Increasing recovery and lowering CO2 intensity though use of next generation inflow control

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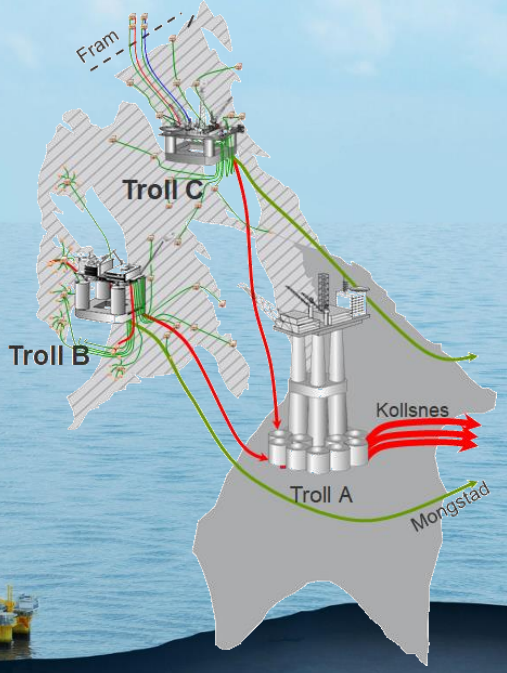
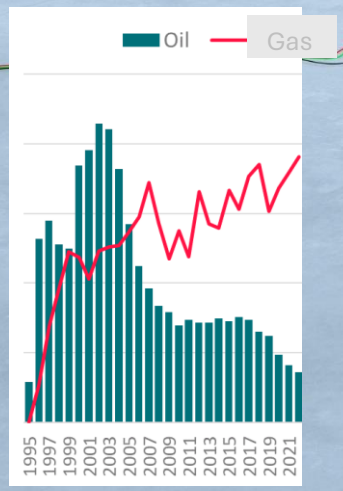
Outline

- The Troll field and the History of AICD
- Field implementation and status of today
- Future needs in Equinor

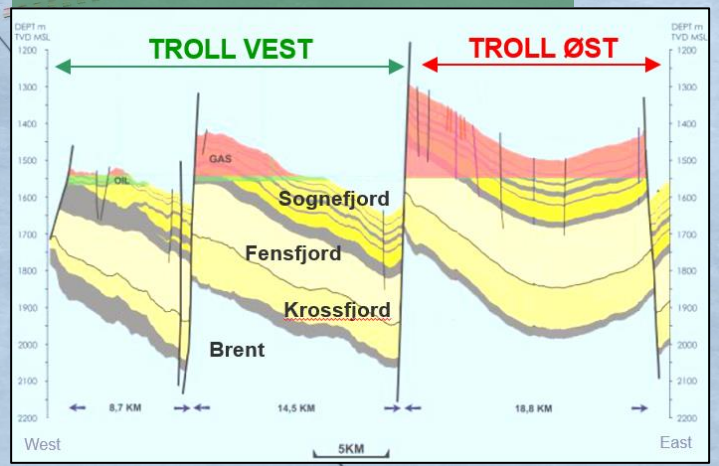
Troll

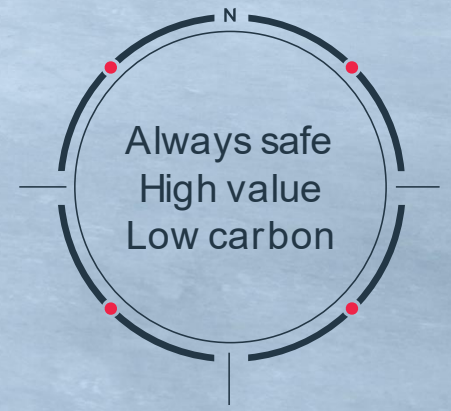
- 3 platforms
- 34 subsea templates, 128 subsea well slots (oil production)
- 48 gas producers at Troll A
- Sandstone reservoirs
- Produced ~1086 MSm^3 o.e.
  - 291 MSm^3 oil
    - Limited potential for IOR.
  - ~1/3 of Norway's gas export
    - Half of the gas reserves remaining



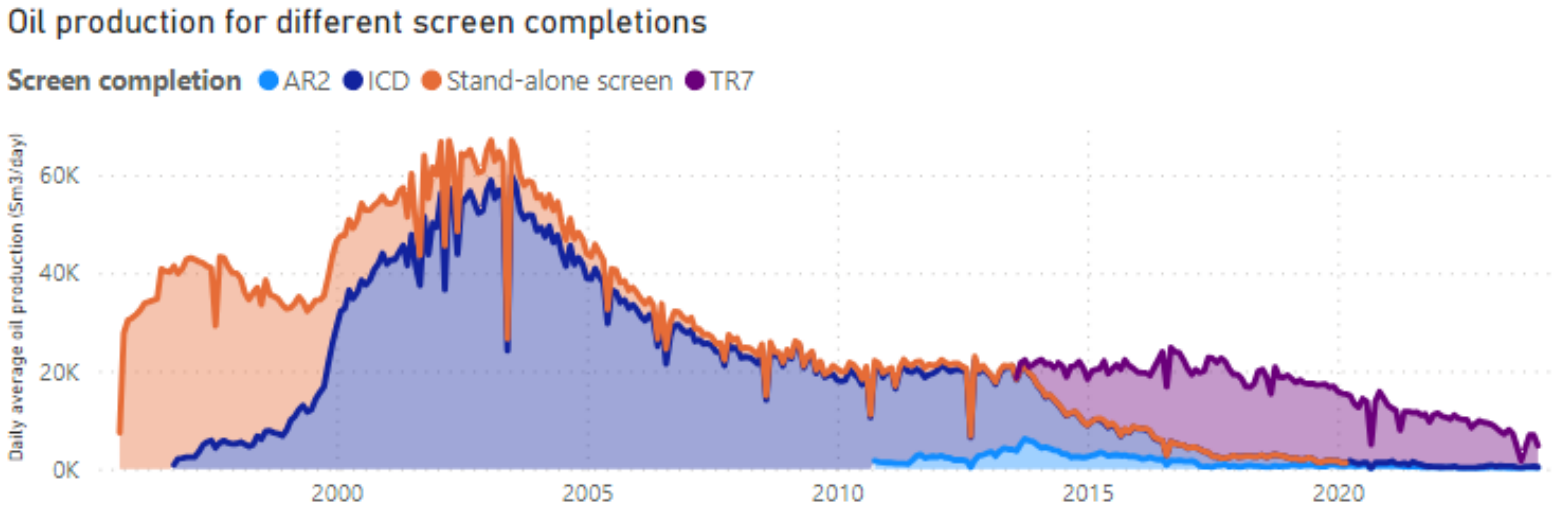


Geological cross-section of the Troll field





Troll inflow control deployment



Troll numbers:

