Challenges in implementation of chemical EOR in Norway

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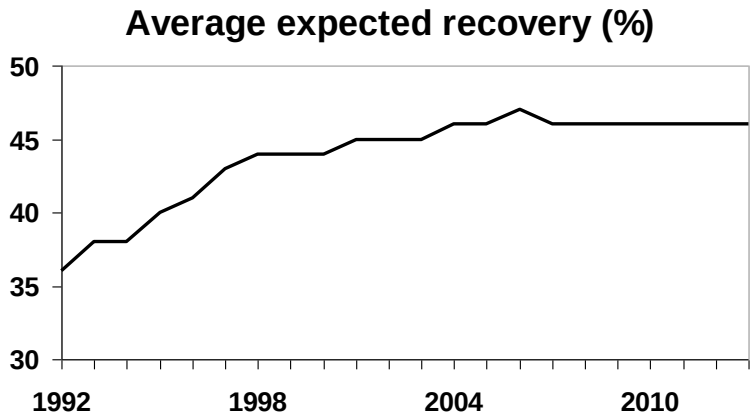
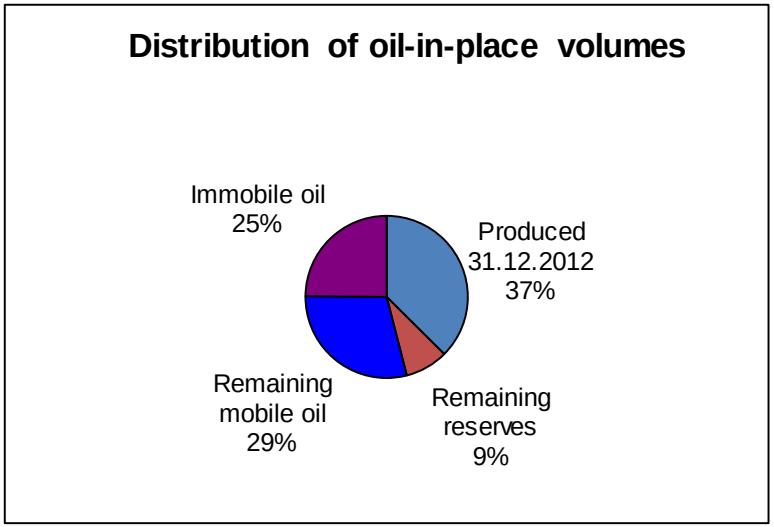
Overview

- Remaining oil in NCS
- EOR technologies
- EOR in Norway
- Challenges EOR offshore
- Conclusion

High recovery factor in Norwegian Continental Shelf



Slow development in the last 10 years.



Close to 15 billion barrels of immobile and 17 billion barrels of mobile oil remains in producing fields.

