Santos Cooper/Eromanga Basins CCUS

DEM 2018 Oil and Gas Roundtable
November 2018
Large scale CCS of Santos & 3rd Party CO₂ provides a pathway to a zero emissions future.

TARGET ZERO NET EMISSIONS

3rd PARTY CO₂ TRANSMISSION & STORAGE

FULL-SCALE SANTOS CCS

CCUS: ENHANCED OIL RECOVERY (EOR)

INFRASTRUCTURE

RESOURCE / RESERVE BOOKING

RESERVOIR DE-RISKING
## Global CCS Projects

+ 17 large-scale (>0.4 Mtpa) Carbon Capture projects presently in operation worldwide

- 13 of these are for EOR
- Capture capacity ranges from 0.5 – 8.4 Mtpa (Moomba Gas Plant ~ 1.9 Mtpa Vent + 0.5 Mtpa Fuel, Flare, Fugitive)
- Primary market is North America
- 4 additional projects under construction including Gorgon Project in Australia (3.4 – 4.0 Mtpa)

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Operation date</th>
<th>Industry</th>
<th>Capture capacity (Mtpa)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrell Natural Gas Processing Plant</td>
<td>USA</td>
<td>1972</td>
<td>Natural Gas Processing</td>
<td>0.5</td>
<td>EOR</td>
</tr>
<tr>
<td>Enid Fertilizer</td>
<td>USA</td>
<td>1982</td>
<td>Fertiliser Production</td>
<td>0.7</td>
<td>EOR</td>
</tr>
<tr>
<td>Shute Creek Gas Processing Plant</td>
<td>USA</td>
<td>1986</td>
<td>Natural Gas Processing</td>
<td>7.0</td>
<td>EOR</td>
</tr>
<tr>
<td>Sleipner CO2 Storage 1</td>
<td>Norway</td>
<td>1996</td>
<td>Natural Gas Processing</td>
<td>1.0</td>
<td>CCS</td>
</tr>
<tr>
<td>Great Plains Synfuels Plant and Weyburn-Midale</td>
<td>Canada</td>
<td>2000</td>
<td>Synthetic Natural Gas</td>
<td>3.0</td>
<td>EOR</td>
</tr>
<tr>
<td>Snøhvit CO2 Storage 1</td>
<td>Norway</td>
<td>2008</td>
<td>Natural Gas Processing</td>
<td>0.7</td>
<td>CCS</td>
</tr>
<tr>
<td>Century Plant</td>
<td>USA</td>
<td>2010</td>
<td>Natural Gas Processing</td>
<td>8.4</td>
<td>EOR</td>
</tr>
<tr>
<td>Air Products Steam Methane Reformer</td>
<td>USA</td>
<td>2013</td>
<td>Hydrogen Production</td>
<td>1.0</td>
<td>EOR</td>
</tr>
<tr>
<td>Coffeyville Gasification Plant</td>
<td>USA</td>
<td>2013</td>
<td>Fertiliser Production</td>
<td>1.0</td>
<td>EOR</td>
</tr>
<tr>
<td>Lost Cabin Gas Plant</td>
<td>USA</td>
<td>2013</td>
<td>Natural Gas Processing</td>
<td>0.9</td>
<td>EOR</td>
</tr>
<tr>
<td>Petrobras Santos Basin Pre-Salt Oil Field CCS 1</td>
<td>Brazil</td>
<td>2013</td>
<td>Natural Gas Processing</td>
<td>1.0</td>
<td>EOR</td>
</tr>
<tr>
<td>Boundary Dam Carbon Capture and Storage</td>
<td>Canada</td>
<td>2014</td>
<td>Power Generation</td>
<td>1.0</td>
<td>EOR</td>
</tr>
<tr>
<td>Quest</td>
<td>Canada</td>
<td>2015</td>
<td>Hydrogen Production</td>
<td>1.0</td>
<td>CCS</td>
</tr>
<tr>
<td>Uthmaniyyah CO2-EOR Demonstration</td>
<td>Saudi Arabia</td>
<td>2015</td>
<td>Natural Gas Processing</td>
<td>0.8</td>
<td>EOR</td>
</tr>
<tr>
<td>Abu Dhabi CCS (Phase 1 being Emirates Steel Industries)</td>
<td>UAE</td>
<td>2016</td>
<td>Iron and Steel Production</td>
<td>0.8</td>
<td>EOR</td>
</tr>
<tr>
<td>Illinois Industrial Carbon Capture and Storage</td>
<td>USA</td>
<td>2017</td>
<td>Ethanol Production</td>
<td>1.0</td>
<td>CCS</td>
</tr>
<tr>
<td>Petra Nova Carbon Capture</td>
<td>USA</td>
<td>2017</td>
<td>Power Generation</td>
<td>1.4</td>
<td>EOR</td>
</tr>
</tbody>
</table>

