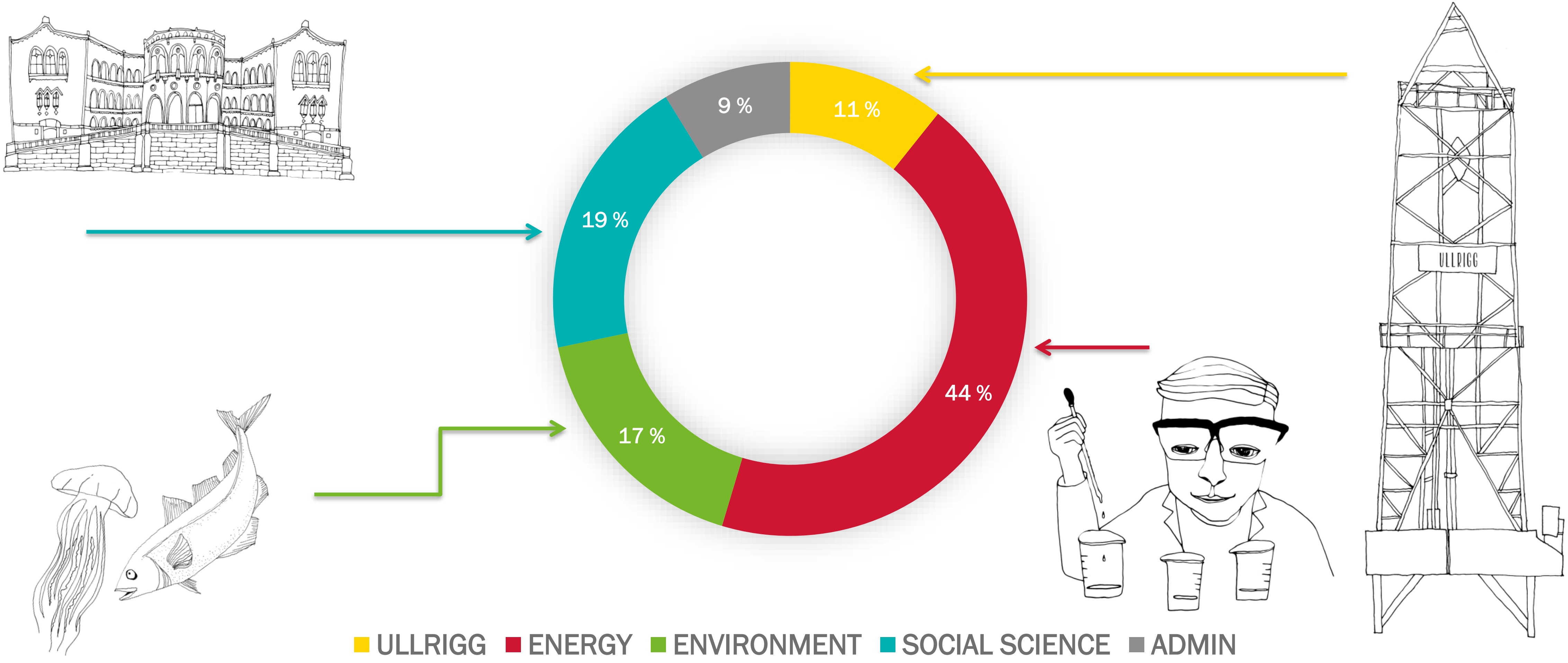
CO2-EOR & CCS at IRIS

FORCE R&D Seminar, April 2018

Ying Guo, IRIS Energy

About IRIS – Departments



About IRIS – Key figures

4 OFFICES

Stavanger, Bergen, Mekjarvik,Oslo

23 NATIONALITIES

198 EMPLOYEES

5 DEPARTMENTS

92 PHD RESEARCHERS

IRIS Energy

R&D areas:

- Petroleum
  - Drilling and well technology
  - Reservoir technology
  - EOR
- CO_2 Storage
- Renewable Energy
- Energy Efficiency

Main target areas:

- Automated Drilling
- Multiphase Reservoir Flow

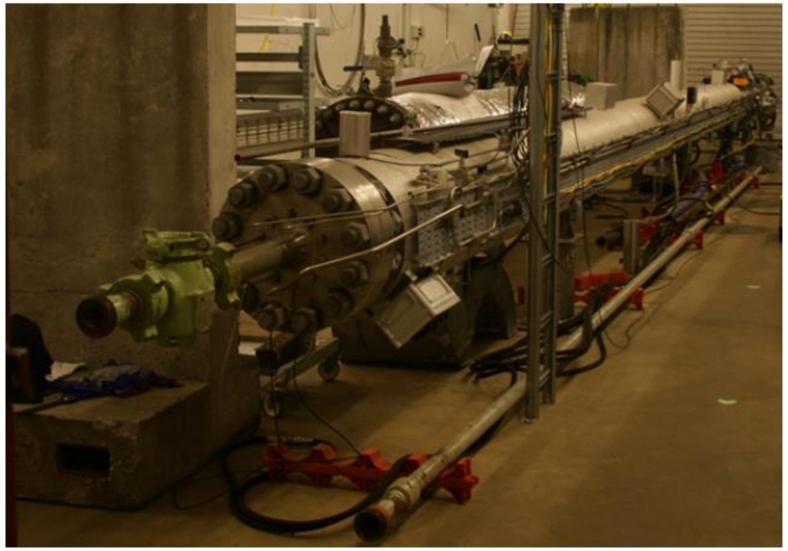
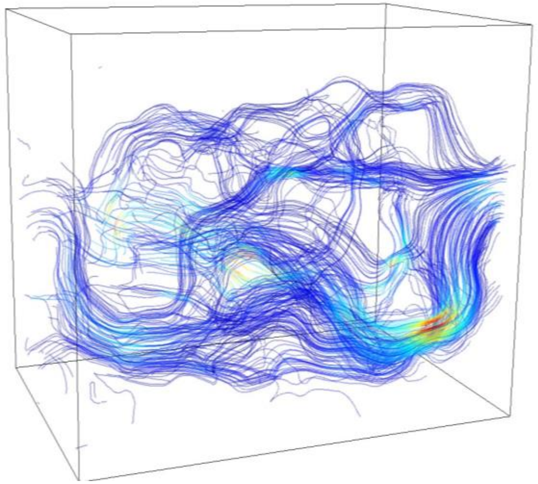


Photo: IRIS

DOWNHOLE INSTRUMENTATION AND CONTROL SYSTEM (DIACS)




WeST Group
CMR

RISAVIKA test facility

NORCE

A pioneer in Norwegian Research and Innovation

NORCE

"Maud" returns home

CMR had two men hired at «Maud”, Harald Ulrik Sverdrup and Odd Dahl. Both helped Roald Amundsen to get his project through and this highly scientific expedition could be realized. Sverdrup was scientific leader from 1918 till 1925, while Odd Dahl was hired as pilot and filmmaker on the last three years of the expedition.

