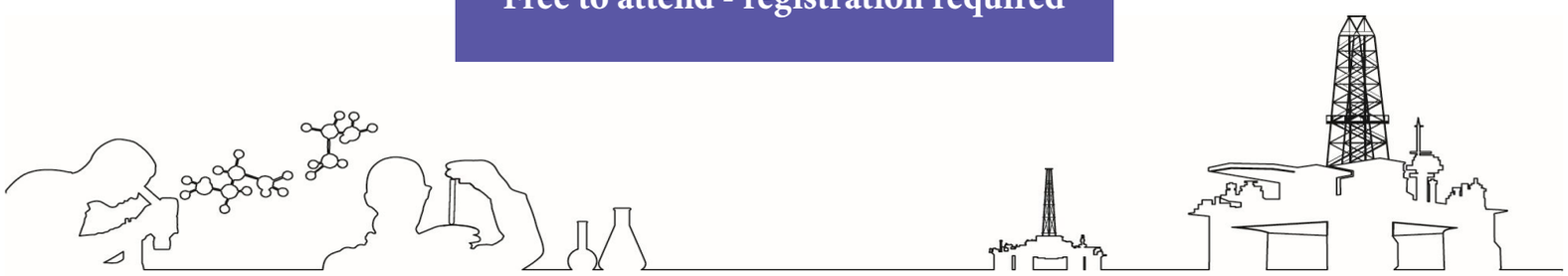


DHRTC - MODIFIED SALINITY WATER FLOODING WORKSHOP

Friday 15 June at DTU Lyngby Campus
Auditorium 1, Building 101A

Free to attend - registration required



Centre for Oil and Gas - DTU
The Danish Hydrocarbon Research and Technology Centre

www.oilgas.dtu.dk

Dear PARTICIPANT

On behalf of the Danish Hydrocarbon Research and Technology Centre we invite you to attend a one-day workshop on Modified Salinity Water Flooding Workshop, to be held at the DTU Lyngby Campus Auditorium 1 - Building 101A, Denmark on Friday 15th June 2018.

The main objective of this workshop is to provide an overview of the current state of research in understanding the underlying mechanisms of the modified salinity water flooding. It is a unique opportunity for the researchers from academia and industry to learn about the status quo, and the future challenges in the research and development of this attractive oil recovery method.

Best regards,

Ali Akbar Eftekhari
Researcher
DHRTC

Hamid M. Nick
Senior Researcher
DHRTC

REGISTRATION DETAILS

To register for the workshop, go to this link to fill in the form https://dhrtc.easysignup.com/6/



SCHEDULE

08:00-08:30	Breakfast	
08:30-08:45	Introduction	
08:45-09:25	Smart Water flooding in Chalk – Insight from experiments and numerical modelling	Aksel Hjorth
09:25-10:05	Role of Brine Chemistry, Rock type and Temperature on Wettability of Carbonate Rocks	Hassan Mahani
10:05-10:35	Break - Poster session	
10:35-11:15	Laboratory Difficulties in Determining Modified Salinity Effects	Jules Reed
11:15-11:55	Crude Oil/Brine/Rock factors influencing chalk wettability	Tina Puntervold
11:55-12:55	Lunch - poster session	
12:55-13:35	Zeta potential of intact carbonates: Impact of carbonate type, temperature, brine composition, wettability and implications for controlled salinity waterflooding.	Matthew Jackson
13:35-14:15	Constraints in Low Salinity Waterflooding of Carbonate Reservoirs	Maxim Yutkin
14:15-14:30	Break	
14:30-15:10	Can we control water induced compaction in chalk reservoirs? Experiences from in-situ core and pore scale studies	Reidar Inge Korsnes & Mona Wetrhus Minde
15:10-15:50	Key aspects of Smart Water EOR in chalk	Skule Strand
15:50-16:10	Closing remarks	

Abstracts

Smart Water flooding in Chalk – Insight from experiments and numerical modelling, Aksel Hjorth, IRIS/University of Stavanger.

