Centre for Research-based Innovation
The Research Council of Norway

Subsurface Well Integrity Plugging and Abandonment

Bore- og brønnfagdag i Trondheim
P&A and well control – selected R&D results

SWIPA – P&A– selected R&D results

Trondheim, November 13, 2025

Elie Ngouamba, SINTEF,
Research scientist and Task Manager in SWIPA

SINTEF NORCE NTNU Norwegian University of Science and Technology IFE Universitetet i Stavanger

Topics

- SWIPA - key targets and organisation
- The SWIPA work packages
- SWIPA projects with specific relevance to P&A and **slot recovery** – *selected results*
- Priorities of well integrity topics in SWIPA
- Collaboration

SFI SWIPA – in short

- **SFI - Centre for Research-based Innovation**
  - **Purpose**; further develop elite, creative research and innovation groups in close collaboration with industry
  - 8 years duration (2020 – 2028)
  - Research Council Norway total financing 96 mill NOK , operating companies 55 mill NOK

- **SWIPA industry partners**
  - 5 R&D partners
  - 4 financing partners
  - 28 in-kind contributing partners
  - SWIPA academic partners: Brazil, US, Canada, Japan, the Netherlands

R&D partners:

SINTEF, NORCE, IFE, NTNU, Universitetet i Stavanger

Financial industry partners:

AkerBP, equinor, Harbour Energy, vår energi

In-kind industry partners:

Baker Hughes, Archer, CANNSEAL, Disruptive Value Group, əDrilling, elogix, EXEDRA, FloPetrol Well Barrier, Funzionano, GCE NODE An industry-driven cluster for ocean technologies, Huisman, HydraWell, Innovation Energy, MAERSK DECOM, Net Zero Technology Centre, Prores, RESTONE, Saferock, ScanWell, slb, STRATUM Reservoir, TYRFING Innovation as, WellGuard, WELLSTRØM, Havtil, NET-ZERO GEOSYSTEMS, CODA Centre of Decommissioning Australia, PTAC Petroleum Technology Alliance Canada

Swipa | Subsurface Well Integrity Plugging and Abandonment

- ***SFI objective:*** To obtain a **scientific understanding** of permanent well barriers and allocate for improved well barrier design methodologies
- ***Benefit:*** Long term well integrity, addressing costs, materials, barrier lengths, operations
- ***Reuse***: Potential for converting petroleum wells into other applications, fluid (CO_2 and H_2) and material repository and geothermal operation is also addressed

The purpose of the Centres for Research-based Innovation (SFI) is to build up and strengthen Norwegian research groups that work in close collaboration with partners from innovative industry and public enterprises. The Research Council of Norway (RCN) announced June 12 2020 their selection of new SFI centres including SWIPA. The centre will receive annual grants from autumn 2020 onwards, centre duration 8 years.

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Swipa | Subsurface Well Integrity Plugging and Abandonment

The overall centre objective is to **obtain a scientific understanding** of permanent well barriers and allocate for **improved well barrier design methodologies.**

The term subsurface integrity comprises important industries and societal issues for the nation. It is a key for utilization and abandonment of subsurface petroleum resources and reservoirs, utilization of deep geothermal energy, subsurface hydrogen storage and integrity for safe disposal of CO_2 and nuclear waste.

In particular for the North Sea basin, more than 7 000 petroleum wells are scheduled for P&A (plugging and abandonment of wells) from now until 2050. The highest portion of field decommissioning cost is represented by P&A, estimated to be 44% of the total decommissioning costs. In Norway alone, the estimated costs are in the order of 800 billion NOK according to the Norwegian Oil and Gas Association.

The centre will utilize and further develop infrastructure such as the Norwegian P&A Laboratories (NorPALabs) and international alliances.

It is the ambition for SINTEF and R&D partners institutions NORCE, IFE, NTNU and UiS to establish an attractive innovation centre on subsurface integrity, disposal and storage. The consortium and collaboration will include operating companies, vendors, service companies and authorities, in addition to international academic partners.

Host institution :

SINTEF

Contact: Research Manager Harald Linga, harald.linga@sintef.no , +47 916 635 23

R&D partner institutions :

NORCE — IFE Institute for Energy Technology — NTNU Norwegian University of Science and Technology — UiS Universitetet i Stavanger

SWIPA – the P&A challenge

Technical performance:

No leakage - for eternity

Cost cut target:

The cost reductions target for P&A operations in particular is set to 50 % *including impact from revised standards and regulations, new operations and well barrier materials.*

Expectations:

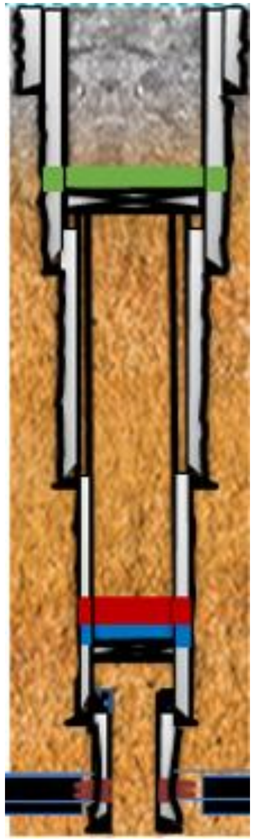
Bloomberg

Business

Norway Bets on Tech to Cut $100 Billion North Sea Oil-Well Bill

- New research center to study cheaper ways to close old shafts
- High abandonment costs can hinder sales of aging oil deposits

By Lars Erik Taraldsen, Laura Hurst, and Morten Buttler
July 8, 2020, 1:03 PM GMT+2



