Potential of CO2-EOR on the NCS

Van Pham

11.06.2019
Agenda

• CO2 EOR projects in the world

• Experience from CO2 storage on the Norwegian Continental Shelf

• Situation and the CO2 EOR potential on the NCS

• Picture is changing: enough CO2 available for EOR projects from CCS projects
Enhanced oil recovery by CO₂ injection

Figure: Cenovus Energy/Malcolm Wilson, PTRC. Over 20 000 of 30 000 bbl/d from CO2 EOR
Graph showing various technologies that are employed for enhanced oil recovery (EOR) in the United States over period from 1984 – 2000. There were in 1998 a total of 92 Thermal (steam) EOR projects producing 439,000 bpd. There were 66 CO2-EOR projects producing 179,000 bpd. With 11 miscible gas injection projects producing 102,000 bpd (Carl-W. Hustad and J. Michael Austell, 2004)
CO₂-EOR projects in the world

Source: Global CCS Institute
Offshore CCS EOR-project in Brasil

Offshore natural gas processing plant capturing around 700,000 tons per annum of carbon dioxide (CO$_2$).
The CO$_2$ is directly injected via a two-kilometre (km) injection riser to enhance oil recovery at the Lula Oil Field, located in the Santos Basin.

**Key Deliverables**
The Petrobras Lula Oil Field CCS Project is located about 300 km off the coast of Rio de Janeiro in Brazil. The project is part of a floating production, storage, and offloading (FPSO) facility that incorporates CO$_2$ separation and injection facilities.
About utilization of CO$_2$

«win-win-win» situation

Storing CO$_2$ through Enhanced Oil Recovery

Combining EOR with CO$_2$ storage (EOR+) for profit

Joint IEA-OPEC workshop on CO$_2$-enhanced oil recovery with CCS

Kuwait City, 7-8 February 2012

IEA and KAPSARC co-host workshop on decarbonisation potential of advanced CO2-EOR

31 January 2018
More than 20 years experience with CCS and CO$_2$ Storage in Norway

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The Snøhvit gas field in the Barents Sea. The well stream, with natural gas, CO$_2$, natural gas liquids (NGL) and condensate, is transported in a 160-kilometre pipeline to the facility at Melkøya near Hammerfest. The gas is processed and cooled down to liquid natural gas (LNG). The CO$_2$ is separated and returned to the field by pipeline for reinjection into the aquifer (Stø reservoir).

These projects are living proof that technology to handle CO$_2$ offshore is possible and available!

Source: Statoil
Situation in the Norwegian continental shelf (NCS)

• No CO2 injection for EOR until now
• CO2 storage (CCS) in Sleipner & Snøhvit
Situation in the Norwegian continental shelf (NCS)

• No CO2 injection for EOR until now
• CO2 storage (CCS) in Sleipner & Snøhvit
• Several studies has been done:
  ➢ BIGCCS: Screening of The North Sea (SINTEF 2007)
    ✓ NCS: 19 fields evaluated
      o 375 MSm3 oil additional recovery
      o 3,3 Gt CO2 stored, of this volume 1,5 Gt in the oil reservoirs
    ✓ UK: 30 fields evaluated
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  - NPD updated the NCS study in 2012
    - confirmed CO2 EOR volume from 23 fields with 320 MSm3 additional recovery
    - 1.5 Gt CO2 stored in the oil fields & 1.3 Gt in buffer- aquifer
  - Detailed studied fields:
    - Gullfaks, Draugen, Heidrun
    - Gullfaks showed high potential, but low oil price and lackage of CO2 were show-stopper
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  ➢ NPD applied an other screening method for 27 largest oil fields in 2017, extended in 2019
    o EOR technical potential of 320-860 MSm3 oil
    o CO2 EOR could give more than 150 MSm3 (75-235 MSm3)
The screening study on 23 oil fields in NCS, 2012

- The economic calculations made and showed a positive gain even with oil prices down to $ 60 / barrel and CO2 price of 25-50 $ / ton.
Tree oil-fields with a access of around 1-3 Mt/y of CO₂

<table>
<thead>
<tr>
<th>Case</th>
<th>Amount of available CO₂ [Mt/year]</th>
<th>Total EOR-oil [mill. Sm³]</th>
<th>Total EOR-oil [% of OOIP]</th>
<th>Total stored CO₂ in oil fields and aquifer [Mt]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.25</td>
<td>24.1</td>
<td>10.9</td>
<td>97</td>
</tr>
<tr>
<td>2</td>
<td>1.35</td>
<td>13.2</td>
<td>8.8</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>3.25</td>
<td>30.1</td>
<td>10.3</td>
<td>98</td>
</tr>
</tbody>
</table>

Source: NPD
Several studies with CO$_2$ for EOR have been carried out on Norwegian oil fields, for example: The Gullfaks Field.

