Experience from implementation of autonomous inflow control (AICD) at the Troll field on the Norwegian continental shelf

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Presenters:
Geir Elseth, Specialist Production Technology Equinor
Lene Amundsen, Leader Petech Equinor

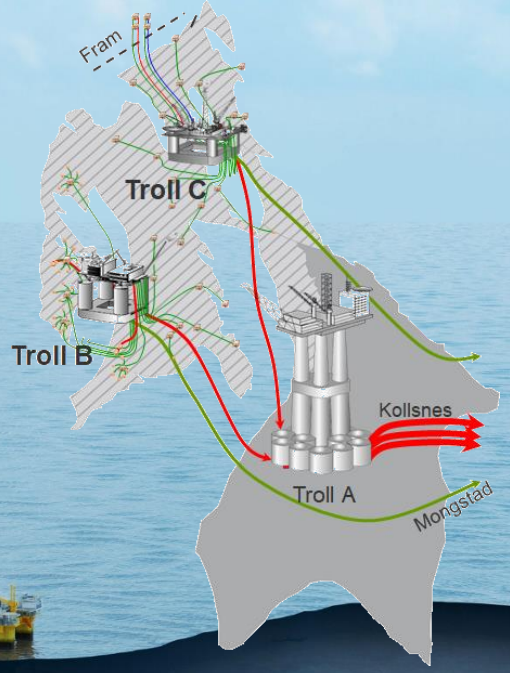
Contributors:
Martin Halvorsen, Leading Advisor Petech Equinor
Andreas Lien, Disc. leader Prod Tech Equinor

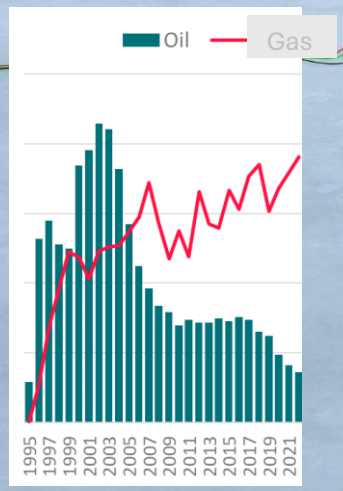
Outline

- The Troll field
- History of AICD
- Field implementation
- Status today
- Future needs in Equinor

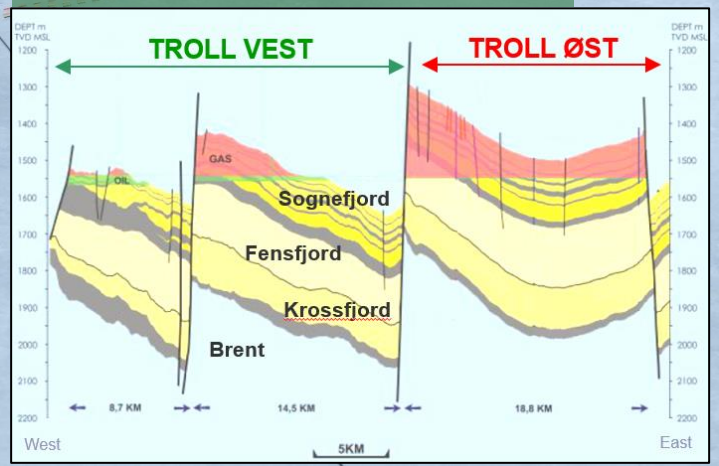
Troll

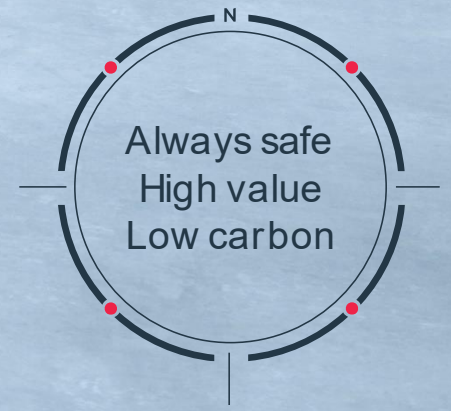
- 3 platforms
- 34 subsea templates, 128 subsea well slots (oil production)
- 48 gas producers at Troll A
- Sandstone reservoirs
- Produced ~1086 MSm^3 o.e.
  - 291 MSm^3 oil
    - Limited potential for IOR.
  - ~1/3 of Norway's gas export
    - Half of the gas reserves remaining