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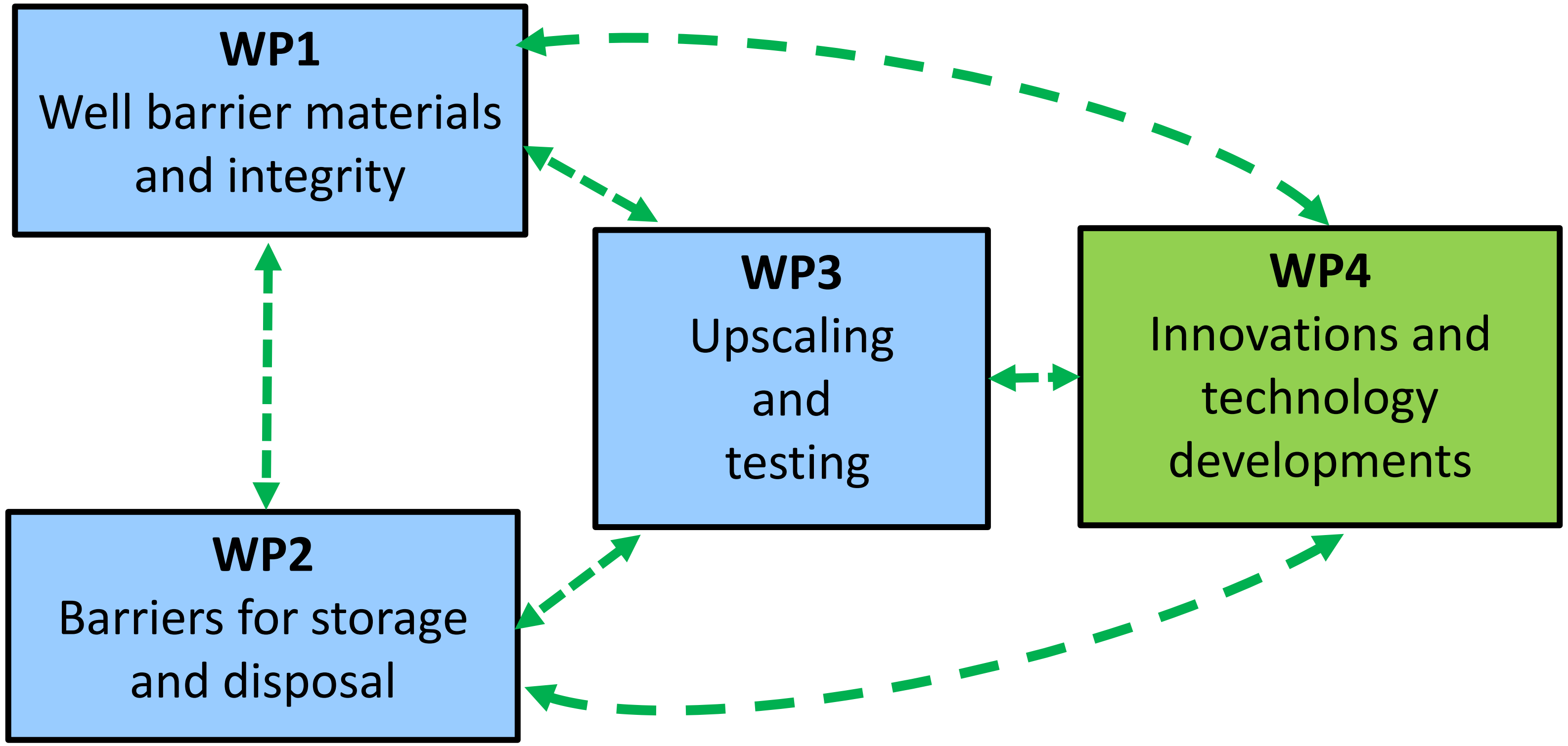
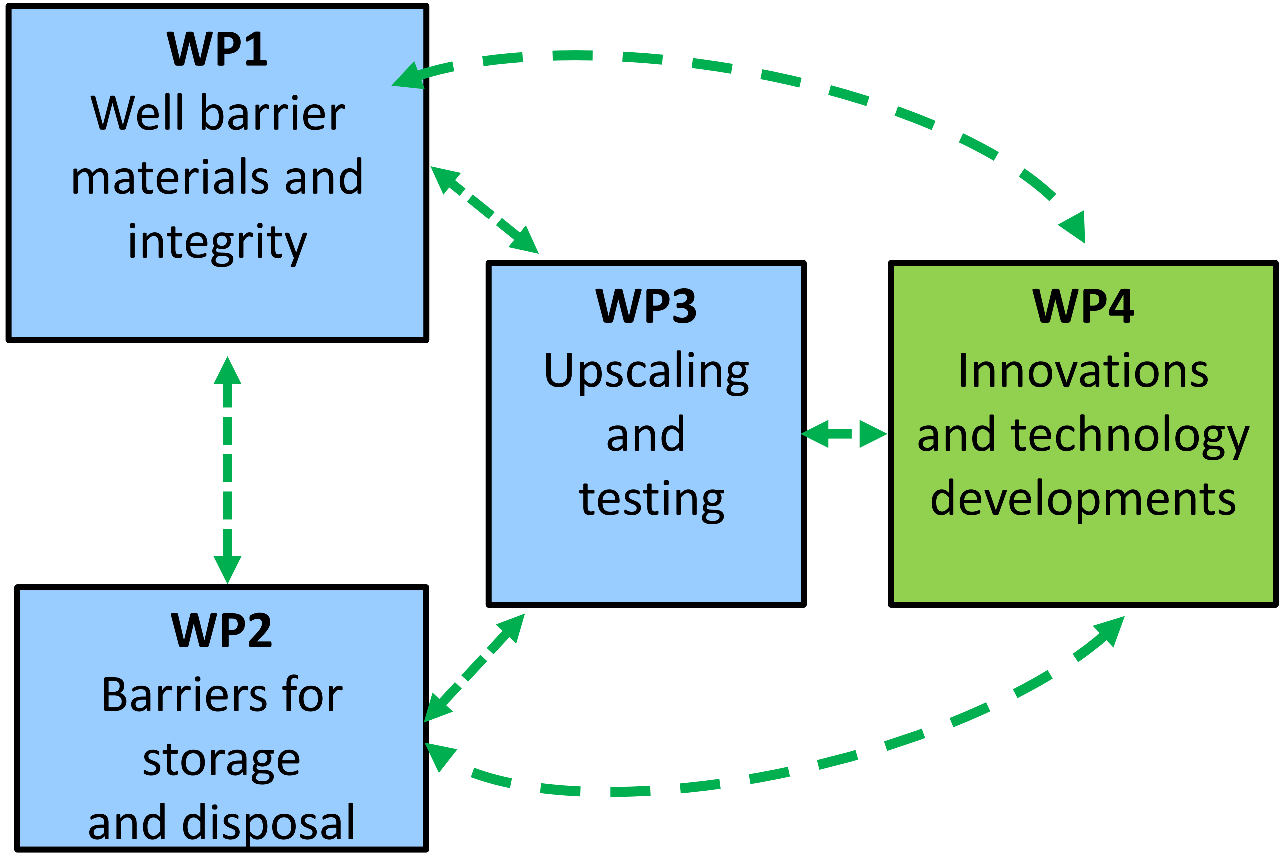
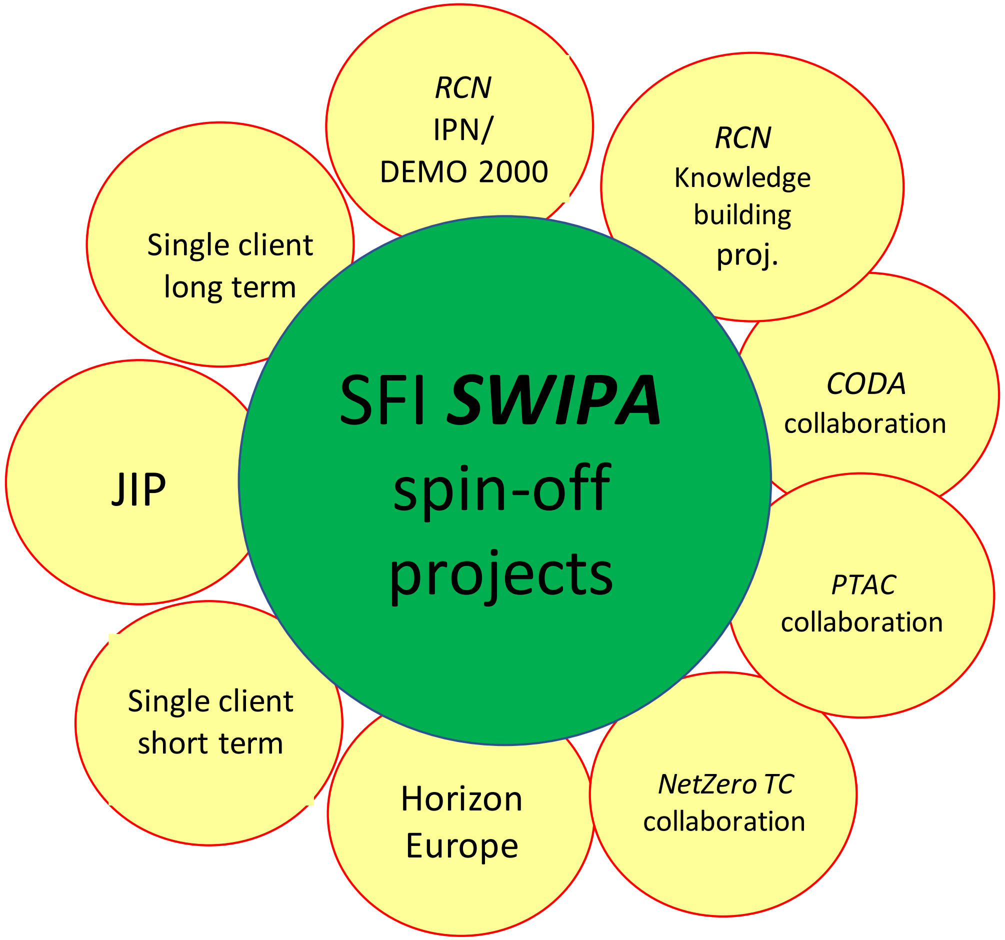
The role of the Work Packages



- Performance description and design methodology
  - Performance testing at lab and large scale
    - Results; evaluation and design for higher TRL qualification
- Impact on Standards and Regulations?

SWIPA results – elevating the TRL with spin-off





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- Selected results with specific relevance to

  Casing removal for P&A and **slot recovery**
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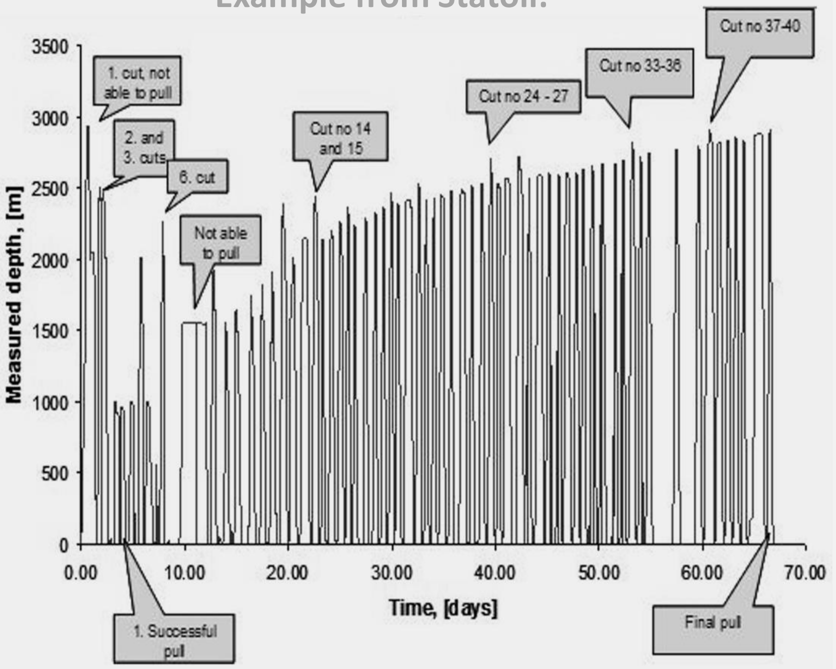
SWIPA Project example:

