Pilot Scale CO$_2$ EOR in Mississippian Carbonate Reservoir at Wellington Field in South-Central Kansas

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Participants
CO₂ Sources Suitable for EOR

- Kansas holds more than 750 million barrels of technical CO₂-EOR potential and ~240-370M metric tons of CO₂ is required for recovery.
- Economic results based on Hall Gurney field suggest an after-tax project IRR of about 20%.
- Access to the significant volumes of ethanol-based CO₂ in Nebraska.
Potential Recoverable Resources: Formations of Interest
Potential Recoverable Resources: Mississippian Group

Mississippian Oil and Gas Production

Mississippian Lime Play

Oil Production since 1970
- Mississippian: 12%
- Arbuckle: 13%
- Simpson: 6%
- Viola: 4%
- Others: 18%
- Pennsylvanian: 47%

Mississippian Group

Mamaton: 190 MMBO (50-70 CO2 MMBO)
Morrow: 150 MMBO (50-70 CO2 MMBO)
Simpson: 250 MMBO (60-90 CO2 MMBO)
Viola: 370 MMBO (90-130 CO2 MMBO)
Mississippian: 980 MMBO (250-360 CO2 MMBO)
Lansing-Kansas City: 1,240 MMBO (310-430 CO2 MMBO)
Arbuckle: 2,290 MMBO (570-800 CO2 MMBO)
Wellington Field, South KS
Plan for CO$_2$ EOR Pilot

- Find, characterize, and prepare oil field
- Find CO$_2$ source
  - Initially, ethanol plant and multiple sources
- Develop strategy for resource recovery through reservoir modeling
  - Several revisions
- Obtain a permit and drill a new injection well
- Organize surface infrastructure and deliver CO$_2$
  - Truck delivery
- Inject $\sim$26,000$\sim$20,000 tones of CO$_2$ at 100-150 tones/day
- Monitor and manage CO$_2$ plume
- Vent produced CO$_2$
Reservoir Characterization

- Very old Neutron logs with or without resistivity logs for all wells
- 16 wells with complete suites of resistivity and porosity logs
- New wells drilled by KGS have a full set of modern logs
- Core is available from KGS #1-32
  - Porosity/permeability
  - Geochemistry
  - Geomechanical data
- 3D Seismic
- Formation fluids analysis
Injection Well Drilling and Coring

- Class II Well Permit
  - 30 days process
- ~100 ft of new core
- 70 ft of ~23% Sor
- 20% Phi
- 15-18 mD
Injection Well Logging

3763 (-2494 ss) -- Original O/W contact
Mina Fazelalvi, KGS

20 ft (6 m)

Average log calculated absolute permeability using NMR compared to whole core C/A
Well Tests

- Drill stem test
- Step rate test
- Interference test
Seismic Stratigraphy Using PSDM
Improved Geologic Model
Capillary Pressure and Relative Permeability
Fluid Properties

- CO₂ Miscibility pressure is ~1650 psi
- Oil API gravity is 30°
- Oil composition
- Water composition
- PVT
Reservoir Modeling

• Strategy for a flood
  – Monitoring optimization
  – Re-pressurization strategy for miscibility
  – $\text{CO}_2$ movement

• Economic forecast
  – Sweep efficiency
  – Oil production
  – $\text{CO}_2$ production
Forecasted CO₂ Movement in Reservoir

Forecasted Pore-Pressure Distribution at the Start of CO₂ Injection
Required miscibility pressure is ~1650
Waterflood Strategy after CO₂ Injection

![Graph showing oil production rate over time with two lines: one for 500 bbls/day and another for 850 bbls/day. The graph illustrates the impact of CO₂ injection on oil production rate.]
Operations: CO₂ Delivery and Surface Facilities
Fluid Monitoring

- Water chemistry
  - Alkalinity
  - pH
  - Cations/anions
  - Microbial

- Production history
  - Oil/water
  - CO₂ account
Geochemical Monitoring: Field Alkalinity Progression

3/23/2016

4/27/2016

6/23/2016 End of CO₂ injection

7/19/2016

High Alkalinity CO₂

Supercritical CO₂ / Small fault
Seismic Monitoring

Housing setup for Sercel (Mark Products) L-22D-3D sensors, ~5 ft below surface to minimize surface noise; installed below frost line in bedrock.
Incremental oil production (subtracted 9 bbls/day) recorded at a pilot area filed battery.
CO₂ production from all installed separators at producing wells and pilot area field battery. At the end of September, 2016, 3 months since CO₂ injection cessation, only ~12% of injected CO₂ was produced.
Summary

• Safe and efficient injection
  – No substantial deviations due to unforeseen circumstances (carbonate reservoir fracturing, temperature, pressure, etc.)

• Successful oil recovery

• Low CO$_2$ production/recovery
  – 13% of total injected CO$_2$ was lost to atmosphere since start of injection

• Manageable and conformable CO$_2$ plume
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