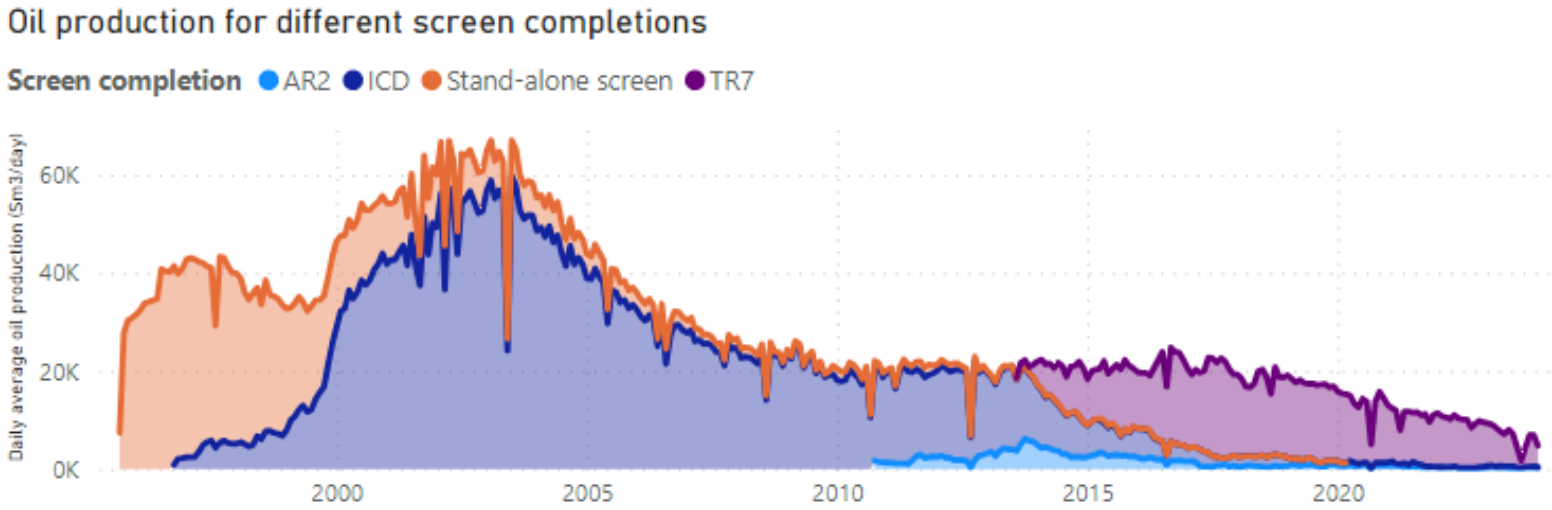


Geological cross-section of the Troll field





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

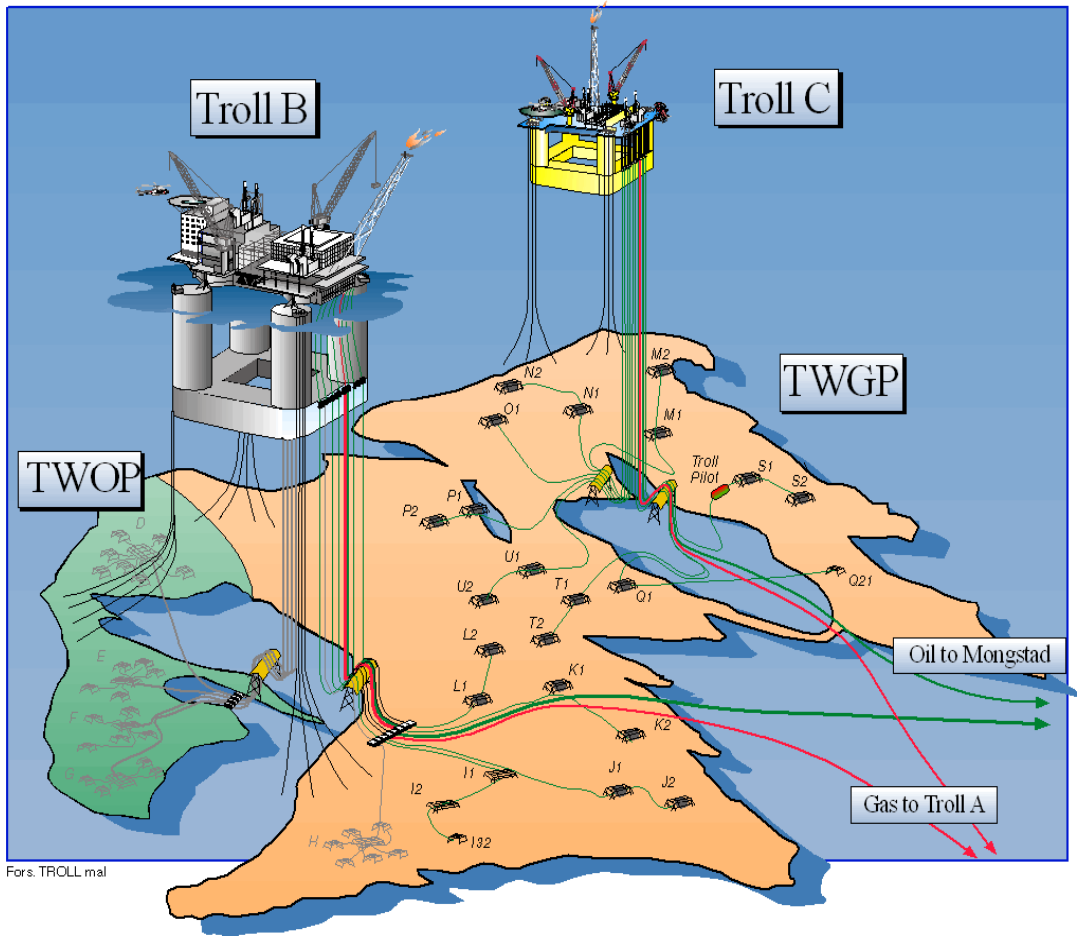
(2006) Swell packer

(2008) AICD

(2023) Last well drilled on Troll Oil

The history of AICD – 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)
  - A few solutions were presented from suppliers, but no game changer
  - Idea from scientists at Equinor research center for a device to choke back gas was selected for implementation at Troll.