Casing removal for P&A and slot recovery

Concerns:

- Slot recovery operation implies casing removal
- Casing pulling challenges frequently occurring due settled solids like barite
- Onset of high frictional resistance – impact from fluid content
- Potential for efficiency and reliability of side tracking and well abandonment operations, ultimately lowering the operational costs and risks

Example from Statoil:



Casing removal took **2 months**

- Casing stuck in clay-like settled mud
- Casing had to be cut into 40 parts
- 2 days to retrieve each part to surface

Source: http://sysla.no/2015/03/30/oljeenergi/statoil-etterlyser-grundere-tjen-stort-pa-bronnplugging_45477/

SWIPA Projects, with specific relevance to

Casing removal for P&A and slot recovery

WP 1 - Well barrier materials and integrity
P1.1: Sealing ability of plugging materials
P1.2: Verification and sealing ability of annulus barrier materials
P1.3: Zonal isolation in shallow gas zones
P1.4: Bismuth applications in well completion and P&A
P1.5: Settled barite as barrier material

WP 3 - Upscaling and testing
P3.2: Handling of alternative barrier materials
P3.3: Barrier material placement
P3.4 Upscaling of alloy-based material systems
P3.5 Large scale settled barite testing

SWIPA Projects, with specific relevance to

Casing removal for P&A and slot recovery

Solutions addressed in SWIPA:

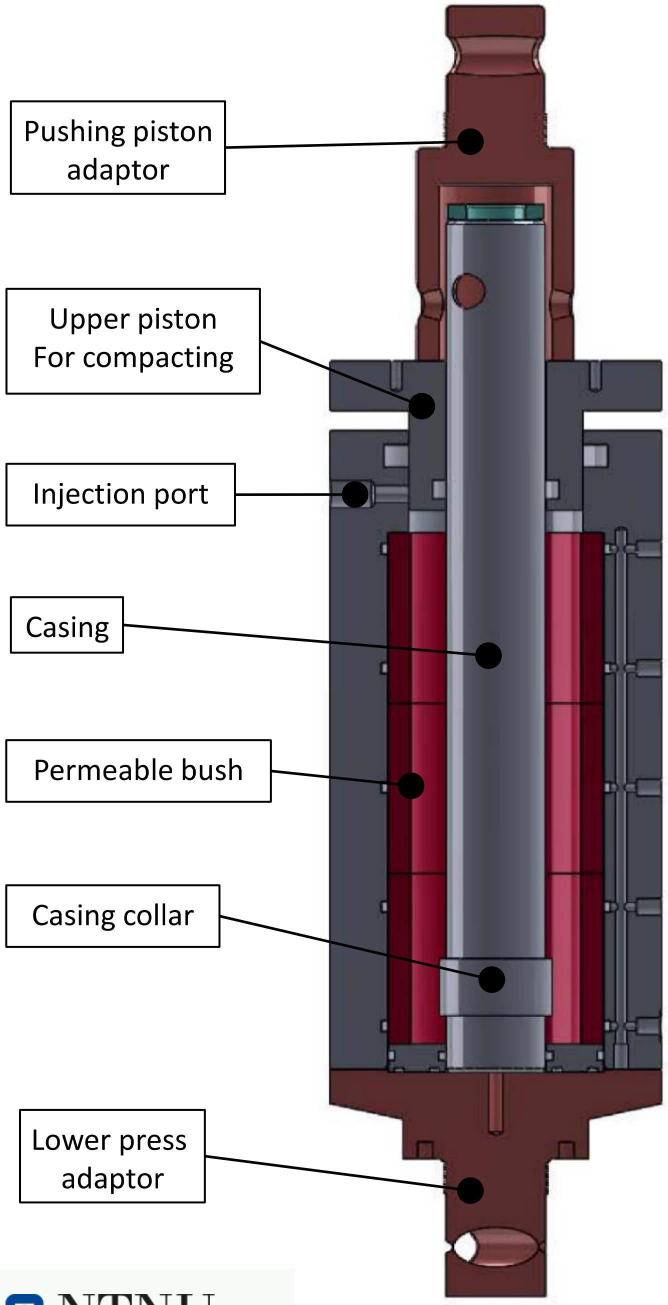
- Method for reducing high frictional resistance; milling holes above casing collars to reduce pulling forces (P1.5)
- Method for dispersing settled barite for reducing frictional resistance (P1.5/P3.5)
- Investigation of manipulating permeability for settled barite, addressing its potential as well barrier (P3.5)

Project P1.5

Project P3.5

Method for reducing high frictional resistance; milling holes – lab set-up

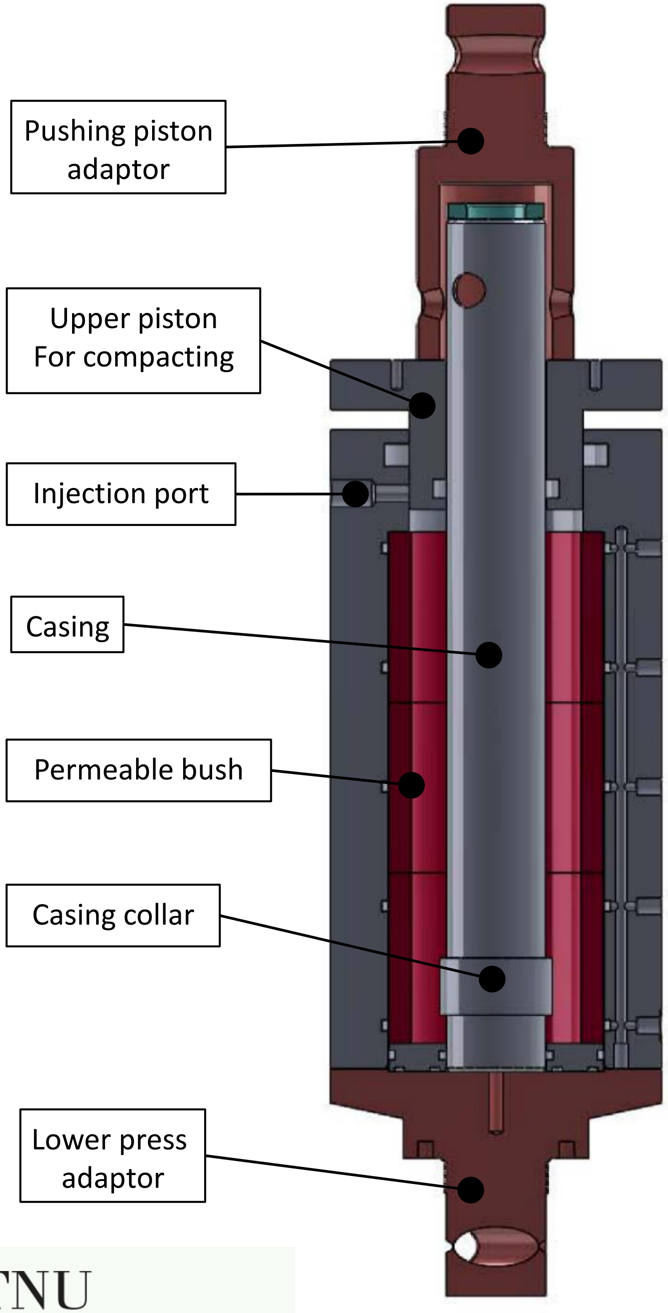
Parameter	Value
Casing outer diameter	60 mm
Casing length	50 cm
Collar diameter	68 mm
Annulus inner diameter	102 mm
Pulling distance	200 mm



Experimental approach

- Test unit: Electromechanical laboratory press, pulling force capacity 300kN
- Settled barite, initial pumpable slurry 2.56 kg/l, filling annulus
- Extracting known water volumes through sintered outer pipe by piston
- Inner casing pulled at constant speed while measuring pulling force