- Well slots: 128
- Well bores: 318
- Branches: 660
- Reservoir meters drilled: 2 300 km
- Longest branch: 10 200 m
- Swell packers: 5747
- Downhole gauges: 427
- Interval control valves: 416
- Gas-cap gas-lift valves: 199

(1995) Troll Oil start-up

(1996) Downhole gauge

(1998) ICD

(1998) Gas-cap gas-lift valve

(2000) Multi-lateral well

(2005) ICV

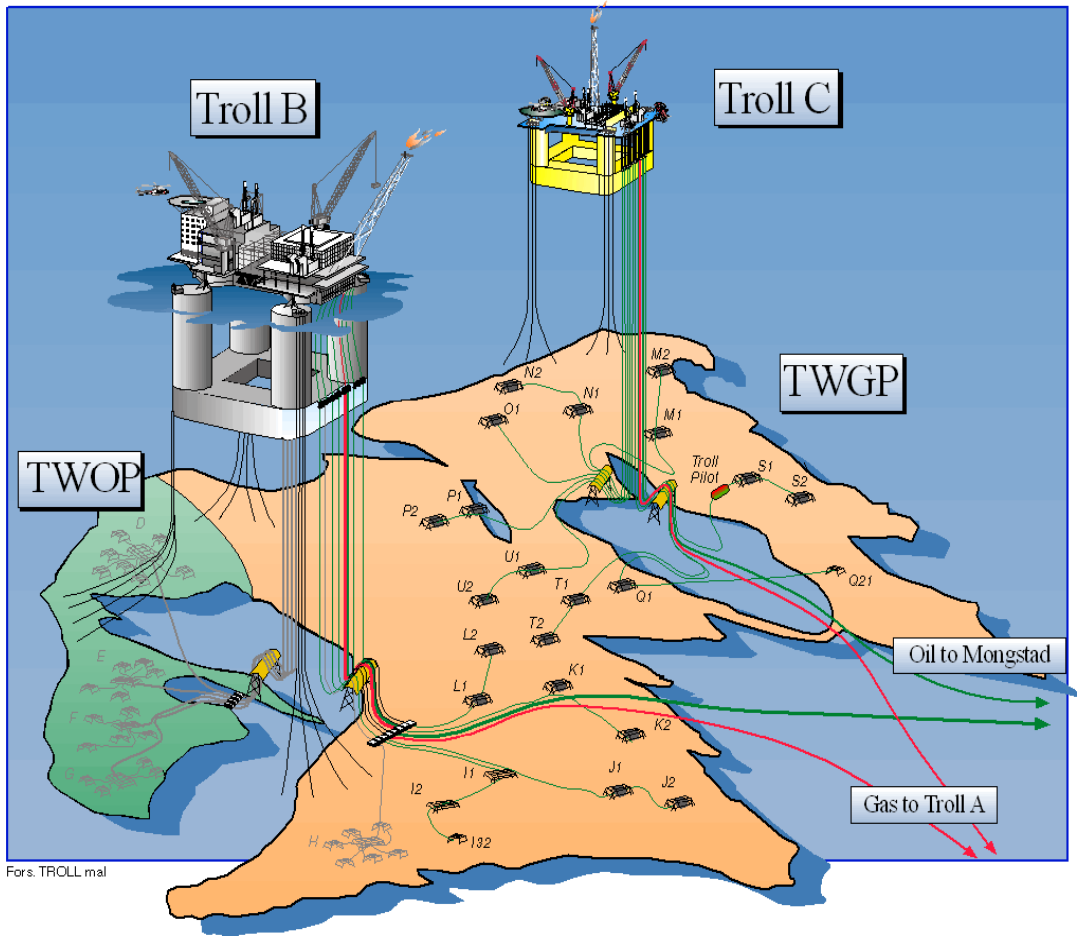
(2006) Swell packer

(2008) AICD

(2023) Last well drilled on Troll Oil

Troll - the pioneer

- Main challenge:
  - Gas processing capacity on Troll B and Troll C
    - Oil wells choked back and sharp production decline
- Good experience from introducing ICD
  - ICDs not effective in choking back gas after gas breakthrough
- A technology challenge was initiated (2006)

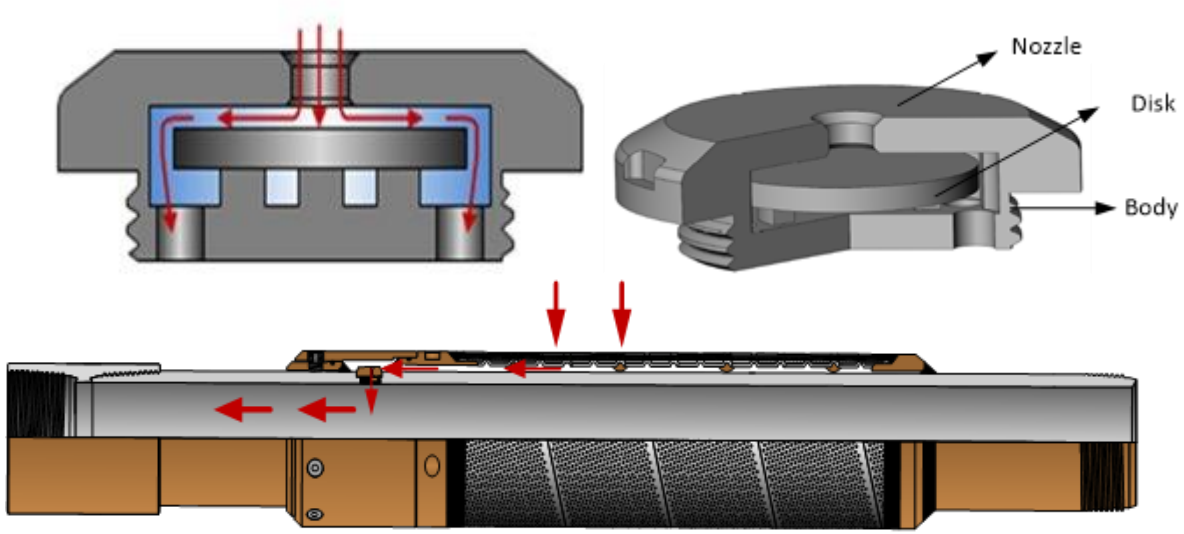


The RCP valve (AICD)