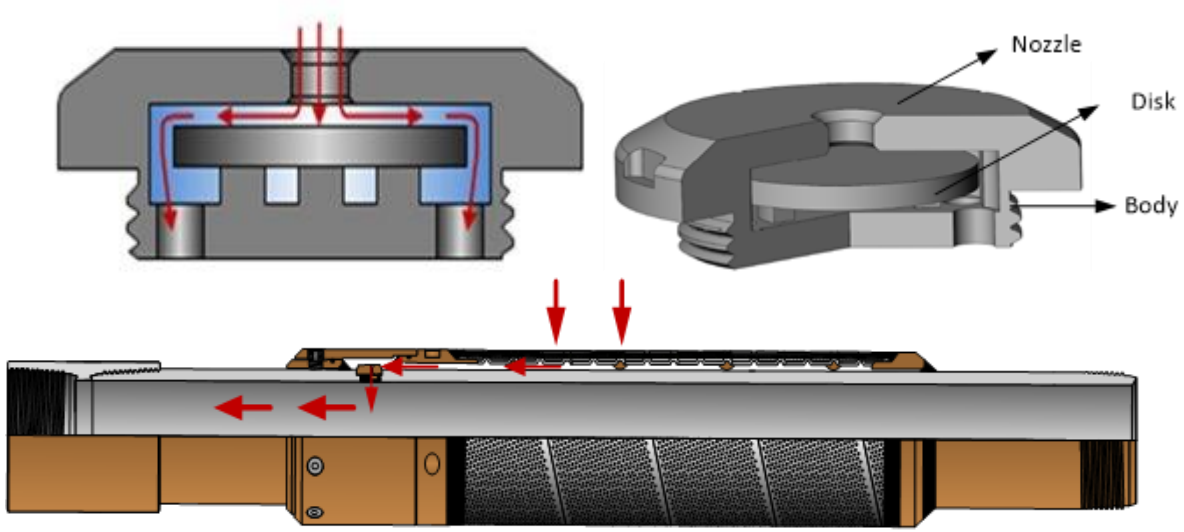


Autonomous inflow control devices (AICDs)

