CO₂ ENHANCED OIL RECOVERY (EOR) IN UNCONVENTIONAL PLAYS

CSLF Mid-Year Meeting 2017
Abu Dhabi
May 2, 2017

John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center (EERC)
University of North Dakota, United States
PRESENTATION OUTLINE

• Plains CO₂ Reduction (PCOR) Partnership Program
• Overview of U.S. Oil Production
• Tight Oil Size of the Prize
• Challenges to EOR in Tight Oil
• Addressing the Challenges
• Future Outlook
PCOR PARTNERSHIP: 2017 & STILL GROWING!
PCOR PARTNERSHIP SINCE 2003

• Region includes:
  – Nine states.
  – Four Canadian provinces.
  – 1,382,089 mi².
• Blue boxes = PCOR Partnership Projects
• Several completed field projects.
• Bell Creek demonstration under way.
• Participation in Aquistore.
• 121 partners.
U.S. OIL PRODUCTION – 2016

• 8.9 million barrels per day (MMbpd)
  – 31 states and Gulf of Mexico
  – Thousands of fields
  – Increasing production and exploration

• Onshore production
  – 7.2 MMbpd
    ♦ 0.3 MMbpd from CO₂ EOR

• Offshore production
  – 1.7 MMbpd

CONVENTIONAL CO₂ EOR: BELL CREEK

• CO₂ storage associated with a commercial CO₂ EOR project.

• Operated by Denbury Onshore LLC.

• CO₂ is sourced from ConocoPhillips’ Lost Cabin natural gas-processing plant and Exxon’s Shute Creek gas-processing plant.
U.S. UNCONVENTIONAL TIGHT OIL PRODUCTION – 2016

Total = 4.2 MMbpd
Bakken = 1.0 MMbpd
Eagle Ford = 1.1 MMbpd
Permian Basin = 1.6 MMbpd

Rapidly increasing production and development of new plays

Bakken Petroleum System Stratigraphy
Bakken Petroleum System Defined

Charlotte 1-22H core photos (UV light)
308’ with 154’ of oil fluorescence (Courtesy Continental Resources)
Technically Recoverable Reserve Estimates

- 7.4 Bbbl (USGS, 2013)
- 24 Bbbl (Continental Resources, 2011)

- Currently, only a 3%–10% recovery factor.
- Small improvements in recovery could yield over a billion barrels of oil.
- Can CO₂ work in the Bakken?
ESTIMATION OF BAKKEN CO₂ EOR POTENTIAL

The DOE methodology for estimating CO₂ EOR and storage capacity (2007) was applied to the Bakken in North Dakota:

**Potential Incremental Oil from CO₂-Based EOR**

- Cumulative Production Method: 648 MMbbl
- Reality?: 4 Bbbl

**CO₂ Needed to Realize Bakken EOR**

- Reservoir Properties Method: 7 Bbbl
- 187 MMt
- 2 Bt
- 3.2 Bt
**Conventional Clastic Reservoir**
- Dominant pore sizes fall within expectations of traditional petroleum reservoirs.

**“Poor Quality” Reservoir/ Lower Seal**
- Pore sizes considered to be a geological barrier to injected fluids, including CO₂.

---

**U. Bakken Shale**

**Middle Bakken**
CHALLENGES OF CO₂ EOR IN THE BAKKEN

• Fractures act as fast flow pathways, limit CO₂ interactions with the matrix.
• High heterogeneity of the lithofacies complicates the understanding of flow regimes.
• Multiphase fluid flow behavior varies substantially depending on the size of the pore throats.
  – Fluid viscosity and density are much different in nanoscale pores than in macroscale pores.
• Sorptive capacity of organic carbon materials affects CO₂ mobility, EOR, and storage?
EFFORTS TO ADDRESS BAKKEN EOR CHALLENGES

CO₂, ethane, methane...
BAKKEN CO₂ STORAGE AND EOR PROJECT PARTNERS
OIL EXTRACTION FROM BAKKEN ROCKS IN THE LAB

- Thirteen core plugs covering all three units were selected to investigate the EOR effects of four potential EOR gases: N$_2$, CO$_2$, CH$_4$, and C$_2$H$_6$.

- 24-hour oil extraction was conducted for the rock samples using different gases.

- All experiments were carried out under reservoir conditions (5000 psi, 230°F).

- Rock is “bathed” in gases, not swept with gases as would be the case in confined flow-through tests.
OIL EXTRACTION FROM BAKKEN ROCKS IN THE LAB

24-hour oil recovery using CO₂.
OIL EXTRACTION FROM BAKKEN ROCKS IN THE LAB

- 24-hour oil recovery comparing methane, ethane, CO₂, nitrogen, and rich gas/CO₂ mixtures.
- C₂H₆ has the best performance while N₂ has the lowest oil recovery.
Simulated a variety of Bakken injection–production schemes.

Best cases showed significant improvement in total recovery factor (some over 100%).

Production response is delayed compared to CO₂ EOR in a conventional reservoir, but appears to improve with time.

Lab work and modeling are great…
But what happens in the real world?
EVALUATION OF PAST BAKKEN FIELD INJECTION TESTS

• Lessons learned
  – Injectivity has been demonstrated.
  – Production responses have been observed, so fluid movement can be influenced.
  – But the improvements that have been predicted by models have NOT been observed in the field tests.

These inform the design the next set of field tests.
2017 BAKKEN EOR PILOT TESTING

The EERC is involved in two Bakken EOR pilot tests:

• CO₂ with XTO Energy.
• Rich gas with Liberty Resources.
Unconventional rich gas EOR deployment may be imminent.

But rich gas supply is limited, so it may be a niche solution.

Widespread deployment of CO$_2$ EOR in Bakken is years away, *largely due to a lack of commercially available CO$_2$*. 
FUTURE OF U.S. OIL PRODUCTION – EIA PROJECTIONS

9.5 million bpd in 2025
11.3 million bpd in 2040

Conventional Onshore Production
– Declining resource (?)

Offshore Production
– Plenty of resources
– Near-term increases expected

Conventional EOR
– Will continue to increase
– Anthropogenic CO₂ capture can be a game changer

Tight Oil Production
– Biggest growth potential
– Tremendous opportunities
THANK YOU