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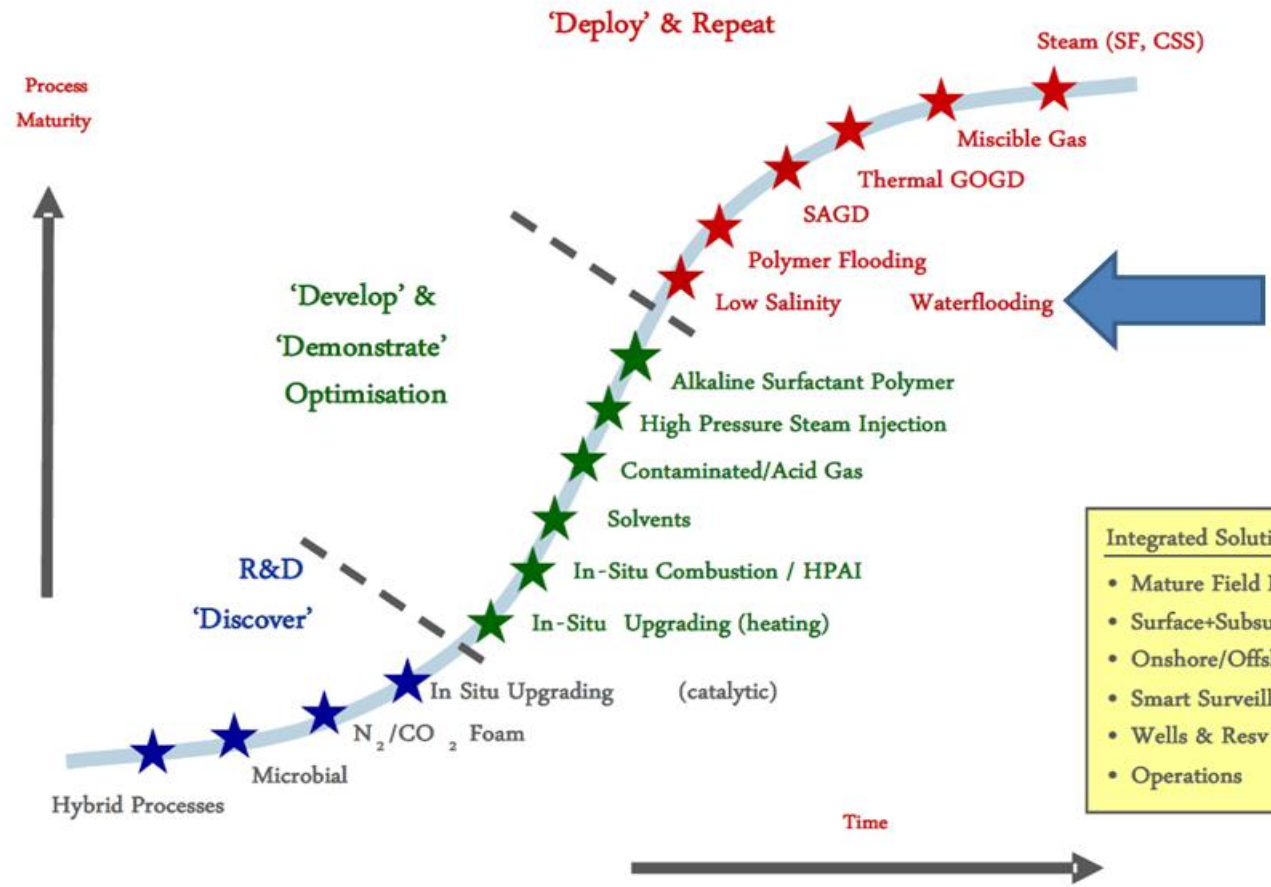
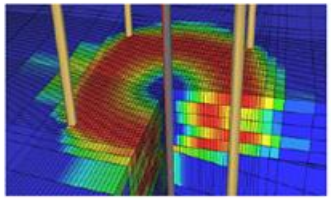
Enhanced Oil Recovery Technologies

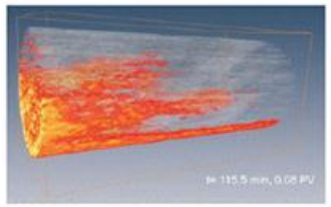
The increase of ultimate recovery through injection of steam, chemicals or gas to more effectively displace the oil bringing RFs to the 50-70% range.



Integrated Solutions

- Mature Field Mgmt
- Surface+Subsurface
- Onshore/Offshore
- Smart Surveillance
- Wells & Resv Mgmt
- Operations