- 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



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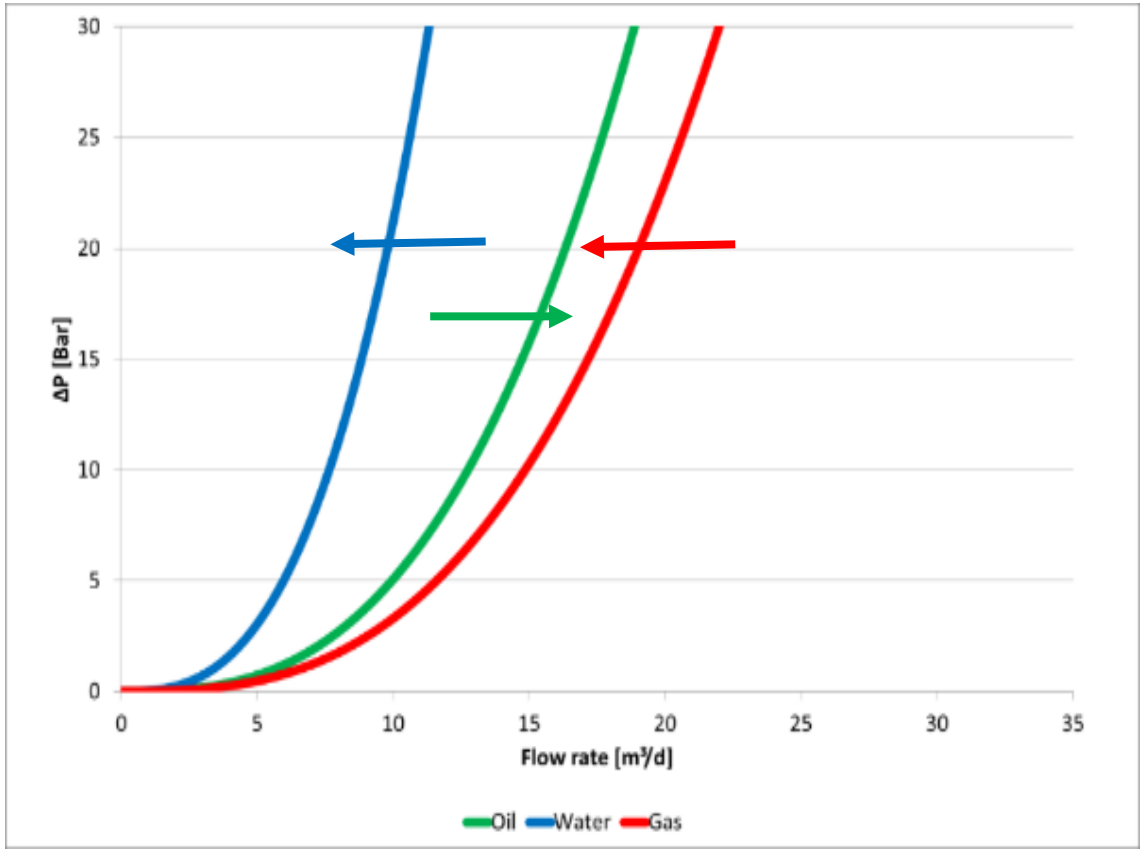
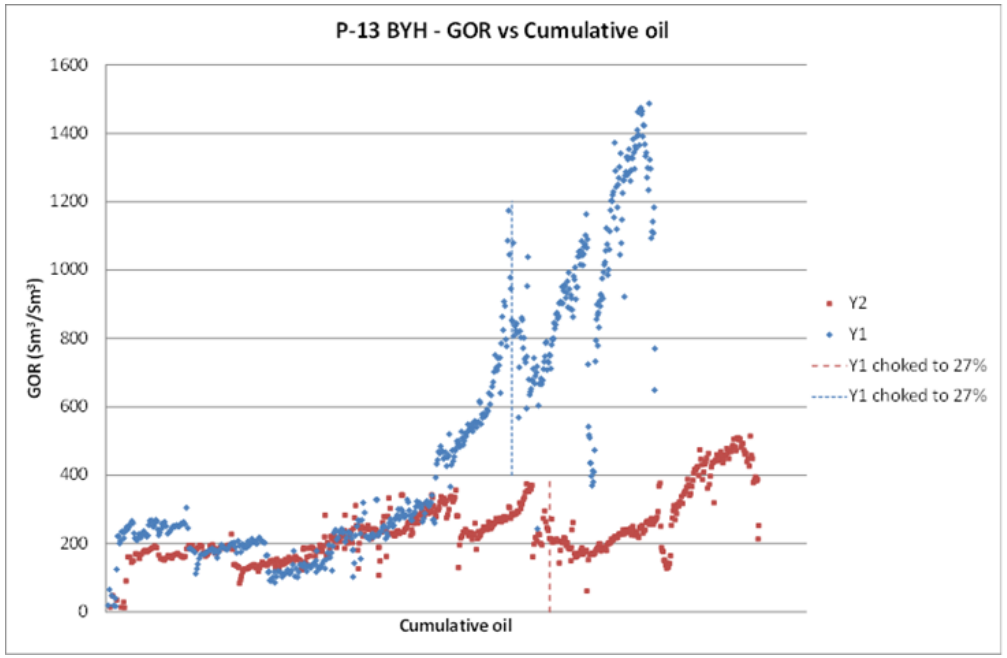
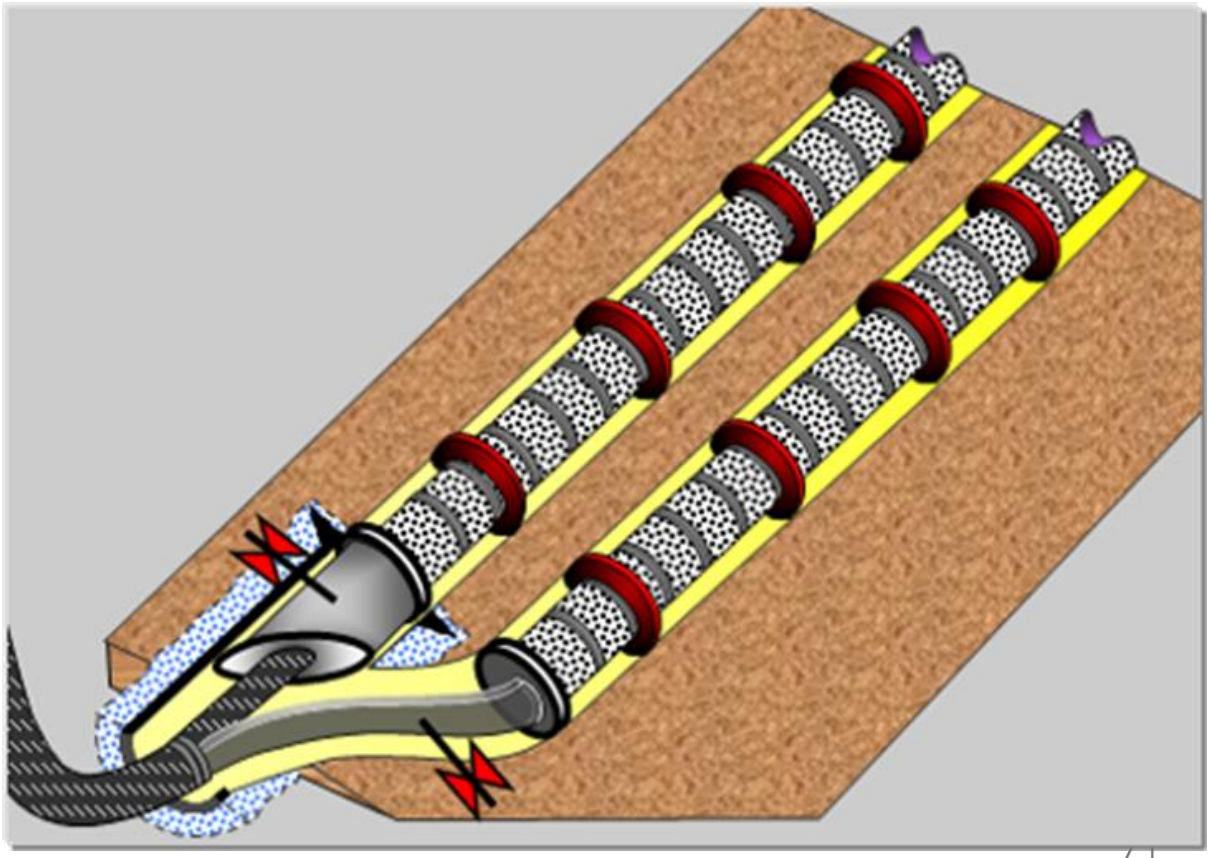


Comparison of ICD and AICD

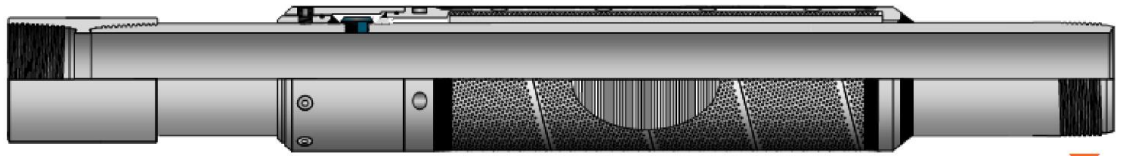
- P-13 was a two-branched well with parallel well paths
  - Y1 was completed with ICD
  - Y2 completed with AICD
- Significantly more rapid GOR development in ICD-branch compared to AICD branch





Broad implementation

- AICD licensed to screen supplier
- AICD design improved by screen supplier
- Costs reduced
  - competition and mass production of AICDs
- Improved model capability
  - Eclipse keyword
  - NETool near well bore simulator
- Increased understanding of how to optimize lower completion
  - Swell packers, screen/blank sections.