NORCE

Nøkkeltall

5 LOKASJONER

Bergen, Haugesund, Stavanger, Grimstad, Kristiansand, Oslo

25 NASJONALITETER

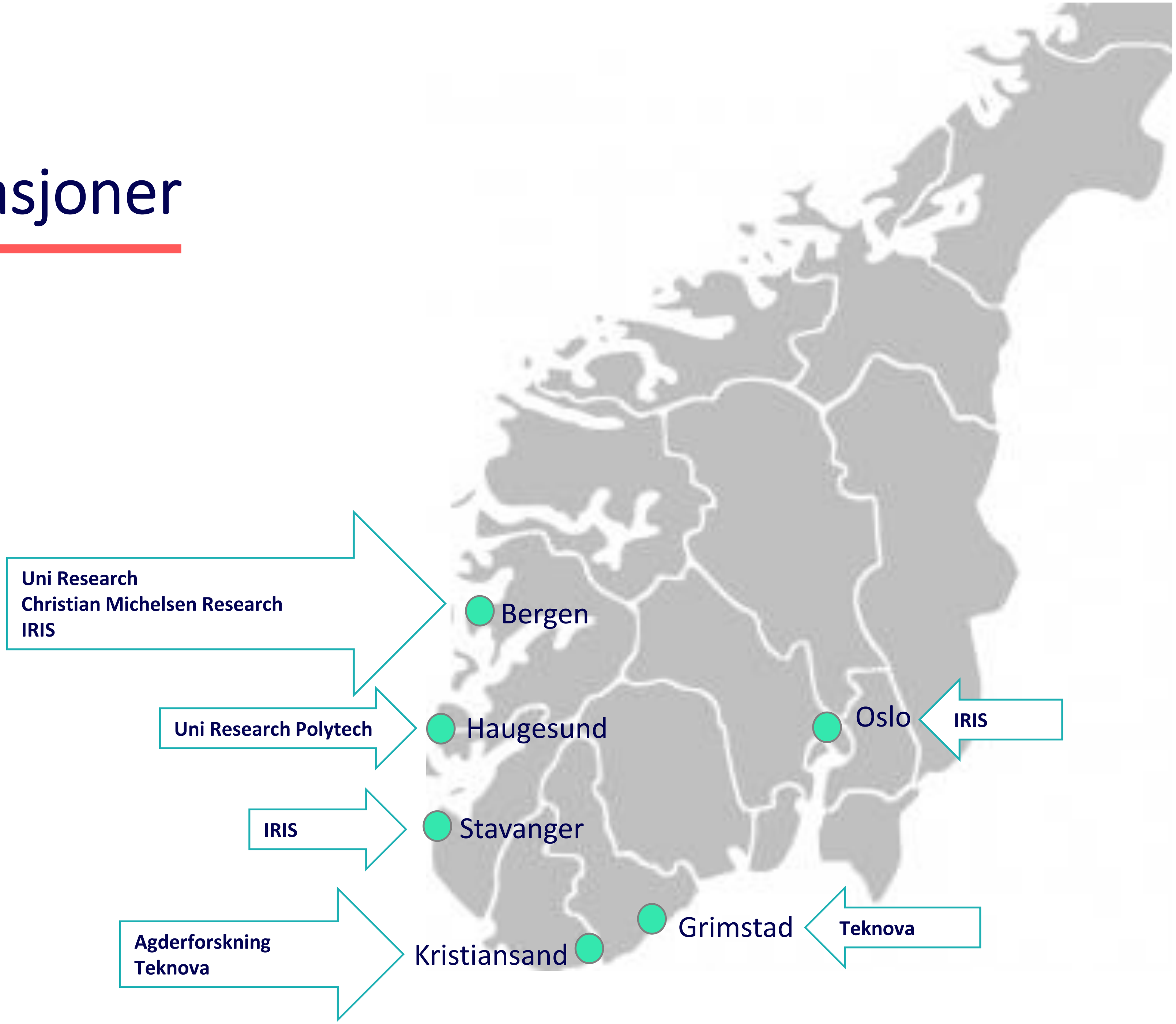
900 ANSATTE

6 FAGDELINGER

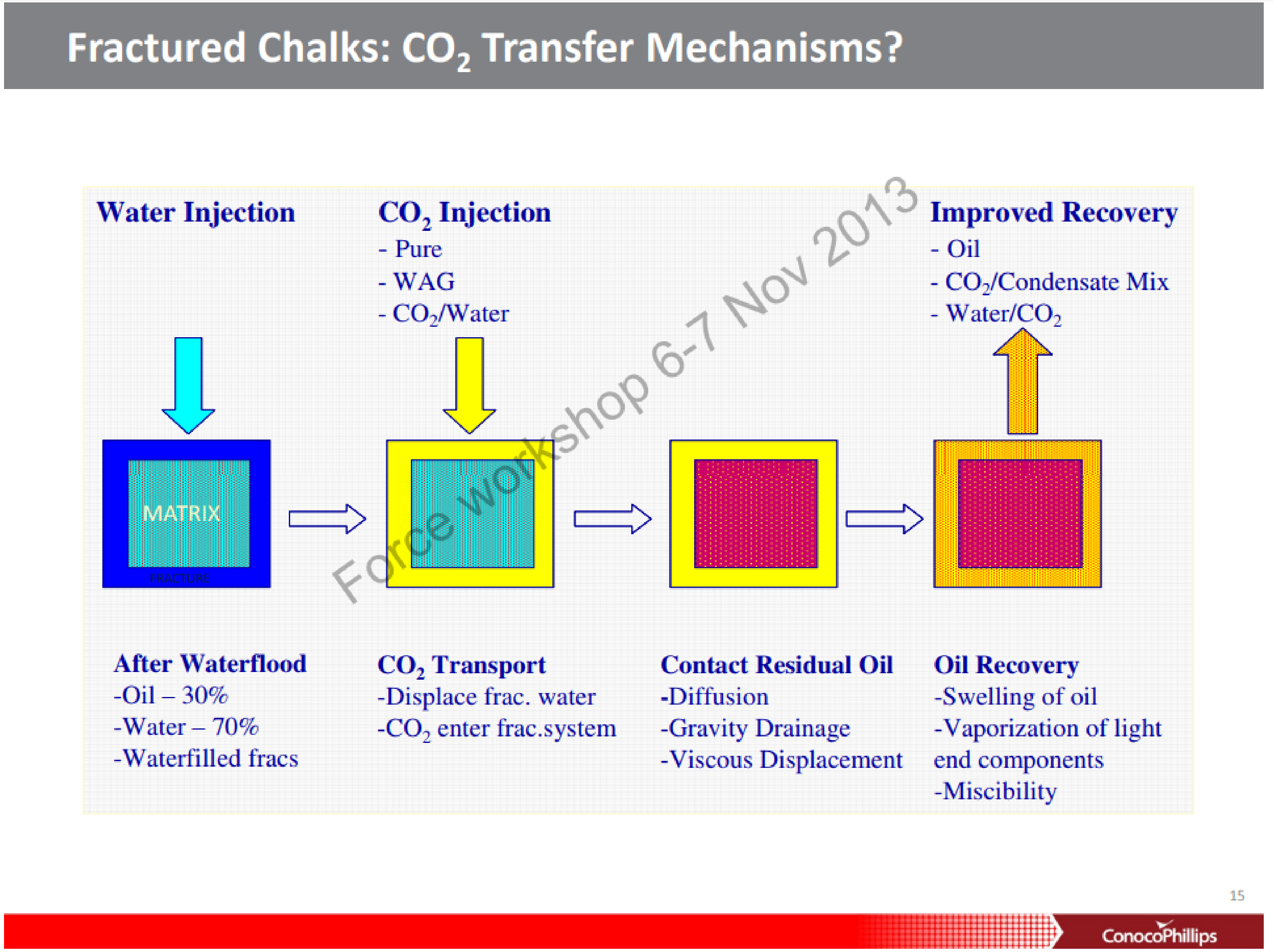
5 LEDENDE INSTITUTTER

CMR, Uni Research, IRIS, Teknova, Agderforskning

Lokasjoner


Uni Research
Christian Michelsen Research
IRIS
Bergen
Uni Research Polytech
Haugesund
Oslo
IRIS
IRIS
Stavanger
Grimstad
Teknova
Agderforskning
Teknova
Kristiansand

CO2 EOR from chalk field



Ongoing CCUS projects at IRIS

- **EU ENOS** (Enabling Onshore CO2 Storage in Europe, 2016-2020) is a large Horizon2020 project involving more than 20 institutions across Europe.
- **EU / ACT - The ECO-BASE** (2017 – 2020) is aimed at utilization of CO_2-EOR as enabler for CCS. The concept is to include prospective revenue streams and related business models as a vehicle to render CO_2 capture-transport-storage economically feasible.
- **CLIMIT Research project UNCOVER** (2017-2020) The primary objective of the project is to establish a set of quality experimental data set to understand and describe the convection-driven dissolution of CO_2 in a porous media containing oil and water.
- **CLIMIT – OPM for CO_2** (2017-2018) Developing simulation tools that can be used for feasibility studies of CO_2 injection at NCS for both storage and EOR purposes.
- **CLIMIT Wettability alteration by carbonated water** (2016-2017) aims at understanding and estimation of the wettability alteration by CO2 dissolved in seawater, and quantify the potential CO_2 storage and EOR effect.
- **BIOTEK2021 BioZement 2.0** (2017 – 2020) The production of concrete accounts for more than 5% of global anthropogenic CO_2 emissions, and new, disruptive technology in the field is needed to make a large-scale impact.

CO2 UTILISTATION AND STORAGE (CCUS) AT IRIS

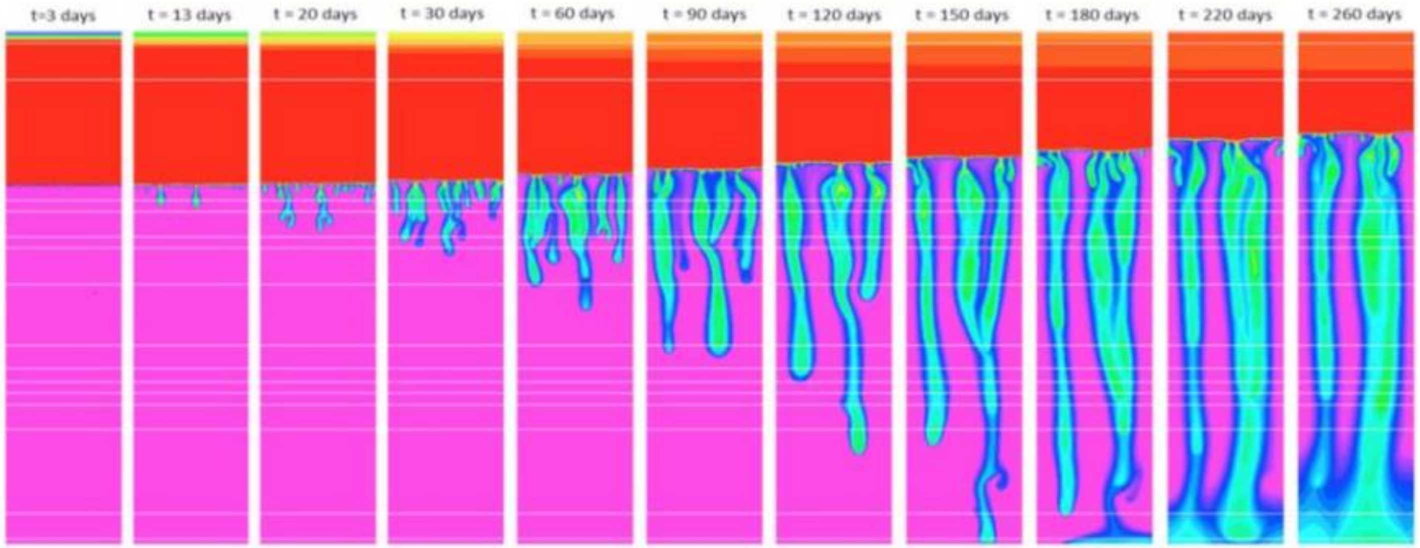
With basis in experience, competence and laboratories developed for petroleum reservoir characterization and improved oil recovery, IRIS is actively involved in CO2 utilization and storage.
Further, the geology and reservoir quality is analyzed through modelling and laboratory measurements to secure safe long term storage.