From Shell EOR Academy, May, 2012

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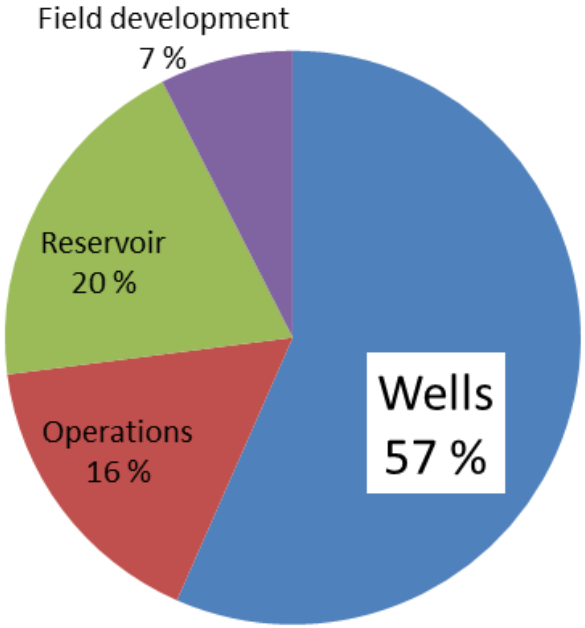
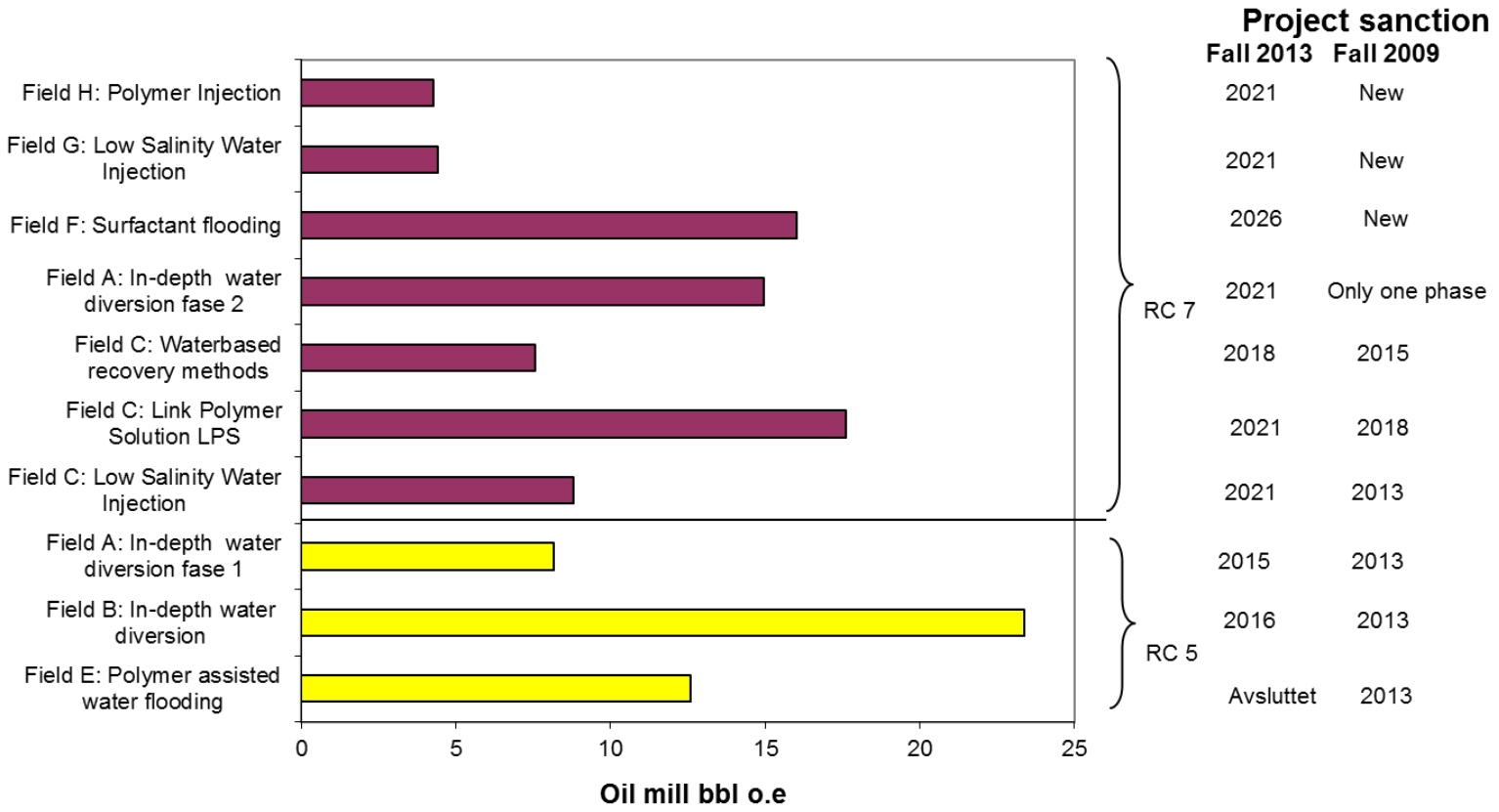
More wells, the main driver to achieve the reserves ambition for oil

Split of reserves ambition 2020



EOR NCS – Status 2013
Limited progress on full field implementation



- In all EOR-projects DG3 has been postponed with 2-3 years since fall 2009.
- One field reported a EOR volume of 2 MSm^3 in RNB2010, but the project is now terminated.