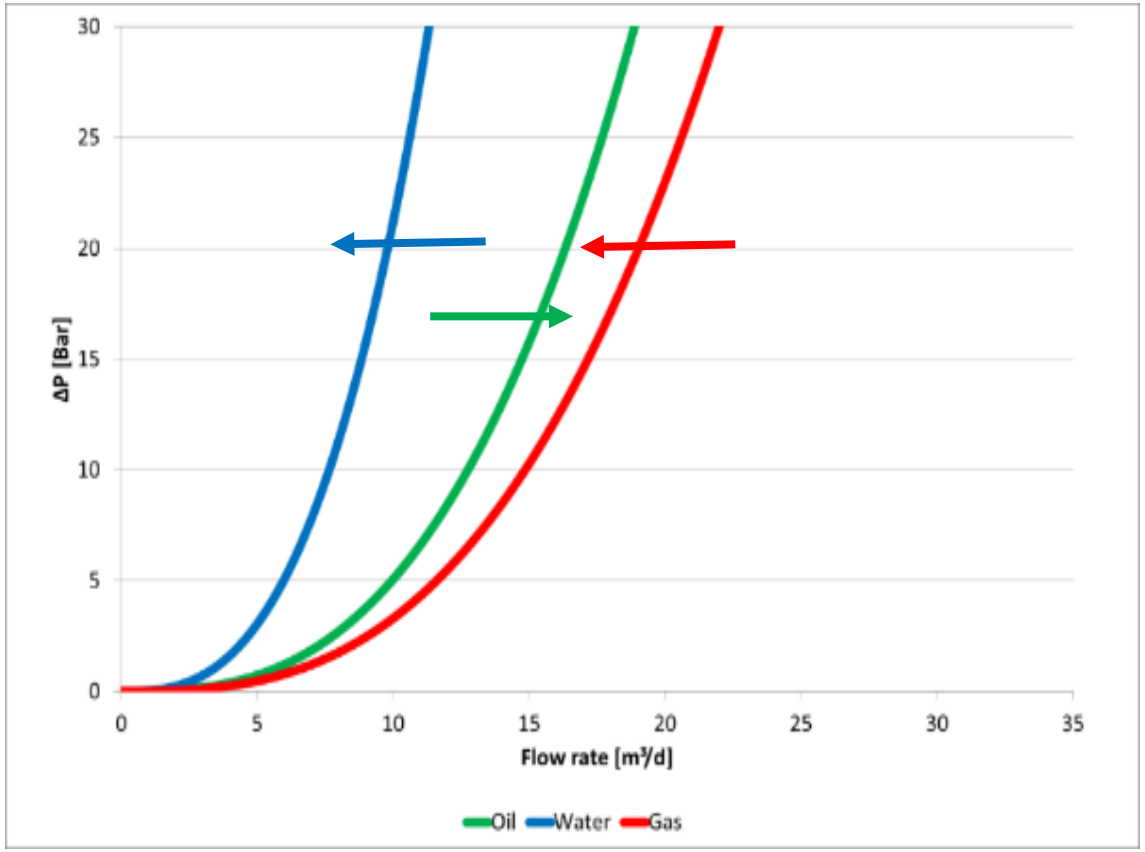
- Designed to choke back gas and water

$$dP = f(flow, viscosity, ..)$$

- Position of disk depends on fluid viscosity
  - Oil : maximum gap
  - Gas/water: minimum gap

