NCS 2030 National Centre for Sustainable Subsurface Utilization of the Norwegian Continental Shelf

University of Stavanger

IOR Centre to NCS2030

Tina Puntervold, Associate Professor, Department of Energy Resources, University of Stavanger

IEA-EOR TCP, Stavanger, 22nd of November 2022

Welcome to Stavanger!

University of Stavanger Campus

University of Stavanger

- Became university in 2004. But the institution has been educating petroleum engineers since the 70'/80's
- About 13000 students
- About 2000 employees

"We will challenge the well-known and explore the unknown."

The National IOR Centre of Norway
- Opening of the centre, 2013-2021

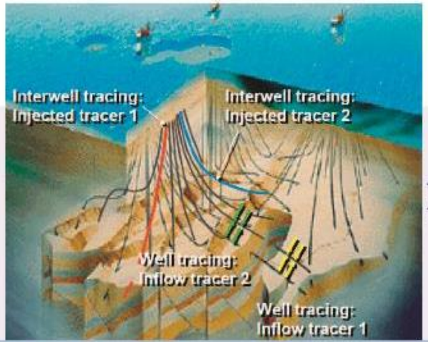
The National IOR Centre of Norway

The main objective and vision of the centre

«to contribute to the implementation of cost efficient and environ-mentally friendly technologies for improving oil recovery on the Norwegian Continental Shelf.»

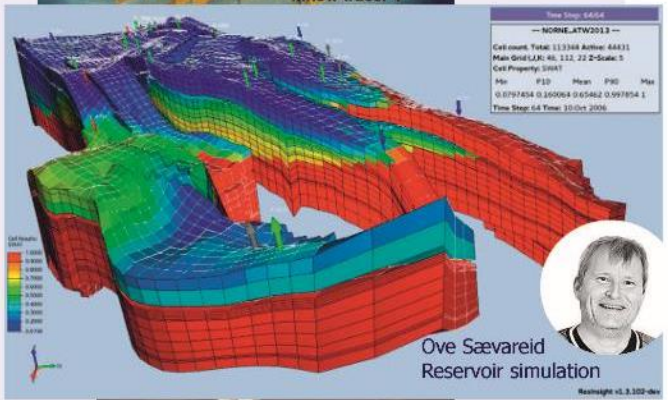
OUR RESEARCH

Udo Zimmermann
Nano/ submicron scale



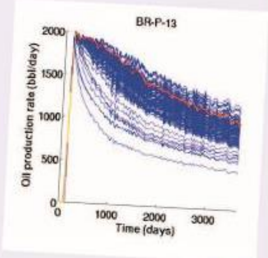
Tor Bjørnstad
Tracer Technology

from lab



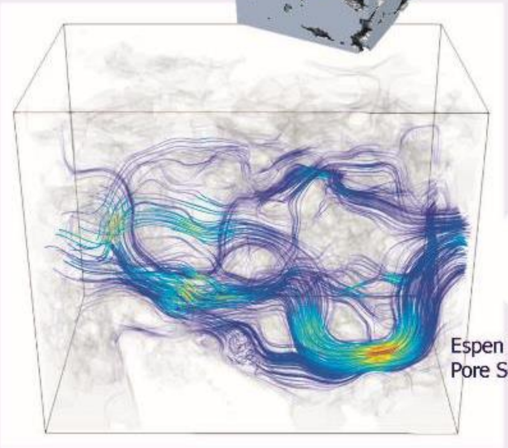
Ove Sævareid
Reservoir simulation

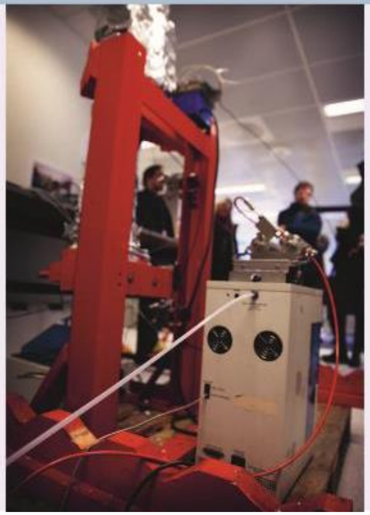
to field

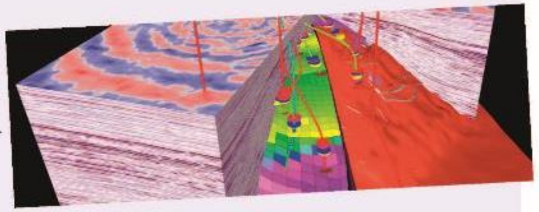


Arne Stavland
Core scale

Geir Nævdal
Field scale evaluation







Espen Jettestuen
Pore Scale

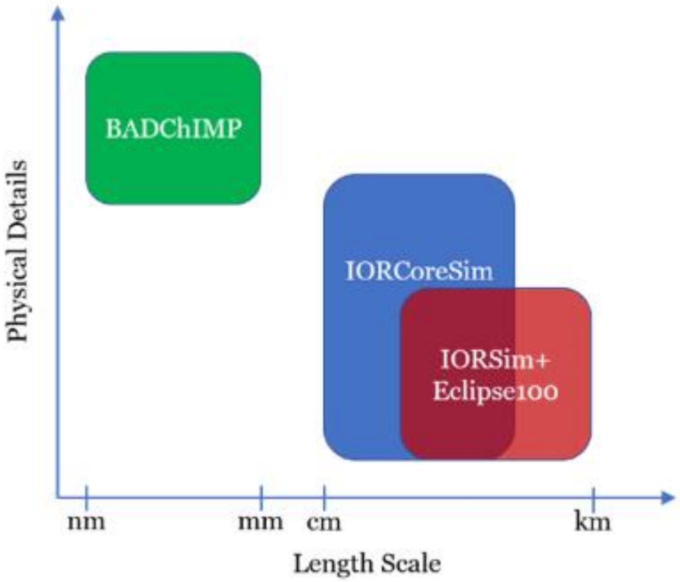
Aksel Hiorth
Upscaling

The National IOR Centre of Norway

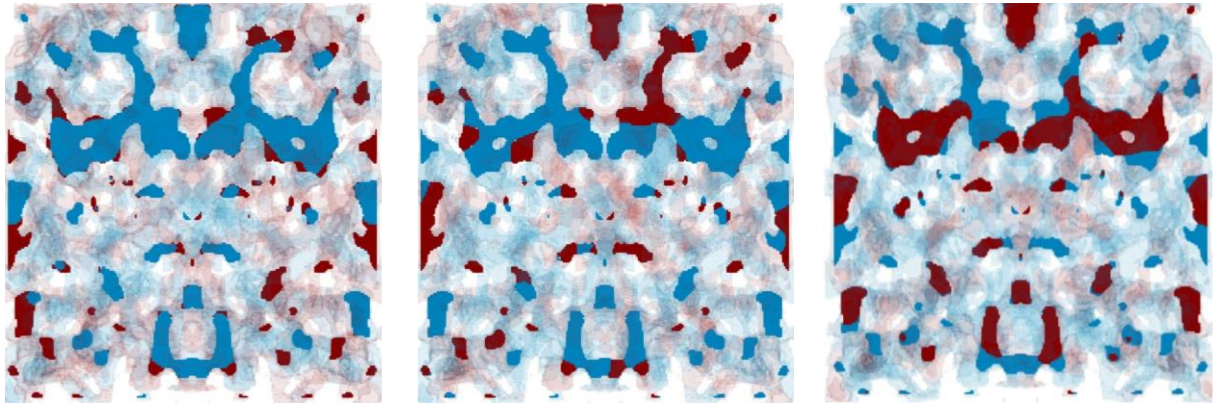
Software

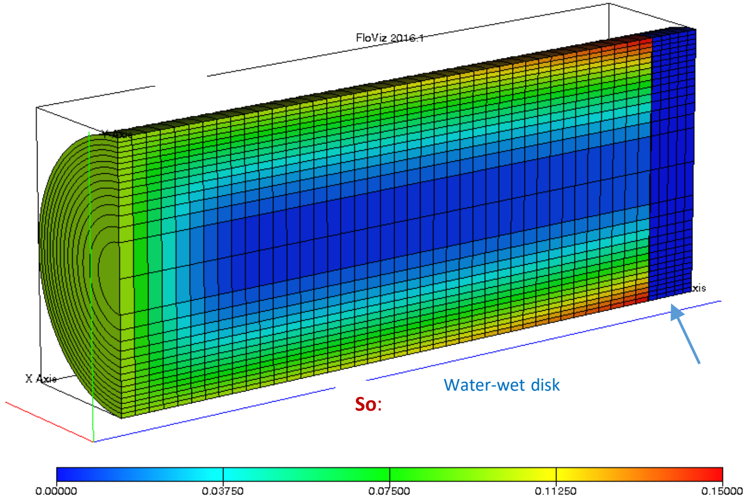
- BadChimp – pore scale
- IORCoreSim – core scale
- IORSim
- OPM

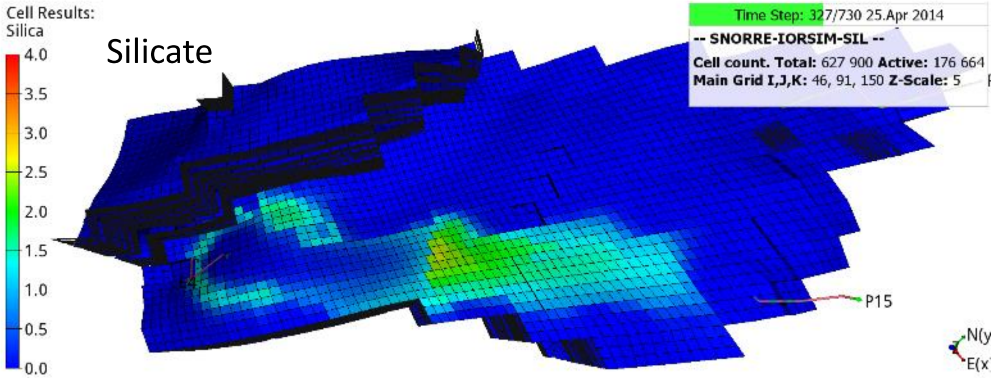
} - field scale



Schematical representation presenting the levels of physical details in the numerical models and at what length scales the simulators are applied.