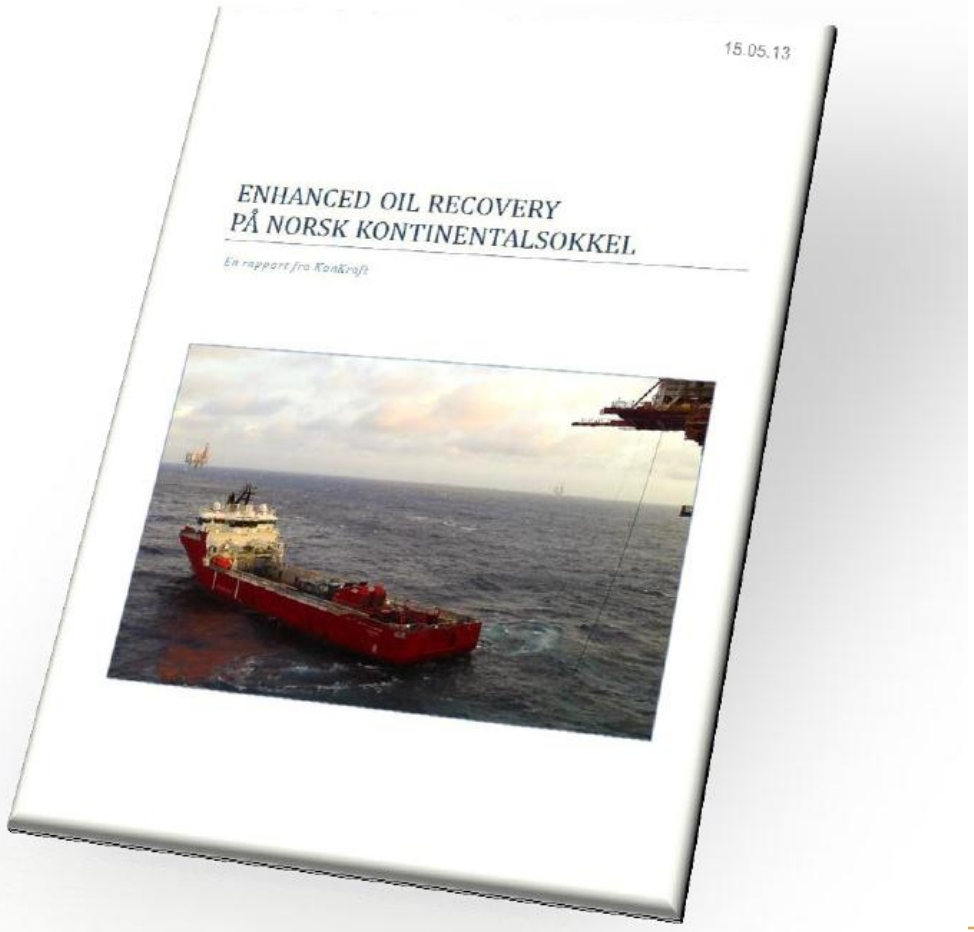
Challenges in offshore EOR

- Placement and number of wells
- Installation limitations
- Stakeholder alignment
- HSE requirements
- Remaining oil distribution
- Simulation technology

KonKraft

Konkurransekraft på norsk sokkel

- Plac
- Insta
- Stak
- HSE
- Rem
- Simu



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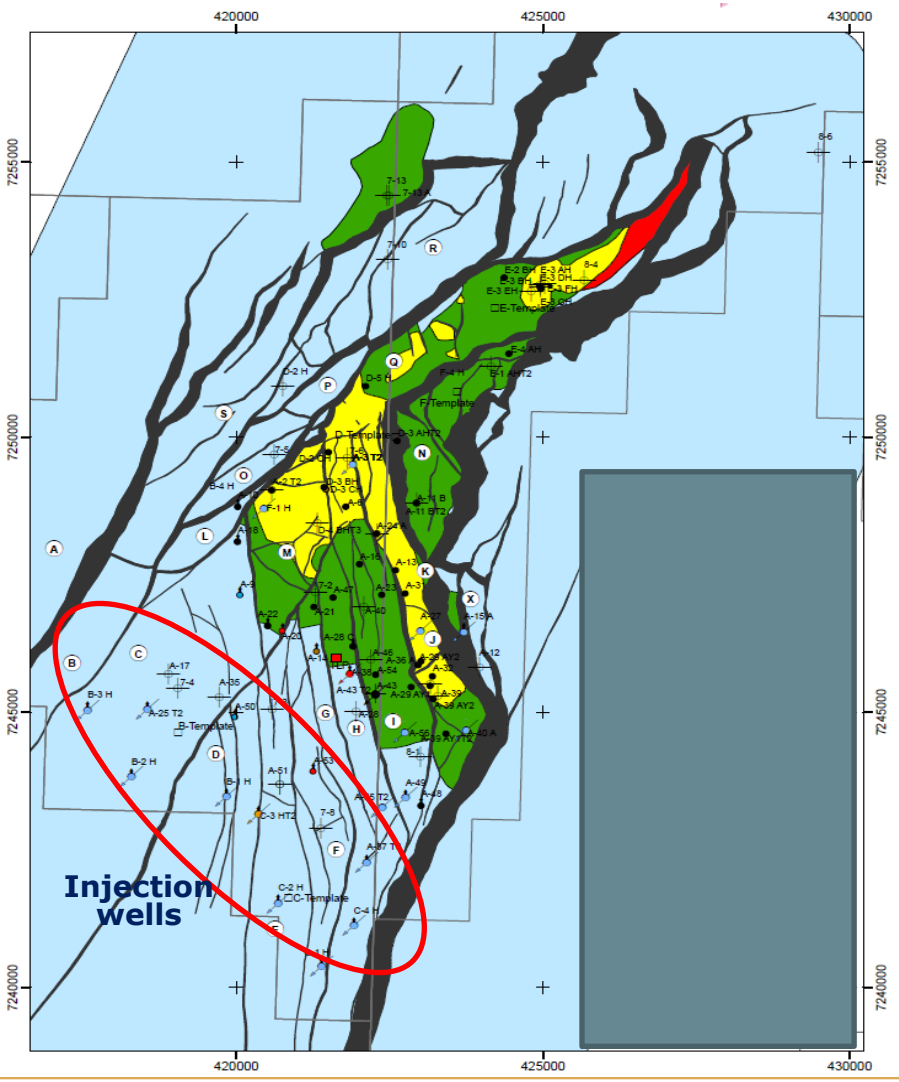
Placement and number of wells