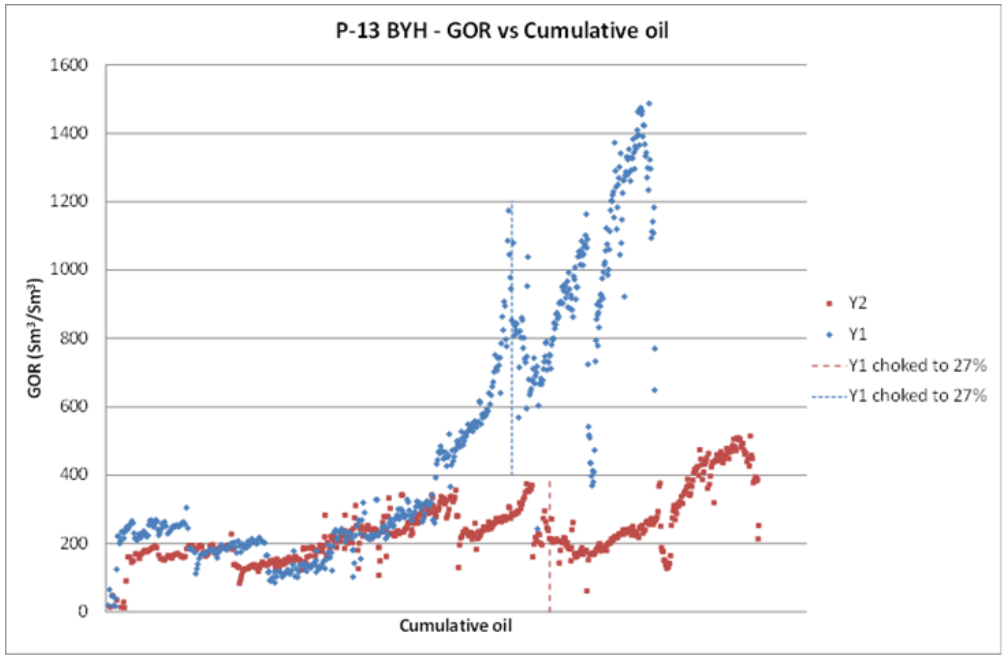


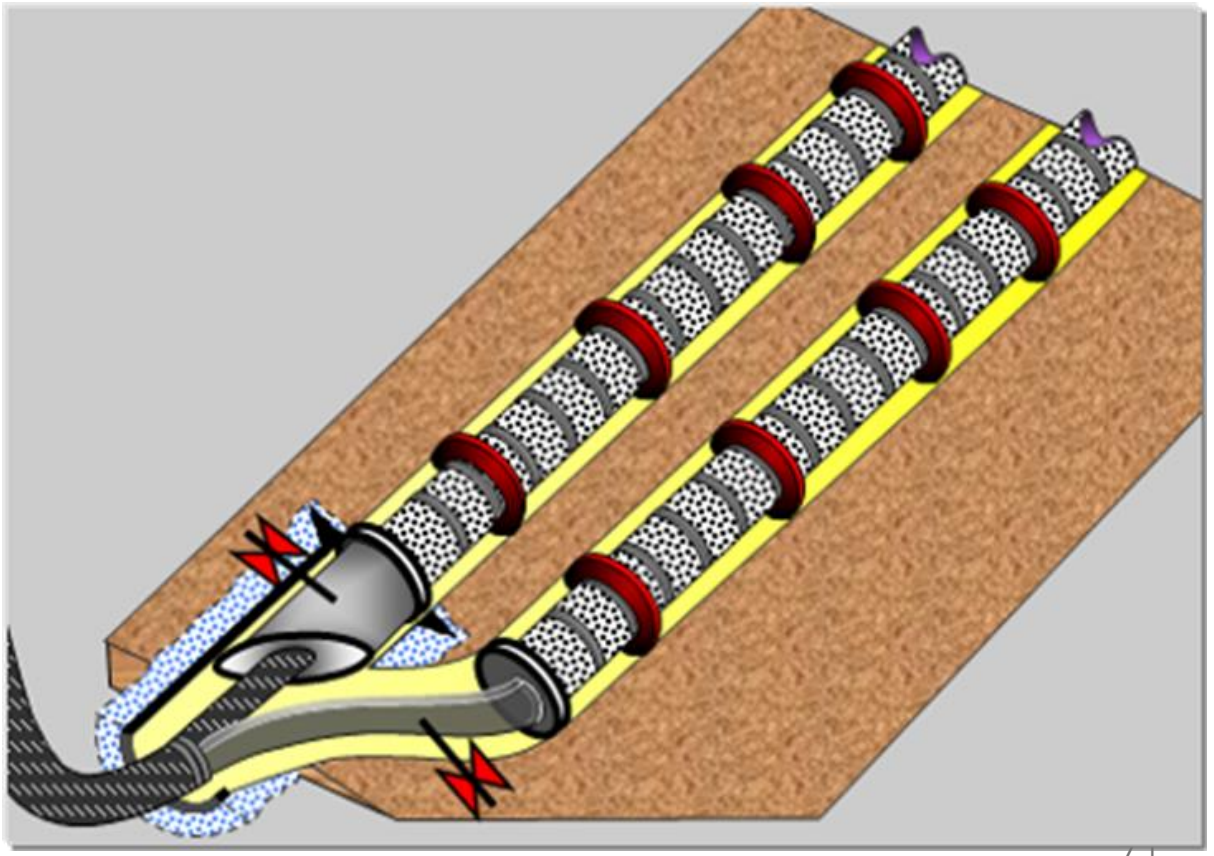
Courtesy of Taqa



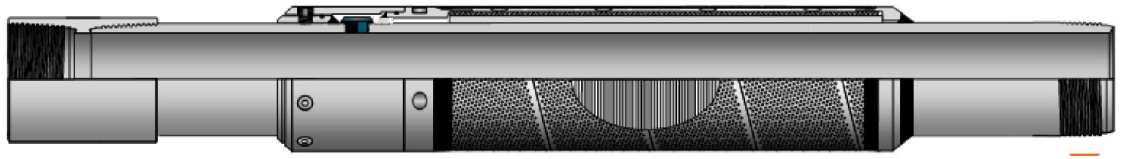
Comparison of ICD and AICD

- P-13 was a two-branched well with parallel well paths
  - Y1 was completed with ICD
  - Y2 completed with AICD
- Significantly more rapid GOR development in ICD-branch compared to AICD branch



