Current Status of CO$_2$ Injection Projects in Croatia

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Production Decline in Croatia

Oil Production, $10^6$ m$^3$/year
EOR Candidates and CO$_2$ Sources
Ivanić Oil Field

Miocene sandstones

- $\phi = 21.5 - 23.6 \%$
- $k = 14.6 - 79.6 \text{ mD}$

- OOIP $= 21.62 \times 10^6 \text{ m}^3$
- Maximum recovery $= 44\%$
- Remaining $= 0.68 \times 10^6 \text{ m}^3$
- $T = 97.8^\circ\text{C}$
- $P_i = 183 \text{ bar}$
- $33.4^\circ\text{API oil}$
Ivanić Production History
Žutica Oil Field

Miocene sandstones

- $\phi = 16\text{-}22\%$
- $k = 5\text{-}90 \text{ mD}$

- OOIP = $52.37 \times 10^6 \text{ m}^3$
- Maximum recovery = 35%
- Remaining = $0.66 \times 10^6 \text{ m}^3$
- $T = 110.7^\circ \text{C}$
- $P_i = 211 \text{ bar}$
- 33.8°API oil
Beničanci

- Massive structure
- Structural / stratigraphical trap
- Miocene breccias (limestone/dolomite)
- OWC = 1955 m ssl
- Closure = 266 m
- $\Phi_{\text{average}} = 8\%$
- $k_{\text{average}} = 200 \text{ mD}$
Beničanci Engineering Data

Temperature: 123.3°C
Initial \( P_{\text{res}} \): 191.0 bar \((P_b = 147.1 \text{ bar})\)
Actual \( P_{\text{res}} \): \(\approx 165 \) bar
Energy regime: water drive (+ pressure maintenance by water injection into aquifer)
OOIP: \(41.8 \times 10^6 \) m^3
Production: since 1972
Water injection: started 1975 (at \( P_{\text{res}} = 167 \) bar, recovery = 4.9%)

Water influx from bottom aquifer
Beničanci Production History

Maximum recovery = 43%
Remaining = \(0.36 \times 10^6\) m\(^3\)
Initial EOR Concept

• CO$_2$ injection in all three fields
  → Near-miscible WAG: Ivanić, Žutica
  → Immiscible crestal injection: Beničanci

• CO$_2$ captured at GTP Molve, transported by pipelines
CO$_2$ Transport

GTP Molve

Ivanić

Žutica

Beničanci
New Concept for Beničanci

• Natural gas injection
  → Locally generated N₂ too expensive for the volume needed
  → Vicinity of current and future gas supply

• Important: UGS potential
  → Operating volume 400 × 10⁶ m³, scalable
Beničanci: Further Activities

- Numerical simulation
- Pilot natural gas injection
Ivanić: 3D Geological Model
Geological Setting

Old

New

SPE 89361, Tulsa 2004
Tertiary Oil Production (2003)
## Incremental Oil & CO₂ Utilisation

<table>
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<tr>
<th>Repressuring</th>
<th>IncrmOil (10⁶ m³)</th>
<th>CO₂ UtRatio (m³ / m³)</th>
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CO$_2$ Pilot Injection Ivanić

Target: reservoir $\gamma_{2/4}$

Estimated ROIP: $683 \times 10^3$ m$^3$
CO$_2$ Injection Site: Iva-28
**CO$_2$ Injection Data**

- Two slugs
  - Nov 2003 - May 2004
  - Nov 2004 - June 2005
- Injection rate: 45,000 Sm$^3$/day (88 t/day)
- Wellhead: $p = 55$ bar, $T = -20^\circ$C
- Downhole: $p = 193$ bar, $T = 60^\circ$C
- Slug size: $8.2 \times 10^6$ Sm$^3$ (16,000 t)
- No operational problems
CO₂ Pilot – CO₂ in Produced Gas

![CO₂ Pilot Graph]

- Water
- CO₂
- Water
- CO₂
- Water

- Iva-11
- Iva-19

CO₂ Concentration in Produced Gas (mol%)

Obtained from CO₂ Pilot

- Confirmation of oil displacement by CO₂ in real reservoir environment
- Source of data for fine tuning of simulation models: pilot area and full field
- Practical experience with:
  - CO₂ injection (including safety systems)
  - Oil production after CO₂ breakthrough
RelPerms vs CO$_2$ Propagation

Old

New
Ivanić Pattern Model (2005)

Refined:
- gridding
- layering

Representativeness:
- reservoir properties
- history match
- wf recovery
  - field: 33%
  - pattern: 36%

SPE 100198, Europec, Vienna 2006
Ivanić Pattern Model

- Compositional simulation of history and predictions
- Upscaling prediction results to full field
Production Prediction: Ivanić
Incremental Oil Predictions
Project Outline

• Two EOR objects
  → Ivanić + Žutica North: CO₂ start in 2008
  → Žutica South: CO₂ start in 2010
Current Activities

• Detailed engineering
  → final choice of injection wells
  → designing well completions
    • choice of materials
    • flow control options
  → planning water/CO$_2$ delivery network
  → surface facilities: Molve, Ivanić, Žutica

• Investment optimisation
  → scheduling costs
CO$_2$ Total Volumes - Simulation

![Graph showing CO$_2$ Injected and Produced (10$^6$ Sm$^3$) across different scenarios.](Image)

**Graph Details:**
- **Y-axis:** CO$_2$ Injected / Produced (10$^6$ Sm$^3$)
- **X-axis:** Scenario (1 to 6)
- **Legend:**
  - CO$_2$ Injected
  - CO$_2$ Produced

**Legend Explanation:**
- Green bars represent CO$_2$ Injected.
- Red bars represent CO$_2$ Produced.

**Scenarios Overview:**
- Scenarios 1 to 6 show varying levels of CO$_2$ Injected and Produced, with Scenario 5 having the highest CO$_2$ Injected and Scenario 2 having the highest CO$_2$ Produced, relative to other scenarios.
CO$_2$ Retention Index - Simulation

CO$_2$ Retention Index vs Scenario
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