- Injection wells far into the aquifer
- Long distance between injection and production wells
- Number of injection and production wells are limited

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Installation limitations

- Modifications challenging
- Expensive retrofitting

Clair Ridge, operator BP, LSWI

Incremental cost of LSWI: 120 MUSD
For: 25000 Sm^3
700 m^2 footprint
1000 tonns

On field A in Norway a 15000 Sm^3 LS plant costs 300 MUSD

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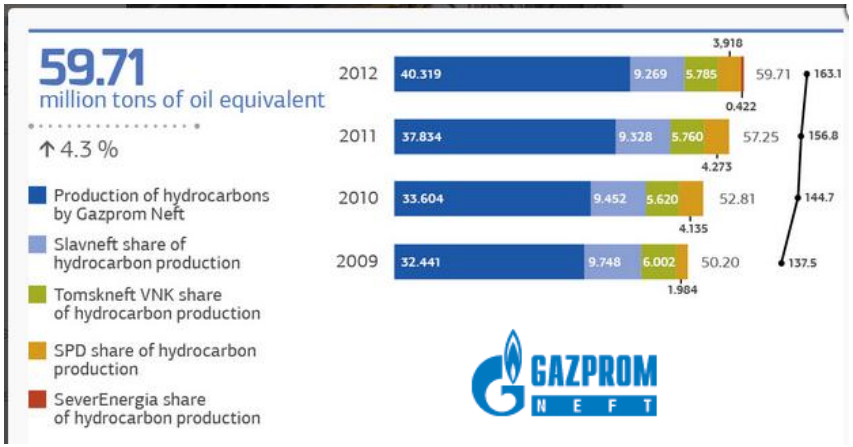
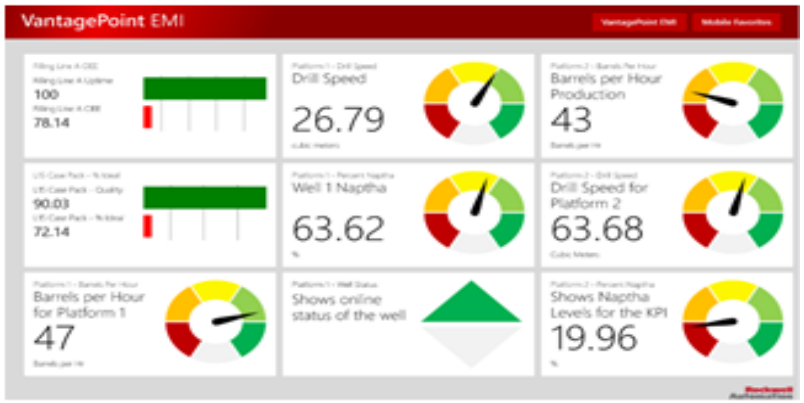
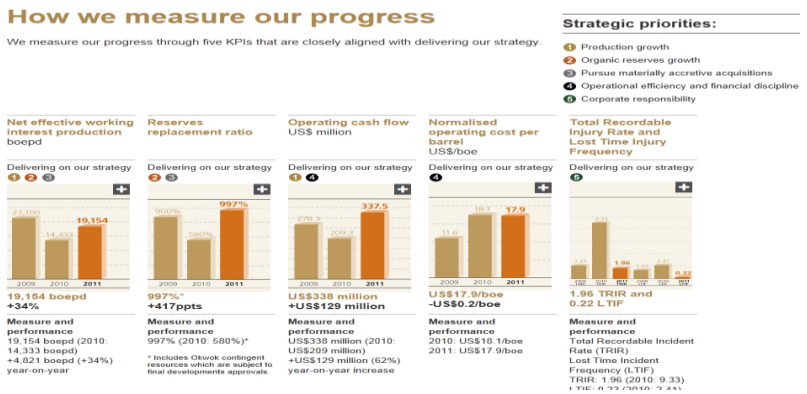
Stakeholder alignment