Numerous core scale experiments demonstrate the importance of brine chemistry on the oil recovery. These experiments have inspired further investigations at nano- and submicron scale, and this activity has led to several mechanisms (>15) being proposed. We argue that in order to identify which of these mechanisms are the correct ones, there is a need for simulation models that can interpret all these experiments. Significant effort has been done in the National IOR Centre of Norway to include most of the important chemical effects into simulation models, such as adsorption, ion exchange, precipitation/dissolution, surface complexation (surface potential), CO_2 dissolved in the oil phase. We are currently working on lattice Boltzmann methods on the pore scale, and Darcy scale models on the core and field scale. The core scale simulator is an extended version of the polymer simulation model presented in Lohne et al. (Comput Geosci, DOI 10.1007/s10596-017-9692-6, 2017), it includes handling of various boundary problems; spontaneous imbibition (1, 2, and 3D), and flooding. In the case of spontaneous imbibition experiments, we take into account the exchange (by diffusion) of ions with the surrounding fluid.

In this talk, we will outline our latest progress, and ideas in these areas. We will discuss important chemical alterations during core experiments- Furthermore, we will discuss how these alterations will translate and propagate on a larger scale in order to estimate a field response.

Role of Brine Chemistry, Rock type and Temperature on Wettability of Carbonate Rocks, Hassan Mahani, Shell Global Solutions International B.V.

The classical research on low salinity started with sandstone rocks, where it was clearly shown that the oil recovery can be improved by manipulation of ionic composition or reducing salinity of the brine. Lately the research was extended to the carbonate rock though doubts were casted on the possibility of the improved oil recovery from carbonates. While there are positive results in this area, there exist cases where no improvement of oil recovery was observed. Various underlying mechanisms have been proposed in this area, which can be categorized into two main groups: rock-fluid interaction versus fluid-fluid interaction. The community consensus is that wettability alteration of rock toward more water-wetting is the main effect of low salinity or at least is one of the mostly observed. It's likely that both wettability alteration and fluid-fluid interaction can have a synergistic effect. There is evidence that without wettability alteration there can be improved oil recovery due to enhanced fluid-fluid interaction resulting in either better coalescence of the oil ganglia or less snap-off.

Due to the importance of wettability in the low salinity process, this talk mainly focuses on the carbonate wettability alteration. Wettability is the result of the rock-fluid interaction and fluid-fluid interaction. This can be represented on a ternary diagram where rock, oil and brine are at each corner of the triangle and the edges represent the physico-chemical interaction. As the temperature influences all these interactions, it can be considered as an extra dimension.

In this talk we show that not all oil/brine/rock (OBR) systems respond to change of salinity/composition/temperature. Despite the common belief, low salinity effect can exist at room temperature and may not be further improved at elevated temperature. The behavior is consistent with the DLVO calculations and suggest that zeta-potential of oil/brine and rock/brine (measured under the relevant reservoir condition) can be used to predict whether change of brine salinity/composition alters wettability of the OBR systems.

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The observed trends can be split into two general scenarios: Scenario I, change of brine salinity/composition/temperature result in same sign zeta-potential on the oil/brine or rock/brine interfaces under which the repulsive force can be enhanced and there would be a positive low salinity effect (wettability alteration). Scenario II, change of brine salinity/composition/temperature results in zetapotentials with opposite signs that translates into an increase in the attractive force. Therefore, no positive low salinity effect can be observed. Moreover, the notable difference in the response of limestone and dolomite to low salinity is also consistent with their zeta-potential trends. These findings could explain the absence of low salinity effect in some of the reported laboratory experiments. It is also noteworthy that in cases where there is wettability alteration, the transition from more oil-wetting to less oil-wetting is not instantaneous and is kinetically slow, though thermodynamically spontaneous. This impacts the way we quantify low salinity oil recovery in the laboratory.

Laboratory Difficulties in Determining Modified Salinity Effects, Jules Reed, Global Core Analysis Manager, Lloyd's Register.

Overall, the physics of coreflooding experiments are little understood by the industry. Many of the laboratory personnel performing coreflood experiments do not fully understand the impact of boundary effects on the short core plug samples being used in their experiments. This leads to inappropriate design and/or interpretation of data. In fact, the cause-effect impact of the full core analysis process (from coring and core handling through laboratory preparation and into experimental testing) is poorly understood, since there are so many variables and potentially altering influences, that it is difficult to control all of these. The author's experience of performing and reviewing numerous modified salinity studies has also highlighted a number of specific difficulties in determining the fundamental mechanisms leading to perceived effects. This presentation will spotlight some of the controlling factors, and some specific difficulties in determining modified salinity mechanism and the modified salinity effect towards improved recovery.