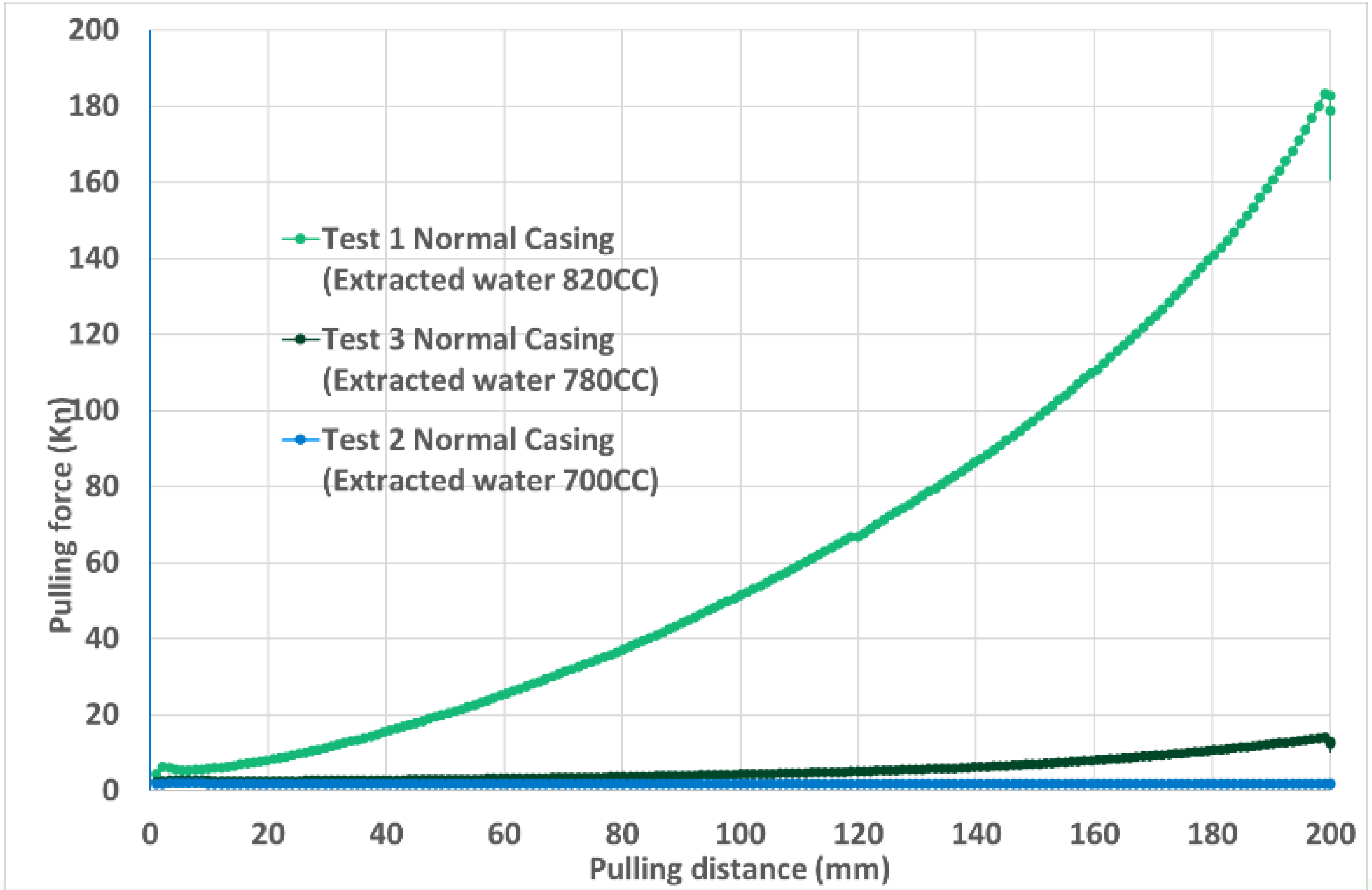
- Manipulation of the permeability for settled barite, addressing its potential to be dispersed or as well being a barrier



Impact from water content/ hardness in settled barite

The pulling force is very sensitive to hardness of the sediment.

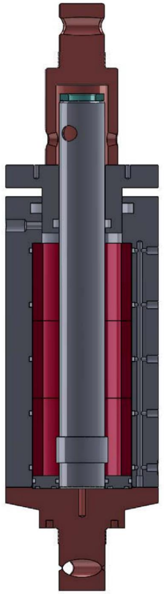
Abrupt change in pulling force going from 780 to 820 cc water extracted from the settled barite volume.

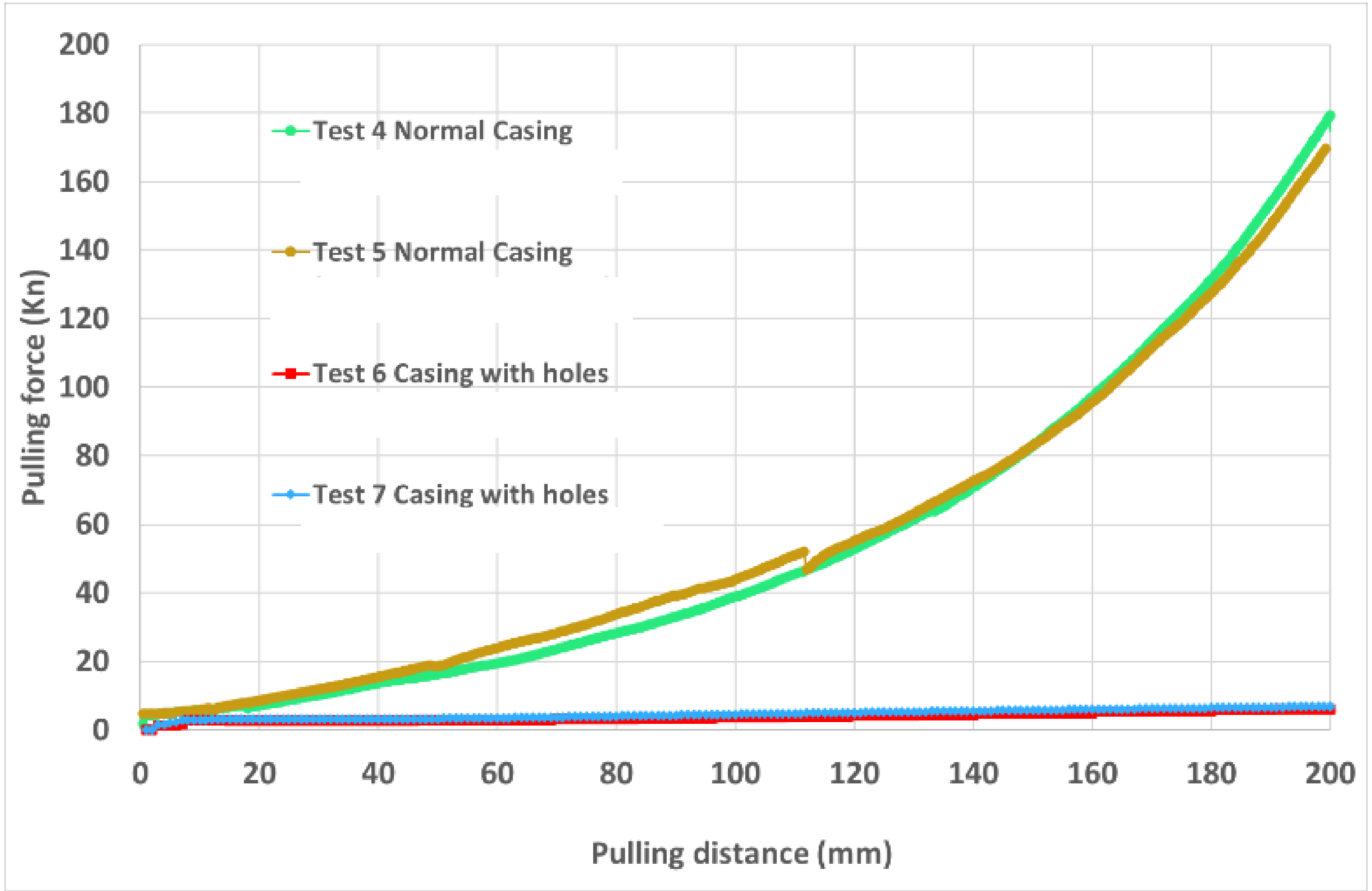


Impact from milling holes above the collar

The pulling force reduces significantly when allocating for holes, allowing the settled barite to escape during pipe pulling.

Hole configuration at the OD 60 mm casing:
3 holes Ø28 mm, closely above top of collar





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SWIPA –

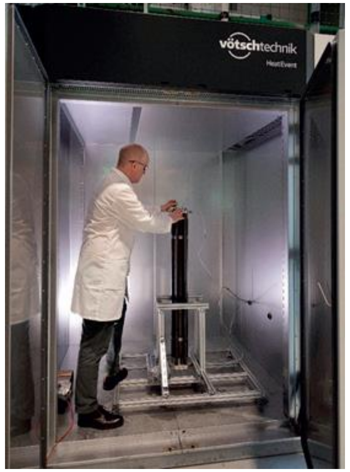
industry partners` feedback on well integrity topics

Well integrity topics		Primary impact towards industry			*Partners priority ranking* **L- Lowest M- Medium H- Highest**
no.	Description	Standards & regulations	Operation	Material selection	
1	Sealant properties of barrier materials	x		x	H
2	Placement of barrier material		x	x	M
3	Verification of barrier integrity	x	x	x	H
4	Re-use of petroleum wells, storage and disposal			x	L
5	P&A tools and operations		x	x	M
6	Evaluation of results, technology qualification, innovations	x	x	x	H

Status – some activities to date…

NorPALabs
Norwegian P&A Laboratories

- Robustness testing of 9 **barrier materials**: geopolymers, other polymers and cements with additives
- Avoidance of **leakage from shallow gas** zones – impact from type cementitious barrier material at low temperature
- Characterisation of **Bi-alloys** as barrier material
- **In-line measurement** system for **slurry** properties of barrier materials
- Spin-off project - CCUS application: **self-healing** of barrier material



