Increased Recovery Opportunities – Norway Learnings

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Increased Recovery Opportunities – Norway Learnings

1 – Introduction
2 – Background - Facts
3 – Governmental Role
4 – IOR/EOR
5 – Summary
IOR/EOR Definition

**Improved Oil Recovery Techniques**
- Secondary Recovery
- Tertiary/EOR Recovery
- Infill Drilling
- Reservoir Management
- Process Optimization
- Horizontal Drilling

**Enhanced Recovery Techniques**
- Chemicals (Polymers, Surfactants, Foam)
- Thermal (Steam, InSitu Combustion)
- Missible Gas (CO2, N2)
- MEOR (Microbes)

**Diagram Overview**
- Primary (Natural Energy) 25% OOIP
- Secondary (Waterflooding/Gas, Recycling) 20% OOIP
- Tertiary/EOR 10% OOIP

**Graph**
- Time (X-axis)
- Oil Production (BOPD) (Y-axis)
Production from immobile oil requires techniques that reduce the residual oil saturation, i.e. transform immobile oil into mobile oil.

Enhanced Oil Recovery (EOR) techniques are necessary.
Cross-section of a reservoir showing an example of oil and water distribution after waterflooding, and distribution of the liquids at pore level.
Proposed definition of EOR/IOR (Stosur, 2003)
Enhancing Oil Recovery

(Courtesy of BP)

FOCUS OF EOR

34%

0.6

0.7

FOCUS OF IOR

0.9

0.9

(example)
EOR Field Projects

EOR Field Project by lithology (based on a total 1507 international projects) (Manrique et al., 2010).
MATURITY & OPERATIONAL WINDOW OF EOR METHODS
SUBSURFACE & ENHANCED RECOVERY

Source: WPC 2010

NCS Fields
Recovery factor by method and oil viscosity (courtesy of Total)
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Norwegian Oil and Gas
Historic milestones

• **1965**: First licensing round – North Sea
• **1969**: Discovery of the Ekofisk field
• **1971**: Ekofisk – first field in production
• **1972**: NPD and Statoil were established

• **1985**: SDFI (State Direct Financial Interest) established
• **2001**: Statoil partly privatized – Petoro established to take care of the SDFI
• **2011**: Barents Sea border agreement with Russia
Resources on the Norwegian Continental Shelf

Total by 2014: 14.1 billion Sm³ oe
2013: 14.2 billion Sm³ o.e.
2012: 13.6 billion Sm³ o.e.
We underestimate the oil reserves
Potential for improved recovery
Average Oil Recovery Factor on NCS

Source: Norwegian Petroleum Directorate.
Projects in resource categories 4A and 5A by type
Development of average rig rate and well cost for wells drilled from mobile units
The size of well targets due to be drilled on producing fields in 2014
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State organization of the petroleum sector

(Source: Ministry of Petroleum and Energy)
Separation of roles and responsibilities

- Ministry
  - National plans
  - Legal basis
  - Licensing
  - Major approvals

- Oil companies
  - Field development
  - Contracting
  - Operations
  - Marketing

- Directorate
  - Advice
  - Overview-Supervision
  - Promotion
  - Data management/Information
Petroleum Act about value creation
Section 4-1: Prudent production

• Production of petroleum shall take place in such a manner that as much as possible of the petroleum in place in each individual petroleum deposit, or in several deposits in combination, will be produced.

• The production shall take place in accordance with prudent technical and sound economic principles and in such a manner that waste of petroleum or reservoir energy is avoided.

• The licensee shall carry out continuous evaluation of production strategy and technical solutions and shall take the necessary measures in order to achieve this.
Norwegian Petroleum Directorate

- Subordinate to the Ministry of Petroleum and Energy (MPE)
  - Advisory body to the MPE
  - Exercise management authority
- Established 1972 in Stavanger
- Appr 240 employees

- The Norwegian Petroleum Directorate will contribute in creating the greatest possible value for society from oil and gas activities by means of prudent resource management, based on safety, emergency preparedness and safeguarding the natural environment.
Balance of economic interest

**INDUSTRY FOCUS**
- Field - license - company
- Faster Cash flow
- High Discount Rate
- Less interest in late production

**AUTHORITIES FOCUS**
- Across licenses - regional - national
- Improved recovery
- Even cash flow over longer time
- Lower Discount Rate

**WIN-WIN SOLUTIONS**

**OPENNESS**

**FAIRNESS**

**PROFESSIONALISM**
The NPD resource classification
Resource categories compared with general project development

General project development model

Project development process

Idea generation exploration

RC8, 9 RC7 RC5 RC4 RC3, RC2 RC0+1

Planning
Feasibility studies
Concept studies
Pre-engineering
Implementation
Detailed engineering
Construction
Testing and start-up
Operation

Start feasibility studies (DG 0)
BOK (DG 1)
BOV (DG 2)
BOG (DG 3)