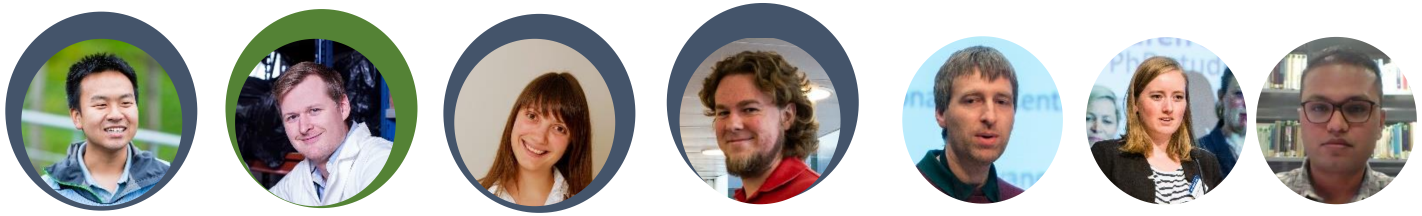
Educated and in-the-loop PhDs

Has defended

Aojie, Kun, Laura, Mona, Oddbjørn, Remya, Mohan

Samuel, Shaghayegh, Jaspreet, Tijana, Dhruvit, Emanuela, Mario, Siv

Defends thesis 2021/2022



Yiteng, Eystein, Anna, Andre, Bjarte, Karen, Mehul

Micheal, Tine, Arun, Panagiotis, William, Nisar, Hoang (2023)

Industry jobs:

- Remya – SEID AS
- Mohan – Resoptima
- Jaspreet – TechnipFMC
- Tijana – Equinor
- Dhruvit – Equinor
- Yiteng – Shell
- Anna – Equinor
- Shaka – Zimmer and Peacock Ltd
- Andre - Schlumberger

Academic jobs:

- Aojie – UiS
- Kun – Shaoxing University
- Laura – University of Milan
- Mona – UiS
- Oddbjørn – UiS
- Samuel – KNUST
- Mario – IFE
- Siv – NORCE
- Emanuela – UiS

Educated postdoc-researchers

Finished


Pål

Aruoture

Tuhin

Bergit

Thomas

Dimitri

Kjersti

Michael


Runar

Trine

Mahmoud

Teresa

Ivan

Yanhui

Still working at the IOR Centre


Aleksandr

Rouholah

Felix

Oddbjørn

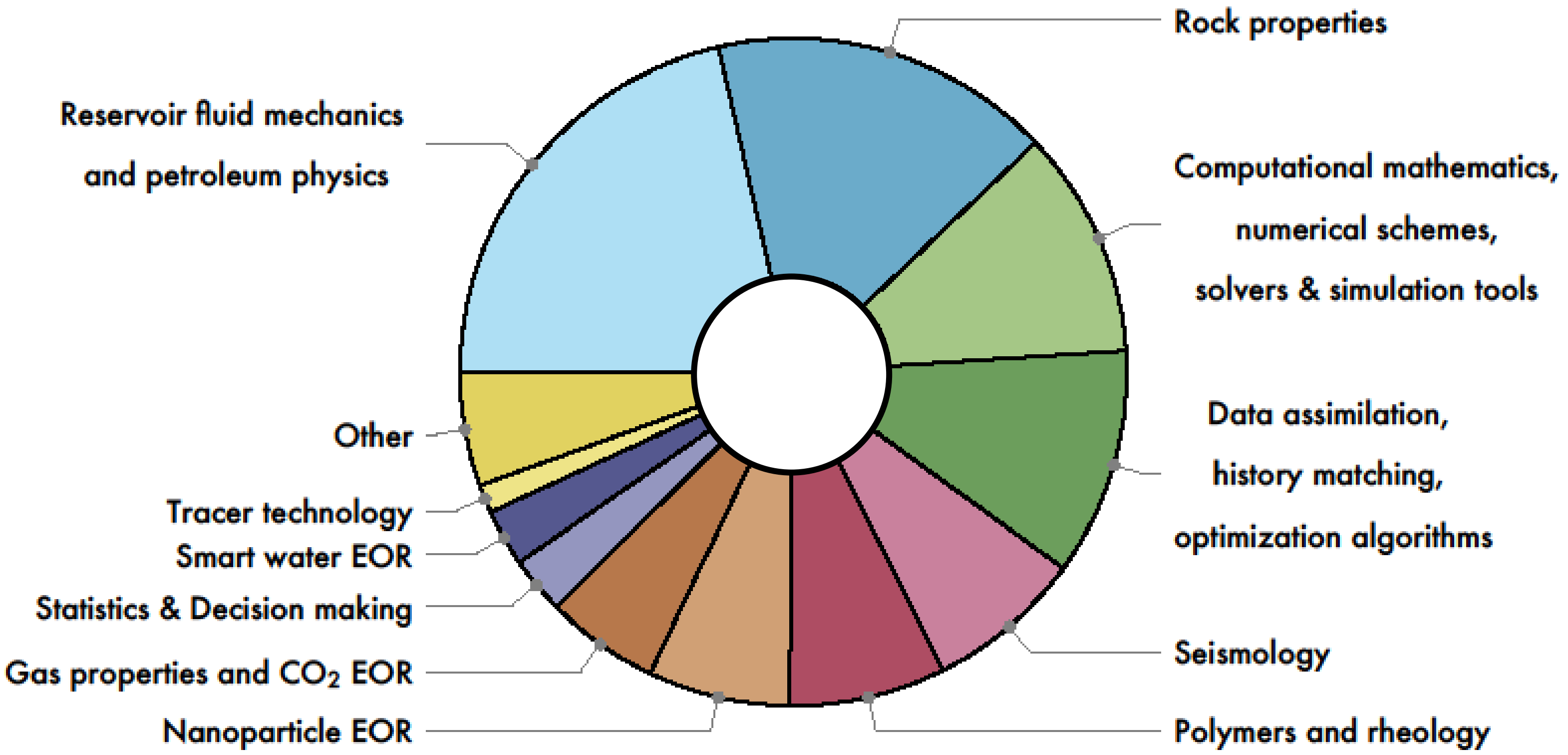
Birane

Industry jobs:
- Thomas – MEXBRAIN/GLINCS
- Mahmoud – SNF
- Teresa – Independent consultant

Academic jobs:
- Pål – UiS
- Aruoture – NORCE
- Tuhin – NORCE
- Bergit – UiB
- Dimitri – UiS
- Kjersti – NORCE
- Michael – DTU
- Runar – Volda University College
- Trine – NORCE
- Ivan – UiS
- Yanhui – KAUST

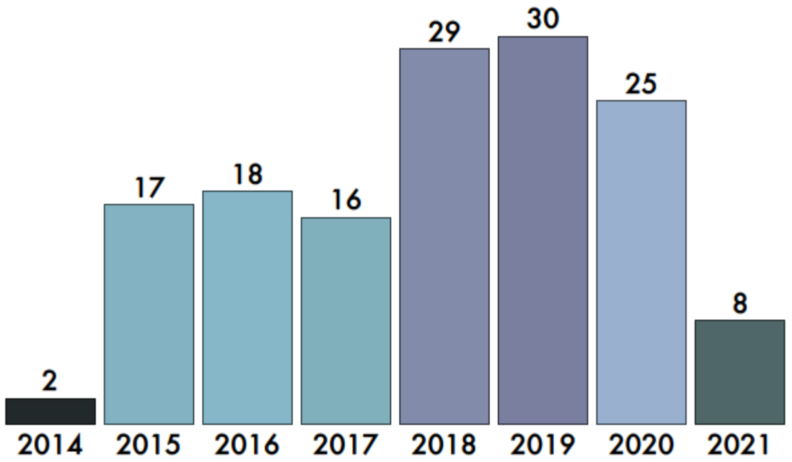
Journal papers

~200 scientific journal papers published and ~1800 citations



More than half in level 2 journals.