- KPI's are about short term oil production ('oil on deck!')
- Partners have different drivers







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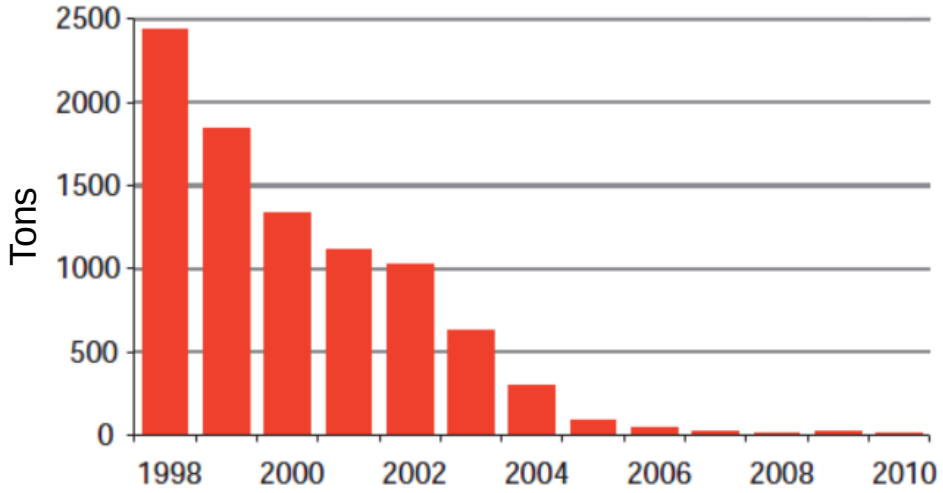
HSE requirements challenging

Norwegian authorities require no discharge of any environmentally harmful liquid into the sea

Discharge of chemical additives reduced by 99% on the NCS over the past 10 years



- **Silicate** is not harmful
- **Bright Water** is expected to remain in the reservoir
- **Polymers** are non toxic and non bioaccumulating but they have low biodegradability
- Injection of **Polymers** and **LPS** will need reinjection with high regularity

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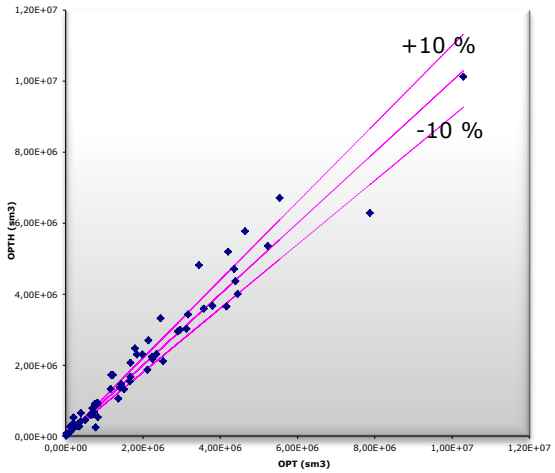
Remaining oil distribution

It is difficult to know where the remaining oil is.

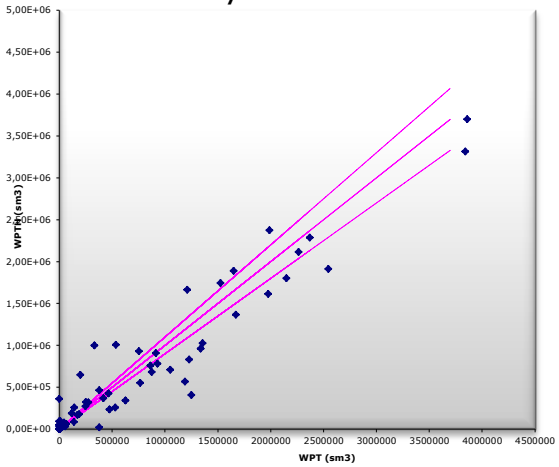
- Data acquisition challenging (Commingled wells, Subsea templates etc.)
  - Expensive, fewer data points
  - More uncertain basis

- History matching of mature fields has proven to be a challenge

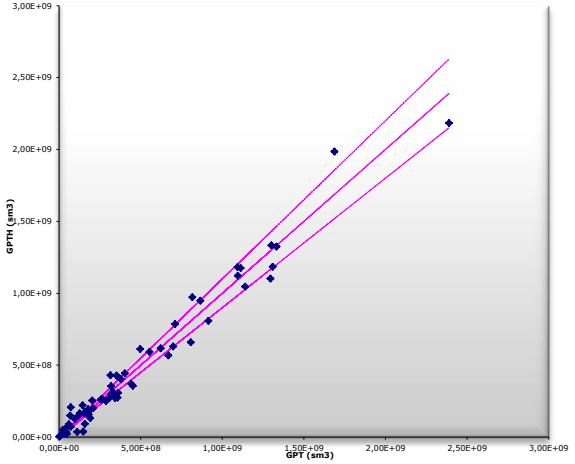
Oil Production Total
History vs Simulation