1 Offshore Operation

Source: [Global CCS Institute](https://www.globalccsinstitute.com/projects/large-scale-ccs-projects)
12 out of 17 global large scale CCS projects are in North America

10 of these projects supply CO₂ for EOR

Access both natural & industrial CO₂ sources

Growth has slowed in recent years primarily due to limits on accessible, affordable CO₂ supply

Significant operations in Permian Basin

Large midstream company Kinder Morgan, with substantial CO₂ distribution assets, also has upstream assets with nearly 100% of production (55kbb/l) associated with EOR
Santos’ Cooper/Eromanga Basin asset is well positioned to develop CCS with EOR (CCUS)

Global CCS Projects (particularly USA):
- Onshore Operations
- EOR Focus
- Oil field practices well accepted by community & regulator.
- Tax/Royalty Fiscal Regime
- Natural & Industrial CO₂ Sources
- Established and extensive CO₂ capture & transmission infrastructure
- Suitable reservoirs

Santos Cooper/ Eromanga Basin Operations:
- Onshore Operations
- Mature Oil Fields (EOR target)
- Oil field practices well accepted by community & regulator.
- Tax/Royalty Fiscal Regime
- Industrial CO₂ source – Moomba Gas Plant
  - Existing CO₂ separation facilities at Moomba Gas Plant. Requirement to establish capture & transmission infrastructure.
  - Assessing suitable reservoirs
Santos EOR History in relation to Australian and global milestones.

A. World first use of CCS for CO₂ miscible flood in SACROC formation, Permian Basin USA, 1972.
B. Santos first volatile oil EOR project – ethane injection for recovery of condensate, ~7 MMstb incremental production.
C. Santos use of methane injection for pressure support in Mereenie oil field, ~2.3 MMstb cumulative production.
D. Santos implementation of waterflood in the Dullingari field for secondary recovery, ~3.5 MMstb incremental production.
E. World first CCS for geological storage – implemented in Sleipner gas field, North Sea – driven by Norwegian tax on CO₂ emissions. Also world’s first offshore CCS.
F. Santos further implementation of waterflood in the Eromanga Basin for secondary recovery – Mulbery, Endeavour, Talgeberry, Gimboola, Cranstoun, Merrimelia, Charo. ~3.5 MMstb incremental production.
G. Santos Fly Lake EOR – methane injection for recovery of volatile oils, ~0.9 MMstb incremental production. Recent operation limited by gas availability.
I. Formation of Santos Energy Solutions Team, renewed focus on CCUS EOR opportunity.
J. Target – 2019 Santos CO₂ injection pilot (Single Well Injection Test)
**Key Learnings From The US**

CO₂ EOR is a long established and scalable base oil-field business. It is driven by economics and reservoir characteristics rather than new technologies.

- CO₂ business is normal oil-field practice
- Significant STO advantage with both CO₂ source & targets
- CO₂ EOR can be phased, scaled & replicated development (Core Energy)
- Key metric US$2/Mcf CO₂ delivered at pressure to field
- Compression requirements (major CAPEX/OPEX driver)
- Key to appraisal activities is asking right questions – injection test to assess residual saturation, core flooding to estimate recovery
- Greatest uncertainty for STO is suitability of reservoirs – project driven by subsurface workflow

**Engagement**

- Operators, service providers and consultants engaged for input to appraisal activities, pilot scoping, concept select/design & reserves justification
- Maintaining dialogue with peers for feedback on technical deliverables and appraisal well objectives
Santos has a ready supply of reservoir CO₂ which is separated and vented at Moomba Gas Plant. The potential for this CO₂ to be used for a CCUS project is currently being evaluated.

**Enhanced Oil Recovery (EOR)**

Some injected CO₂ remains in situ, remainder is recovered and re-injected.

Evaluation of CO₂ delivery costs & scalability

Full implementation will require substantial infrastructure investment.
Both Jurassic and Permian reservoirs in the Cooper/Eromanga Basins appear to be suitable for miscible CO₂ flooding EOR.