Research topics

- ❑ Laboratory experiments
- ❑ Flow modelling & Field scale simulation
- ❑ Simulator development (OPM)
- ❑ Optimized CO2 storage during EOR
- ❑ Cap rock characterization
- ❑ Reservoir characterization
- ❑ Risk evaluation and liability

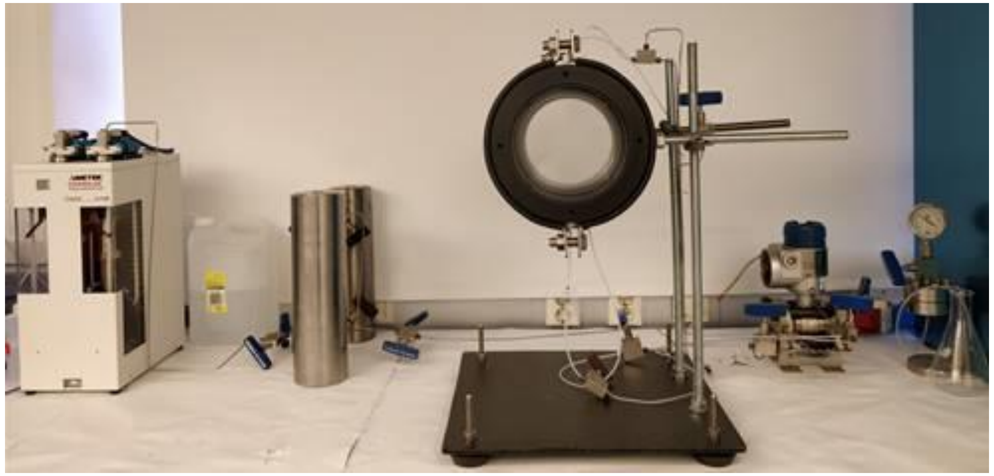
CO_2 EOR at IRIS – Project example

UNCOVER - **Un**derstanding of **CO**2 dissolution in oil by con**v**ectiondriven mixing and wettability alt**er**ation



Collaborators

- UNI - CIPR - Sister project CHI - '*Fundamentals of CO2-HC Interactions for CO2 storage with EOR*'
- HWU – UK
- UFRJ / COPPE - Brazil



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CO_2 EOR at IRIS – Project example

Simulation Tools for CO_2 Storage and CO_2-EOR

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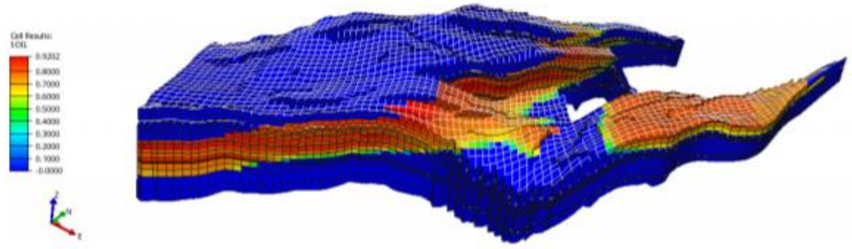
Atgeirr Flø Rasmussen (atgeirr@sintef.no), SINTEF ICT
Andreas Lauser (and@poware.com), DIGITRAIL

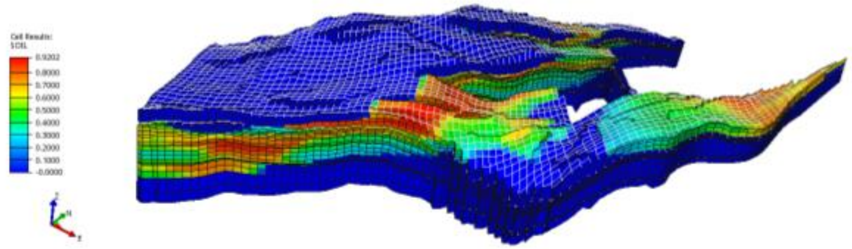
Objective

Develop an *open-source community code* that will improve the understanding of ongoing and prospective CO_2 storage operations. Conduct case studies that demonstrate the potential economic benefits that can be obtained by optimizing CO_2-EOR operations with respect to both enhanced oil recovery and carbon trapping.



Project goals

- build a robust, baseline simulator that handles *industry-standard, black-oil models* and is easy to extend with *new modelling capabilities*
- implement flow physics relevant to CO_2 storage and CO_2-EOR
- verify and validate new simulators using data and models of *real oil fields*
- study ongoing or prospective CO_2 storage operations, and perform conceptual studies to demonstrate benefits of co-optimizing CO_2 storage and enhanced oil recovery



IRIS

A unique European Research Laboratory on CO_2 geological storage formed by a network of public scientific institutes durably engaged in mitigating climate change

The CO_2 Capture and Storage Joint Programme (CCS-JP) involves over 30 members from more than 12 countries who have committed more than 270 person years /year to carry out joint R&D activities.

The programme has been officially launched at the SET-Plan conference in Brussels in November 2010.

SUCCESS – A 8-year Research Program ending 2018

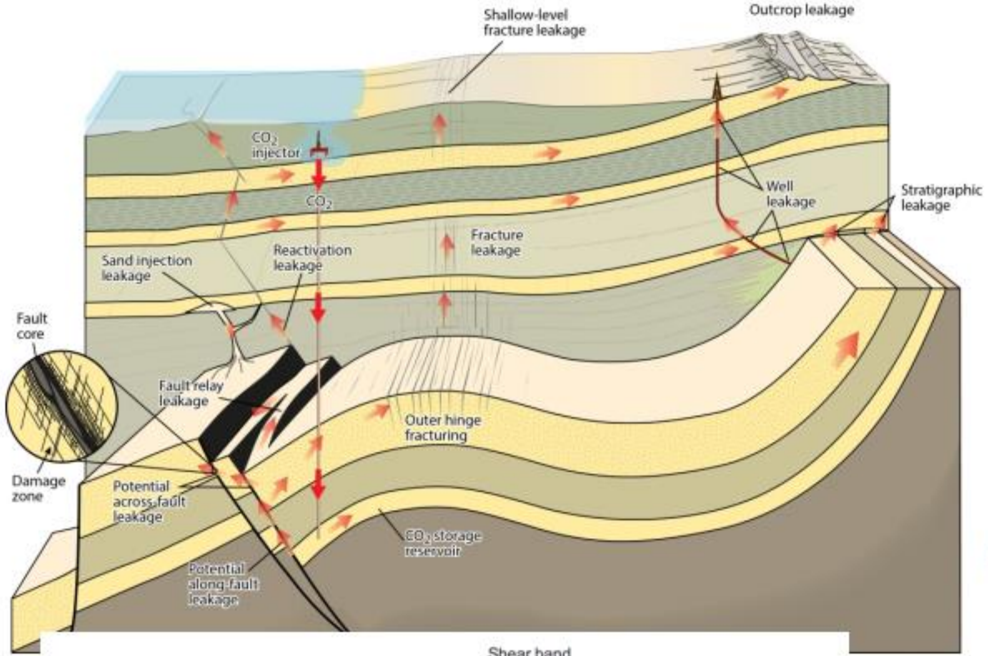
http://www.fme-success.no/index.cfm?id=355252

Christian Michelsen Research (CMR)
Dea Norge AS
Institute for Energy Technology (IFE)
Norwegian Geotechnical Institute (NGI)
Norwegian Institute for Water Research (NIVA)
OCTIO AS
Research Council of Norway
Statoil Petroleum ASA
UniResearch (Uni)
University of Bergen (UiB)
University of Oslo (UiO)
University Centre in Svalbard (UNIS)

- The SUCCESS centre addresses several important areas for CO2 storage in the ***subsurface: storage performance, sealing properties, injection, monitoring and consequences for the marine environment***. The “CO2-School” is in addition a major educational program

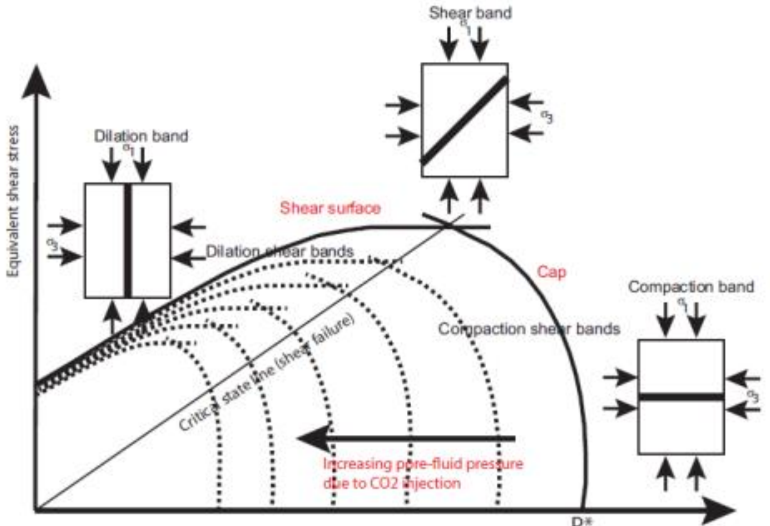
Impact of fault rock properties on CO_2 storage