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SINTEF

NORCE

NTNU Norwegian University of Science and Technology

IFE

UiS Universitetet i Stavanger

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SWIPA - Collaboration

- The national team in well integrity www.swipa.no

SINTEF NORCE NTNU Norwegian University of Science and Technology IFE Institute for Energy Technology Universitetet i Stavanger

- R&D infrastructure on plugging &abandonment

NorPALabs Norwegian P&A Laboratories

- International collaboration; universities and industry

Brazil, Australia, Canada, UK, Japan, Netherlands, USA

- National & international authorities

Havtil Norwegian Ocean Industry Authority CODA Centre of Decommissioning Australia Net Zero Technology Centre Technology Driving Transition PTAC Petroleum Technology Alliance Canada

Swipa | Subsurface Well Integrity Plugging and Abandonment

www.swipa.no

CO2 well control –selected results

Bore- og brønnfagdag i Trondheim 2025

E. N’gouamba, B. Feneuil, T. Sakia, J.O. Skogestad, H. Linga
(SINTEF, Applied geosciences, Norway)

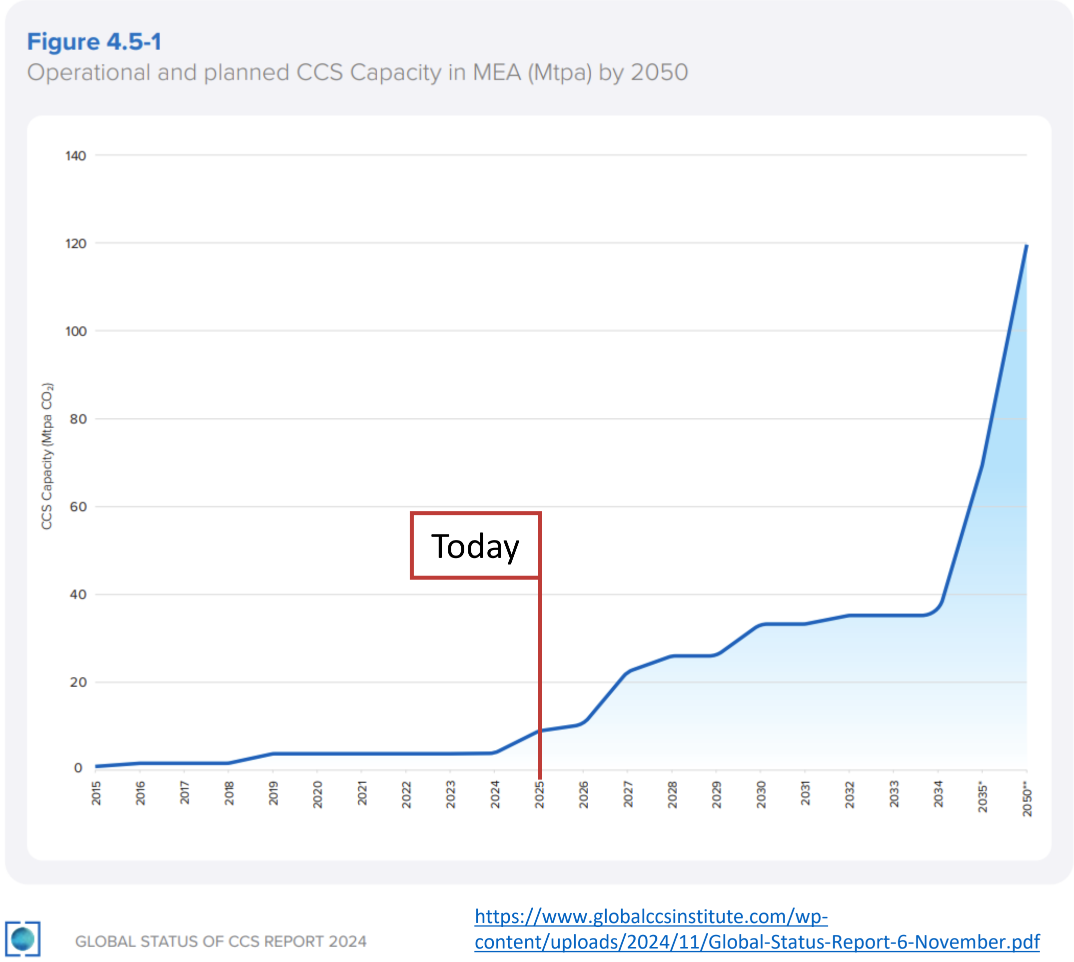
Well control for CO_2 infill wells

To meet climate goals, Carbon capture and storage (CCS) is required

As storage sites mature, more wells are needed – also penetrating formations that already contain CO_2

- Maximise storage capacity utilization
- Problems with existing wells
- Unexpected plume migration

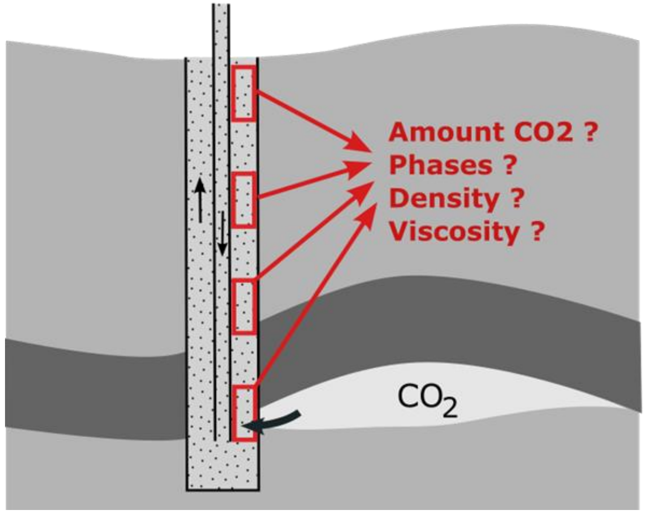
Need to handle risk of CO_2 influx!



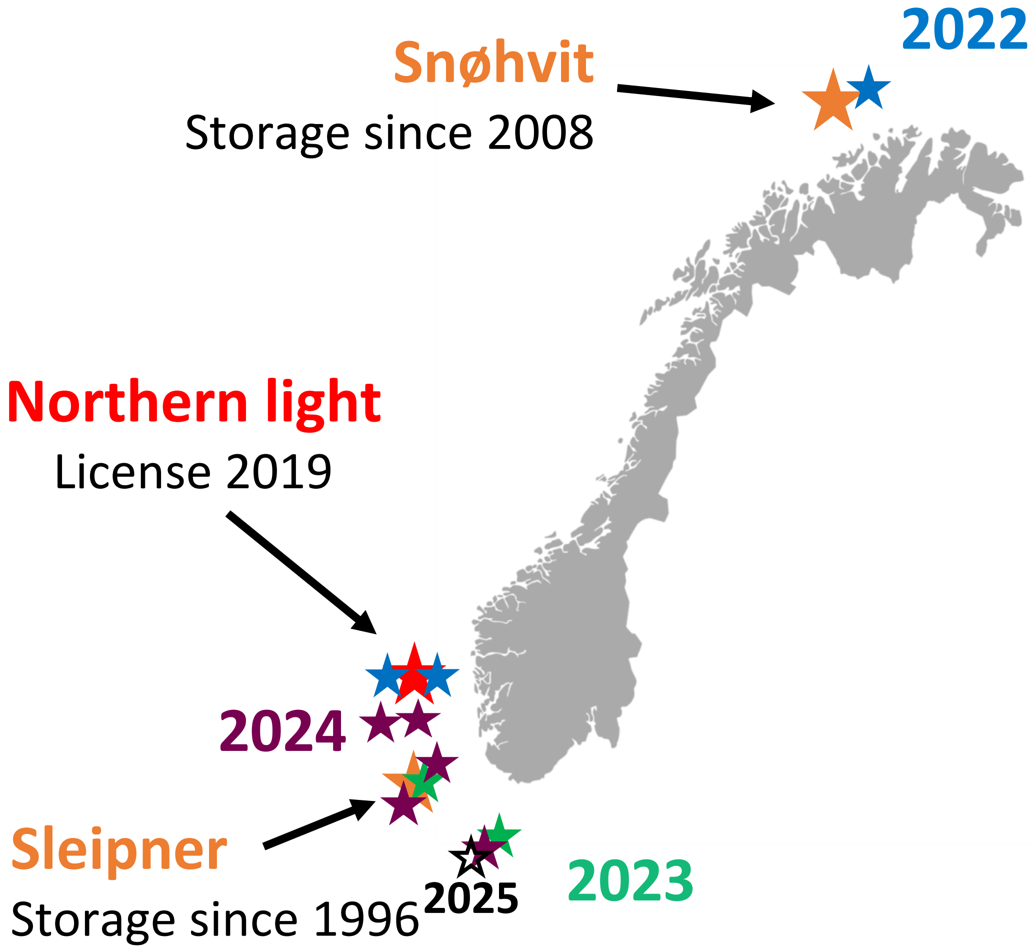
https://www.globalccsinstitute.com/wp-content/uploads/2024/11/Global-Status-Report-6-November.pdf

Motivation

- Well control events with CO_2 as the dominating influx fluid
- Impact on:
  - Drilling fluid
  - Equipment
  - Well control procedures
- Need to understand:
  - Impact of CO_2 on drilling fluid properties
  - Time to react
  - Differences and similarities between methane and CO_2
- How can the evolution of a well control scenario be predicted reliabliy?