Start of operation (DG 4)
Experience 1 year operation

OD 0808001
### NPD vs. SPE PRMS

#### SPE PRMS 2007

**Project Maturity sub-classes**

<table>
<thead>
<tr>
<th>Production</th>
<th>RESERVES</th>
<th>CONTINGENT RESOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Production</td>
<td>Approved for Development</td>
<td>Development Pending</td>
</tr>
<tr>
<td>Approved for Development</td>
<td>Justified for Development</td>
<td>Development unclarified or on Hold</td>
</tr>
<tr>
<td>Justified for Development</td>
<td></td>
<td>Development not Viable</td>
</tr>
</tbody>
</table>

| Unrecoverable               |                            |                      |

**Resource class**

- **PROSPECTIVE RESOURCES**
  - Prospect
  - Lead
  - Play

### NPD 2001

<table>
<thead>
<tr>
<th>Resource class</th>
<th>Project status category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>Sold and delivered</td>
</tr>
<tr>
<td>1</td>
<td>In production</td>
</tr>
<tr>
<td>2 F/A</td>
<td>Approved PDO</td>
</tr>
<tr>
<td>3 F/A</td>
<td>Licences have decided to recover</td>
</tr>
<tr>
<td>4 F/A</td>
<td>In the planning phase</td>
</tr>
<tr>
<td>5 F/A</td>
<td>Recovery likely but undecided</td>
</tr>
<tr>
<td>6</td>
<td>Recovery not very likely</td>
</tr>
<tr>
<td>7 F/A</td>
<td>Not yet evaluated</td>
</tr>
<tr>
<td>8</td>
<td>Prospect</td>
</tr>
<tr>
<td>9</td>
<td>Lead and Play</td>
</tr>
</tbody>
</table>
Reserves are like fish

• Proved Developed
  • The fish is in your boat.
  • You have weighed it, you can smell it and you will eat it.

• Proved Undeveloped
  • The fish is on your hook in the water by your boat and you are ready to net it.
  • You can tell how big it looks (they always look bigger in the water).
Reserves are like fish

• Probable
  • There are fish in the lake and you may have caught some yesterday.
  • You may even be able to see them, but you have not caught any today (yet).

• Possible
  • There is water in the lake and someone may have told you that there are fish in the lake.
  • You have your boat on the trailer but you may go golfing instead.
Contingent resources are also like fish

Has all the same physical certainty categories as Reserves but can't catch, sell, or eat the fish because:

• Market/ Infrastructure
  • The whole country is totally vegetarian.
  • There are no refrigerated trucks to get the fish to market.

• Political
  • You don't have a fishing license.
The winners of the NPD IOR award

- 2014  Martin Landrø, NTNU
- 2012  Statoil
- 2010  FMC
- 2009  COREC and Tor Austad, IRIS/UiS
- 2007  Talisman
- 2006  Halliburton and Baker Hughes
- 2005  Arne Skauge, CIPR
- 2004  Statoil and the Gullfaks license
- 2003  BP and the Valhall license
- 2001  Norne lisensen and Egil Sunde, Statoil
- 2000  Phillips Petroleum Company
- 1999  Saga Petroleum
- 1998  Norsk Hydro and the Troll license
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Closing the gap

Reservoir description
Best reservoir model
Reservoir communication

Simulation methods
Better predictions

Enhanced oil recovery methods
Move trapped oil
Sweep improvement

Monitoring
Find best drilling targets
IOR & EOR toolbox

EOR methods
- Miscible gas/WAG
- Low saline flooding
- Surfactants
- CO₂ injection
- ___

IOR/Production optimization
- More wells
- More advanced wells and well control
- More water and gas injection
- Better use of IO, 4D seismic etc.
- Prolonged lifetime
- ___

Immobile oil - 47 %
Mobile oil - 53 %

Water diversion
- Polymers
- WAG/CO₂
- Gas diversion
- ___
Gullfaks – 4D seismic

Source: 2-D map as delivered by Statoil to the NPD. Courtesy of the NPD; R. Helland of Statoil, "Gullfaks," World Petroleum Congress, 2008
Well technology

Complex geometry
Multi-laterals
Multiple wells
The Troll Field, Huge gas and oil field with the best of Norwegian technology
Water injection

- $S_{orw} = 0.20-0.35$
- Normally stable front
- Easy access to water (in the North Sea)
Gas injection

- $S_{\text{org}} = 0.05 - 0.20$
- Often a stable front (if injection from the top)
- Gas is not always available
- Sensitive to uncertainty in the reservoir description

Gas injection over the oil zone, the oil is displaced
Typical Water based IOR/EOR

- Microscopic Sweep Improvements (Sor)
  - Low salinity water injection (LSW)
  - Surfactants
  - Bacteria (MEOR)

- Macroscopic Sweep Improvements / Mobility control
  - Polymer injection

- Diversion methods
  - Linked polymer solutions (LPS)
  - Gels
  - Bacteria (MEOR)

- Other
  - Hybrids (LSW + Polymer + Surfactants)
Typical Gas based IOR/EOR

• Macroscopic Sweep Improvements / Mobility control
  • Water Alternating Gas injection (WAG)
  • Foam

• Diversion methods
  • Foam

• Miscibility
  • HC gas
  • CO2 injection

• Other
  • Flue gas
  • N2 / Air
  • Hybrids (i.e. CO2-WAG, FAWAG)
Ekofisk – a major IOR success

- Successful waterflood
- Extended field lifetime
- Drilling and completion technology
- Recovery of flank reserves

+40 years more to go?

