Some IOR Methods

- Water Injection
- Gas injection, miscible and immiscible
- CO₂ injection
- Air injection (Fire flooding)
- WAG (Water-alternating-gas) –injection
- Surfactant flooding
- Polymer flooding
- Foam
- FAWAG (Foam assistant WAG)
- MEOR (Microbiological EOR - Adding nutrients to injected water
- 4D seismic, New visualization techniques
- Infill (advanced) drilling, branched wells, intelligent wells
- Under balanced drilling

Methods for increased recovery.....

<table>
<thead>
<tr>
<th>Reservoir Management</th>
<th>4D seismic</th>
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<tr>
<td>Water- and Gas Injection</td>
<td>Smart wells</td>
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<table>
<thead>
<tr>
<th>Recovery rate</th>
<th>1986</th>
<th>1998</th>
<th>2000</th>
<th>Objective</th>
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<tbody>
<tr>
<td>Statfjord</td>
<td>49.4%</td>
<td>61.4%</td>
<td>66.6%</td>
<td>67%</td>
</tr>
<tr>
<td>Gulfstream</td>
<td>46.6%</td>
<td>49.4%</td>
<td>54.8%</td>
<td>60%</td>
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Water Injection

Gas for injection: Principe sketches
Gassinjeksjon Grane

Gas injection in Norway
Effect of Gas Injection

- Injection of natural gas has given Norway 180-220 million Sm³ more oil and condensate
- It is expected that this will increase to appr. 300 million Sm³ based on the current plans for gas injection

WAG (schematic)
How does CO₂ injection work?

When to use CO₂ injection?
Foam applications in North Sea

Goal: Reduce unwanted gas production

Tools:
1. Use foam to shutoff gas in production wells (Oseberg, Snorre, Beryl)
2. Foam to improve swept area by gas (Snorre, Brage, Statfjord)
   a) Poor area sweep
   b) Gas channeling
   c) Gravity override

Snorre FAWAG

Expect segregated flow within the channel sands

Objective:
- reduce gas mobility
- divert gas into unswept areas
Polymer-gel can be used to delay or hinder water break-through

- The injection water is mixed with chemical additives making it thick like 'soup' (gel) and blocks the pores in the reservoir
- Pilots on the Norwegian shelf: Gullfaks and Statfjord
- Currently only used during well operation / completions
MEOR – Microbiological EOR
use of bacteria for IOR

Used on Norne field

• What do the bacteria produce?
• Likely effect by
  • Gas
  • Tensides
  • Thickening substance
  • ??
• Cheap
• Difficult to evaluate

EOR – what method to use?

Achieve more effective flooding by:
• Water (also using additives)
• Gas (methane, rich gas, CO₂, nitrogen, + others also with additives)
• Water + Gas (WAG, SWAG, FAWAG, with additives)
• Other advanced methods (bacteria/MEOR, air, etc)
in large, medium or small scale,
often done as combinations in the same field
Current drainage strategy at Statfjord field

High Recovery factor: Active use of VAG
Drilling and well mng. opportunities

Drilling and well technology for IOR

- Infill drilling
  - Deviated wells, horizontal wells, branched wells
  - Re-completions, reuse of existing slots
  - Cheap wells
- Sub Sea completions (SS)
  - Interventions when needed
- Advanced (smart, automated) wells
  - Remotely controlled: SCRAMS / DIACS etc
  - With measuring devises (MVD) during drilling and production (P, T, flow)
- Well placement after 4D seismic
  - Visualized data interpretation, inter disciplinary teams
Troll branched Well

Smarter drilling and well interventions

✓ Long reach and horizontal wells
✓ Geo-steering and Real Time Data Acquisition
✓ Low cost wells
✓ Improved well intervention
Smart well completion in an injector and producer at Snorre B.
Seabed, multi component seismic

How to get to the IOR-volumes?

[Bar chart showing various methods and their percentage contributions to IOR-volumes]
IOR and environmental impact

- International goal to reduce emissions of CO₂
  - could the CO₂ be used for IOR?

- Zero emissions of harmful compounds to sea
  - may make it more difficult to use chemicals and to prolong field life
  - but may make it more attractive to reinject produced water
  - could that be used for IOR?