process: 30 $/t with today’s oil

- Typical cost split (ref US):
  - CAPEX (corrosion-resistant equipment): 5-15 $/b
  - Opex: 10-15 $/b
  - Prod. Tax, royalties, differentials: 15 $/b
  - CO₂ cost: 10-15 $/b (3 times lower than current cost)

- Carbon credits much too volatile and too low to ensure economics at present day
- Strong governmental fiscal/legislation incentives required
CO$_2$ EOR outside USA (1)

- Hungary, Turkey: CO2 EOR pioneers since four decades at small scale
- Canada: the world’s largest industrial source CO2 demonstration project, Weyburn (25 000 b/d; 6500 t CO2/d)
- Malaysia: abundant natural CO2 (natural CO2 fields and associated CO2):
  - The world’s largest CO2 EOR project in the offshore (Dulang; immiscible WAG CO2); foam process investigated.
  - Objective: produce 1 Gb by CO2 EOR
CO₂ EOR outside USA (2)

• Brazil: oil fields in pre salt carbonates have 6-15 % CO₂ content (Estrella, 2011)
  • Reinjection as an early EOR possibility (current test in Lula field WAG pilot)
  • Impact on carbonate matrix: calcite / dolomite dissolution /precipitation?

• Middle East: NOC’s are launching R&D projects in CO₂ EOR
  • United Arab Emirates:
    • capture in Masdar ecocity+ Plants:
    • pilots; R&D phase;
    • long term plan: capture of 9 Million t/y which is 12 % of their Industrial CO₂ emissions (70 Million t/y), an enormous effort;
    • increase UAE oil production only by 2.4 % (72 000 b/d)

  • Saudi Arabia: R&D phase (industrial source CO₂)
  • Iran: projects related to natural CO₂ fields; R&D phase
  • Major issues: reactive CO₂, mobility control (foam), impact on carbonate matrix, capture technology
2014 – 2024 EOR CO2 Market

North Sea/UK: significant technical potential for CO2 EOR but strong limitations due to offshore plus source of CO2 with significant volumes.

USA remains the biggest market

Strong increase in Brazil from 2019+: pilote Lula started mid-2011) → AllFPSO include CO2 compression & injection system

Regular increase in China: emission reduction & local oil production

ADNOC: MASDAR Project

15 companies leading EOR CO2 in North America

Source: Visioggain 2013

CONCLUSIONS

• CO2 EOR is mostly developed in USA but starts receiving a large attention elsewhere in the world (Brazil, Canada, Middle East, Far East Asia etc).

• 5-15 % additional recovery technically widely demonstrated, but early gas breakthrough is a killing factor

• Mostly considered today where large and cheap sources of natural CO2 are readily available (CO2 fields, associated CO2).

• Big opportunity for Next Generation C02 EOR
  • Chemically enhanced CO2 EOR (foam);
  • Intrinsic geologic risk;
  => requires detailed reservoir/lab/pilot studies

• Industrial source CO2 EOR faces the high current costs associated with capture of CO2 and will develop only under specific conditions (incentives, cost reduction etc): Target: 30$/t