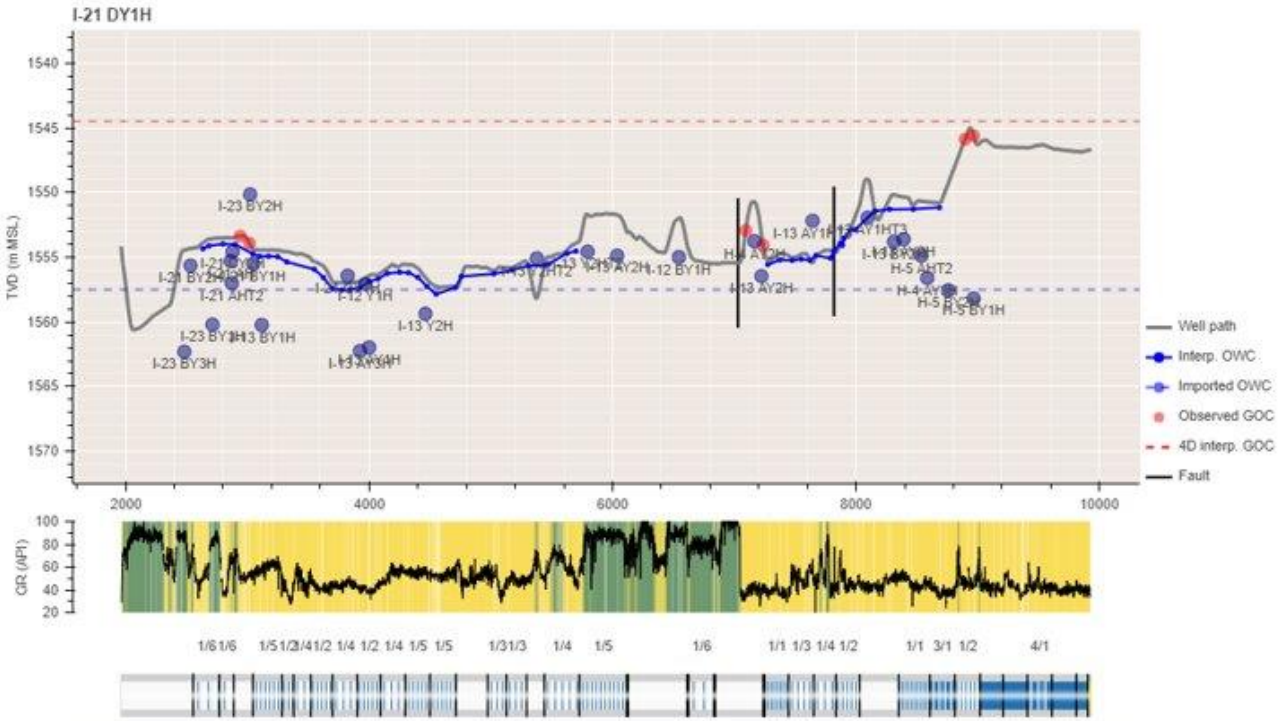


Broad implementation



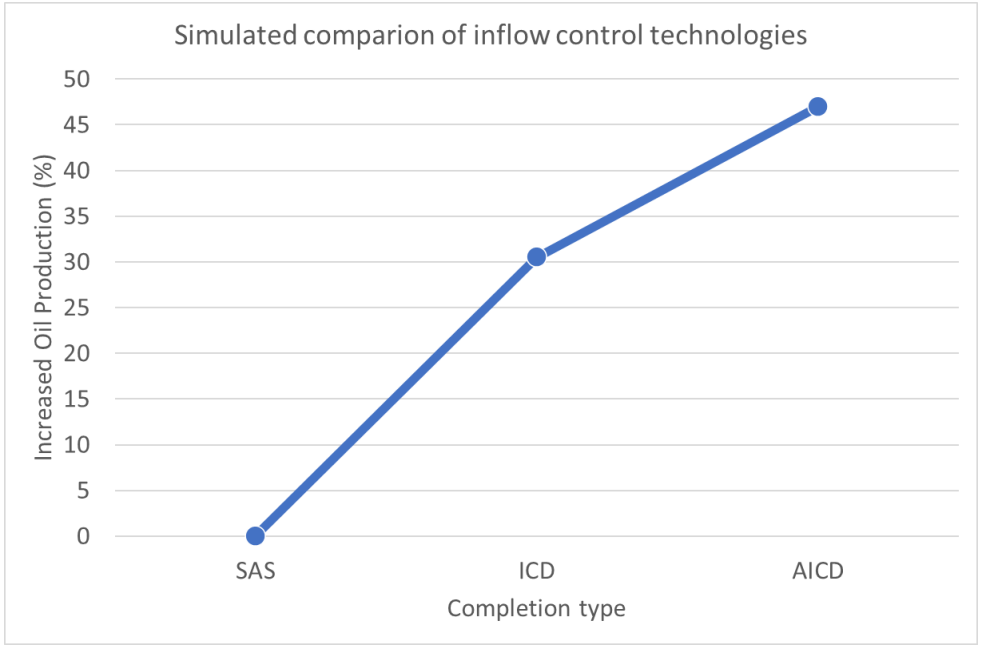
Courtesy of Taqa

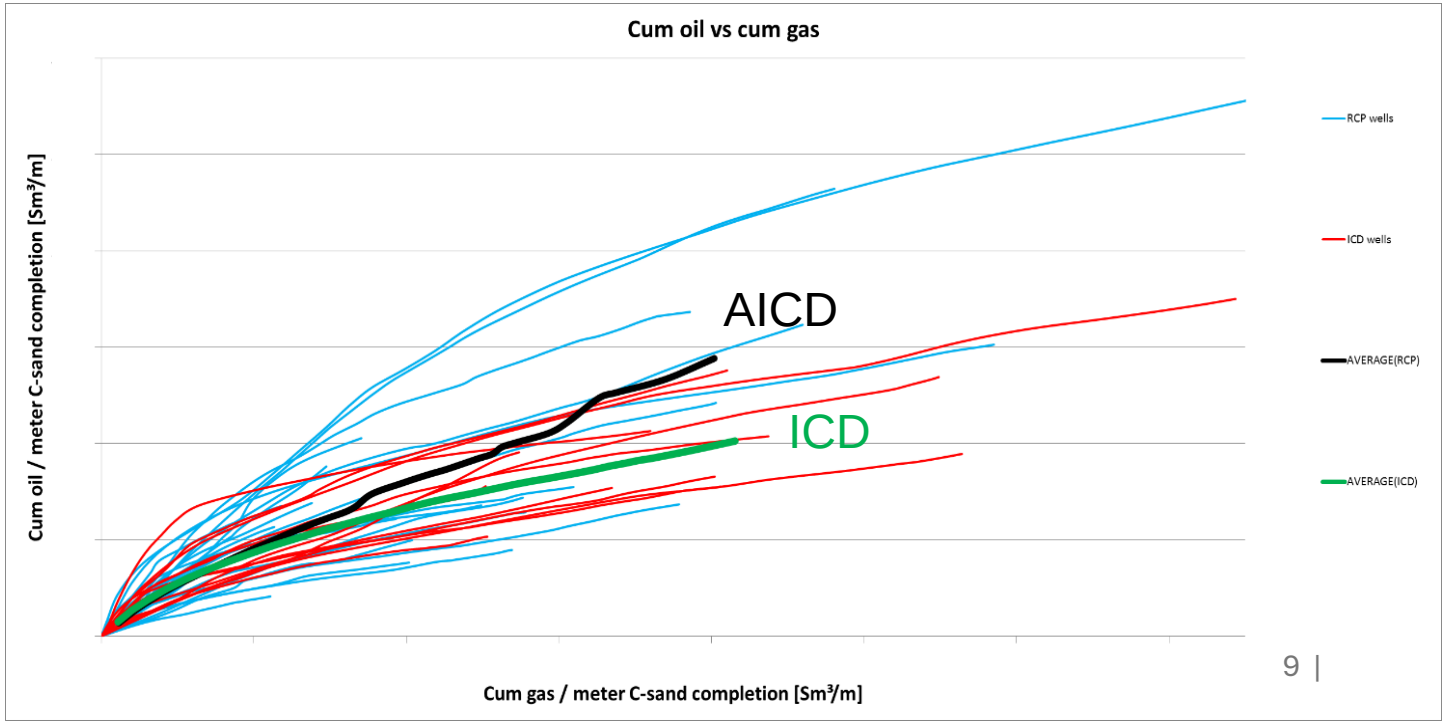
- The RCP valve (AICD) licensed to screen suppliers
  - Design improvement
  - Cost reduction
- Justification and Improved modelling
  - Eclipse keyword
  - NETool near well bore simulator
- Optimization of lower completion
  - Swell packers, screen/blank sections



Quantifying the effect

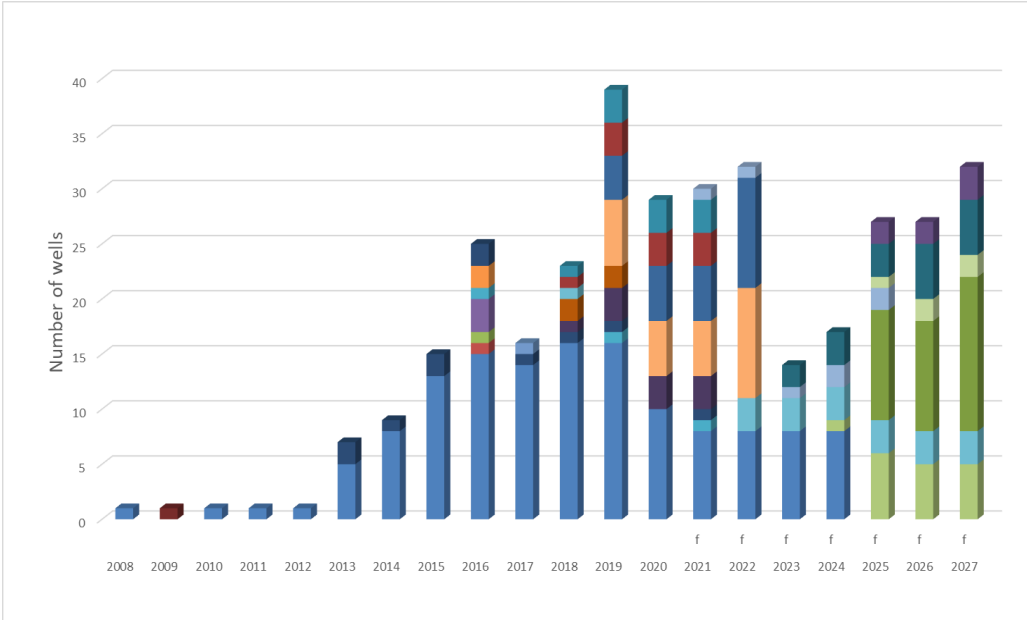
- Show effect to stakeholders (Important)
- Expectations - reservoir simulations
- Production data - statistical comparison