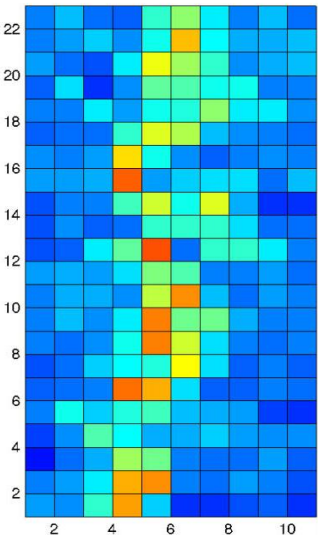
Water Production Total
History vs Simulation



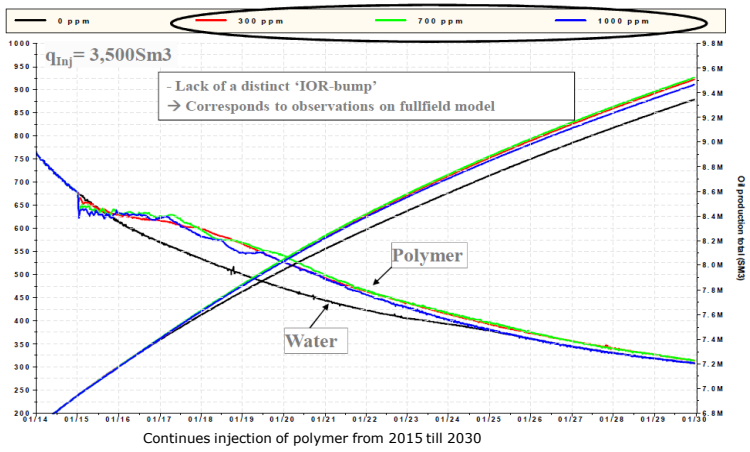
Gas Production Total
History vs Simulation



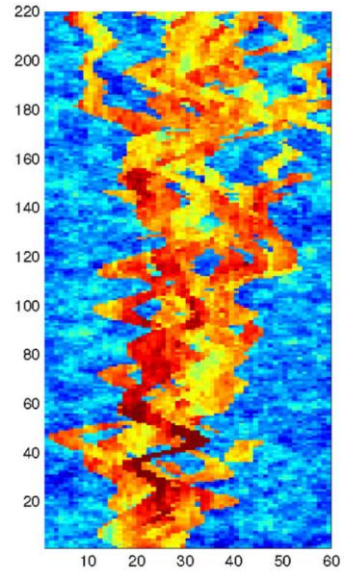
Resolution of simulation grids



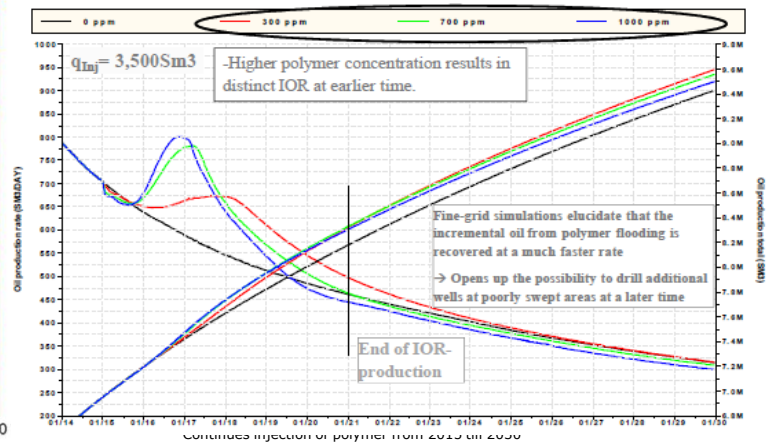
..., but the effect almost disappears when is simulated in a full field model used in the business case.