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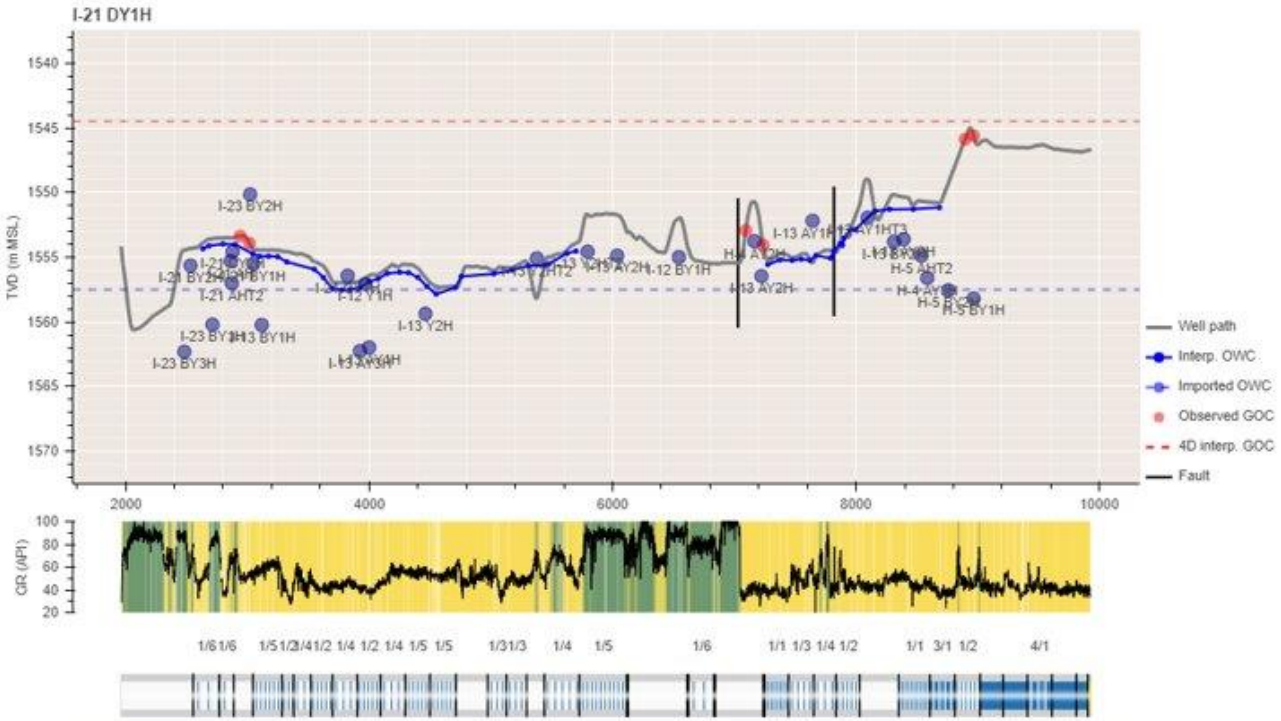
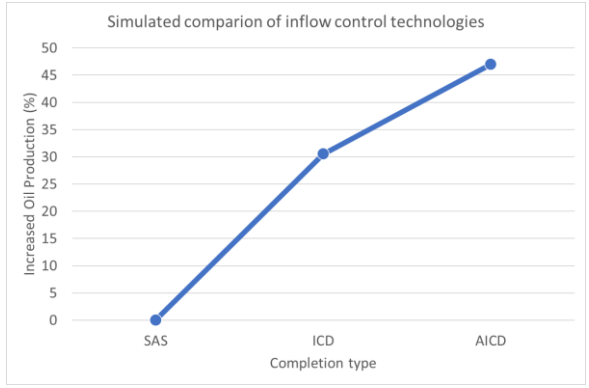
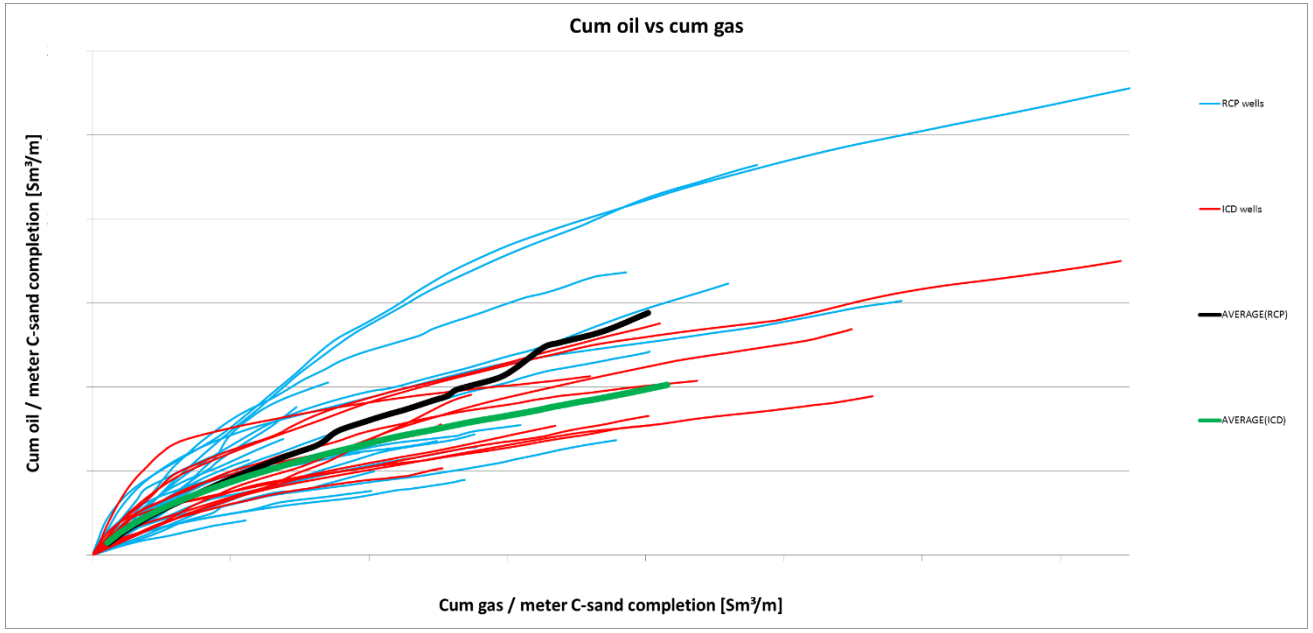