Crude Oil/Brine/Rock factors influencing chalk wettability, Tina Puntervold, University of Stavanger.

Smart Water EOR is based on wettability alteration from a mixed wettability to a more water-wet case, generating capillary forces and improving the microscopic sweep efficiency. The Smart Water EOR potential for a reservoir is dependent on the initial wetting state, and the EOR potential increases with decreasing water wetness. Optimized core restoration procedures are needed to restore wetting states that are representative for the reservoir wettability.

Initially, very water-wet outcrop Stevns Klint chalk cores with reproducible properties were used in parametric studies. The influence of crude oil components, formation water composition and rock impurities on the core wettability investigated. Spontaneous imbibition tests were performed, giving results reflecting the initial wetting of the cores prepared in different ways.

The experimental results show that the core wettability is very much dependent on the amount of acidic components in the crude oil, the acid number. Higher acid number lead to lower degree of water wetness. The ion composition and salinity of the formation water also affected the initial wetting. Deionized water as formation water decreased water wetness the most, promoting adsorption of crude oil components onto chalk. Cores, which contained initial sulphate from impurities, behaved much more water-wet than cores, which had the sulphate removed. Sulphate prevented adsorption of polar crude oil components onto chalk.

Chalk wettability is influenced by all phases present in the reservoir; the rock, the crude oil and the formation water. The chemical properties of all phases present must be characterized and considered when performing laboratory work, and evaluating reservoir wettability.

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Zeta potential of intact carbonates: Impact of carbonate type, temperature, brine composition, wettability and implications for controlled salinity waterflooding, Matthew Jackson, Imperial College London.

Despite the broad range of interest and applications, controls on calcite surface charge in aqueous solution, especially at conditions relevant to natural systems, remain poorly understood. Numerous papers have reported inconsistent or contradictory data and models. There is still active debate over the relationship between calcite surface charge and electrolyte pH, the concentration of ions such as Ca^{2+}, Mg^{2+}, CO_3^{2-} and SO_4^{2-} in aqueous solution, the partial pressure of CO_2, the difference between natural and artificial calcite, the role of dissolution and/or precipitation, the effect of temperature, and the link with wettability when crude oil is present.

This presentation will briefly review methods and results for measurements of the zeta potential in intact natural carbonate samples equilibrated with brines of varying composition and ionic strength, and crude oils of varying composition, over the temperature range relevant to oil reservoirs. The zeta potential is an important measure of the electrical potential at the mineral surface, and the magnitude and sign of the zeta potential control the electrostatic interactions between the mineral surface and polar species in aqueous solution, and between the mineral surface and other charged interfaces such as the water-oil interface. Measurements of zeta potential in low concentration solutions and at laboratory conditions are relatively straightforward. Most studies of the calcite mineral surface have reported measurements of zeta potential or the closely related property of electrophoretic mobility. Other approaches to determine surface charge, such as potentiometric titration, are challenging to apply in calcite because rapid dissolution kinetics and the buffering effect of carbonate ions in solution can affect the results. The primary data source to understand calcite surface charge comprises measurements of zeta potential.

Results show that rock wettability and improved oil recovery (IOR) during smart waterflooding are strongly correlated to changes in zeta potential at both the mineral water and oil-water interfaces. Rock wettability correlates with changes in zeta potential after aging in formation brine. Improved recovery during controlled salinity waterflooding occurs only when the change in brine composition induces a repulsive electrostatic force between the oil-brine and mineral-brine interfaces. A key challenge for any model of controlled salinity waterflooding is to explain why IOR is not always observed. Results suggest that failures using the conventional (dilution) approach may be caused by a positively charged oil-water interface that had not been identified.

Constraints in Low Salinity Waterflooding of Carbonate Reservoirs, Maxim Yutkin, KAUST.

