Taking CO₂ EOR offshore

Subsea well stream processing potential enabling solution / Ship transport options

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Presented by Philip Ringrose (Statoil)
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 CO$_2$ 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 CO$_2$ source and offshore
Available Subsea processing building blocks:

- Subsea multiphase cooler
- Subsea gas compressor
- Subsea gas/liquid separator
- Subsea liquid/liquid separator
- Subsea de-sanding equipment
- Subsea produced water de-oiling equipment
- Liquid pump
- Multiphase pump
- Subsea control systems
- Subsea power solutions

Subsea process system building blocks
Two important subsea building blocks

Compression System

2010 – 2015 Åsgard:
- 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
A subsea separation solution for the well stream
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
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
CO₂ TRANSPORT BY SHIP: FLEXIBILITY FOR STORAGE AND EOR

› Offshore CO₂ storage or CO₂-EOR in Europe
  › Demand driven – but only if there is sufficient supply
  › Typical CO₂-EOR project: ~5 Mtpa
  › Typical commercial CO₂ capture project: 1-4 Mpta
› Transport by ship offers flexibility in connecting supply and demand of CO₂

› Is ship transport feasible?
  › Heating & compression on board ship
  › Offloading / injection rates

Distances from Rotterdam: 400, 800 and 1200 km
### SHIP TRANSPORT RESERVOIRS

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<th>Unit cost €/tCO2</th>
<th>Capacity Mtpa</th>
<th>Number of ships</th>
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- **Saline formations at depths 1-4 km**
  - Good quality (100 mD)
  - High quality (1000 mD)

- **Depleted hydrocarbon reservoirs, same depths**
  - 80% depleted
  - 50% depleted

Injection rates limited by:
- reservoir pressure,
- flow-induced vibrations in well,
- thermal effects in reservoir,
- hydrate formation,
- offloading pressure
Transport distance 400 km, ship capacity 30 kt and offloading into temporary storage:
- Unit cost 14 – 21 €/tCO₂
- Capacity 2.6 – 4.7 Mtpa

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CO₂ TRANSPORT BY SHIP: CONCLUSIONS

- Direct injection from ship or to temporary storage (lowest cost) is feasible
- Unit cost 14 – 28 €/tCO₂, depending on ship size, distance, etc.
- Rates 2.5 – 4.7 Mtpa, with ships 30-50 kt, depending on reservoir depth, etc.
Acknowledgements

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