Taking CO2 EOR offshore
“Driving CCS forward in Norway” workshop
Oslo, 10th of September 2015
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Available Resources on the NCS for CO2 EOR

Increased Recovery Potential:

2002: Gullfaks, Heidrun; ~ 5 – 7 %

2005: NPD; ~ 5 – 7 %

2014: Lindeberg; ~ 7 %

2014: This work; 5 – 9 %
Challenges Related to Offshore CO2 EOR

- No CO₂ supply chain established – limited availability – **assumed need for big volumes over time**
- Non-optimized well locations
- No existing pipelines
- Facilities and wells not corrosion resistant
- **Limited weight and space available for topsides separation**
  - Extremely costly retrofits or additional installations
- High cost of CO2 at wellhead
- Higher cost level than onshore
  - Offshore operation costs
  - **Loss of production due to shut down in retrofit period**
- Logistics between onshore CO₂ source and offshore
Two important subsea building blocks

Compression System

2010 – 2015 Asgard:
- 21 MSm³/d flow rate
- 2 x 11.5 MW compressor power
- 300 m water depth
- 40 km step-out distance
- Topside Variable Speed Drives, Circuit breakers and UPS
- Delivered by Aker Solutions

Compact membrane packing

- Onshore stacking not feasible subsea
- Compact packing arrangement developed by AKSO
Some Subsea processing arrangements

Simplest arrangement:
• Separation and reinjection of HC gas and CO2 use qualified subsea compressor system

More advanced arrangement:
• Gas separation
• Reinjection enriched CO2

Advanced arrangement:
• Gas separation
• Water separation
• Reinjection enriched CO2
Key Data Medium – Large Scale Generic CO2 EOR Project

- Reservoir simulations on actual reservoir – up scaled
- Increased recovery factor: ~ 7%
- Production period: 8 years
- CO2 supply:
  - 3.5 Mt/y over a 3 years period
  - Separation system allows recirculation
- CO2 sources and transportation
  - CO2 from onshore plants
  - Onshore conditioning
  - Shuttle tankers from point sources
  - Injection vessel
  - Subsea injection system
Principles and Cases Subject to Cost Estimation

- Case 2 – Commercial scale – ship transportation

- Case 3 – CO2 supply from European trunk line

- General
  - CO2 costs as long term unit costs
  - AKSO data base and external references
  - New key components estimated as expected long term costs
  - Incremental revenue and costs
### Project Economics

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Case 2 (ship)</th>
<th>Case 3 (trunk line)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil production</td>
<td>Mb</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>CO2 purchase</td>
<td>Mt</td>
<td>10.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Oil revenue</td>
<td>MNOK</td>
<td>24 960</td>
<td>24 960</td>
</tr>
<tr>
<td>- Capex &amp; Opex</td>
<td>MNOK</td>
<td>9 905</td>
<td>8 513</td>
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<tr>
<td>- CO2 purchase</td>
<td>MNOK</td>
<td>5 828</td>
<td>3 494</td>
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<tr>
<td>+ CO2 Quota</td>
<td>MNOK</td>
<td>1 789</td>
<td>1 789</td>
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<tr>
<td>Cash flow</td>
<td>MNOK</td>
<td>11 016</td>
<td>14 742</td>
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<tr>
<td>NPV (8%)</td>
<td>MNOK</td>
<td>1 748</td>
<td>4 374</td>
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<tr>
<td>IRR</td>
<td>%</td>
<td>11</td>
<td>16</td>
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<tr>
<td>Break even oil price (0%)</td>
<td>USD/b</td>
<td>45</td>
<td>33</td>
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<tr>
<td>Break even oil price (8%)</td>
<td>USD/b</td>
<td>69</td>
<td>52</td>
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<tr>
<td>CO2 capture cost</td>
<td>NOK/t</td>
<td>560</td>
<td>336</td>
</tr>
</tbody>
</table>

- Figures in MNOK, Oil Price: 80 USD/b, USD exchange rate: 6 NOK/USD
Offshore CO2 EOR Challenges - Mitigations

- No CO2 supply
  - Pipeline
  - Ship supply
- Space limitations on platforms
  - Subsea installation
- Weight limitations
  - Subsea installation
- Power availability
  - Less power needed than gas injection, heavier fluid
- Corrosion issues
  - 13% Cr needed – standard for subsea wells
- High cost when modifications done topsides
  - Short/no downtime with subsea installation
- HSE concern by sudden topside release
  - No issue subsea
Other Aspects Subsea Technology Concept

- Reduced installation costs – subsea separation
- Overlap of EOR production with conventional oil production
- Small subsea facilities serving segments in large reservoir
- Facilities available for injection of CO2 for permanent storage as a final CCS stage
- Retrievable modules – limited operational time - reuse
SUMMARY

- CO2 used for increasing value through added oil production seen as a mandatory step towards CCS
- CO2 EOR combines value creation with GHG abatement
- New technology concepts provides commercially attractive solutions
Acknowledgements

■ CLIMIT/Gassnova for funding
■ Statoil for funding, performing reservoir simulations and valuable discussions
■ CIPR for valuable simulations and discussions

Important lesson:
■ The synergy created by cross discipline cooperation!

Thanks for your attention!