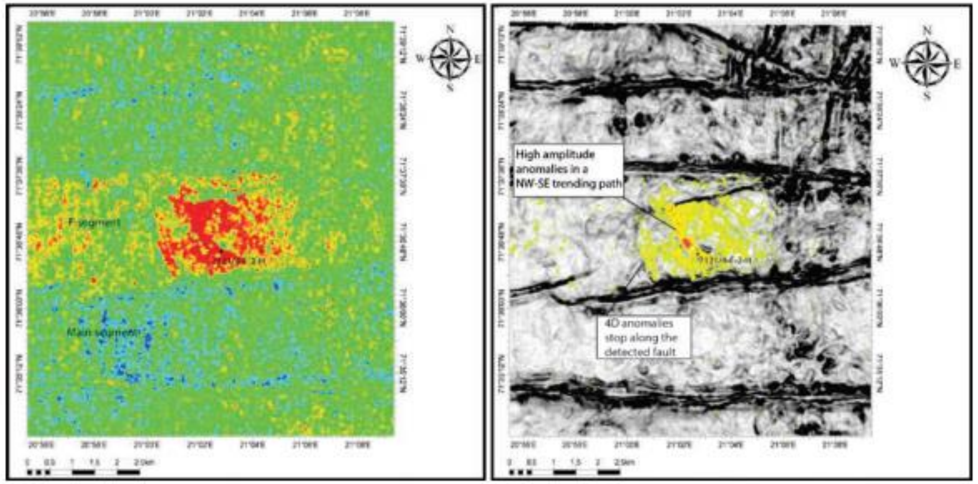
CLIMIT, Statoil funded, MNOK 10, led by Anita Torabi, partners: NGI, UiO, Univ. Grenoble Alpes, Northwestern University (US), 2011-2014

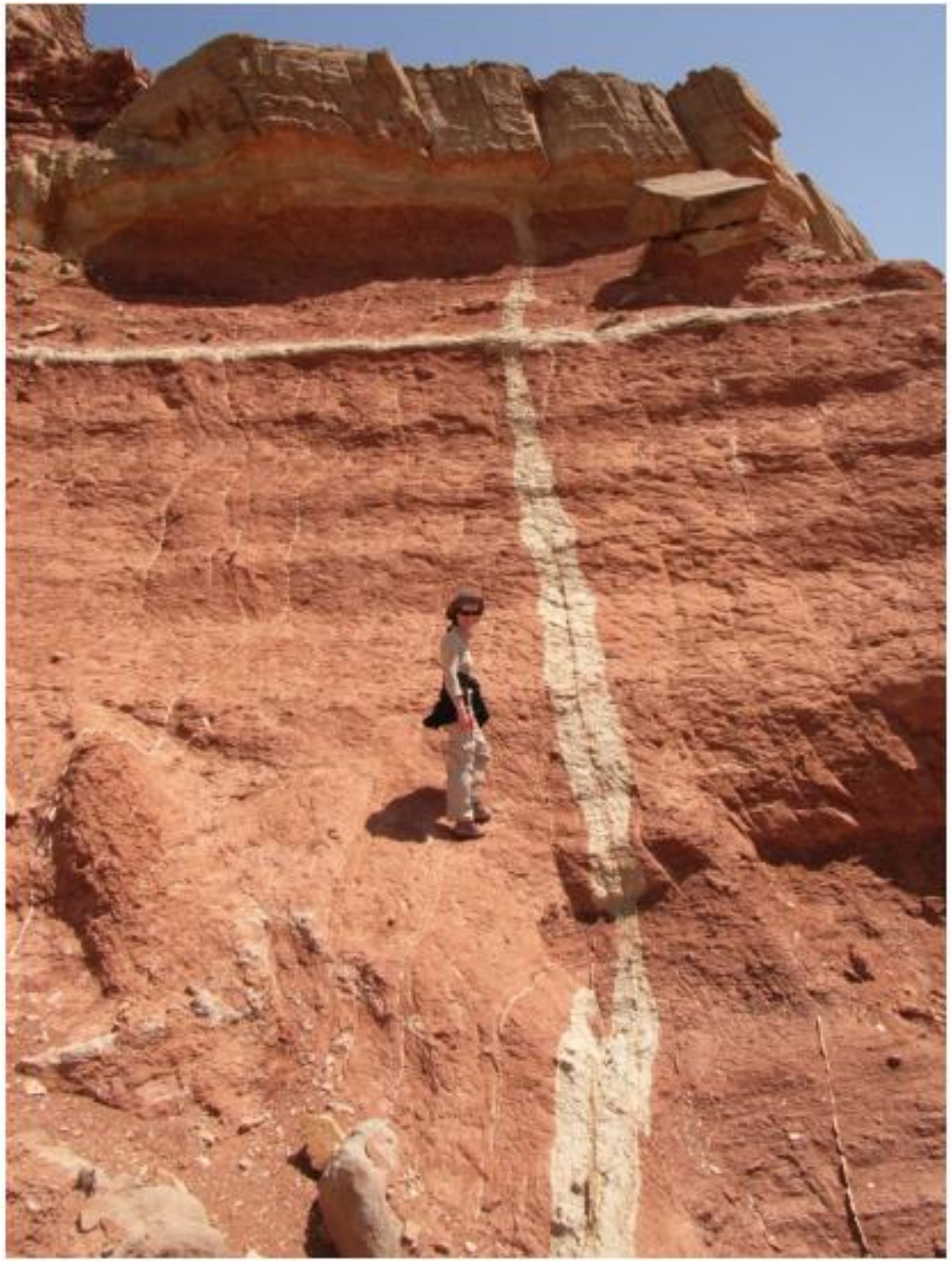


- Outcrop studies
- Triaxial experiments
- Numerical modelling
- Seismic studies for Snøhvit

For a summary, see Torabi et al., 2015 in First Break







SUCCESS to investigate Smeaheia

Smeaheia is the recommended site for storage of carbon dioxide from Norwegian onshore sources. This was the result of Statoil's feasibility study, which was approved by Gassnova 1 July 2016. SUCCESS has therefore decided that next year's work on storage capacity will be on the Smeaheia case. For that purpose we have received Statoil's Petrel model on Smeaheia from Gassnova. However, the objective of our study will be different from Statoil's objective. In the feasibility study, Statoil's objective was to study injection of 1.3 Mt CO_2 per year over 25 years. Our objective will be to investigate the storage capacity of the field and evaluate the injectivity and risk of leakage.