Journal papers per year



Workshops 2017-2021

2021
- Workshop with Schlumberger
- Production optimization, value of information and decision-making
- Webinar series for PhDs and postdocs
- IOR NORWAY workshop: Symposium on Wettability

2020
- IORSim
- Ensemble-based 4D seismic history matching
- Delivery Forum Webinar

2019
- IORSim
- Interpore
- CO2-EOR
- Core Preparation
- PhD dissemination skills seminars
- IOR NORWAY workshop: Wettability

2018
- Smart Water
- Polymer EOR
- IOR NORWAY workshop: Integrating the value-chain of IOR research in field development plans
- Integration of research activities
- Environmental Risk Assessment (ERA)

2017
- Open Porous Media Seminar
- IOR NORWAY workshop: Offshore polymer EOR; how to make polymer work in the field
- PhD dissemination skills seminars

IFE UiS NORCE

The National IOR Centre of Norway

Delivery Forum

- To better illustrate the Centre's main deliverables and how our projects are integrated to manage and achieve the specifications of our work plans, the centre management developed delivery forums for these areas:

  - Wettability and Smart Water EOR
  - Polymer EOR
  - Upscaling
  - Field Application

IOR NORWAY

2015

2016

2017 (EAGE)

2018

2019

2020 (webinar)

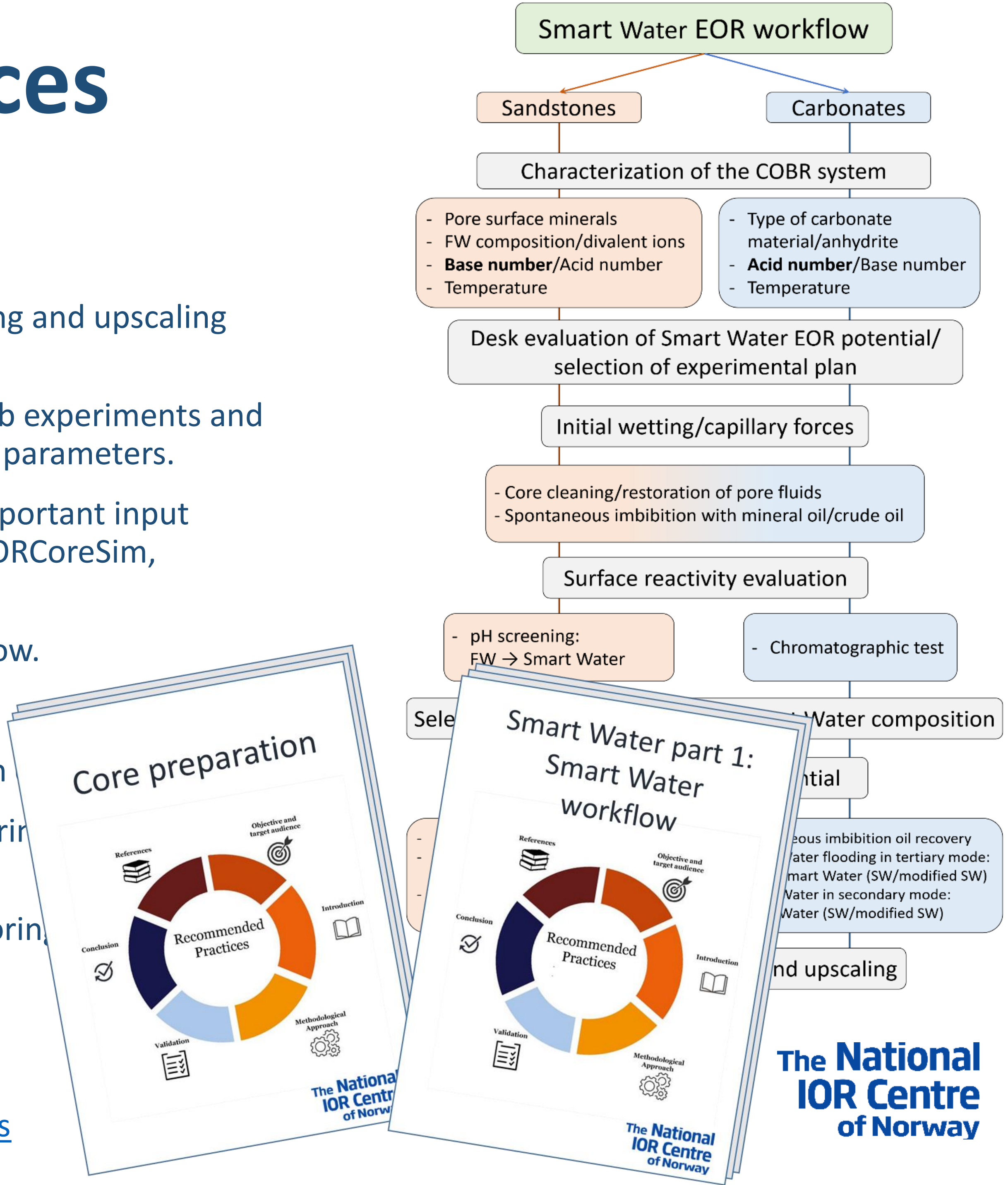
2021 (Wettability Symposium)

See all the presentations from IOR Norway 2021 here: https://www.uis.no/en/research/ior-norway-2021

The National IOR Centre of Norway

11 Recommended practices

1. Core preparation
2. Smart Water part 1: Smart water workflow.
3. "Smart water flooding - Important input parameters for modeling and upscaling workflow".
4. Polymer part 1: Recommended workflow (including design of lab experiments and interpretation by IORCoreSim) to extract essential Polymer EOR parameters.
5. Polymer part 2: Identification and usage recommendation of important input parameters for modeling and upscaling of polymer processes, IORCoreSim, BADChIMP.
6. Polymer part 3: Polymer flooding - Simulation Upscaling Workflow.
7. Workflow on adding 4D seismic data in history matching
8. Methodological developments for ensemble-based optimization
9. Recommended practices for tracer-based interwell SOR-monitorir various EOR-method efficiencies.
10. Recommended practices for tracer-based near-well SOR-monitorin various EOR-method efficiencies.
11. Environmental Risk Assessment for IOR on NCS.



[Department of Energy Resources (IER) | UiS Scholarly Publishing Services]

The National IOR Centre of Norway

Final report

Link to the report:

https://www.uis.no/sites/default/files/2022-07/Final_report_IOR_wo_appendix.pdf

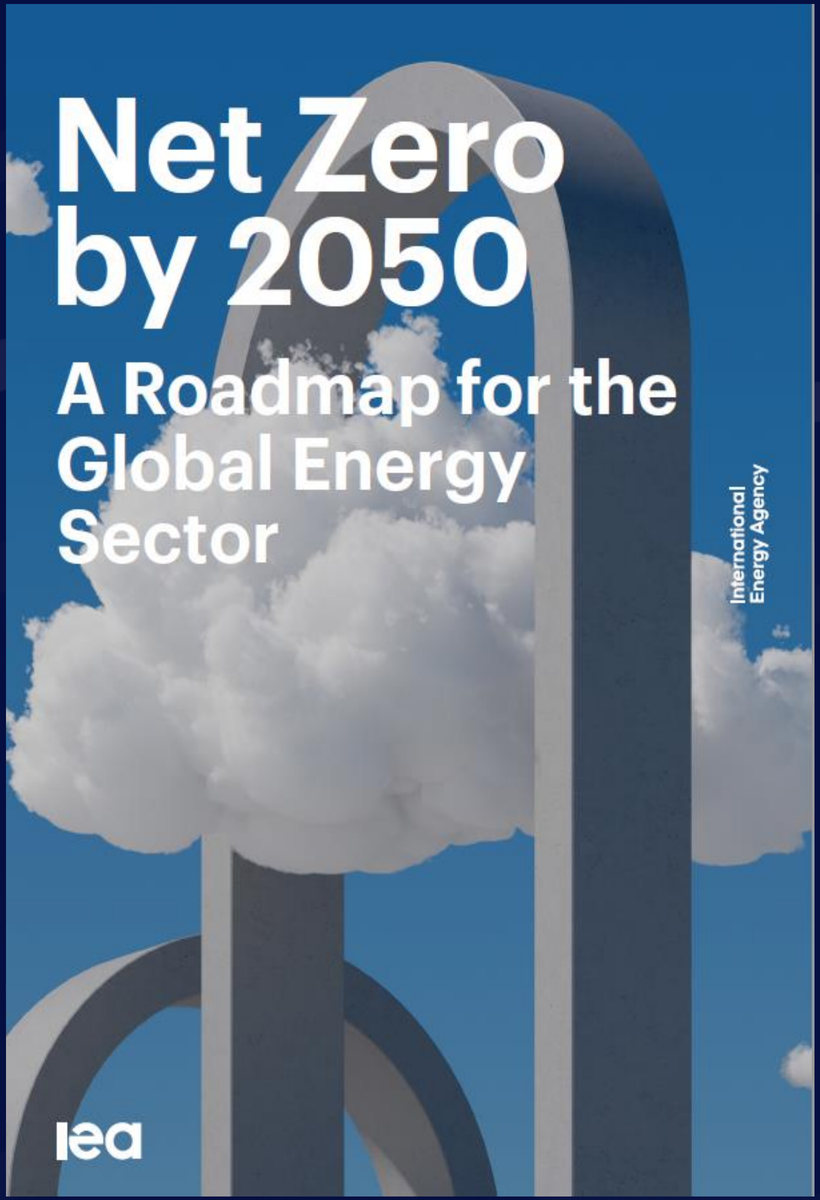
NCS 2030

National Centre for
Sustainable Subsurface Utilization of the
Norwegian Continental Shelf