CO_2 storage licences in Norway



Source: https://www.sodir.no/fakta/co2-lagring/tillatelser-til-co2-lagring/

SINTEF

Industry projects: Well control for CO_2 wells

- Operators, service and supply companies, software vendor and research institute
- **Pions (eDrilling)** project leader
- **SINTEF** research partner

Project partners:

pions, Shell, eni, ebn, equinor, Transocean, Baker Hughes, Noble, CNOOC, Wild Well Control, SINTEF, Gassnova

Laboratory

Equilibrium fractions of dissolved and free CO2 vs. pressure, temperature, and CO2 mass fraction for each fluid.
Result: PVT, bubble point, rheology, phase distribution

Local models

Develop Local models from laboratory tests including documentation and test results

Integrated model

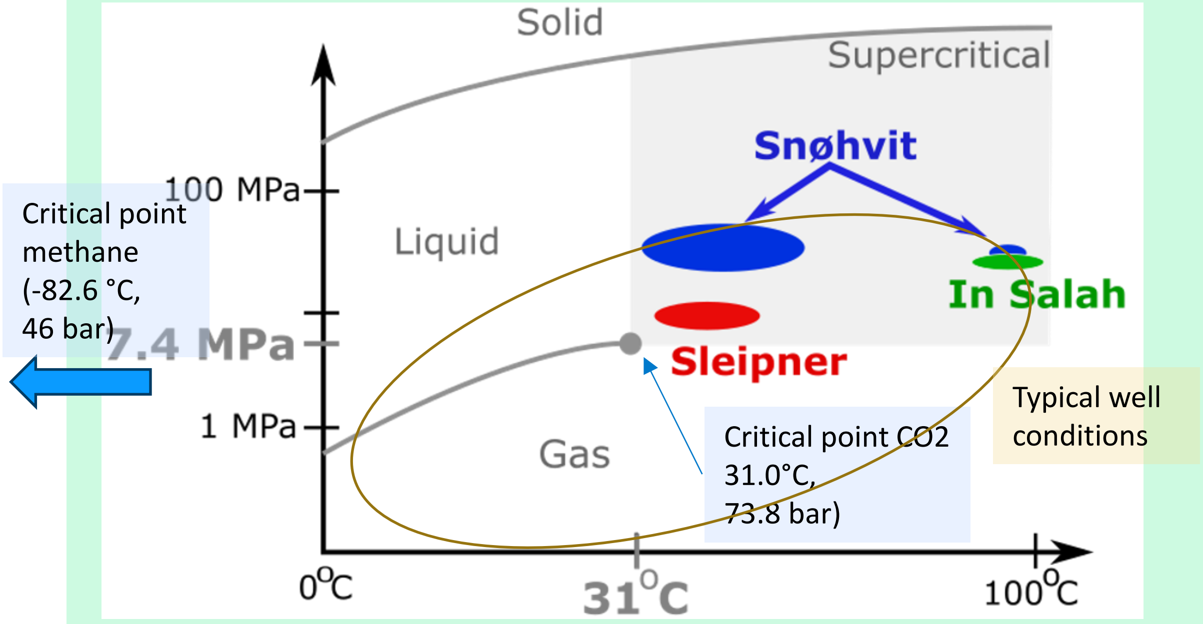
Upgrade the existing well control model to calculate pressure, temperature and flow rates with inflow and transportation of CO2 to topside. Includes local models and the Joule Thompson effect.

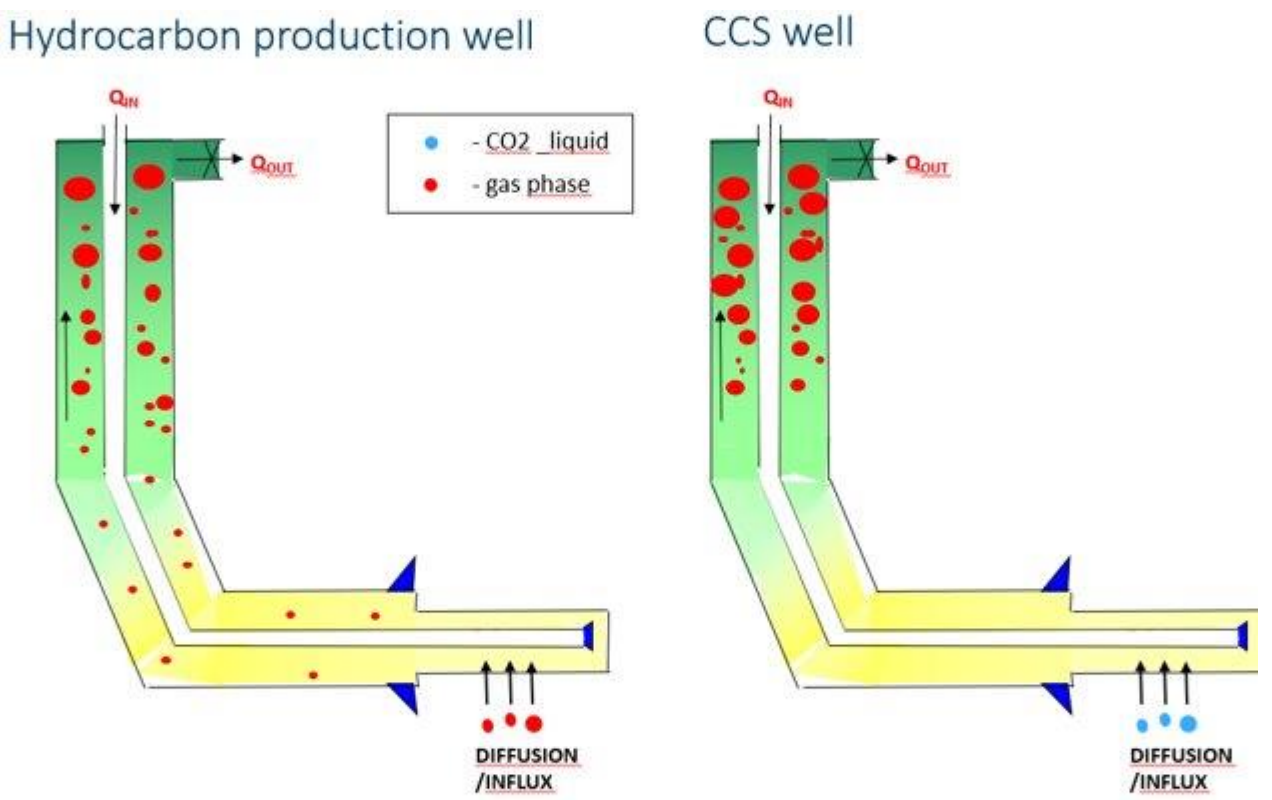
Software product

Implement models and UI/UX for well control in CO2 wells. Implement data pipelines (for Microservices).

Process and influx/ degassing scenarios for hydrocarbon well and CCS wells wells

- Example CO_2 reservoirs + PVT properties of *pure* CO_2:





CO_2 versus methane

- Many differences, but also similarities:

Property/concern		Methane	CO_2
Flammable		Yes	No
Heavier than air / asphyxiation risk		No	Yes
Severe Joule-Thomson cooling		No	Yes
Phase change in operational region		No	Yes
Solubility in oil		High	High
Solubility in water		Very low	Low
Risk of uncontrolled blow-out		Yes	Yes