IAa

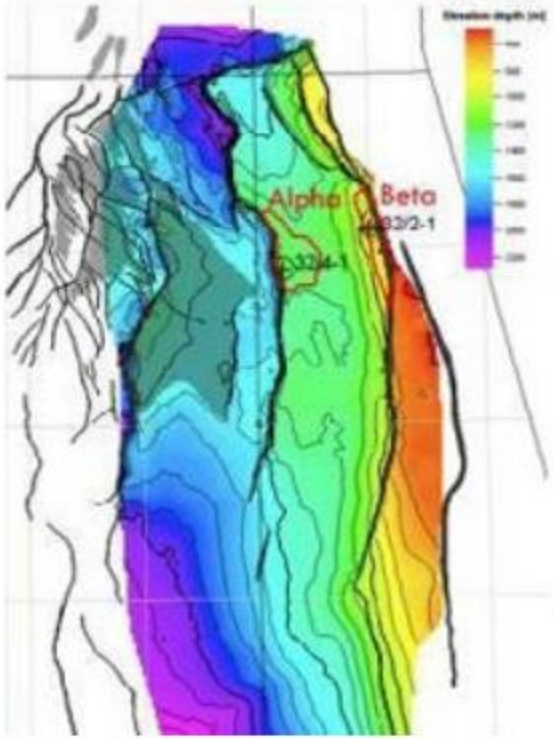
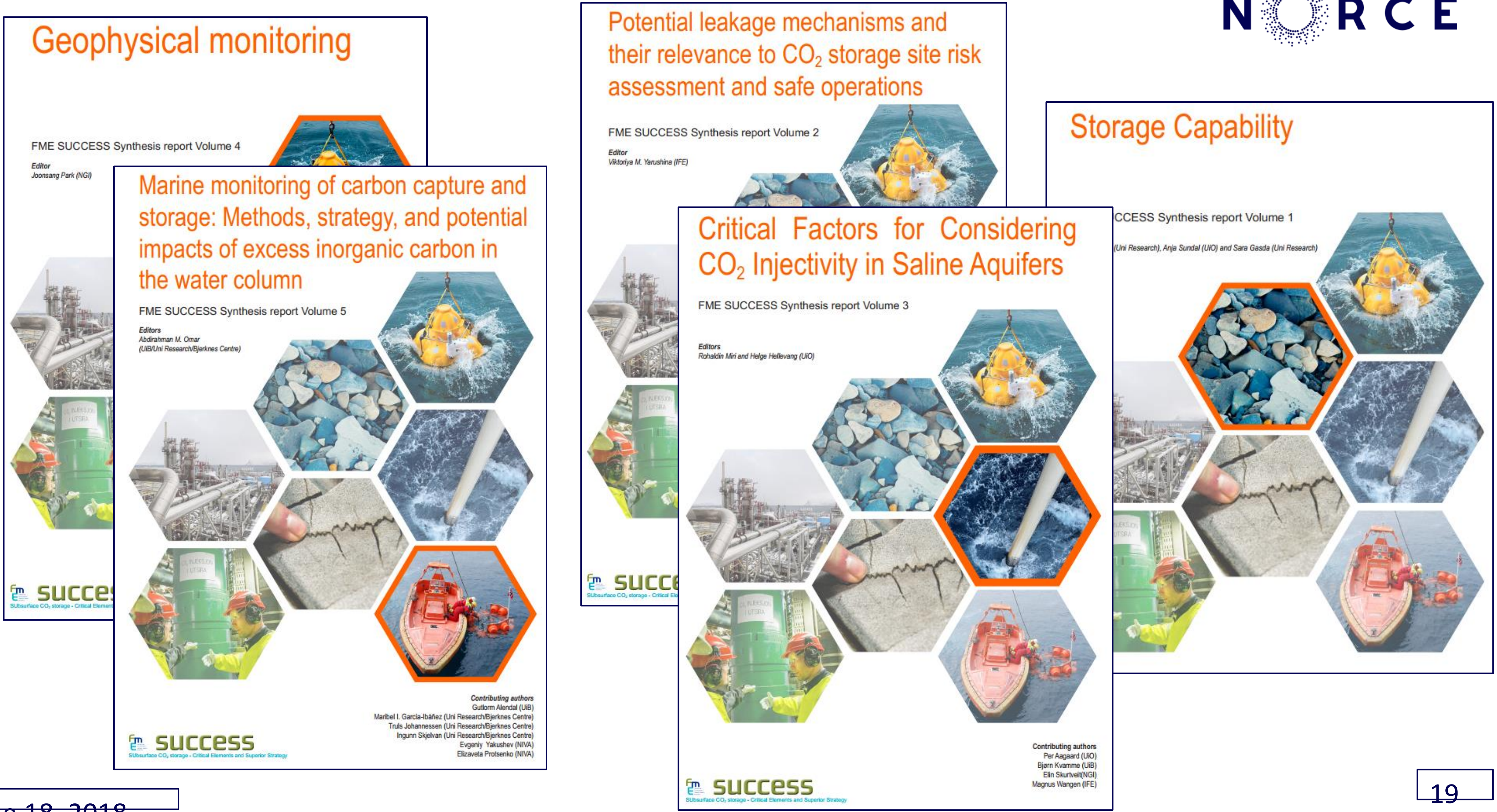


Figure: Location of possible injection structures in the large fault block of Smeaheia.

NORCE


Geophysical monitoring
FME SUCCESS Synthesis report Volume 4
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Storage Capability
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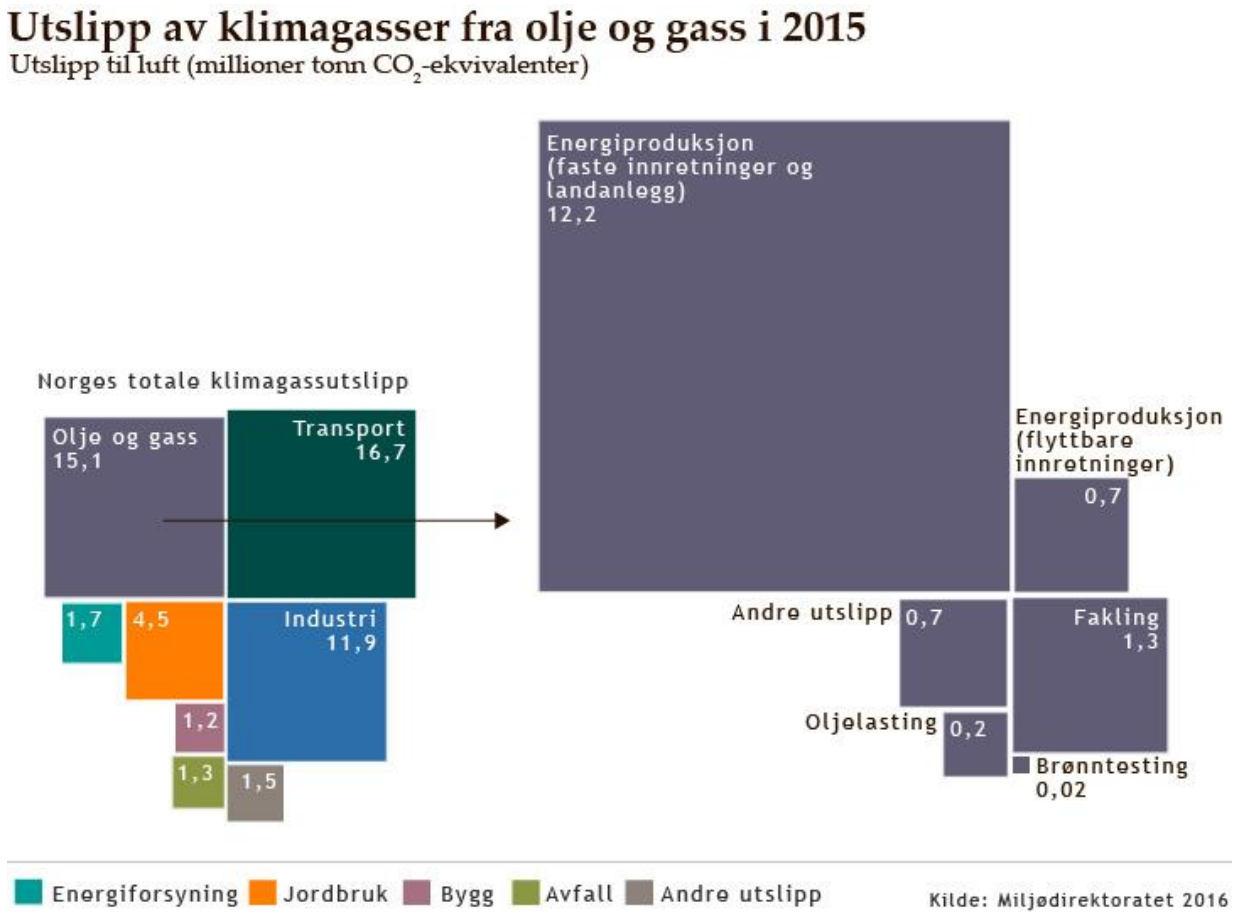
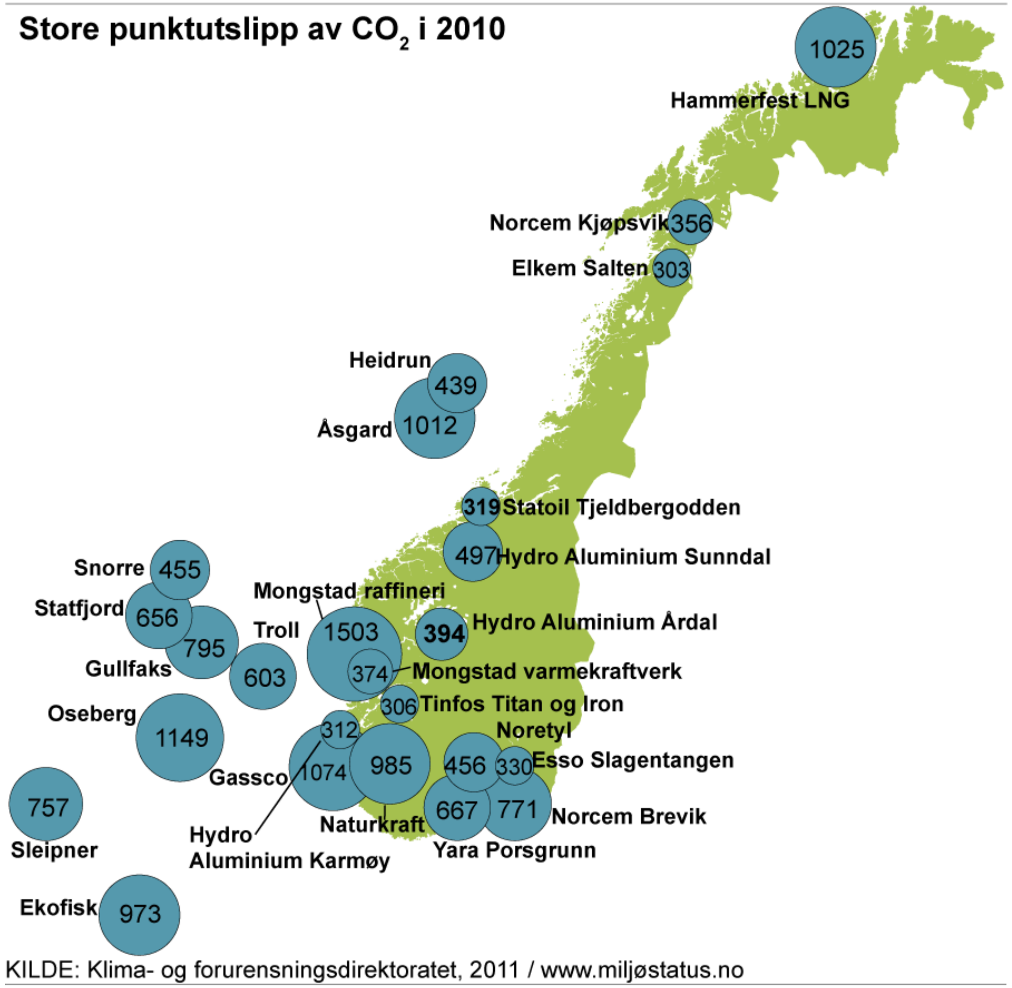
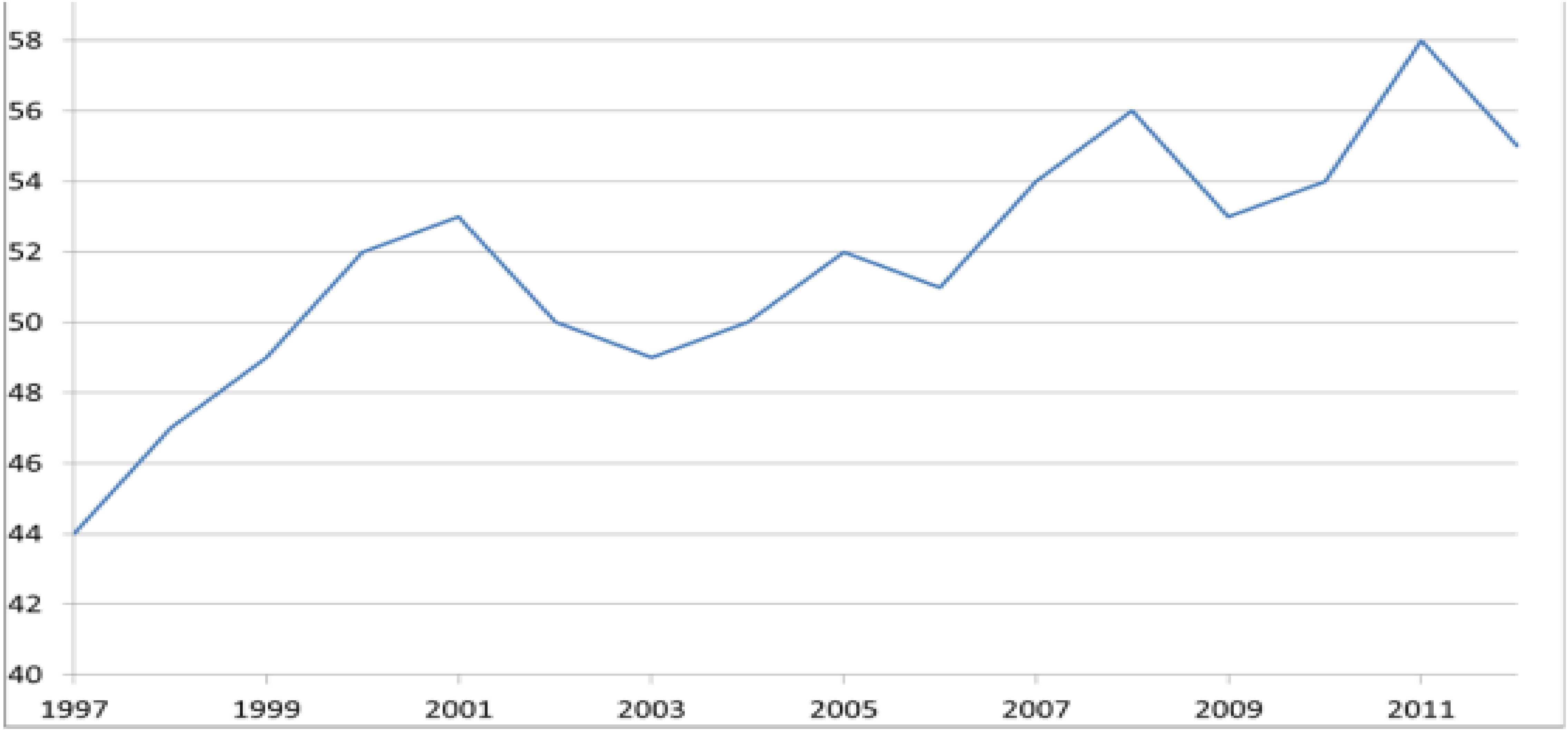
(Uni Research), Anja Sundal (UiO) and Sara Gasda (Uni Research)