EOR?
Ekofisk Field: 1% increase in RF represents 80 mmboe
Low Salinity Water Injection (LSW)
Polymer water flooding

- Polymers added to the injection water to improve mobility ratio between the injected water and the oil

\[ M = \frac{\lambda_d}{\lambda_o} = \frac{k_d \mu_o}{k_o \mu_d} \]

- A favorable mobility ratio will give
  - Smoother displacement of oil
  - Enhanced macroscopic sweep efficiency
  - Delayed water breakthrough
  - Reduced water cut
  - Reduced / delayed water coning
Low salinity polymer

![Graph showing the effect of low salinity polymer on oil production](image)

**Source:** Behruz Shaker Shiran and Arne Skauge, 2012

**Resultat fra PETROMAKS prosjekt**
Snorre IOR
IOR/EOR experience in Norway

- Oseberg – TOGI
- Troll – Thin oil zones – Well technology
- WAG – Gullfaks, Statfjord, Snorre, Ula
- MEOR – Norne
- FOAM – Snorre, Oseberg, Brage, Veslefrikk
- CEOR (Surfactants/polymers) – Gullfaks, Oseberg, Heidrun
- LoSal – Snorre, Heidrun
Norwegian CCS initiative

Source: Sleipner, Snøhvit, Mongstad TCM, HeidelbergCement

Capture: Snøhvit CCS

Transport: Conducted several studies

EOR: Sleipner West and Snøhvit

Injection: Storage and Monitoring

Monitoring: Reservoir system
Pro’s and Con’s - CO2 for EOR

• **Pro’s:**
  ✓ Swelling → improve flow characteristics
  ✓ Vaporize → oil components recovered
  ✓ Reduce oil viscosity
  ✓ Soluble in water
  ✓ Miscibility at ‘low’ pressures
  ✓ Supercritical CO2 (gas viscosity and liquid density)
  ✓ Reduces oil/water IFT
    ➢ Very efficient EOR agent

• **Con’s:**
  ✓ Reliable source
  ✓ Reduces sales gas quality
  ✓ Corrosion
  ✓ High modification costs (pipelines, wells, process equipment, pumps, etc)
  ✓ Declining demand over time, need for storage
Organization of the Petroleum research

 Ministry of education and research
Research council

 Ministry of petroleum and energy
OG\textsubscript{21} National strategy

 TTA1
TTA2
TTA3

 Strategic programs (RCN)

 Petromaks

 Demo2000

 JIPs (Joint industry projects)

 Basic strategic research in petroleum
Basic research, User driven research
Pilot qualification of technology

Time to commercialisation

Organisational line
--- Strategic guidelines
OG21 - Technology Target Areas (TTA):

OG21 brings together oil companies, universities, research institutes, suppliers and Governmental bodies, to develop and implement a national petroleum technology strategy for Norway.

Focus on four Technology Target Areas:

1. Energy efficient and environmentally sustainable technologies
2. Exploration and increased recovery
3. Cost-efficient drilling and intervention
4. Future technologies for production, processing and transportation

http://www.og21.no
The National IOR Center in Norway

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Main factors for increased recovery

Important factors for Norwegian achievements regarding increased oil production:

1. Managed to maintain the reservoir pressure due to water/gas injection from the start up of most fields
2. Drilled more production wells than originally planned in the PDO
3. Systematically and continuously collected new information to improve the understanding of the reservoir, and adapt plans to new information
4. Focus on R&D and technology development

These four factors are still valid and will be emphasized by the NPD also in the future.
Technology to solve future challenges

- Installations in harsh environment
- Sub-sea processing
- Geological and geophysical methods

- Reservoir and production
- Well and drilling technology
- Environment
Still work to be done within IOR/EOR...

**Some selected Enhanced Oil Recovery technologies**

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<th>Technology</th>
<th>Prognosis</th>
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**Goal**

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- **Green**: Proven technology
- **Yellow**: Progress needed
- **Red**: Unsolved

....and drilling technology...

Drilling technology evolution

Manual

Mechanization

Remote control

How to cope with today's and next challenges?
- Complex wells with narrow margins
- Harsh or inaccessible environments

http://www.iris.no
Summary – roadmap to next level

• Common focus on IOR – authorities, R&D, service industry and oil companies
• Promote R&D and piloting of new IOR/EOR technologies
• Promote cost efficient technology development
• Optimize development of new resources in an areal perspective – utilize synergies
Thank you for your attention!