Continues injection of polymer from 2015 till 2030



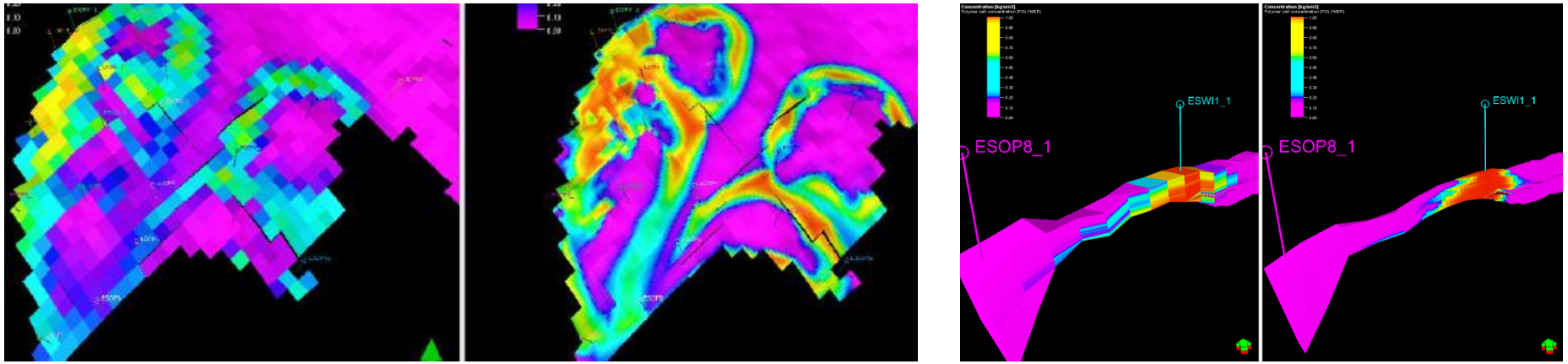
The effect of polymer injection into a "fine-grid" reservoir model in a small part of the field is promising.



- To demonstrate a business opportunity through reservoir simulation a high resolution model is required.
- Need a detailed simulation grid to take best account of:
  - Incremental rate bump
  - Water front arrival time
  - Well level effects

Challenges of full field simulation with current simulators

- Run times of > 1 week for desired resolution
- Parallel or Multiple Realization runs or LGRs won't help!
- Sector model or coarse model FFM?
- Risk of decision delay or decision based on ¨simplified problem study¨



Polymer concentration in coarse grid vs. fine grid

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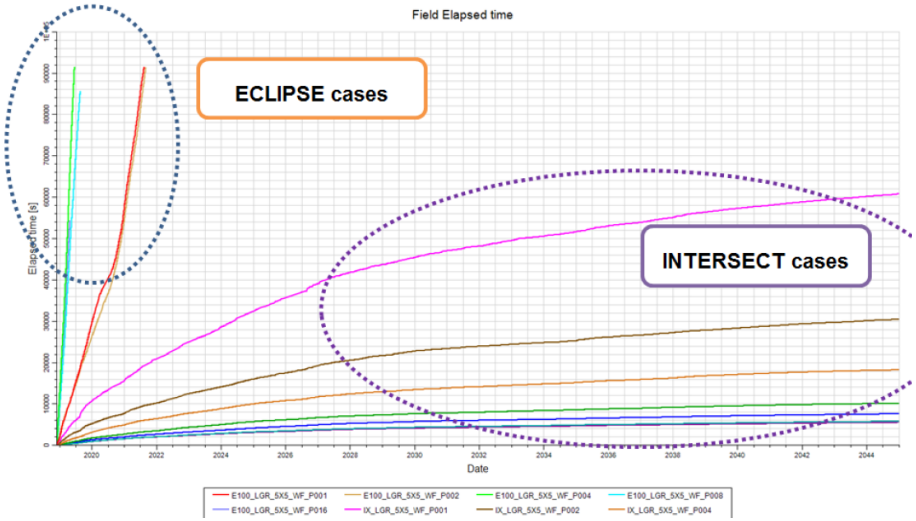
Are we ready to deploy the next generation of simulation tools?

- Eclipse came 30 years ago and is still a tool of choice for conventional models!
- Eclipse solution algorithms are not designed to exploit today's increased computing capacity.
- most of the development potential and increased speed potential are already realized.
- Next generation simulation tools, enabling simulations with much greater resolution in significantly less time.
- With new simulators an increased number of sensitivities could be investigated with improved quality => quantified uncertainty in business case



Conclusion

Implementation of EOR is challenging for mature fields offshore.

What about Green fields?

Some of the EOR has been designed for late life time of the field

- Polymer gel particles and Na-silicate for flow diversion
- Bright Water
- LPS

Early evaluation of some EOR methods in green fields is important to capture the full potential.

- Low salinity water injection
- Surfactants (PASF)
- Polymers

Probably, it is time to consider not all of EOR methods as tertiary (at least in offshore fields).

- BP – Mad Dog in GoM and Clair Ridge UK, LoSal from day 1

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