CO2 source at our backyard

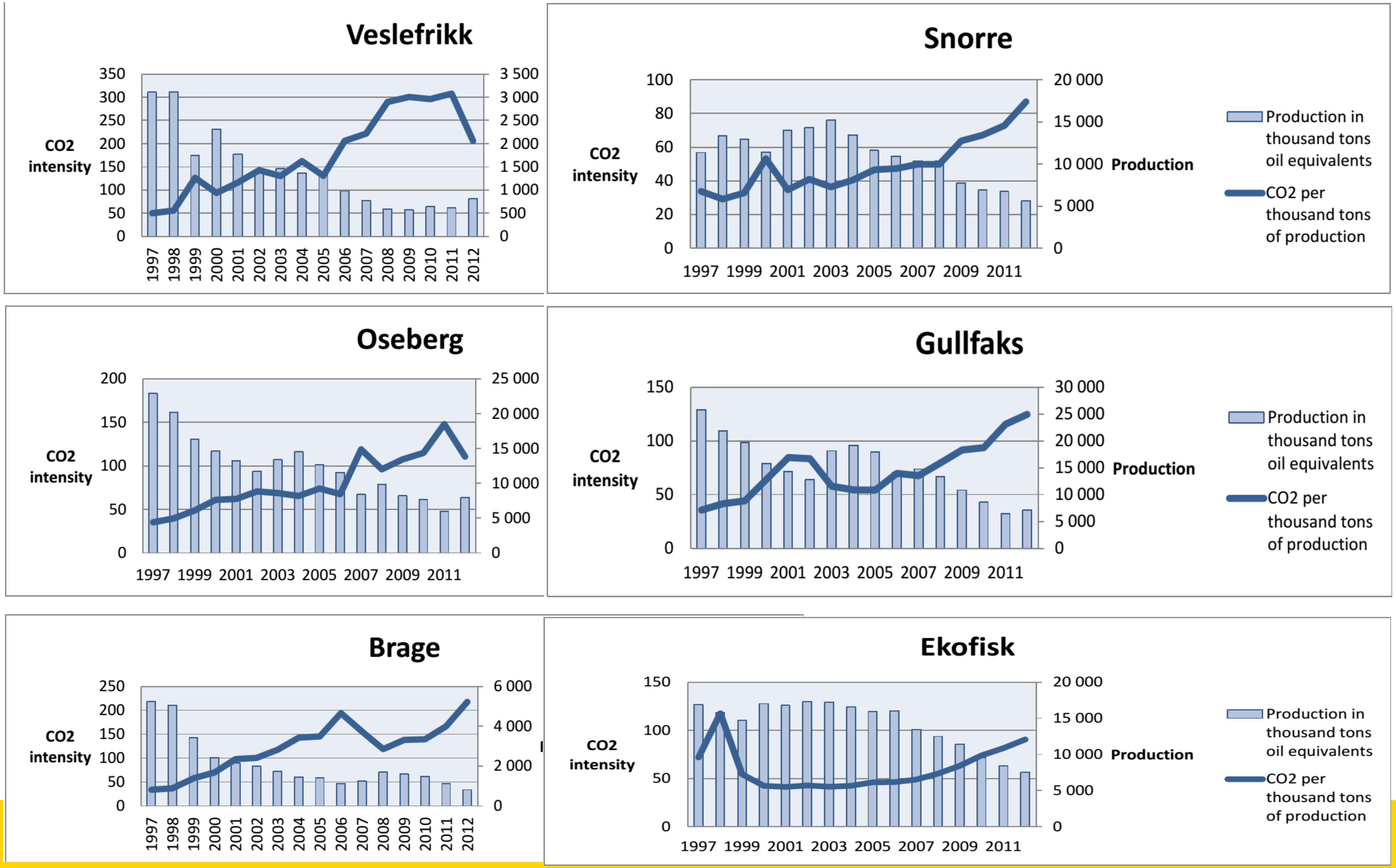




Development of average CO2-emissions per unit of oil and gas in Norway from 1997 to 2012. Kg CO2 per toe (Statistics Norway)



6-field case - CO2 emission



Data source: Master Thesis: "On the way to a Cleaner Future: A Study of CO2 Emissions on Norwegian Contiental Shelf, 2014, Norwegian University of Life Sciences

6-field case:
CO2 emission and cost of CO2 tax - A conservative estimate

- A total about 12 billion NOK in CO2 taxation based on the 2015 CO2 tax rate
- 75% of the CO2 emission comes from gas turbines.
  - Capture of 50% indicate a saving of tax of about 6 billion NOK.
- The Norwegian total CO2 emission (~50 Mt/year, 14 Mt comes from NCS) will be reduced by 14 % !
  - If implemented for all fields, and with the capture efficiency of 50%

	Annual Production (MSm3 o.e.)	Annual Production (~ 1000 tonn)	Annual CO2 emission (tonn / 1000 tonn o.e)*	Annual CO2 emission (tonn)	CO2 tax in MUSD (70 USD/tonn CO2)	CO2 tax (MNOK)	Reserves pr 2015 (MSm3)	CO2 tax for remaining field life** (MNOK)
Gullfaks	2,1	1 819	65	118 235	8,28	58	15,9	517
Gullfaks Sør	6,6	5 602	65	364 098	25,49	178	72,6	2 360
Snorre	5,6	4 777	45	214 965	15,05	105	64,0	1 439
Ekofisk	8,0	6 775	58	392 921	27,50	193	122,3	3 545
Oseberg	5,8	4 913	71	348 823	24,42	171	104,5	3 709
Brage	0,6	544	93	50 592	3,54	25	5,4	251
Veslefrikk	0,9	765	65	49 725	3,48	24	5,4	174
TOTAL	29,64	25 194		1 539 359	108	754	390	11 993
Ca oil density		850	kg/Sm3					
Dollar exchange rate		7	NOK/USD					
** increasing CO2 by a factor of 1.2								

1,5 Mt/year !