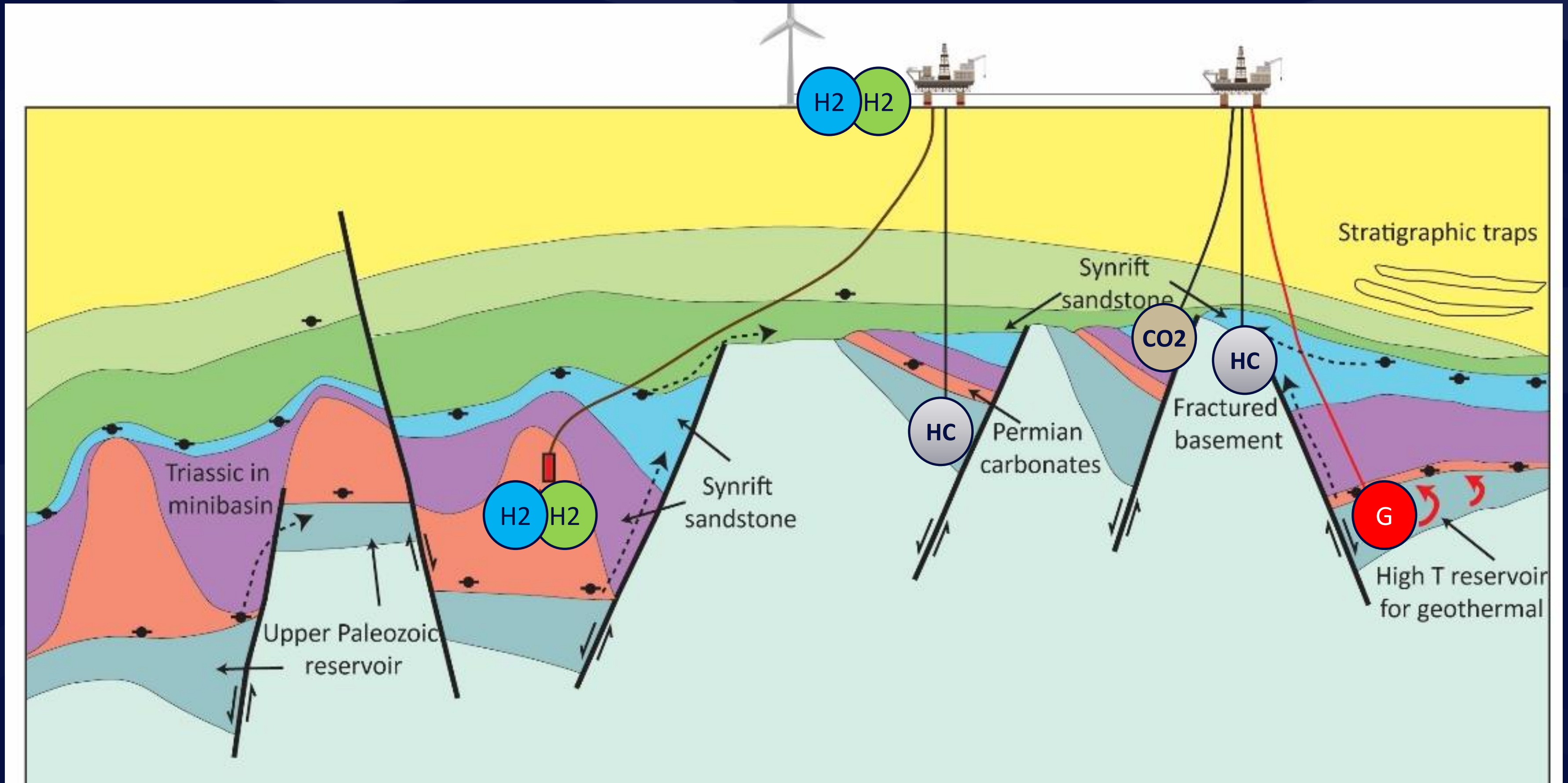
University of Stavanger

Challenge in the next decades:

- ***Provide energy security*** (energy mix)
  - while accelerating the transition towards a sustainable society
  - and reach ***50% emissions cut by 2030*** and net-zero by 2050



The energy transition requires large scale and multipurpose utilization of the subsurface



Sketch of the North Sea Subsurface

Inspired by OG21 and NPD strategies

4.4 SUBSURFACE UNDERSTANDING

The prioritized technology and knowledge areas for TG2 are:

- Offshore CO_2 storage and late life deposits.
- Data acquisition for subsurface understanding and models.
- Data management for subsurface understanding and models.
- Subsurface understanding and models.
- Water management.

The "data acquisition" and "data management" technology areas, described in detail on the next pages, are enablers for the "subsurface understanding and models" technology area. This is shown in Figure 43.

The TG2-prioritized technology areas are important for all the competition indicators described in Section 3.

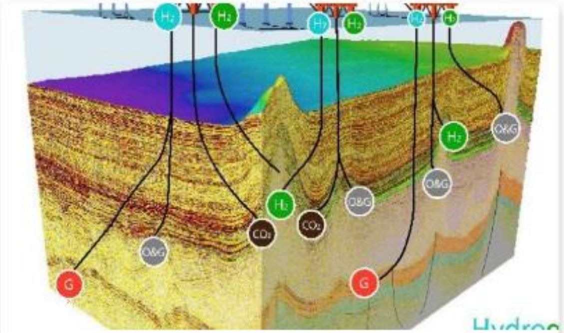
For instance, the improved subsurface understanding and models, building on data acquisition and the management related to it, will provide the fundament for:

- Finding and maturing new resources.
- Cost-efficient reservoir drainage.
- Safe and cost-efficient drilling.

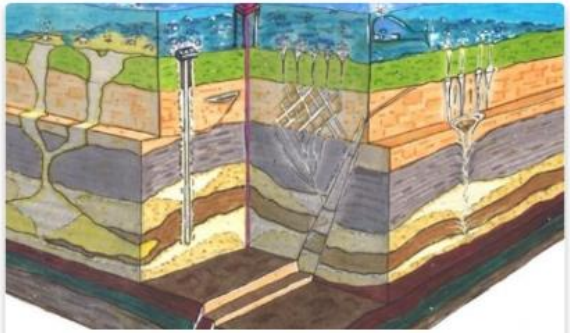
Offshore CO_2 storage has, in addition to receive and store large amounts of CO_2 from industry sources in Norway and abroad, the potential to extend the lifetime of fields beyond the cessation of O&G production.

Improved water management will lead to significant reductions in water cycling, and thereby lower emissions from power generation. It is also expected that improved water management will accelerate HC production and yield higher resources by a more efficient reservoir drainage, as well as savings related to less energy consumption for processing of both injection and produced water.

Research



Near Field Resource Evaluation ›



Reservoir Utilization for Energy Transition ›

Net-Zero Emission (NZE) Production ›

Efficient Water Management for NZE ›

User partners & observers

Funded by
The Research
Council of Norway

equinor

vår energi

AkerBP

OKEA

HALLIBURTON
Landmark

NORWEGIAN PETROLEUM
DIRECTORATE

DNO
EST - 1971

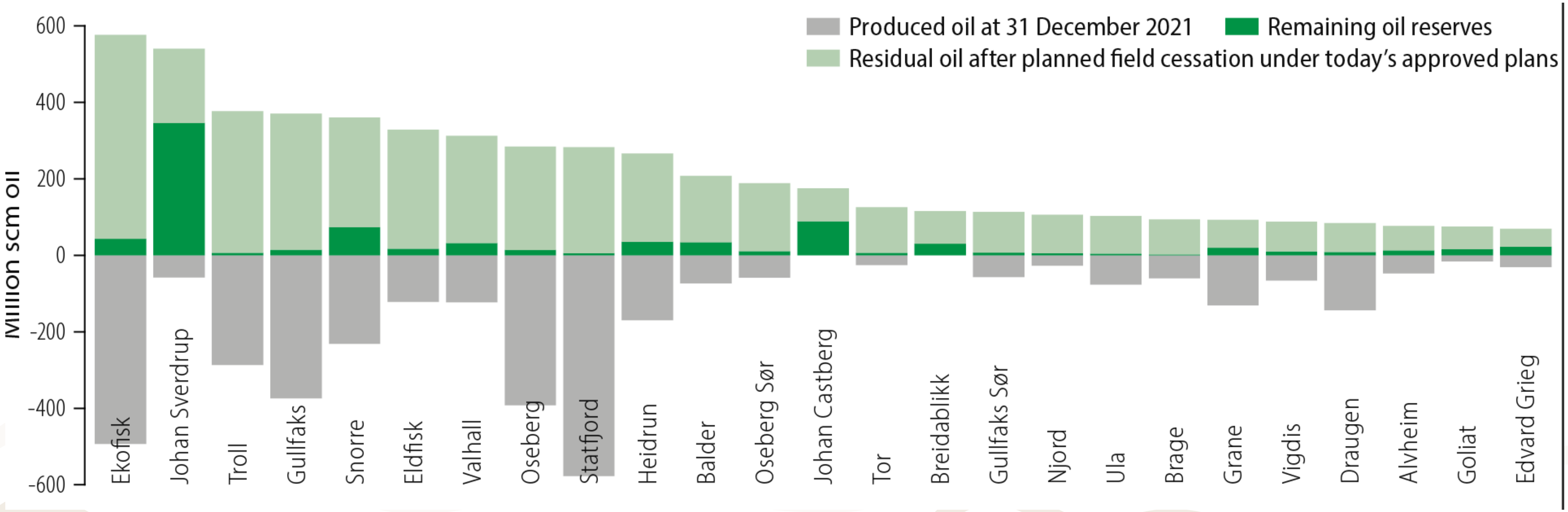
wintershall dea

slb

petoro

How can IOR/EOR contribute to reaching the ambitious emission reduction goals?