Good reservoir quality, but highly faulted STOOIP in Brent reservoir 441 MSm$^3$

Initial waterinjection recovery factor 60%

Study: 5 Mill CO$_2$ yearly

2007-2020: 36.4 GSm3 with 33 injectors
- Effect: 4.1% of STOOIP
- IOR: 18 MSm$^3$

2007-2030: 42 GSm3
- Effect: 6.4%
- IOR: 28 MSm$^3$

30 wells has to be redrilled
Install CO$_2$ handling equipment on 3 platforms
- No ability to pay for the CO$_2$ delivered at the platform
- Technically feasible, but not economic,
- Oilprice: 17.5 $/bbl- can pay: $26-33/bbl
Halten CO$_2$ Project in Mid-Norway

Halten CO2 project, joint Statoil/Shell task force
For example: the Ekofisk field

Challenges:

- High cost due to facility modifications
- 400 wells - high potential for leakage
- Risk of well/integrity failure due to compaction/subsidence
- Fractured reservoir - early breakthrough

Source: ConocoPhilips, Force 2013
This work covered 27 of the largest fields on the NCS, which contain about two billion scm of immobile oil. The results show an overall technical EOR potential of 320-860 million scm for both mobile and immobile oil.
The potential from 7 EOR methods

CO2 EOR could give more than 150 MSm3 (75-235 MSm3)

Source: NPD
CO2 becomes available on the NCS

Northern Lights: a part of the fullscale CCS value chain

Source: Equinor
The first CO$_2$ storage licence (EL 001) awarded by the King in Council January 2019

January 2019 was the first time the authorities gave permission to exploit an area for injection and storage of CO$_2$ according to the new regulations.
A possible future for the North Sea
(a 2023+ scenario)

Source: One North Sea, 2010
Technology development for the NCS

CO₂ EOR without modification on existing platforms

• CO₂ from CCS to EOR in existing oilfield in the North sea
• Separate and reinject the “breakthrough” CO₂ with subsea solution
• CO₂ will be permanent stored after EOR is finished

Source: Aker Solutions
CO2 storage Atlas, 2011-2014

• Storage locations mapped could be very important for buffer-injection during intermission of EOR projects
• «win-win-win» situation, CO2 EOR together with CCS.
CO2 EOR for Residual oil zones (ROZs)

- Residual oil zone: depressurized and/or low oil saturation zone.
- Assessment methods for ROZs still are being developed.
- Additional ROZ CO2-EOR and CO2 retention data and reservoir simulations are **needed** to calibrate national ROZ assessment estimates.
- Define the location and distribution of ROZs on a national scale

Warwick P. D. at alt, GHGT14 - 2019
“IOR and EOR in NCS, co-operation between industry and research enviroment is important.”
Thank you for your attention!
The screening study on 23 oil fields in NCS, 2012

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil price</td>
<td>90 USD/bbl</td>
</tr>
<tr>
<td>CO₂ cost</td>
<td>25 USD/tonne</td>
</tr>
<tr>
<td>Cost per well</td>
<td>75 mill USD/well</td>
</tr>
<tr>
<td>Interest rate</td>
<td>7 %</td>
</tr>
</tbody>
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The screening study on 23 oil fields in NCS, 2012

<table>
<thead>
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<th>Total EOR olje, mill. Sm³</th>
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<td>Total EOR, % av OOIP</td>
<td>7</td>
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CCS EOR-prosjekt aktiv i Canada i dag - Weyburn - Midale project

Capture type: Pre-combustion capture (gasification)
Transport type: Onshore to onshore pipeline 315.00 km
Storage type: Use of CO2 in enhanced oil recovery

Location: Southeastern Saskatchewan, Canada
**CCS EOR demo-prosjekt aktiv i Saudi Arabia i dag**

**Uthmaniyah CO₂ EOR Demonstration Project**

Capture type: Pre-combustion capture (natural gas processing)

Transport type: Onshore to onshore pipeline 70.00 km

Storage type: Use of CO₂ in enhanced oil recovery

0,8 Mt CO₂ injiseres over 3 år. CO₂ fra Hawiyah gassanlegg. Injeksjon i endel av Ghawar-feltet. Feltet er ferdig produsert og økt utvinning med CO₂ skal prøves. 4 injektorer, 4 produsenter og 2 observasjons brønner. Omfattende overvåkingsprogram.

**Location:** Ghawar field, Saudi Arabia

**Proponent:** Saudi Aramco
The pilot plant of this project has entered into operation and was the first commercial CO₂ enhanced oil recovery operation in China.

After the successful injection of around 200,000 tpa of CO₂ from a natural gas processing plant in the first phase, CNPC is planning to expand capacity to 800,000-1,000,000 tonnes per annum by 2015.

Estimated CO₂ capture over the life time of the project is 11 – 20 million tonnes.

Estimated transport distance to planned CO₂ storage facility is 151km - 200km, with the operation of the transport infrastructure planned to commence by 2015.

Key Deliverables

• CO₂ available for storage (capture operation start date) is planned for 2015.
• CO₂ injection testing is estimated to start in 2015.