700 MNOK /year !

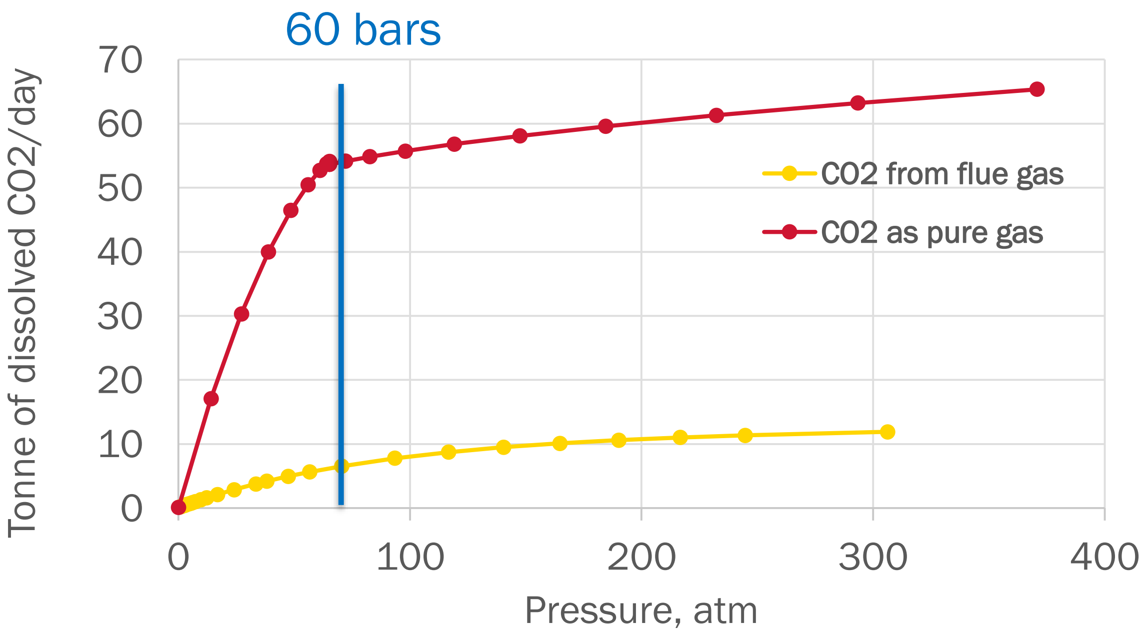
12 BNOK total

6-field case:
How much CO2 can be blended in the injection water

- The total amount of the water injection is about 66 MSM3 / year (2014, data from NPD)
- Total amount of CO2 in saturated seawater at 60 bars (current concept): about 10-50 t/1000 SM3 water

  ⇒ 460 – 3 300 kt/year CO2 can be blended to injection water

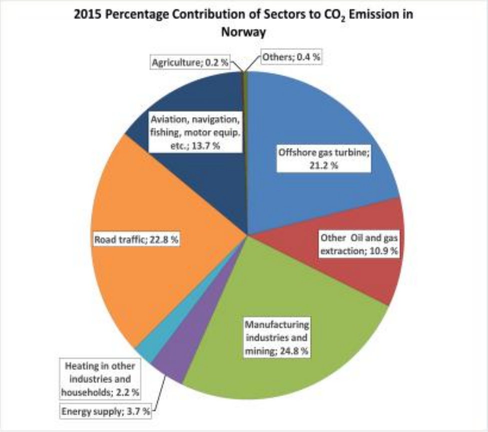
  ⇒ This represent about 100% of the total CO2 emission for the best case.



Transport of CO2 from exhaust gas in reservoirs

(Extract from the TCCS9 2017 poster by Ingebret Fjelde and Aruoture V Omekeh from IRIS)

Motivation

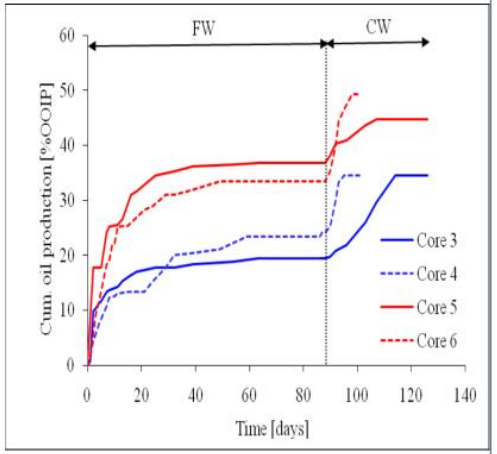


In 2015, the CO_2 emission from offshore gas turbine was 9.5 million Tonnes amounting to 21.24% of Norway's CO_2 emissions (Statistics Norway (SSB)) and NOK 4.2bn in tax prices

CO_2 is much more soluble in water than the other flue gas constituents

CO_2 dissolved in water, carbonated water (CW), has been found to improve oil recovery in chalk cores over formation water (FW) (Fjelde et al., 2011)

CW doesn't require as much CO_2 source as traditional CO_2 flood and has better sweep



CW transport:

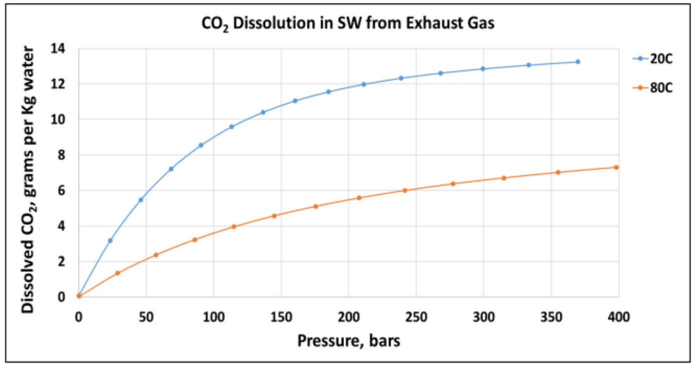
Phreeqc simulations in 1Km 1D model with flow rate 1 feet/day

CW by dissolving CO_2 in seawater (SW) at 80°C and 300bar

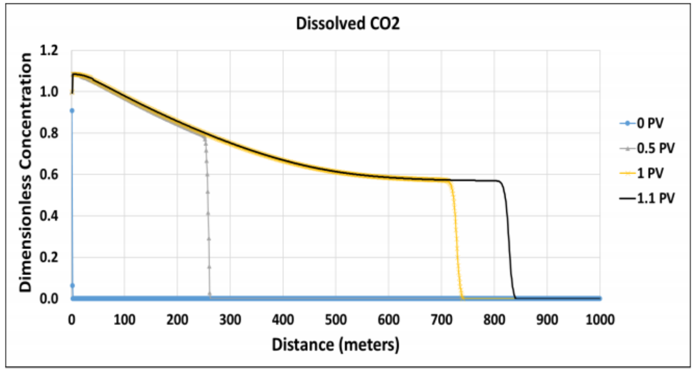
Sandstone Mineral composition based on 4 different North Sea Sandstone Fields