NCS – Large potential for the next decades



NPD Resource report 2022

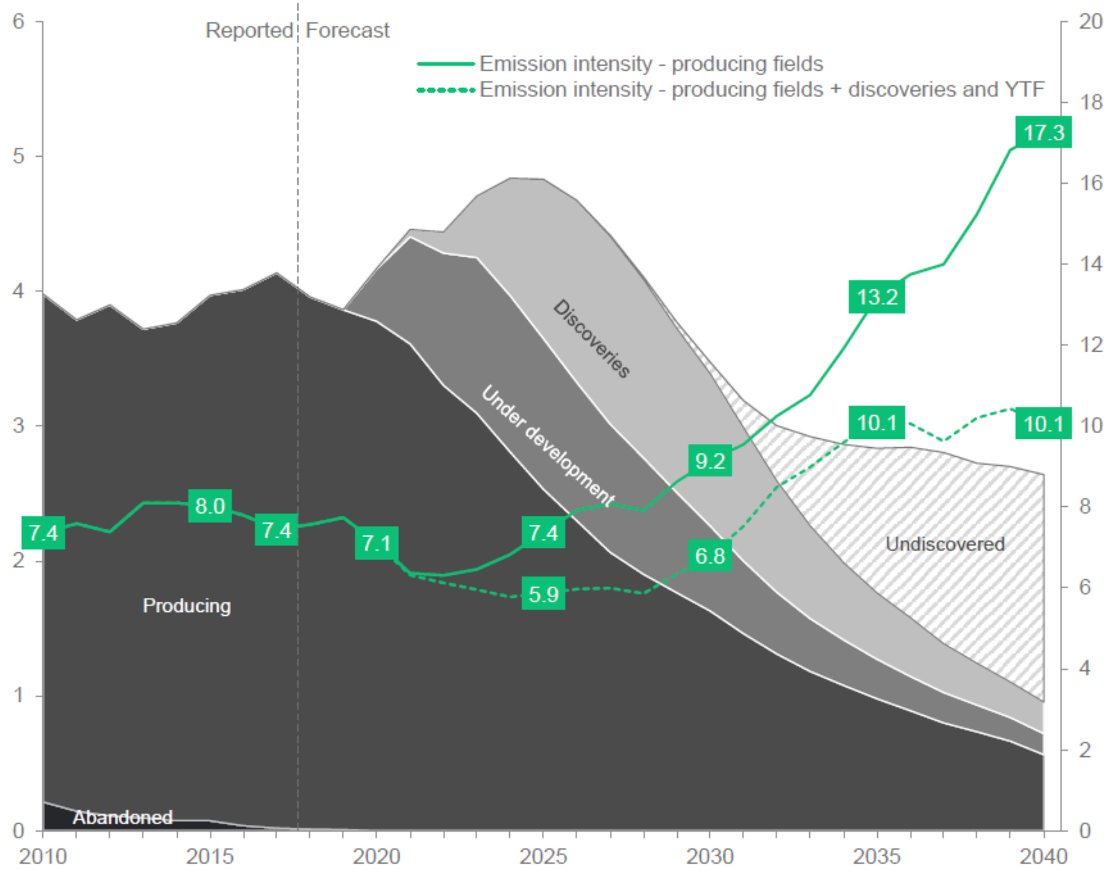
NCS – CO_2 intensity is increasing

With NCS production in decline post 2025, CO_2 intensity increases unless measures are taken

Emissions

Production on the NCS by lifecycle
Million boe/d

Upstream CO_2 emissions intensity on the NCS*
Kg CO_2 per boe



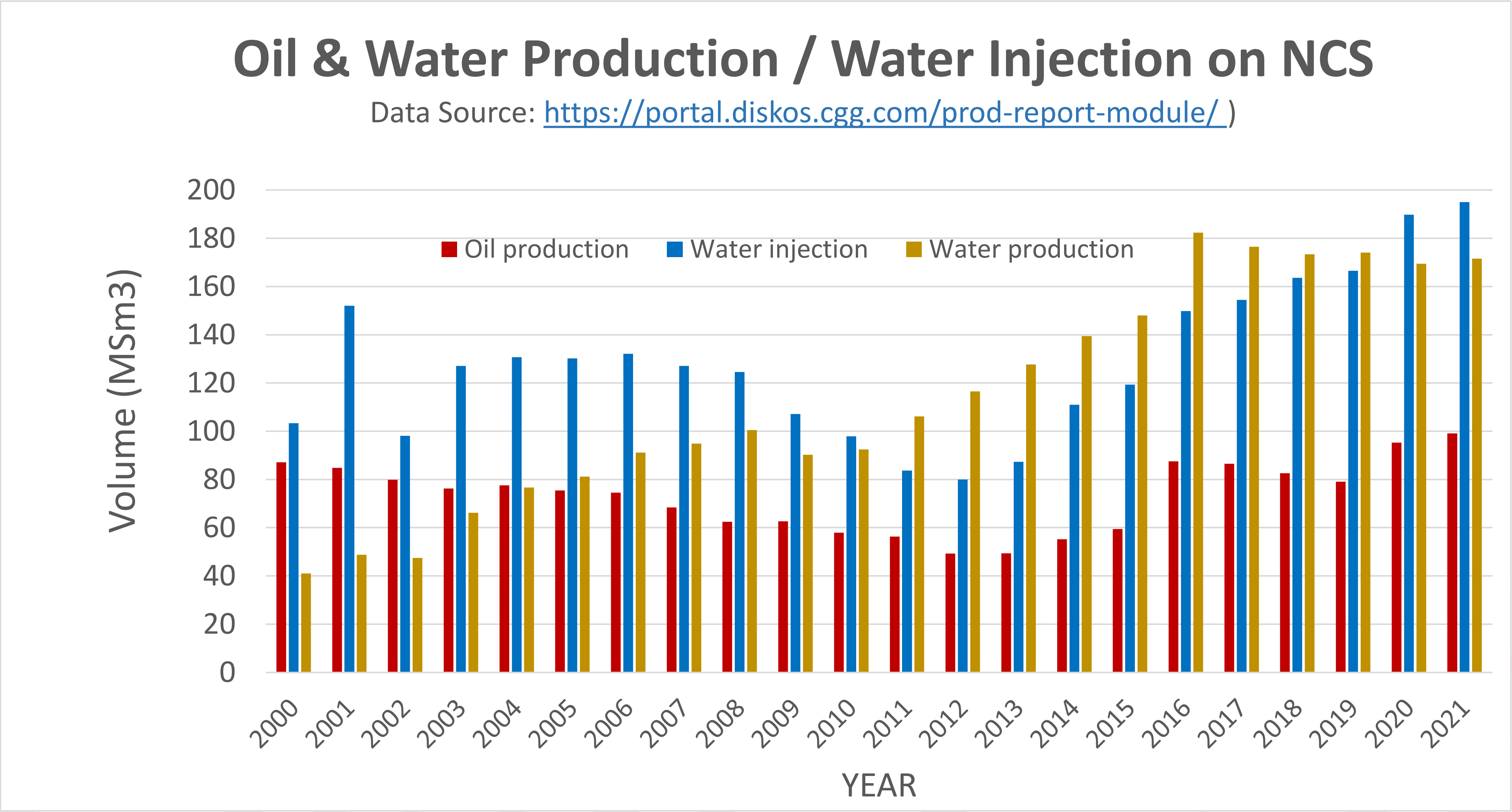
- *The area chart shows production from all fields on the NCS, while the lines represent the weighted average emission intensity on the NCS from 2010 to 2040, the dotted line excluding discoveries and fields yet to be found.*
- *Emissions intensity is a metric for emissions generated per barrel of oil equivalents produced.*
- *From 2025 onwards, the NCS production is in decline. However, as shown on the previous slide, upstream CO_2 emissions remain relatively stable, despite production dropping as conventional fields mature. This is driven by more efforts required to extract late phase barrels, typically resulting in increased need for separation due to high water cut and increased injection activity to maintain reservoir pressure.*
- *This effect is particularly profound when looking at intensities for the NCS as we know it per today, i.e., only regarding producing fields and fields under development.*

*Fields to be electrified do not contribute to CO_2 emissions in the intensity metric, and includes Johan Sverdrup (all phases), Valhall West Flank, Martin Linge, and the remaining fields on the Utsira High after the startup of Johan Sverdrup phase 2 (Edvard Grieg, Gina Krog and Ivar Aasen); Source: Rystad Energy UCube; Rystad Energy research and analysis

RYSTAD ENERGY

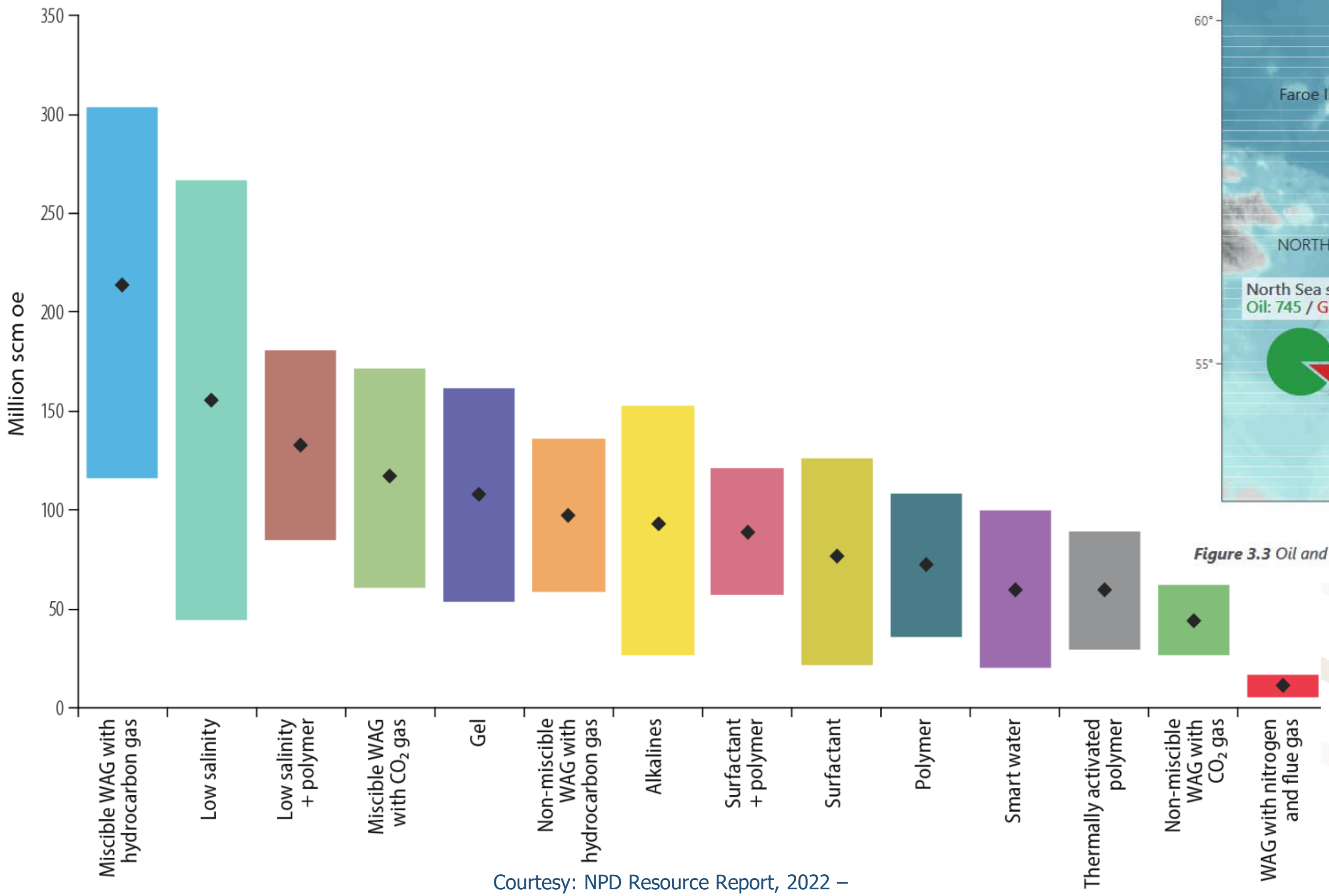
Courtesy: Rystad supporting report, 2019, www.og21.no