AICD technology today

- Proven technology
  - AICD is now used in many Equinor assets and by other operators
  - AICD technology available from several suppliers
- New and improved AICD solutions becomes available
- AICD technology implemented in simulation tools (Eclipse, NETool, Reveal etc.)
- Multiphase flow loop for testing and qualifying new versions and technologies (Porsgrunn, Norway)



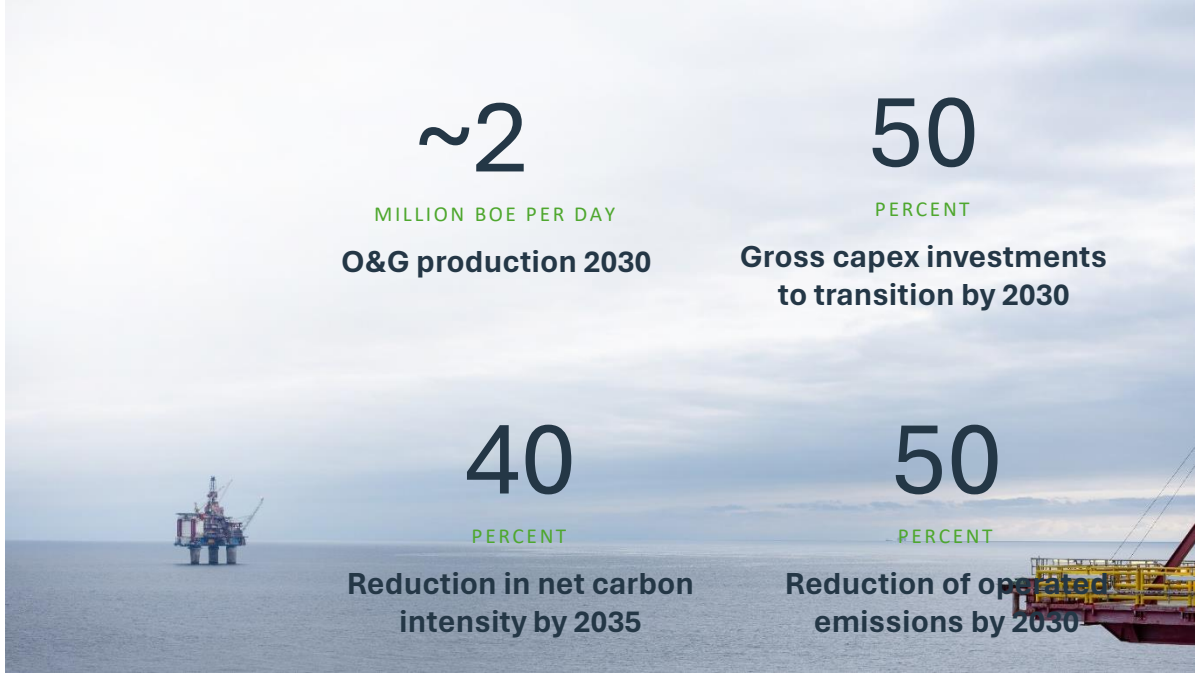
Preparing for the future

Increase oil and gas recovery - and reduce CO2 intensity

Technology needs
- Water shut-off in gas producers
- Increase performance, flexibility and reduce well cost

New technologies – Operator/supplier collaboration
- New AICDs and continuous improvements of existing AICDs - Density driven AICDs
- Retrofit solutions and Electrical ICD

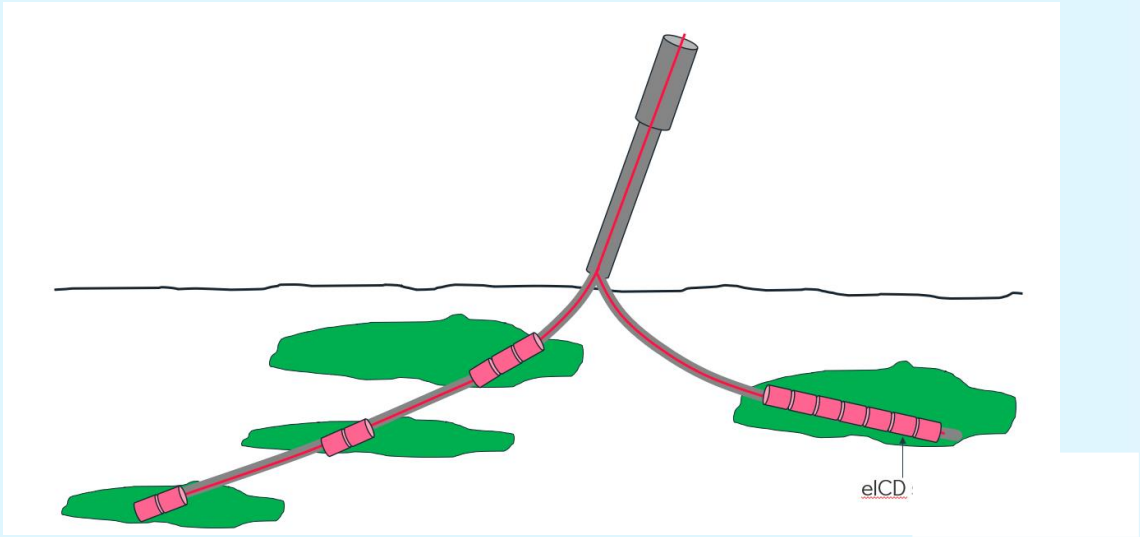
Smart solutions for our wells to come
- Smaller & challenging reservoir targets
- Connecting into existing infrastructure