Quantifying effect of inflow control

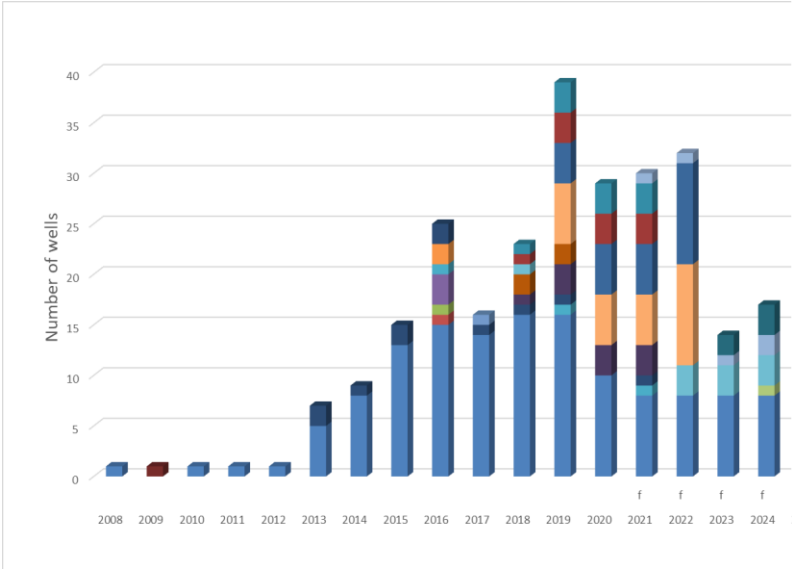
- Important to show effect of inflow control to stakeholders
- Evaluating well performance
  - Reservoir/well simulations
    - Compare well completions
  - Aggregate production data
    - Compare actual to expected well production
    - Statistical comparison of well completions





AICD technology today

- Proven technology
  - AICD is now used in many Equinor assets and by other operators
  - AICD technology available from a number of vendors
- 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

- Smaller and more complex reserves
  - Many fields in late life
  - Tie-in to existing infrastructure
- Large remaining volumes not considered producible today
  - Large IOR potential
- Drill many new wells
  - 50-70 increased recovery wells annually in this decade
  - Use new technology; retrofit multilateral wells, multistage fracking, and advanced completion solutions reducing our cost and the increasing production (BE 20 USD/bbls)
  - 20-30 exploration wells
  - Electrification
  - Low pressure projects, 300 well interventions annually

~2

MILLION BOE PER DAY

O&G production 2030

50

PERCENT

Gross capex investments to transition by 2030

40

PERCENT

Reduction in net carbon intensity by 2035

50

PERCENT

Reduction of operated emissions by 2030

44 E Development and deployment status on inflow control technologies

Challenges to solve

To get there.
Together

- Decrease production of un-wanted fluids
- Production Optimization under uncertainties
  - Uncertainty in well flow rate, availability and reliability in sensor data, models
- Less operational flexibiliy with a changing operational envelope over time
  - Due to late life production and smaller/more complex reservoirs
- Ensure profitable wells
- Determine effect of new technologies, Innovation key enabler

Transforming through technology

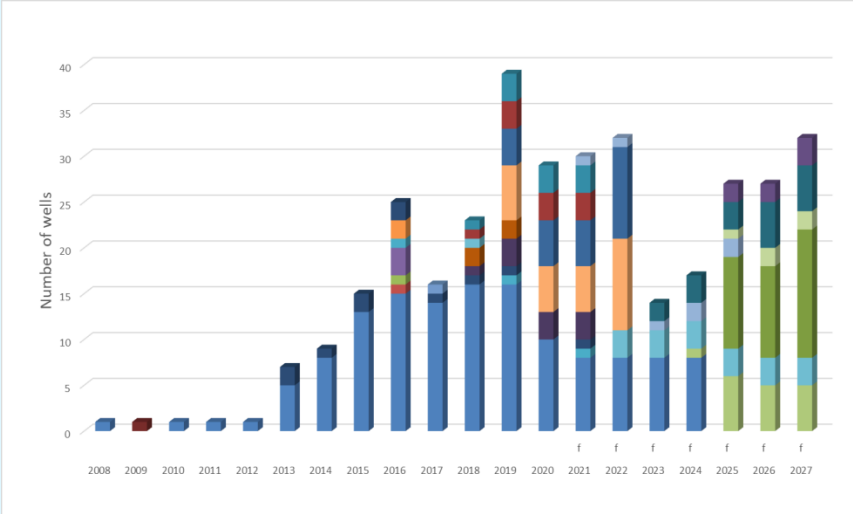
To get there.
Together

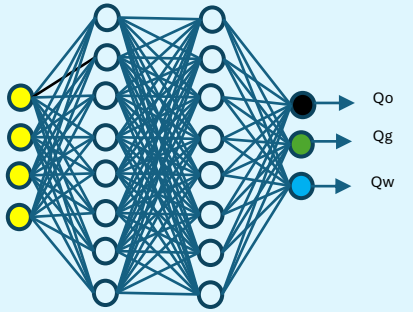
Inflow control technologies

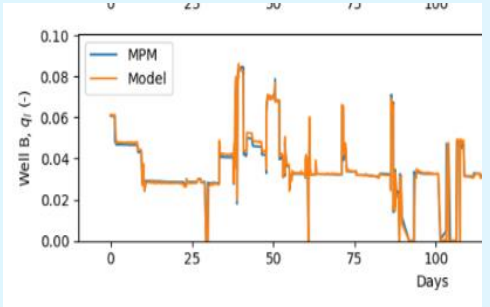
- Improve performance of existing AICD's for gas choking
- Technologies for water choking/shut-off
  - Qualification of new AICD solutions (density driven)
- Wireless inflow control valves technologies
- Electrification of inflow control technologies