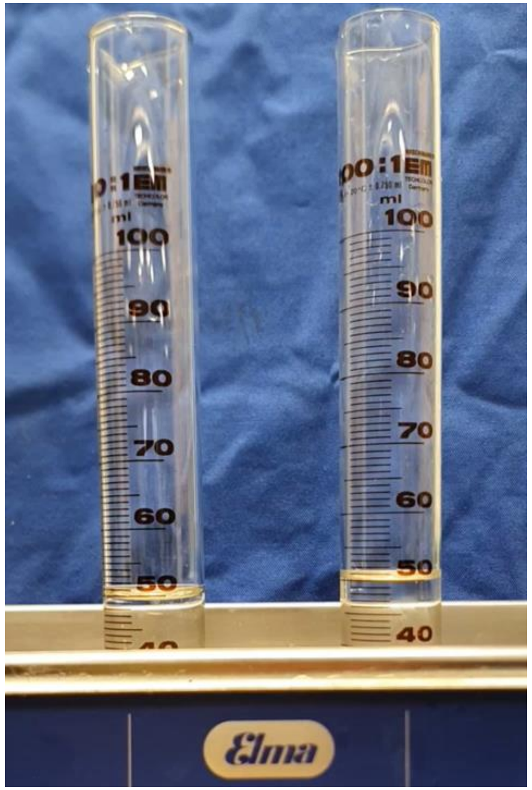
SINTEF

CO_2 degassing experiments

CO_2 behaves differently with different fluids

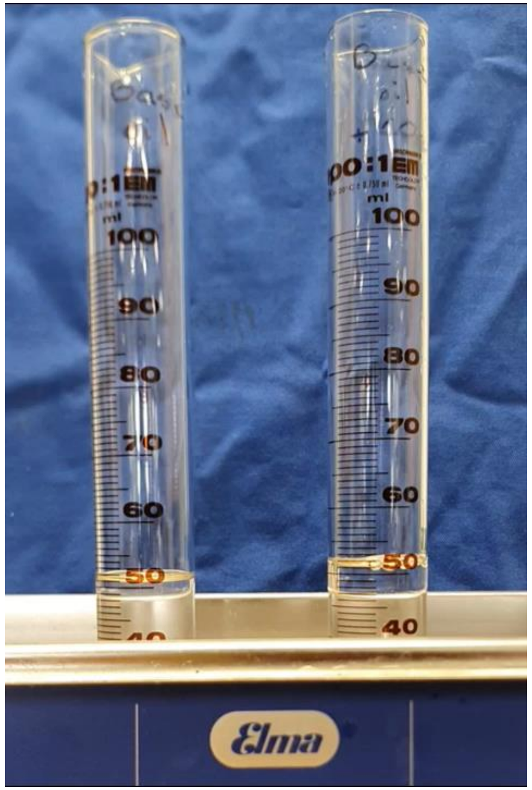
Water

No CO_2 With CO_2



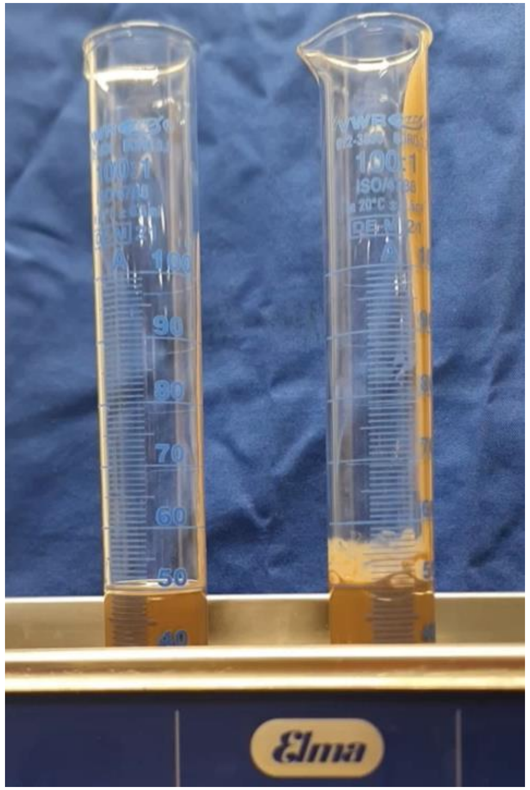
Base oil

No CO_2 With CO_2



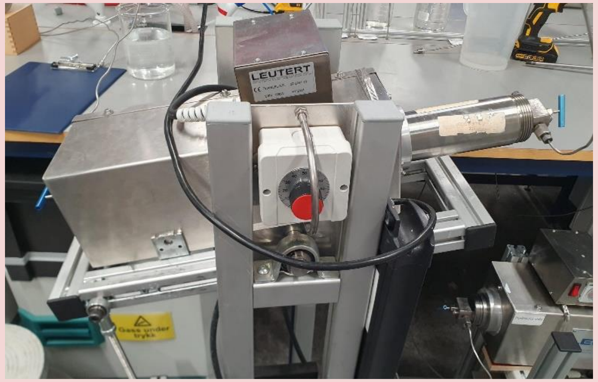
Oil-based mud

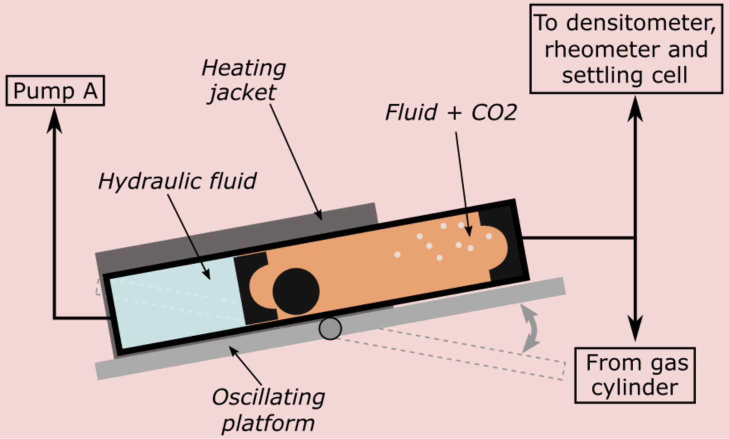
No CO_2 With CO_2



Experimental setup: Overview

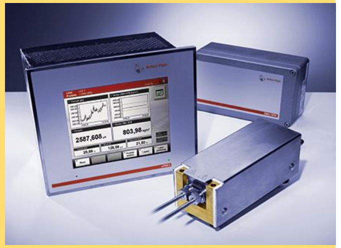
MIXING





DENSITY

Densitometer



VISCOSITY

Concentric cylinder cell

1 - 1000 bar

20°C – 300°C

HYDRATE FORMATION

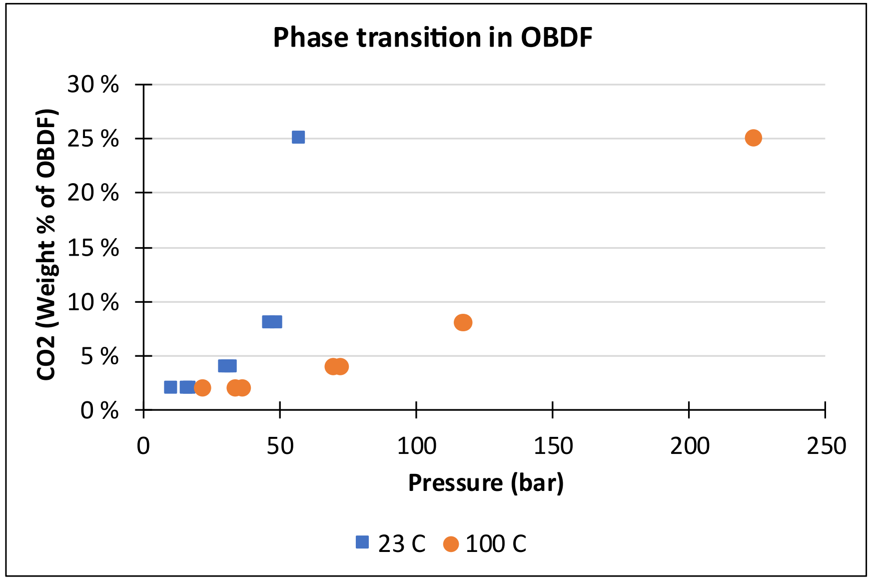
Concentric cylinder cell

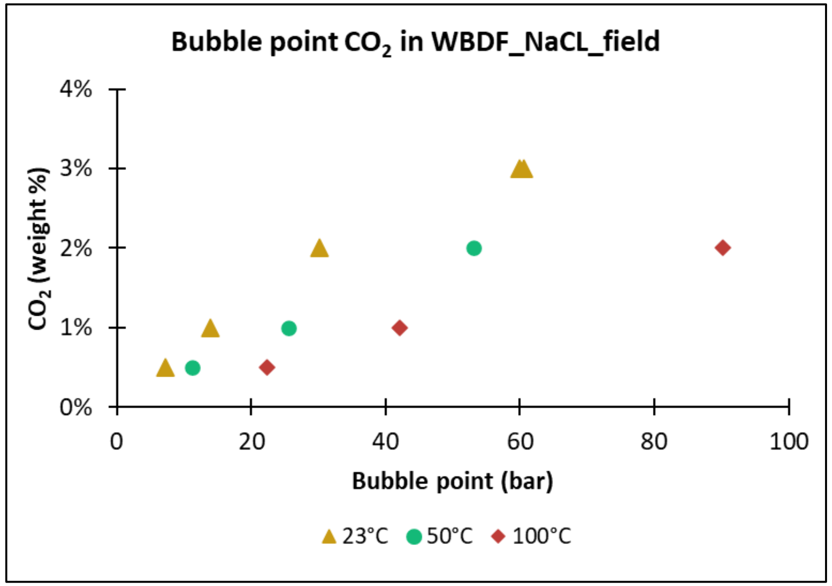
1 - 150 bar

-20°C – 180°C

J.O. Skogestad et al.: “CCS well control impact of CO_2 on drilling fluid performance”, *IADC/SPE Drilling Conference*, 2024, SPE-217711-MS