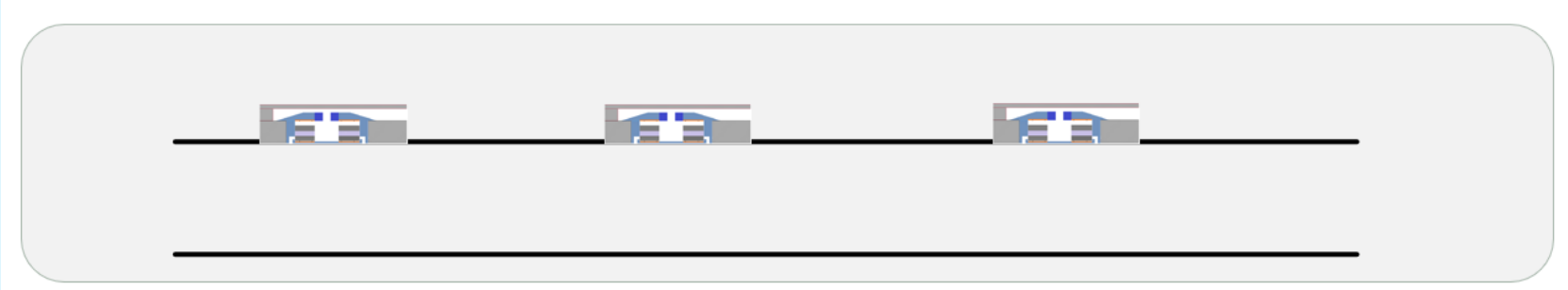


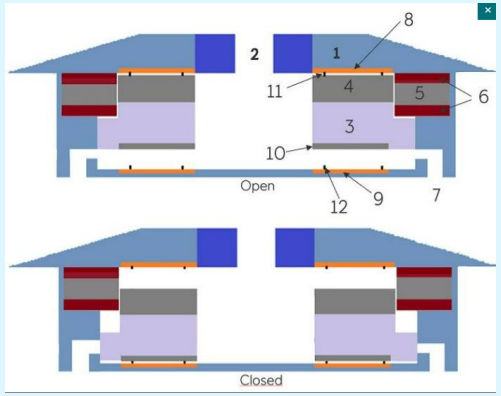
Equinor Electric ICD Well Concept

To get there.
Together

- Electrically operated valves in each screen - cable or powered tubing/screens
- Technology need: reaching more targets in one well & increase production potential per well
- Important, since many of our new wells will be tied into existing infrastructure
- Interval Control Valves vs electrical ICD's
- Supplier collaboration: Co-innovate with partners. Develop solutions together with business areas
- Integrate new ideas - Electromagnetism and smart motors



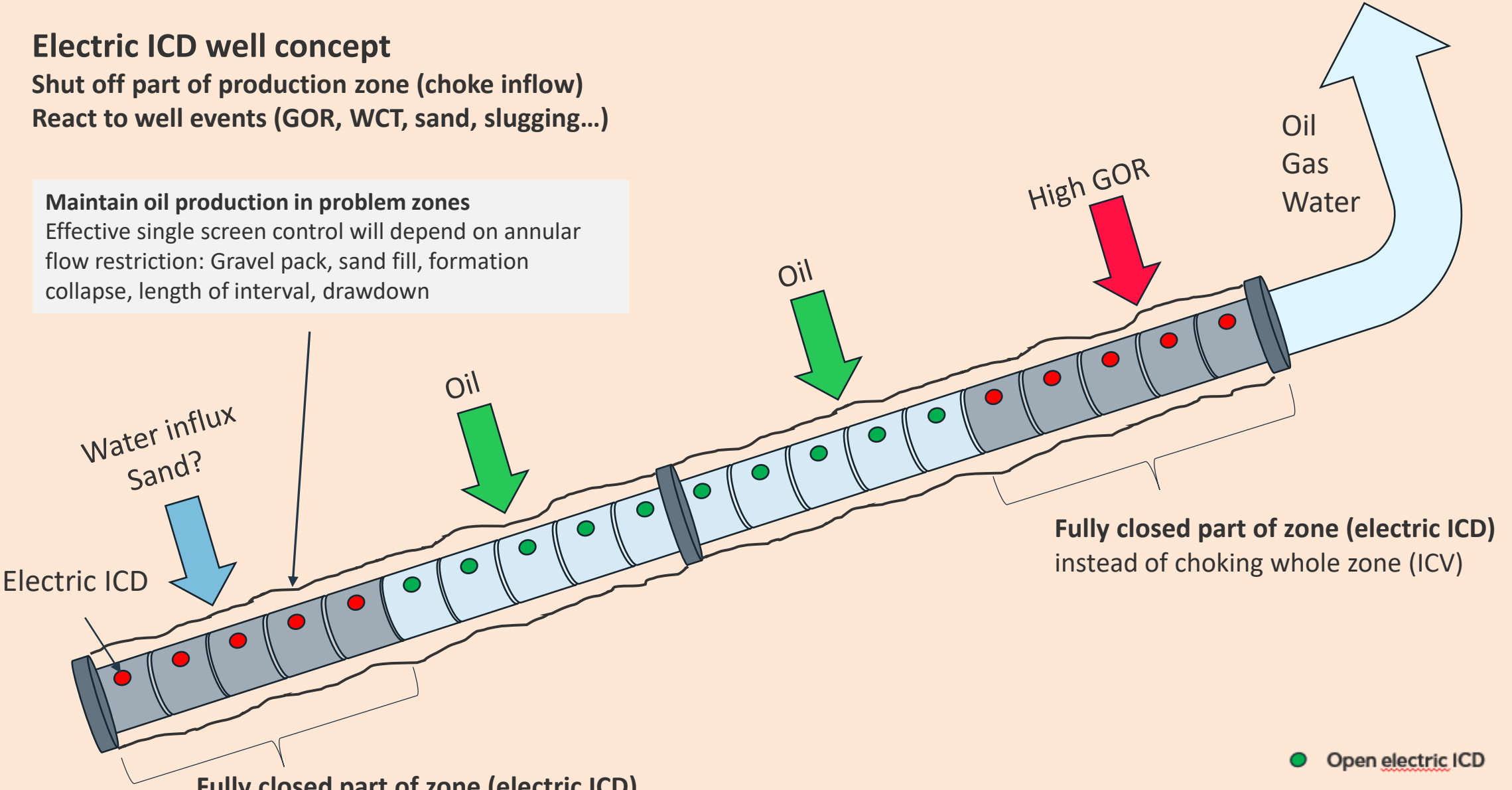




Electric ICD well concept

Shut off part of production zone (choke inflow)
React to well events (GOR, WCT, sand, slugging…)

Maintain oil production in problem zones
Effective single screen control will depend on annular flow restriction: Gravel pack, sand fill, formation collapse, length of interval, drawdown



Time schedule for electric ICD development

	2022	2023	2024	2025	2026	2027	2028
Feasibility study all electric							
Decide on concept							
Validate and test concept							
Control system/Machine Learning							
Full-scale flow loop test							
Qualification - including monitoring and control system							
Implementation first well/asset							
Second well/asset							
Main milestones	SDG1	TRL1/SDG2	TRL2		TRL4/SDG3	TRL5/TRL6	TRL7/SDG4

Acknowledgements

The Troll field, operated by Equinor, including partners (Petoro, Total, Shell, ConocoPhillips)

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Geir Elseth, specialist production technology Equinor