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



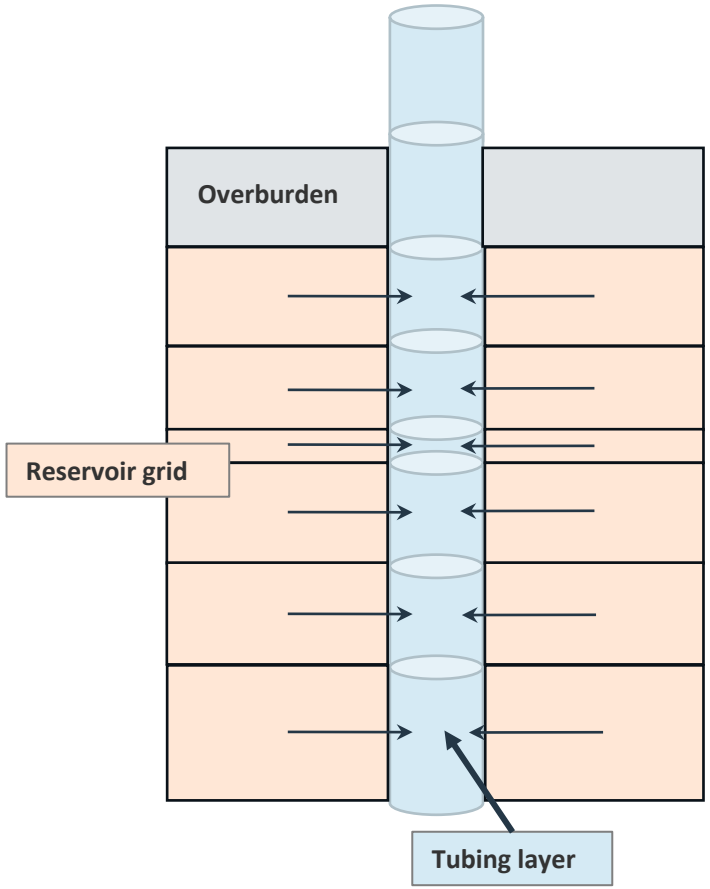




Sees everything

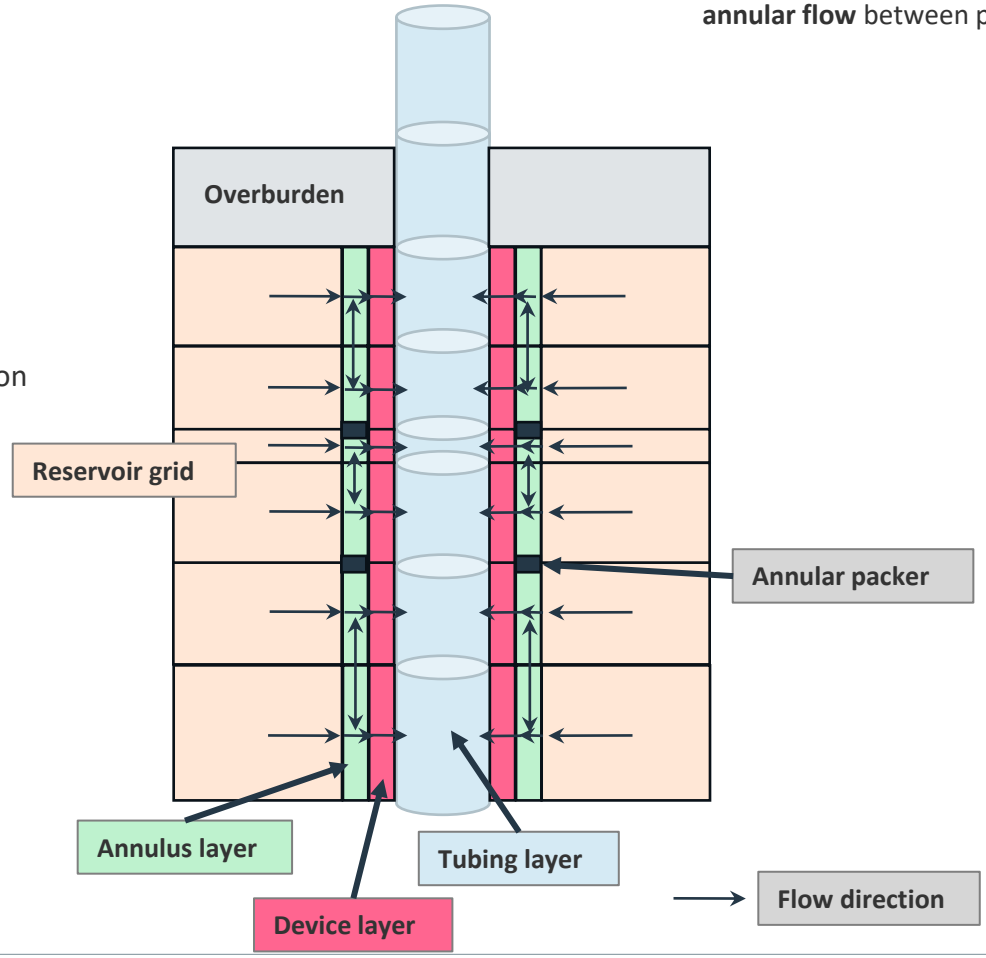
Completor® going open source

Initial multi-segmented well model from a pre-processor



Completor® modification

Completor® lower completion setup



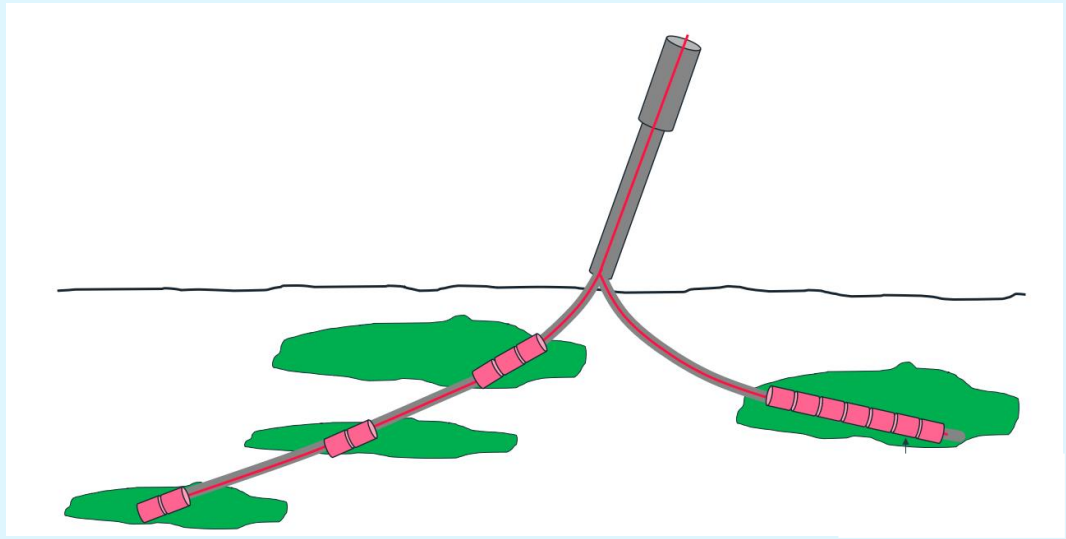
Model single- and multi-branch wells with lower completion such as:

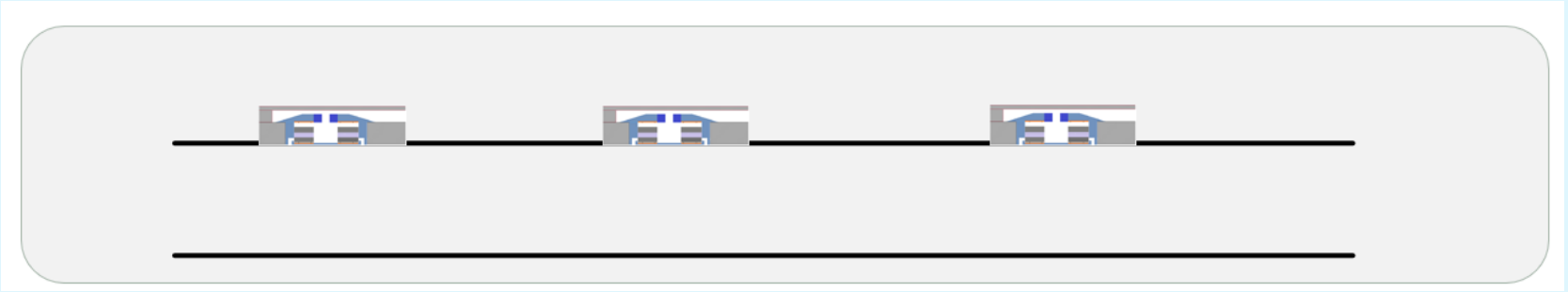
- Tubing screen with inflow control and **gravel packed** annulus
- Tubing screen with inflow control and **annular flow** between packers

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 motor





How

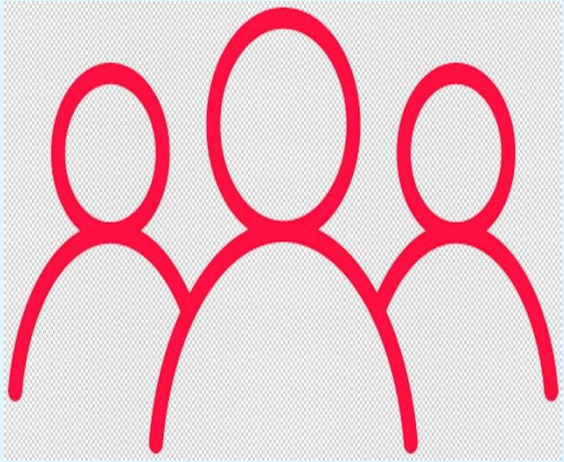
To get there.
Together

Increased external collaboration

- Open source to accelerate implementations, standard way of modelling, further development together with suppliers and academia; E.g. Completor®
- Innovating together
  - Early involvement
  - Understand future challenges e.g. CO2 injection
- Integrated solutions

Robust long-lived teams

- Cross-disciplinary and agile
- Common goal: support customers needs on new technology and use
- Team competence profile; e.g. inflow control team - Production, reservoir, well completion, drilling, software and hardware development
- Build team competence to ensure future capabilities



Acknowlegdments

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

Inflow control technologies and future needs

Geir Elseth, specialist production technology Equinor
Lene Amundsen, leader petec Equinor