Success of low salinity waterflooding (LSW) is attributed to increasing water wettability of the reservoir rock. Consequently, surface chemistry of the crude oil/rock/brine interfaces is a critical component of the process. A large number of laboratory studies, therefore, focus on wettability measurements including, for example contact angles, surface charge densities, ion exchange, and zeta potentials, in addition to oil-recovery flooding. In carbonate rocks, however, injected chemistry is drastically altered by reaction with reservoir minerals, making injection chemistry irrelevant to in-situ conditions. We demonstrate both experimentally and theoretically that carbonate reaction rates demand local equilibrium in the rock. We also present a new flow model of reactive transport that includes involved carbonate reaction chemistry, detailed reaction kinetics, and axial dispersion. For the first time, we predict local aqueous-species compositions and concomitantly, in-situ surface-chemistry species during forced displacement. The reactive transport model is solved for all species at constant (residual) oil saturation and constant unity water fractional flow. For reaction rate constants larger than 10-9 m/s, equilibrium is achieved in the pore-fluid composition. Since experimental dissolution rate constant is approximately 10^- 5 m/s the calcium concentration front moves as an equilibrium shock wave through the core (with neglect of dispersion).

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There is no rock dissolution/precipitation except immediately at the very beginning of the core (or reservoir). Flow experiments on 6-cm Indiana limestone cores confirm model predictions. We conclude that aqueous equilibration with carbonate rock is essentially instantaneous. This conclusion has major implications for understanding LSW. First, injected flooding concentration is not that appearing in the reservoir pore fluids. For example, we find that no matter the injected pH, the in-situ pH is below saponification threshold (Yutkin et al.; 2017). Second, the proposed dissolution or surface reconstruction (Chen et al.; 2017) recovery mechanisms are not possible. We assert that nowhere in the reservoir, except directly at the well bore, is there rock dissolution/precipitation. Any recovery mechanism that relies on rock dissolution/precipitation cannot occur on reservoir scales. The suggested dissolution mechanisms can only take place in laboratory experiments. Next, we emphasize that all characterization laboratory experiments, such as zeta potentials, contact angles, surface charges, etc., must be performed with rock pre-equilibrated aqueous solutions so that reservoir conditions are correctly mimicked. Otherwise, generated results are unrealistic. Care must be taken to ensure that pore-fluid equilibrium is achieved in laboratory studies.

Can we control water-induced compaction in chalk reservoirs? Experiences from insitu core and pore scale studies, Reidar Inge Korsnes & Mona Wetrhus Minde, University of Stavanger.

Water injection into chalk reservoirs is extensively applied as pressure support and to increase oil recovery. An example is the Ekofisk field in the North Sea, where it was decided to initiate a water injection program after primary production had led to significant reservoir compaction and the pore pressure was depleted close to the oil bubble point. Initial recovery estimate was 18%, but due to the successful water injection, the recovery rate is now approaching 50%. A surprising outcome of seawater injection was, however, that reservoir compaction and seabed subsidence continued even after reservoir re-pressurization. This effect was termed the water weakening of chalk.

The relationship between enhanced oil recovery and mechanical properties of chalk and pore fluids has ever since been of significant interest in both scientific research and industry.

The inherent fluid–rock interactions and subsequent changes in wetting state and mechanical properties have led to investigations towards better understanding of these interactions and thereby more optimal injection fluids. Seawater and seawater-like brines have been studied as enhanced oil recovery (EOR) fluids for decades, and these studies show that certain ions; SO_4^{2-}, Ca^{2+} and Mg^{2+} play an important role when it comes to increasing oil recovery in carbonates. These ions are able to change the wettability towards more water-wet conditions and as such improve oil recovery. When the brine composition is optimized for EOR purposes, it is also important to study its effect on mechanical properties. Geomechanical studies have shown that the same ions affecting wettability alteration also have a significant impact on the mechanical properties.

To be able to design the best suited EOR fluid and simultaneously predict and control reservoir compaction, it is of high importance to understand how ions in the injected fluid affect the rock`s mechanical properties through chemical rock – fluid interactions. This presentation will give an overview of our results from geomechanical experiments at in-situ conditions, and sub-micron studies focusing on understanding howany changes in brine compositions, test temperatures and chalk mineralogy will affect the mechanical properties of chalk.

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Key aspects of Smart Water EOR in chalk, Skule Strand, University of Stavanger.

Waterflooding of oil reservoirs has been, and still is the most important technique to increase oil recovery from both carbonate and clastic oil reservoirs. Significant improvements in the general understanding of the wetting properties of oil reservoirs have been the fundament for a lot of research during the last 15-20 years with the objective to optimize the oil recovery by wettability modification. The injected water, with a favourable ionic composition, can modify the reservoir wettability during production, and improve the displacement efficiency of oil. This Smart Water EOR technique is environmentally friendly, because no external chemicals are needed. The EOR effect can be significant, especially in carbonate reservoirs. Therefore, water-based EOR by wettability modification has received great interest among oil companies.