Carbonate Mineral composition based on calcite

CO_2 dependent reaction rates of minerals from literature

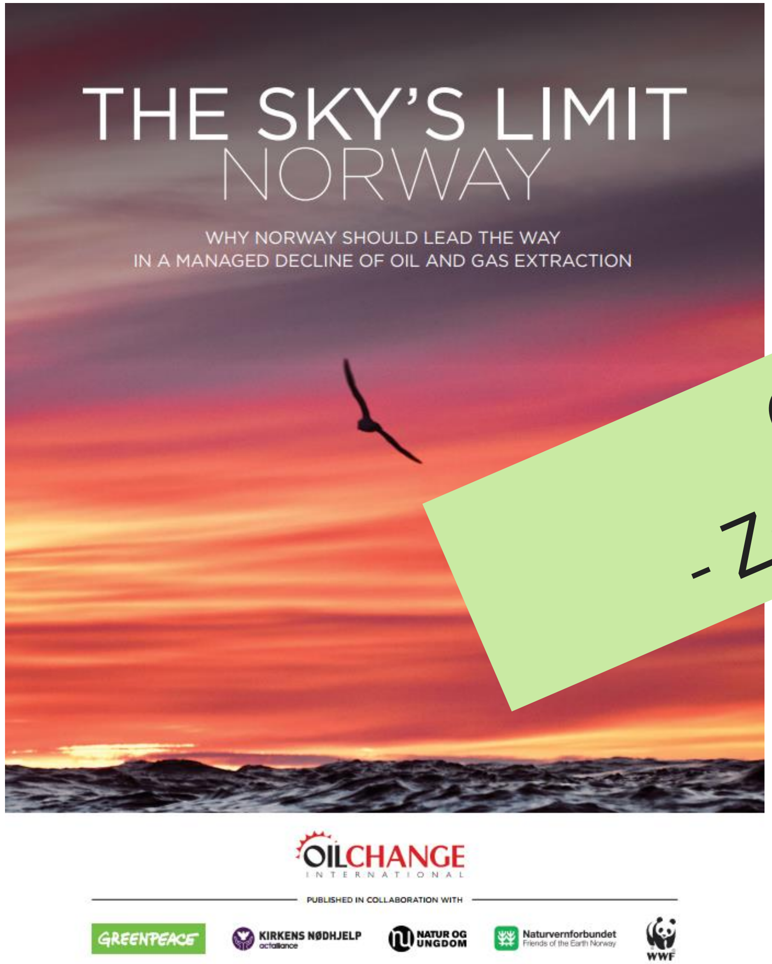


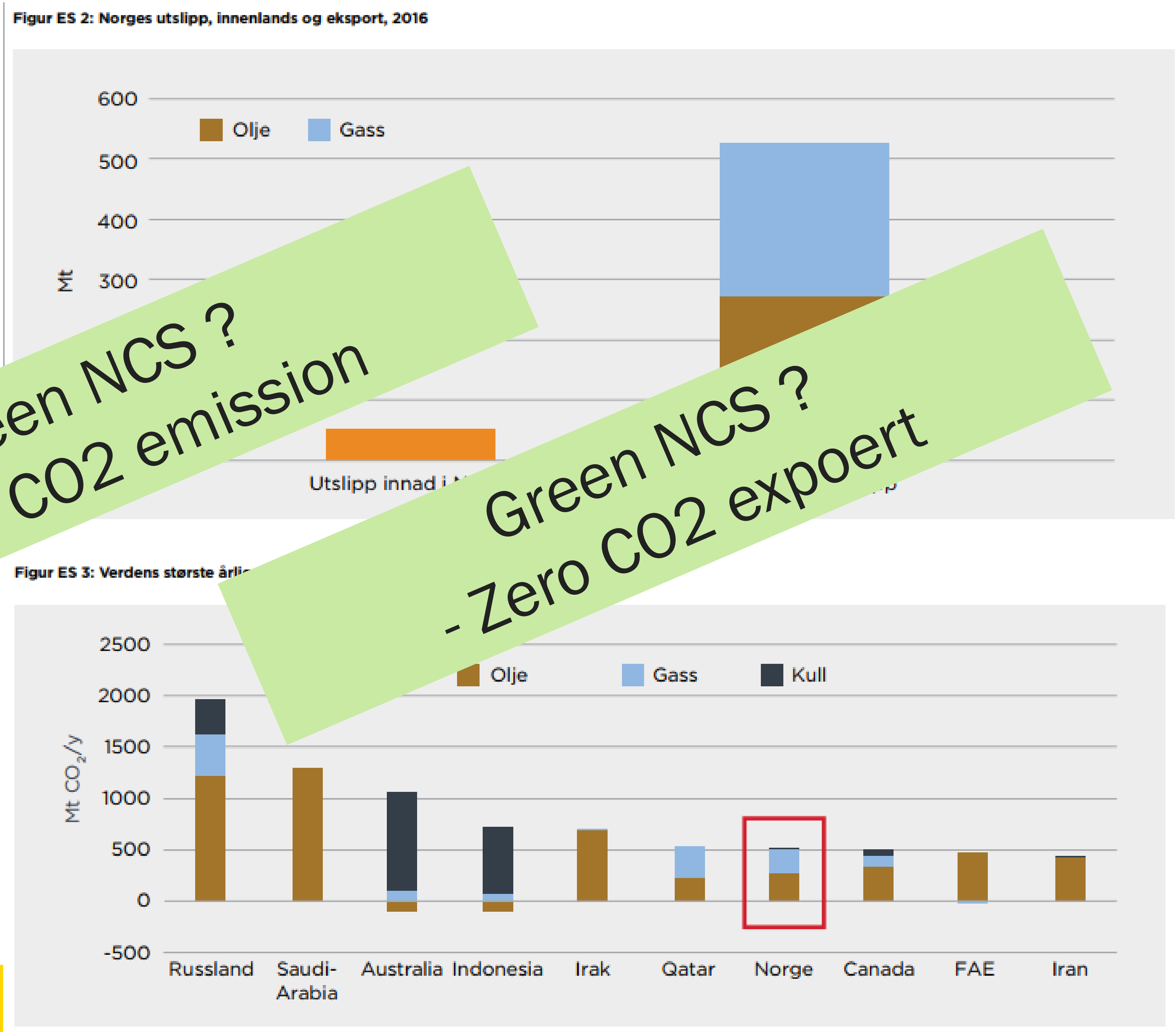
Sufficient solubility of CO_2 from exhaust gas in seawater (SW)



Retardation in CO_2-front as a result of mineral trapping of CO_2. It takes more than 1.1 PV for CO_2 front tot reach the producer

CO2 foot print - Norway

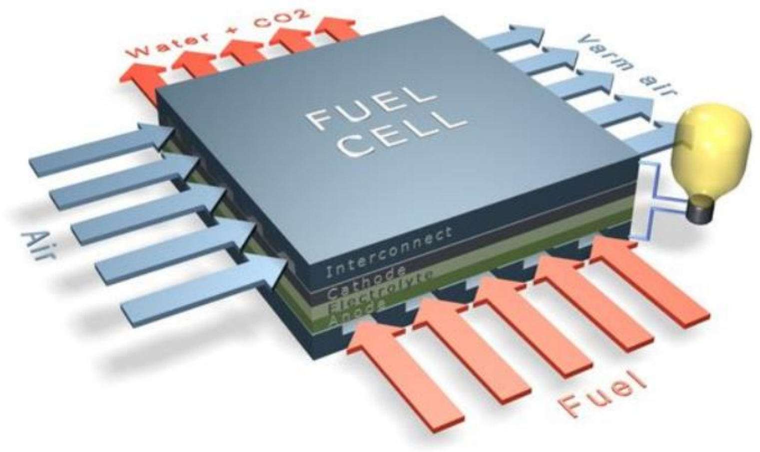




Safe and Cost-effective CCS combined with CO2-EOR in the North Sea – New technology

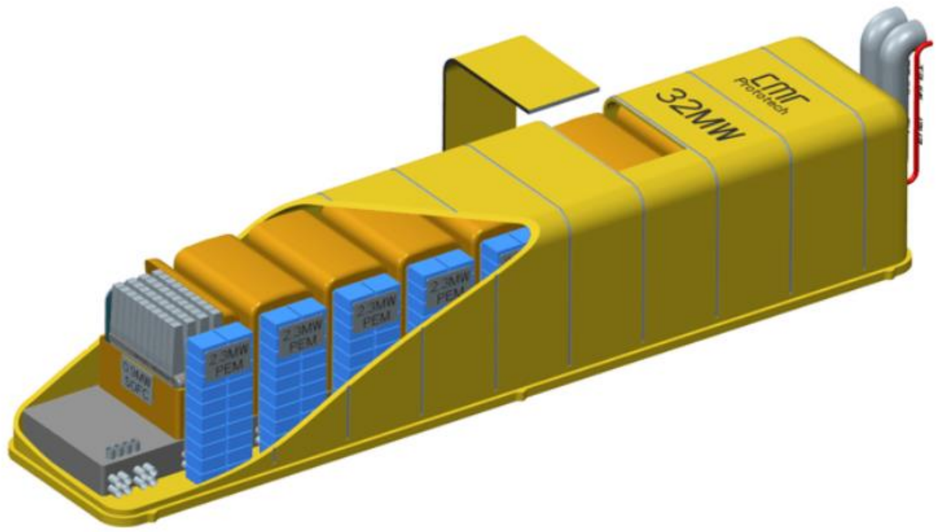
Fuel Cell Power Systems

Around ten tons of greenhouse gases per person in Norway are discharged into the atmosphere per year. The government requires concrete measures to reduce these emissions before 2020. Is it possible to create a society without pollution emission, while also ensuring profitability and jobs?



Clean Highly Efficient Offshore Power (CHEOP)

Prototech is building a robust 10kW solid oxide fuel cell (SOFC) stack ideal for offshore use, while simultaneously designing a MW-scale system for future applications where the SOFC stack will be one of the basic building blocks.



For the offshore industry to reduce emissions, increase power efficiency and limit the need for long power cables to remote offshore locations, a fuel cell system developed for offshore power is an ideal candidate. With electric efficiencies of 60%, the fuel consumption and CO2 emissions can be reduced to 50% of the original values. The long-term vision is zero emission power production by including carbon capture and storage (CCS).

https://www.statoil.com/no/magasin/hywind-oil-industry-expertise.html

Statoil

Safe and Cost-effective CCS combined with CO2-EOR in the North Sea – New technology

A proposal under preparation at IRIS

Use of Wind Power for CO_2 or water injection in NCS

- Extension of DNV's WIN WIN feasibility study from 2016
- When the wind-powered injection is dependent on the weather or seasonal variations, the fluid to be injected and the well and reservoir pressure variations must be handled, and the responses to the reservoirs must be understood

A standard wind turbine is mounted to a floating foundation. This foundation also serves as a platform for the water injection system.

Source: https://www.dnvgl.com/energy/feature-articles/win-win-wind-powered-water-injection.html

Thanks for your attention !