NCS Fields are maturing



Courtesy: Ying Guo (NORCE), 2022.05

NCS - IOR / EOR are still very important for producing oil and decreasing water cut



Courtesy: NPD Resource Report, 2022 – Discovery and fields. www.npd.no

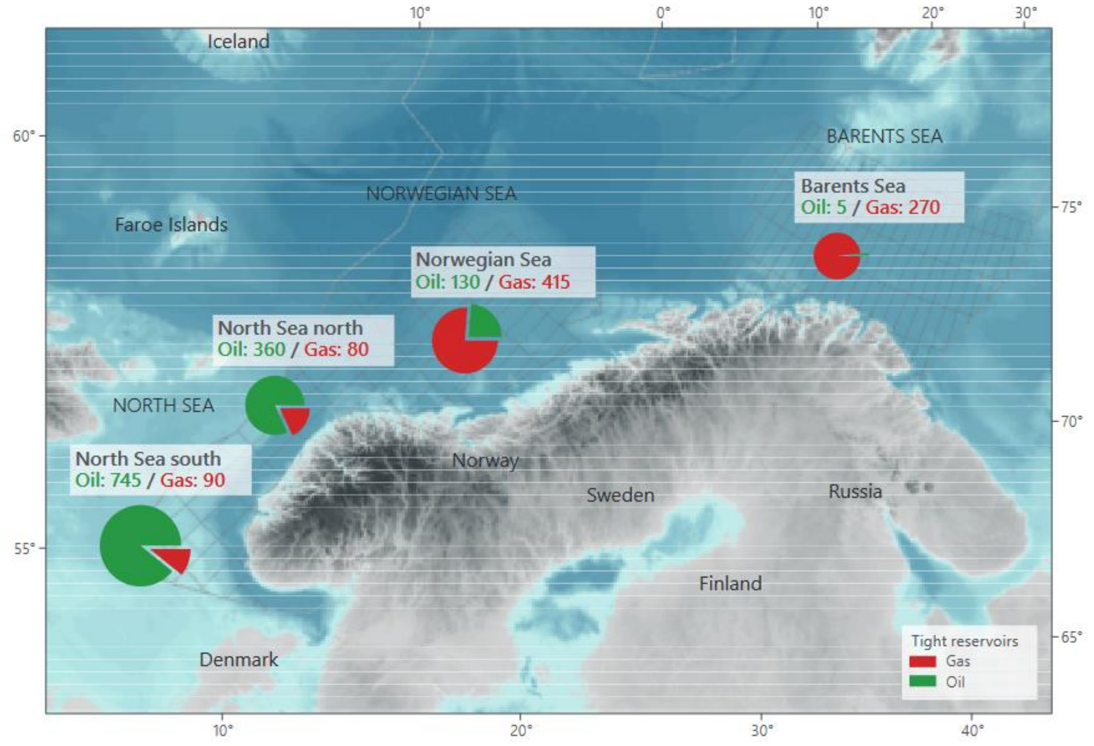
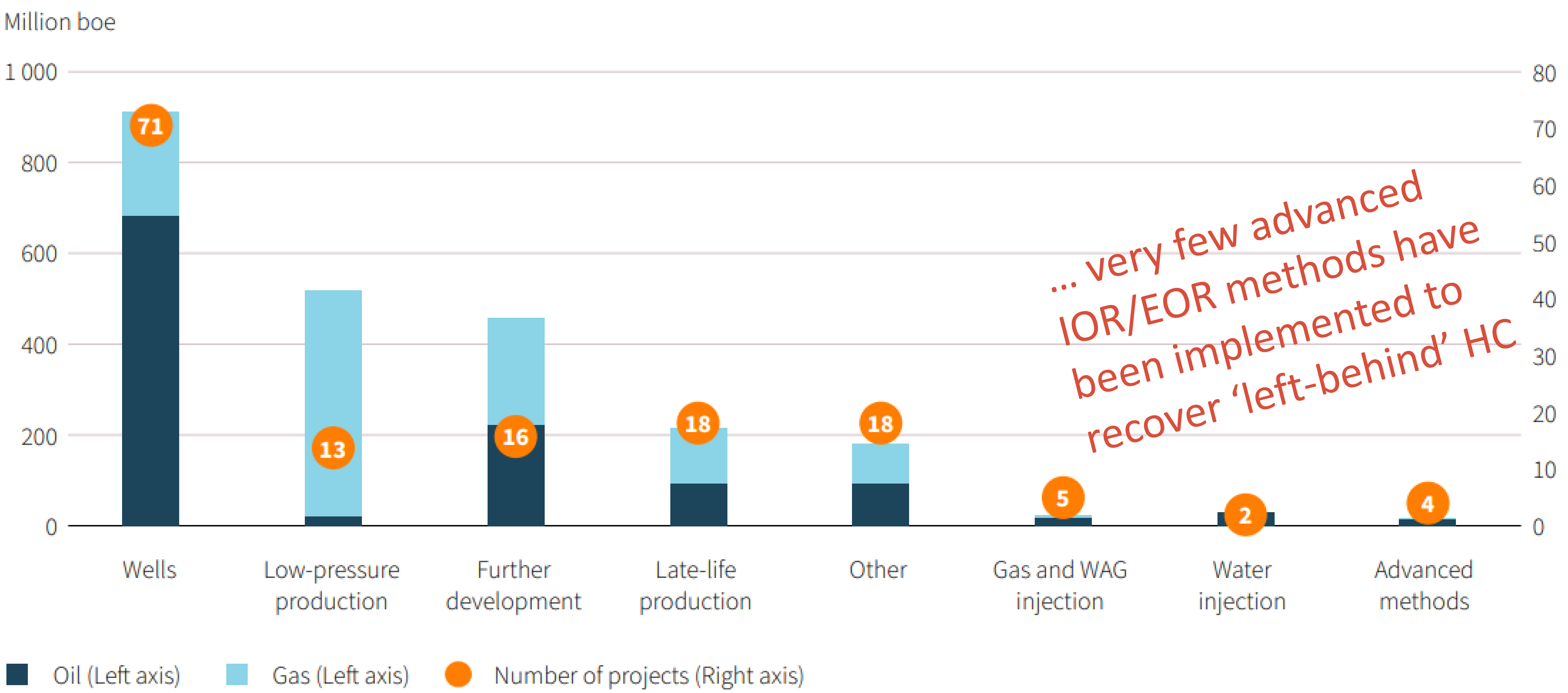


Figure 3.3 Oil and gas in place in tight reservoirs by area. Amounts in million scm oe