Back-up slides

Transforming through technology

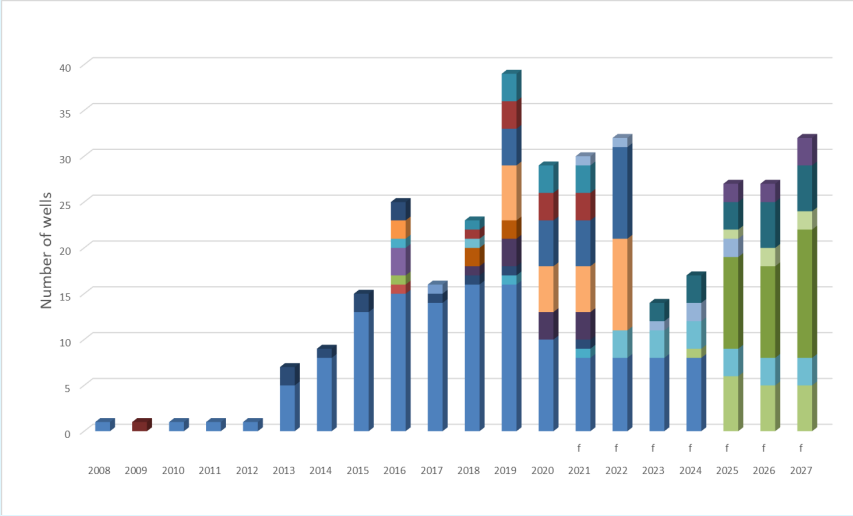
To get there.
Together

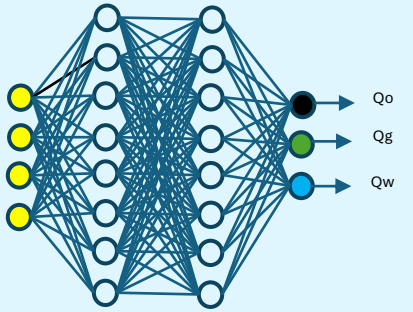
Inflow control technologies

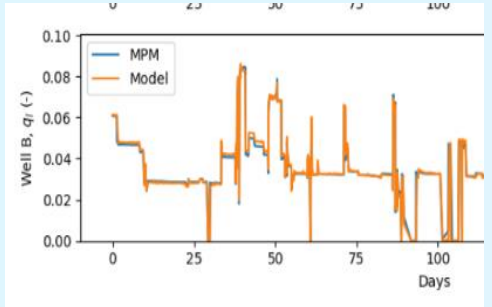
- Improve performance of existing AICD's for gas choking
- Technologies for water choking/shut-off
  - Qualification of new AICD solutions (density driven)
- Wireless inflow control valves technologies
- Electrification of inflow control technologies

Standardization and efficient work processes through digitialization

- Standard software and tools for assessing technology
  - Internal develop software Completor® going open source
    - Modelling wells with inflow control technology
- Digital Production Optimization Solutions
  - Use all available data, efficient data flow,
  - Uncertainties and visualization
  - Reliable sensor and models for rate estimation
  - Machine learning for production optimization and rate estimation







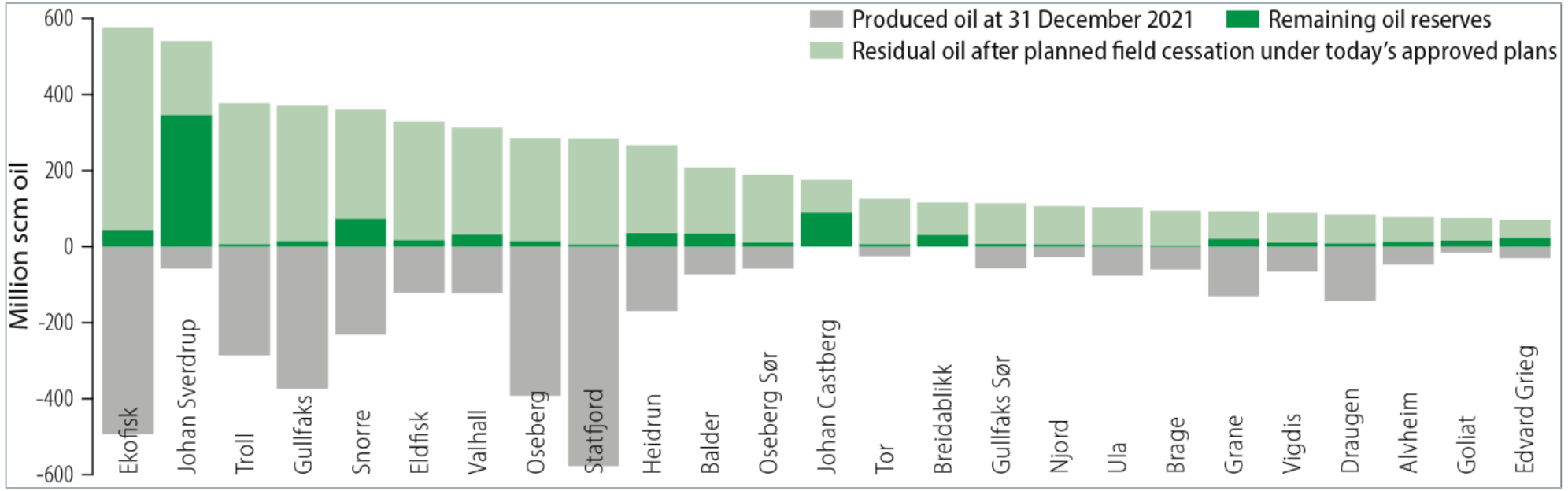
Sees everything

Preparing for the future

- **Small remaining reserves**
  - Many fields in late life
- **Small targets**
  - 2/3 of remaining targets are below 300 000 Sm3
    - Half of these are below 100 000 Sm3
- **Large remaining volumes** not considered producible today (RF~50%)
  - Large IOR potential

Two approaches to address challenge and opportunities:

1. **Increase reserves per well** (combine volumes/targets)
   - Mitigate uncertainty by flexible low-cost smart well technology (digital intervention)
2. **Low-cost wells** - simplified well solutions and TTRD



NPD 2022

Summary

- Increase oil and gas recovery - and reduce CO2 intensity
- Technology needs
  - Water shut-off in gas producers (low viscosity contrasts)
  - Increase performance, flexibility and reduce well cost
- New technologies – Operator/supplier collaboration
  - New AICDs and continuous improvements of existing AICDs - Density driven AICDs
  - Retrofit solutions
  - Electrical ICD
- Smart solutions for our wells to come
  - Smaller & challenging reservoir targets
  - Connecting into existing infrastructure

Huge investment in new test rig at Herøya

Equinor's research center in Herøya Research Park is receiving 130 million NOK for a new major expansion. "Best day at work ever."

A new research rig is being built next to Equinor's existing multiphase rig at Herøya. Here, Eirik Lunde, manager of Equinor's lab and test facilities, and Tor Kjeldby, task lead in flow assurance, are in front of today's multiphase rig and the R&D flagship, built in Herøya Research Park in 1992.

Abstract

The presentation will describe tools for reduction of unwanted fluids. Focus will be on technology development, qualification and implementation and both challenges and opportunities will be addressed.