Solubility experiments

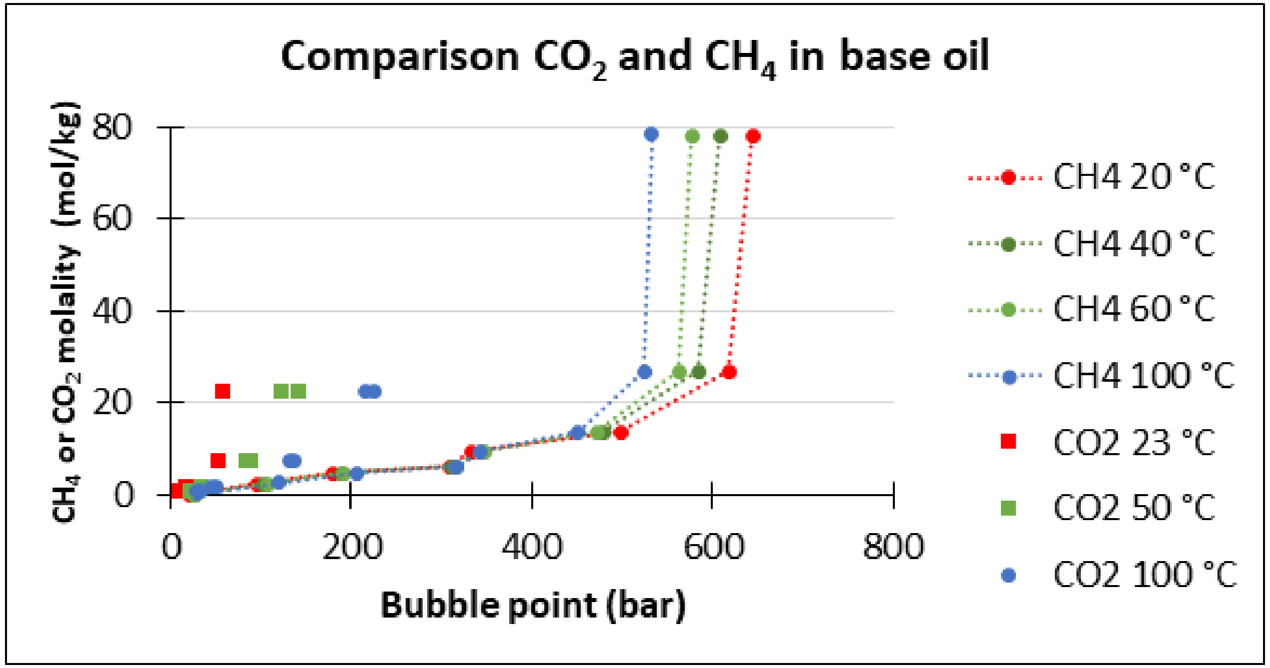




- Solubility of CO_2 much higher in oil- than in water-based drilling fluids
- Decreasing solubility with temperature

Solubility measurements

Oil-based drilling fluids - Comparison CO2 and natural gas

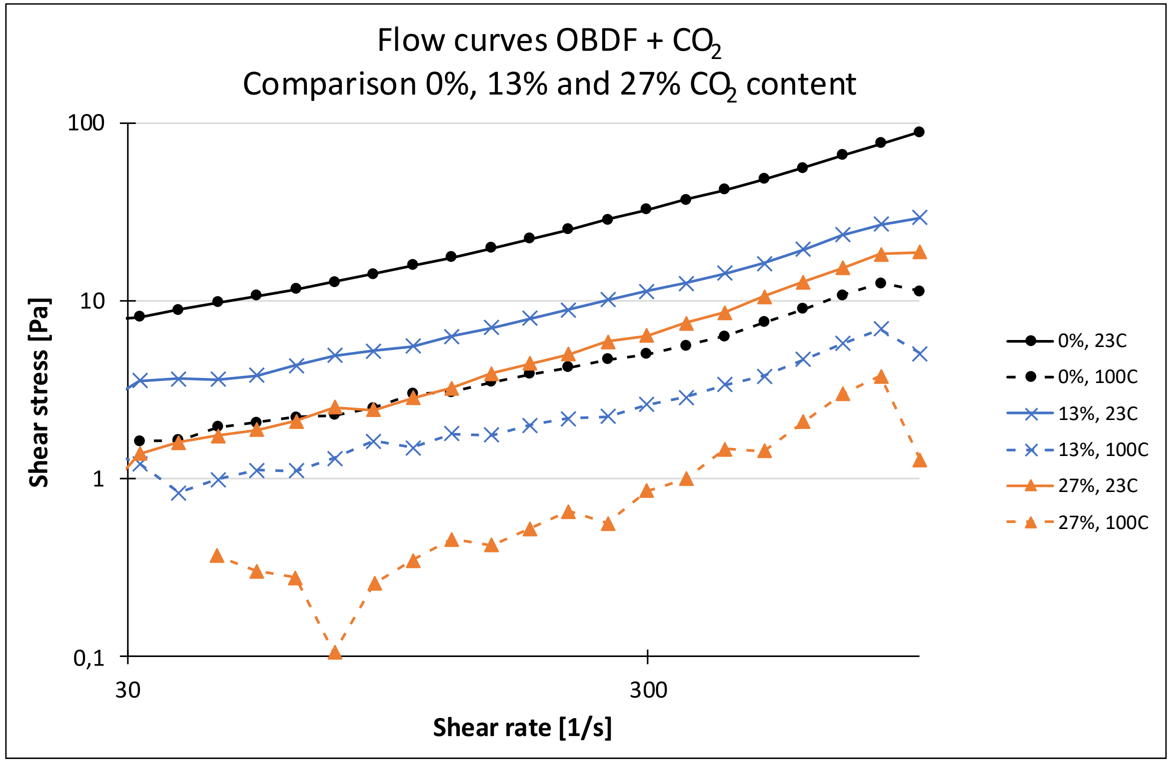


=> CO_2 is far more soluble than methane
=> Larger temperature dependence for CO_2

[1] A. Torsvik, J. O. Skogestad, and H. Linga, 'An Experimental Study of Gas Influx in Oil-Based Drilling Fluids for Improved Modeling of High-Pressure, High-Temperature Wells', *SPE Drilling & Completion*, vol. 32, no. 04, pp. 245–254, 2017, *SPE-178860-PA*, doi: 10.2118/178860-PA.

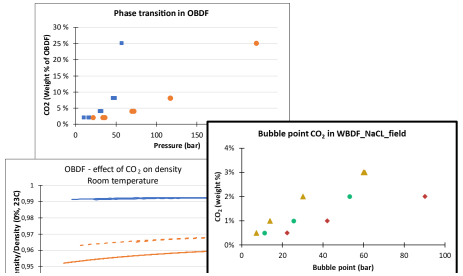
Rheology / flow curve measurements

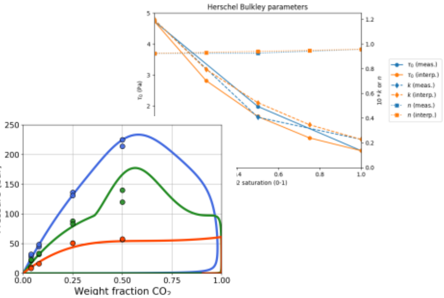
- OBM: Dissolved CO_2 has considerable effect on rheology; reduces efficient viscosity
- WBM: Little to no effect

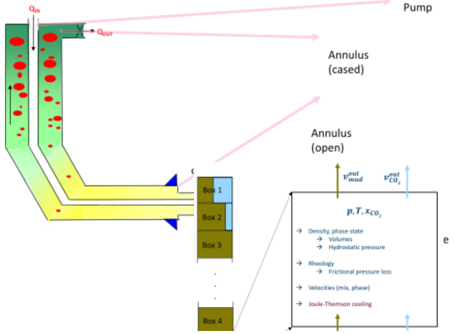


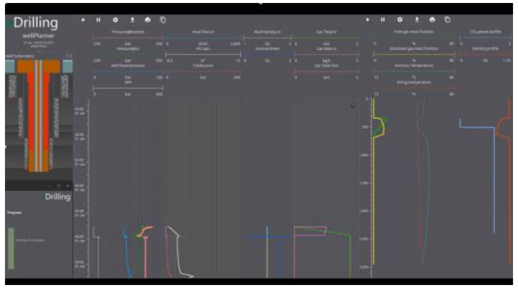
Summary

- Updated well control models to handle influx of CO_2 achieved through laboratory studies, model development and integration, product development and testing
- Further work:
  - Absorption/degassing kinetics, relief wells, blow-out kill, further hydrate studies
  - Enhance/refine models
    - to ensure realistic CO2-drilling fluid representation
    - cover a broader range of scenarios
  - Implementing in software modules/features
  - ++









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SINTEF

Teknologi for et bedre samfunn