Courtesy: NPD Resource Report, 2019 – Discovery and fields. www.npd.no

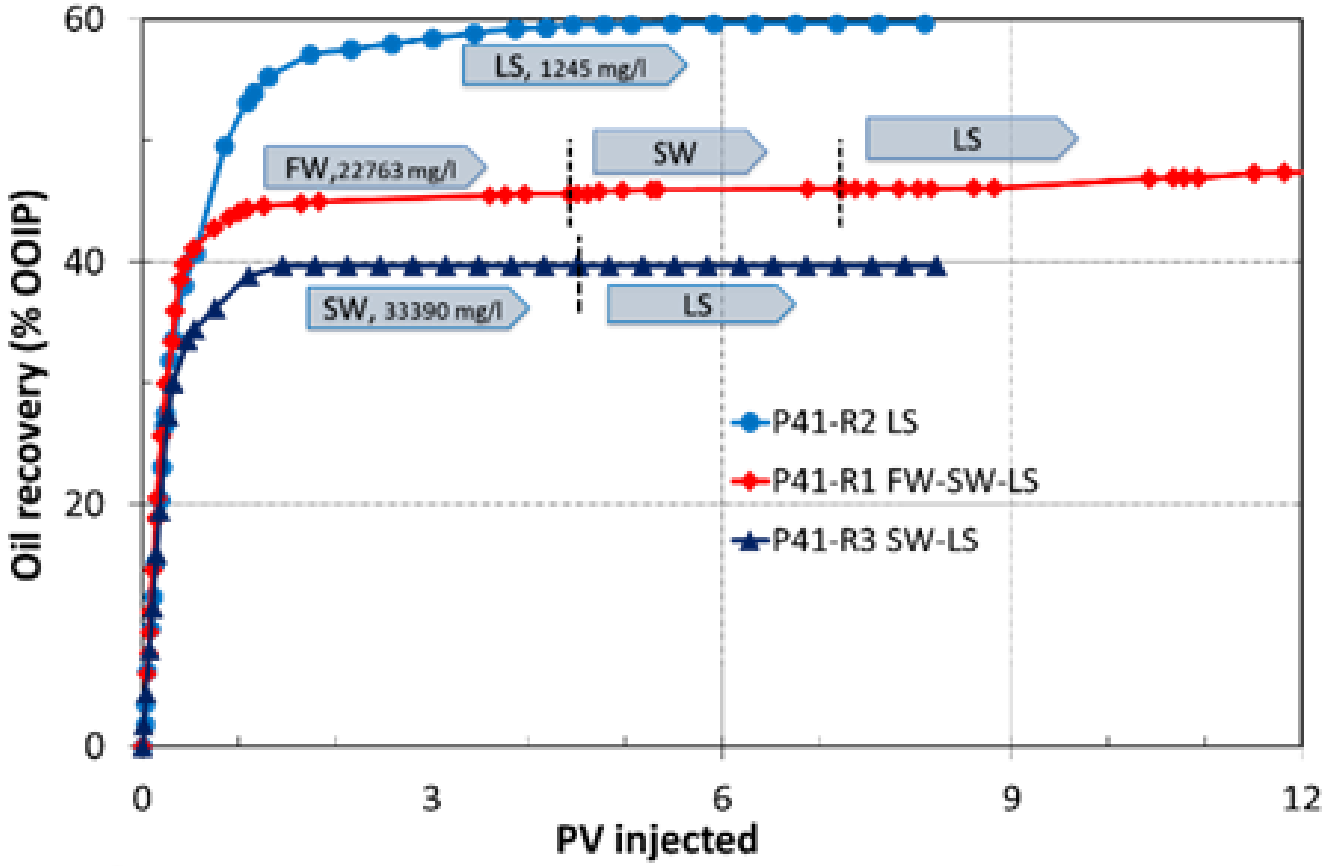
NCS – Competetive recovery rate, but…

Figure 27. Projects and estimated recoverable volumes for oil by project category (NPD, 2019)



Ref: OG21 – Strategy 2021

We need to start early! Example of low salinity waterflooding



Reservoir B at NCS T_{res}> 130 °C

Brines tested:

-LS (1 245 ppm) in secondary and tertiary

- 0.3 mM Ca^{2+}, 1.8 mM Mg^{2+}

-FW (22 763 ppm) in secondary.

- 3.5 mM Ca^{2+}, 1.4 mM Mg^{2+}

--SW (33 390 ppm) in secondary

- 13 mM Ca^{2+} , 45 mM Mg^{2+}

(Ref. Z. Aghaeifar PhD-thesis 2020)

- **LS injection most promising!**
- **<u>No LS EOR effect after seawater flooding in this case!</u>**

NCS 2030

We should not wait to do EOR when we can use "EOR-methods" to do IOR instead.

6 projects linked to IOR starting this year

WP	Project number	Project name	Project Manager	Partner
WP1	1	WP1.1 Quantitative cross-disciplinary resource evaluation	Tuhin Bhakta	NORCE
WP1	2	WP1.2 Salt characterization and modeling for the future energy mix (PhD)	Dora Marín	UiS
WP1	3	WP1.3 Basin-scale fluid connectivity	Stéphane Polteau	IFE
WP1	4	WP1.4 Next Generation of Petroleum/CO2 -Brine System Models	Stéphane Polteau	IFE
WP1	5	WP1.5 Develop new workflows in the salt province of the Norwegian North Sea for evaluating the potential for CO2/H2 storage and geothermal energy	Rob Berendsen	Landmark
WP1	6	WP1.6 Near field resource evalaution using solutions from the DELFI's Petrotehcnical Suite	Pierre Le Guern	Schlumberger
WP2	1	WP2.1 Physics of focused fluid flow in sedimentary basins	Viktoriya Yarushina	IFE
WP2	2	WP2.2 Recommended practice for numerical modelling of geomechanical behavior of various fields on the NCS	Viktoriya Yarushina	IFE
WP2	3	WP2.3 Tracers and tracing methods for utilization of the NCS in the energy transition	Mário Silva	IFE
WP2	4	WP2.4 Hydrogen storage and back-production in porous media	Ingebret Fjelde	NORCE
WP3	1	WP3.1 Tight reservoir solutions (PhD)	T. Puntervold/A. Omekeh	UiS/NORCE
WP3	2	WP3.2 CO2 utilization (UiBPhD)	Z. Alcorn/I. Fjelde	UiB/NORCE
WP3	3	WP3.3 Improved tracing	Sissel Viig	IFE
WP4	1	WP4.1 Deep water diversion for minimizing CO2 footprint	R. Askarinezhad/P. Andersen	NORCE
WP4	2	WP4.2 Optimization of injection water for IOR (PhD)	T. Puntervold/I. Fjelde	UiS/NORCE
WP4	3	WP4.3 IORSim modeling for near wellbore geochemistry and geomechanics (NorcePhD)	B. Antonsen/A. Omekeh	IFE/NORCE
WP5	1	WP5.1 Federated Knowledge Cloud for Subsurface Digitalization across Multiple Sites (UiSPhD)	Chunming Rong	UiS
WP5	2	WP5.2 Multi-fidelity models, scenario evaluation and probabilistic forecasts for the digital subsurface (UiSPhD)	Kristian Fossum	NORCE
WP5	3	WP5.3 Reservoir-management workflows for decision-making	Geir Evensen	NORCE
WP5	4	WP5.4 Hybrid ensemble algorithms applied to CO2/H2 utilization and storage (UiSPhD)	Xiaodong Luo	NORCE
WP5	5	WP5.5 Develop and support knowledge cloud for subsurface digitalization across multiple sites	Rob Berendsen	Landmark
WP5	6	WP5.6 Explore, develop, test and deploy new automated workflows that utilize cloud storage data and cloud compute infrastructure	Pierre Le Guern	Schlumberger
WP6	1	WP6.1 NCS, the business climate, and market characteristics	Torfinn Harding	UiS
WP6	2	WP6.2 Avoidance of stranded assets	Torfinn Harding	UiS
WP6	3	WP6.3 Energy transition and the NCS	Mari Authen	IFE
WP6	4	WP6.4 Acceptance evaluation	Torfinn Harding	UiS

WP3 | Net Zero Emission production

Background

Approximately half the reserves on the Norwegian Continental Shelf are left behind by the end of the field lifetime due to unfavourable reservoir properties and conditions (challenging barrels).

Field production in the coming decades must comply with the Net-Zero ambition. At the same time, it is our obligation to maximise value creation from existing fields and invested infrastructure.

Aim

Contribute to carbon-neutral future on NCS by further developing cost- and energy-efficient HC recovery methods for improved and accelerated HC production at low environmental footprint.

Develop new technologies with focus on GHG emission reduction and to benefit from renewable energy sources offered by the upcoming sustainable offshore industries.

Build competence and new solutions integrating CCUS technologies for transitioning to CO2 storage for late life fields.

Task 3.1 | Maximizing value creation on NCS

- Further mature EOR methods to reduce remaining oil and accelerate oil production at lower environmental footprint (smart water, green polymer, CO2 usage combined with storage)
- IOR-solutions for tight reservoirs – The challenging barrels
- Develop improved methods for in-situ determination and tracing of S_{or} and wettability
- Develop improved near-well modelling capabilities (IORSim) for chemical reactions, hydrodynamics and injectivity issues

Task 3.2 | Real field applications for Net Zero emission production

- Life cycle analysis methodology for Net Zero field improved production and emission quantification for existing and new solutions
- Create net-zero emission field scenarios in collaboration with field operators
- Implement new modelling capabilities for technical feasibility and economic analysis (OPM/IORSim)
- Method development for improved reservoir modelling (e.g. time-lapse geophysical measurements and fibre optic data).

3 projects starting in 2022

WP3.1
Tight reservoir solutions

Project Manager: Aruoture Omekeh (NORCE)/ Tina Puntervold (UiS)
Key Personnel: R. Askarinezhad, A. Lohne (NORCE), A. Mamonov, S. Strand, A. Hiorth, P. Andersen, R. Korsnes (UiS), M. Wangen (IFE), Z. Alcorn (UiB)

Substantial hydrocarbon reserves are loca
tal Shelf (NCS). These reservoirs are chal
neity, low permeability, and deep location
the productivity in such reservoirs. Sever
suitability to NCS need to be evaluated.
egy. Gas/Waterflooding can be used for p
of water into the oil-containing matrix ca
recovery optimization. Can optimized injec

WP3.2
CO_2 utilization

Project Manager: Zachary Alcorn (UiB)/Ingebret Fjelde (NORCE)
Key Personnel: A. Graue (UiB), A. Omekeh (NORCE); R. Gholami, P. Andersen, T. Puntervold (UiS); M. Silva (IFE)
Budget: 2.9 MNOK

CO_2 storage in subsurface reservo
This potential will give rise to com
mobility of CO_2, unstable displace
CO_2 displacement storage potentia
efficiency can be improved by the

WP3.3
Improved tracing

Project Manager: Sissel Viig (IFE)
Key Personnel: M. Silva, A. Krivokapic, B. Antonsen, L. Stavsetra (IFE); I. Fjelde (NORCE), A. Hiorth (UiS)
Budget: 2.4 MNOK

The purpose of this project is to develop tracers to increase the knowledge about the flooded volume of the reservoir and thereby generating data to maximise the value creation on the NCS. Tracers and tracer methods for investigation and evaluation of important parameters as remaining oil saturation, relative permeability and wettability will be the focus for the development. The goal is to have a tracer method that can determine several of the parameters in-situ from the same tracer test by co-injection of tracers with different properties in the near well region. The main focus in 2022-2023 will be on tracers for wettability.