<table>
<thead>
<tr>
<th>Fluid/Reservoir Characteristic</th>
<th>Miscible Flood Requirement</th>
<th>CO₂-EOR Analogues (USA)</th>
<th>Eromanga Basin Jurassic Oil</th>
<th>Cooper Basin Permian Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>&gt; 3000ft</td>
<td>3,000 ² - 11,600ft</td>
<td>4,000 - 6000ft ✓</td>
<td>10,000ft ✓</td>
</tr>
<tr>
<td>API Oil Gravity</td>
<td>&gt; 25</td>
<td>28 - 42</td>
<td>47 ✓</td>
<td>50 ✓</td>
</tr>
<tr>
<td>Viscosity</td>
<td>&lt; 10 cP</td>
<td>0.4 - 6.0 cP</td>
<td>0.8 cP ✓</td>
<td>0.1 cP ✓</td>
</tr>
<tr>
<td>Permeability</td>
<td>-</td>
<td>1 - 100s mD</td>
<td>100s - 1000s mD</td>
<td>0.1 - 1 mD</td>
</tr>
<tr>
<td>Temperature</td>
<td>80 - 285 degF</td>
<td>80 - 260 degF</td>
<td>190 degF ✓</td>
<td>280 degF ✓</td>
</tr>
<tr>
<td>Residual Oil</td>
<td>&gt; 25%</td>
<td>27 - 90 %</td>
<td><strong>Assess 1H 2019</strong></td>
<td>up to 80 % ✓</td>
</tr>
<tr>
<td>MPP Achievable</td>
<td>Yes</td>
<td>93 % of fields miscible flood</td>
<td>Positive lab test results. ✓</td>
<td>Confirmed ✓</td>
</tr>
</tbody>
</table>

**Other positive factors**
- Good waterflood performance (good sweep efficiency, reasonable throughput rates and good voidage balance)
- Extensive CO₂ infrastructure
- Large potential volumes in Residual Oil Zone (ROZ)
- Previous ethane flood
- Well studied & understood reservoirs.

**Negative Factors**
- Severe reservoir heterogeneity, adjacent loss zones (gas caps), dominant fracture systems
- n/a
- Confirmation of ROZ properties required (coring)
- Low permeability requires close well spacing, facility complexity ($$$)

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1 Enhanced Oil Recovery (EOR) Survey 2012, Penn Energy Research, as published in Oil & Gas Journal, April 2, 2012
2 Depths as shallow as 1,150ft for Salt Creek Field operated by Anadarko, however majority of fields are over the 3000ft threshold
Subsurface overview – key uncertainties

US informed subsurface (uncertainty) workflow and appraisal plan.

1. **Fluid sampling & Analysis** Main Pay Zone (MPZ) – Existing well, assess miscibility of CO₂ and oil, (i.e. determine whether CO₂ flooding is technically feasible)

2. **Drill & core appraisal well(s)** in Residual Oil Zone (ROZ) – Assess residual saturations ($S_{or}$) and define oil volume in place (i.e. establish the size of the prize)
   - 2a. **Core Flooding** – Assess fraction of recoverable oil and CO₂ utilisation efficiency (i.e. define recoverable volumes)

3. **Single Well Injection Tests (SWIT)** – Assess in situ application of miscibility and demonstrate mobility of previously immobile oil (i.e. confirm miscibility & recovery at reservoir conditions)

INITIAL

MAY 2018

POST-PRODUCTION

1H 2019

Q3 2019
Opportunity progressing as per roadmap; prove feasibility by 2H 2019.

- **Project Roadmap**
- **Concept Refresh**
  - Cost estimates for 20+ technology concepts
  - Estimated cost of CO₂ delivery 50% lower than US benchmark of $2/Mcf
  - ISSUED

- **Fluid Sampling & Analysis**
  - Sampling complete, Gidgealpa oils suitable for miscible flood.
  - COMPLETE

- **Subsurface Workflow**
  - Static models & preliminary reservoir analysis complete
  - Reservoir simulation underway.
  - APPRAISAL SANCTIONED

- **Drilling & Coring Activities**
  - Workshop covering specialized coring activities and operations integration (Nov 2018).
  - Q1 2019

- **Single Well Injection Test (SWIT)**
  - Collaboration - CSI RO, Halliburton, CTI
  - Suppliers engaged for supply of CO₂
  - Q3 2019

- **Feasibility**
  - 2H 2019

**FUTURE ACTIVITY**

- Sanction Small Scale Development
- EPC Facilities + Subsurface Development
- CO₂ Injection Commences
- First Incremental CO₂ EOR Production
- 2020
- 2020-22
- 2022
- ~2023

CO₂ Injection Wellhead - Yates Field, W. Texas (Kinder Morgan)

~26km
Cooper Basin CCUS Opportunity Summary

Carbon capture, utilisation & storage (CCUS) can convert an emissions liability into a revenue stream.

- **Leverage mature asset base in the Cooper Basin to grow production & reserves**
- **Draw on experience & success in the US**
- **CO\textsubscript{2} available from Moomba Gas Plant at globally competitive cost**
- **Opportunity for substantial long-term infrastructure investment**
- **Successful implementation could lead to transport and utilisation of 3\textsuperscript{rd} Party CO\textsubscript{2}**