This paper gives a chemical review of the Smart Water EOR technique in carbonates. It is not obvious that Smart Water can be applied in any type of carbonate oil reservoirs. Therefore, detailed knowledge of the chemical mechanism for the wettability alteration process is crucial for application in field situations. This review has a focus on Smart Water EOR in chalk. The results confirm that seawater is able to change the wettability towards more water-wet conditions and improve the oil recovery both in viscous flooding and spontaneous imbibition processes. The Smart Water EOR effect increases with increasing temperature. Key parameters affecting both the initial wettability and the wettability alteration process are documented. The results also describe how the ionic composition of seawater could be modified both for improving the efficiency and lowering the temperature window for Smart Water EOR processes. The results are at the end summarized in a chemical model describing the Smart Water EOR process for chalk reservoirs.

Speakers biography



Aksel Hiorth is a Professor in reservoir technology at University of Stavanger and Chief Scientist at IRIS.

He has a PhD within theoretical physics from University of Oslo. In 2013 he was part of the management team that was awarded the National Center for Improved Oil Recovery by the Research Council of Norway. His main research interest is reactive flow in porous media. He develops and implements models that couple flow, and geo- and electro-chemical interactions on pore- and Darcy scale. These codes have been tested against lab experiments, nano scale and submicron investigations. In the last couple of years, he has also been working on how to translate the pore- and core scale interactions to field (reservoir) scale. Part of this work has led to SR Bank's Innovation Award in 2010, the NPD's IOR prize in 2010 as part of the COREC team and Lyse`s Research Award in 2013.



Hassan Mahani is a research scientist at Shell Global Solutions International in The Netherlands.

He joined Shell in 2007 in the Improved-Oil-Recovery team in Rijswijk to perform applied and fundamental research on enhanced-oil-recovery methods, reduced fracturing, pressure transient analysis for polymer flooding and low salinity waterflooding. In 2012, Mahani joined the Rock and Fluids Physics laboratories in Rijswijk. The labs have been recently moved to the Shell technology center in Amsterdam. Hassan currently leads low salinity flooding research and development and special-core-analysis laboratory activities as principal investigator. His current research interests include low salinity EOR, wettability and thin films, special core analysis, pore-scale physics including tomography and visualization of pore-scale phenomena. Mahani was recognized as an SPE Outstanding Technical Editor in 2015, 2016 and 2017 and a 2012 Top Reviewer by Journal of Petroleum Science and Engineering. He currently serves as associate editor for SPE Reservoir Evaluation & Engineering and Journal of Petroleum Science and Engineering. Mahani holds a PhD degree in petroleum engineering from Imperial College London and a master's degree in chemical engineering from Sharif University of Technology.

Speakers biography



Jules Reed is the Global Core Analysis Manager, at Lloyd's Register.

He has over 25 years' experience in core analysis, including; routine core analysis, special core analysis and reservoir conditions coreflood studies (including CO_2 injection, miscible gas injection, WAG, mWAG, sWAG and other EOR and IOR analyses) gained with Core Lab, Corex UK, ResLab (Chief Engineer), and most recently, Weatherford Labs where he was Technical Director, Core Services.

His 8 years as Chief Engineer with ResLab/Weatherford Labs was particularly focused on dynamic reservoir properties and laboratory EOR feasibility analysis, including solvent injection, chemical injection and low salinity waterflooding. He is co-author of the book, "Core Analysis: A Best Practice Guide", part of the Elsevier, "Developments in Petroleum Science" series. He has specialized in product development, data quality control, training and design and interpretation of specialist coreflood/dynamic test studies, but his specific areas of technical/theoretical expertise are in wettability, capillary pressure and relative permeability. Jules is a former president of the international Society of Core Analysts (and former VP Technology). He currently serves on the board of the society as Director – North & East Europe. He is an active member of the SPE, as a peer reviewer for the SPE Journal of Reservoir Evaluation & Engineering and serving on the board of the Aberdeen chapter and was formerly a Chapter Chairman (2009) and secretary (2007-2009) of SPE Trondheim Section.



Tina Puntervold is an Associate Professor of reservoir chemistry at the Department of Petroleum Engineering at the University of Stavanger, Norway.