NCS 2030

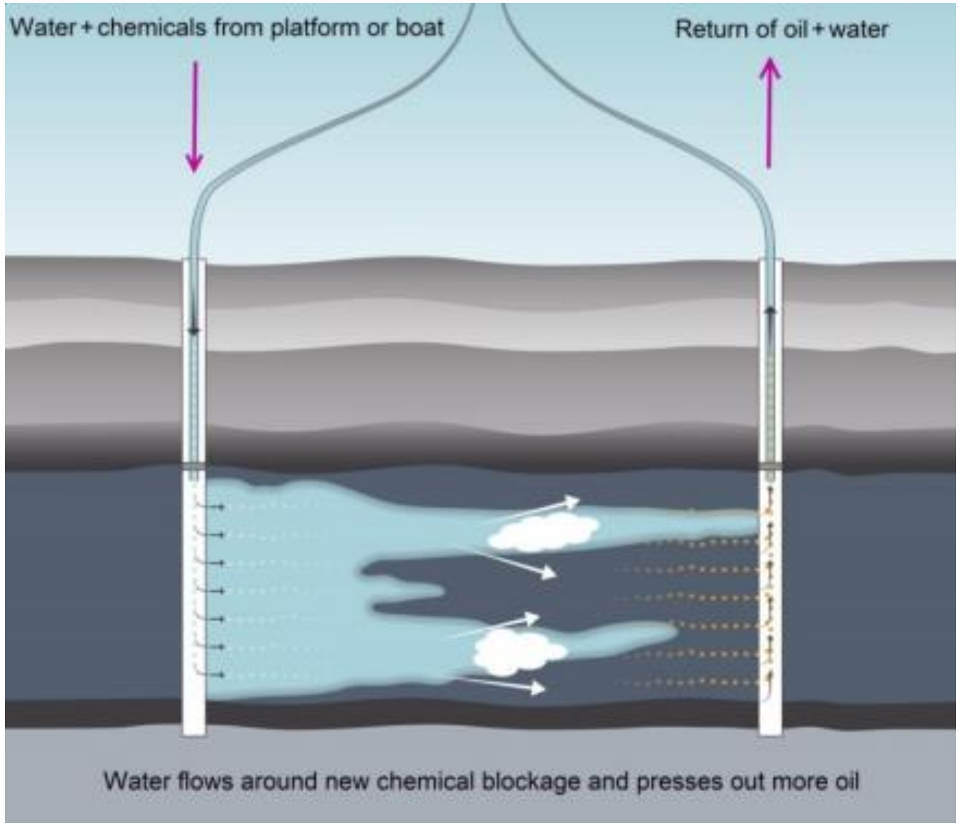
WP4 | Efficient water management

Background

Increasing amount of water is injected into and produced from aging fields. Water management is energy-consuming and costly. Large amount of injection water is recirculated and should be minimised by conformance control technologies. Reservoirs should be efficiently swept to minimize CO_2-emissions.

Aim

Deliver solutions for minimizing injection water recirculation with reduced energy needs, thus reducing the CO_2-emissions, by efficiently managing water injection and production through improved macroscopic sweep of the reservoir.



Courtesy Equinor

Task 4.1: Develop water-management solutions for energy-efficient production

- Improved injection water conformance: Reduce back produced water and accelerated oil production at lower environmental impact.
- Evaluate PWRI and water injection combined with CCS.

Task 4.2: Near-well modelling tools

- Develop near-well modelling tools that incorporate the relevant injection, smart well completion and stimulation processes, including new tracer deployment methods.

Task 4.3: Real field applications for no water discharge to sea

- Demonstration of methods/methodologies on field cases.
- Testing/application of methods/methodologies in industry workflow with assistance from researchers.

3 projects starting in 2022

WP4.1
Deep water diversion for minimizing CO_2 footprint

Project Manager: Reza Askarinezhad (NORCE)/Pål Andersen (UiS)
Key Personnel: A. Stavland, Y. Guo, A. Lohne (NORCE); Børre Antonsen (IFE)
Budget: 2.0 MNOK

The CO_2 footprint depends strongly on
and -production in high water-cut fields.
er CO_2 emission by more than 50%. Oil v
prove the sweep efficiency will minimize
oil production at lower water-cut and CO
from large perspective when making de
dustrial practice at companies in the pr
estimate cost and feasibilities. New eler
are CO_2 emission, cost saving related to

WP4.2
Optimization of injection water for IOR

Project Manager: Tina Puntervold (UiS)/Ingebret Fjelde (NORCE)
Key Personnel: A. Mamonov, S. Strand, A. Hiorth (UiS); A. Omekeh (NORCE); M. Silva (IFE)
Budget: 2.9 MNOK

Water flooding of heterogenous reser
process. Modifying currently injected
duce back produced water will theref
possibilities of using environmentally
from back produced water, CO2 and c
improve water flooding and reduce b

WP4.3
IORSim modelling for near wellbore geochemistry and geomechanics

Project Manager: Børre. Antonsen (IFE)/Aruoture Omekeh (NORCE)
Key Personnel: J. Sagen (IFE); Y. Guo, A. Lohne, (NORCE); A. Hiorth (UiS)
Budget: 3.9 MNOK

IORSim is an IOR process simulator linkable to commercial reservoir simulators. It was developed as part of The National IOR Centre of Norway. IORSim will in this project be further matured for smart water applications combined with geochemistry. A near wellbore module will also be developed for evaluation of chemical water shut-off processes and tight rock production.

NCS 2030

Planned NCS2030 Master thesis topics 2023 related to the ongoing projects

New energy and storage opportunities:

- Lithological heterogeneities in the Zechstein Group: Implications for hydrogen storage and drilling risk
- Geothermal energy opportunities in the Utsira High
- High-temperature storage systems opportunities in the North Sea
- Lateral extension of the Rogaland sandstone in the southern North Sea: Implications for CO_2 storage

Efficient Water Management for NZE

- Wellbore and reservoir leakage detection and monitoring with downhole gauges
- Net-Zero effect of selected conformance improvement techniques at NCS – a preliminary study
- CO_2-based foams for conformance improvement at the NCS - Also to reduce CO_2 footprint?
- Laboratory study of selected water diversion techniques
- Preliminary study of the LCA for various suitable conformance improvement techniques at the NCS
- Use of conformance control chemicals as CO_2 barrier for geological storage of CO_2

Reservoir Utilization for Energy Transition

- Deformation of unconsolidated sediments and its impact on CO_2 storage
- Modeling of induced seismicity during subsurface operations

Net-Zero Emission (NZE) Production

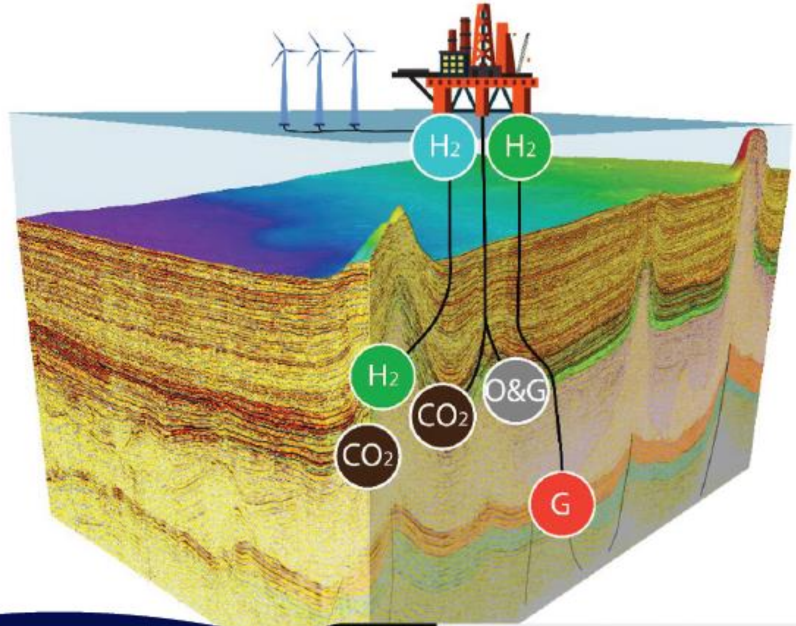
- Well stimulation for tight North Sea reservoirs
- Interactions of H_2-phase with rock/minerals and fluid phases during geological storage of H_2
- Alteration of rock properties during geological storage of H_2
- Injectivity of carbonated water with different CO_2 concentration into different rock types
- Rock integrity during injection of carbonated water into different rock types
- Improvement of volumetric sweep efficiency during oil production using ECO-clay
- Optimization of reinjection of produced water into different reservoir types
- Experimental work on multiphase flow and fluid production in core plugs
- Reactive flow modelling with presence of a catalytic reaction in porous media – an insight into hydrogen production in a porous medium

Digital Subsurface for Improved Decisions

- Core images and ML tools in the public and private repositories for rock property estimation

Energy Norway

Subsurface for energy security and sustainability



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