She is currently involved in Smart Water EOR projects related to both carbonates and sandstones. She holds a PhD in petroleum technology from the University of Stavanger, and an MSc in physical chemistry from the University of Bergen, and she has co-authored more than 20 scientific research papers on Smart Water EOR.



Professor Matthew Jackson is TOTAL Chair in Geological Fluid Mechanics at Imperial College London from 2011.

Previously, he served as a Senior Lecturer (2006-2011), Lecturer (2002-2006), and Research Associate (1997-2002) at the same institute. He holds a PhD from the Department of Earth Sciences, University of Liverpool (1993-1997) and a BSc in Physics from Imperial College (1990-1993). His research interests include investigation, prediction, quantification, and measurement of transport processes in heterogeneous geological porous media, using field, experimental, mathematical and numerical techniques. He is the recipient of multiple awards including the EAGE Norman Falcon award (2015), SPE Regional Outstanding Achievement Award (2011), and AAPG Distinguished Lecturer (2010-2011).

Speakers biography



Maxim Yutkin is a Research Scientist at Ali I. Al-Naimi Petroleum Engineering Research Center at King Abdullah University of Science and Technology (KAUST).

He holds a PhD degree in chemistry from Novisibirsk State University, Russia. He pursued post-doctoral appointment in South Korea, and then joined one Schlumberger's Engineering and Development centers, where he worked on development of fracturing fluids. At KAUST Dr. Yutkin is involved in research on low salinity water injection for incremental oil recovery. His research interests span widely from functional materials to surface chemistry, interfacial phenomena, and reactive transport.



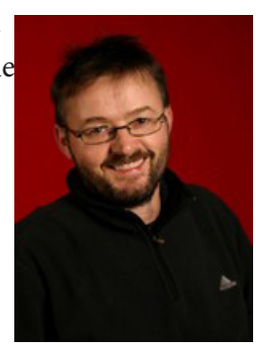
Reidar Inge Korsnes is Chief Engineer at the Department of Petroleum Engineering at the National IOR Centre of Norway, University of Stavanger.

He has a PhD in Geomechanics from the University of Stavanger. He has more than 15 years of experience with experimental rock mechanics. His current research interests are the interplay of physical and chemical interactions on rock properties along with how compaction affects oil recovery.



Mona Wetrhus Minde is currently finishing her PhD in Petroleum Technology at the National IOR Centre of Norway, University of Stavanger.

The focus of her thesis is micro- and nano-analytical methods to study fine-grained sedimentary rocks in an EOR perspective. In practical terms, the work involves studying rock samples at nano-scale to investigate the mineralogical changes induces by injection of non-equilibrium brines, and link these alterations to the geo-mechanical properties of the rock. She was awarded the Skjæveland award at the IOR Norway 2017 conference for best PhD poster presentation. She has a MSc and a BSc in Petroleum Geoscience Engineering and a BSc in Media Technology.



Skule Strand is an Associate Professor of reservoir chemistry at the University of Stavanger, Norway.

His main research work is within the field of reservoir chemistry and enhanced oil recovery from carbonate reservoirs. Dr. Strand defended his PhD degree in petroleum technology in 2006, and has since then been author or co-author of more than 30 international journal papers, mainly on Smart Water EOR.

About DHRTC

The Danish Hydrocarbon Research and Technology Centre (DHRTC) is the joint initiative of five leading Danish research institutions, and is based at the Technical University of Denmark.

DHRTC was founded in 2014 as part of Denmark's long-term national energy strategy. The partners in Danish Underground Consortium (DUC) have entered into an agreement on the financing of the centre, which is a partnership between five leading Danish research institutions: Aalborg University, Aarhus University, the University of Copenhagen, the Geological Survey of Denmark and Greenland (GEUS), and Technical University of Denmark.

The overarching purpose is to identify new technological and conceptual solutions that boost oil and gas recovery in the Danish region of the North Sea. The goal of the research centre is also to provide the framework for international research and lay the foundations for relevant, research-based study programmes with the potential to support interdisciplinary and interdepartmental research programmes.

Registration Details

Registration for this event is free but the number will be restricted to 50 attendees. Places will be allocated on a first come, first served basis though preference will be given to those presenting posters. Coffee breaks and lunch are included in registration.

Location: Anker Engelunds Vej 1 Building 101A, 2800 Kgs. Lyngby, Denmark

