The National IOR Centre of Norway

ANNUAL REPORT

2017

THE 2017 PARTNERS

IFE · IRIS · University of Stavanger

ENGIE · wintershall · MAERSK OIL · eni eni norge

DONG energy · HALLIBURTON · Schlumberger · ConocoPhillips

Lundin Norway · Statoil · DEA · AkerBP

OBSERVERS

With funding from
The Research Council of Norway

NORWEGIAN PETROLEUM DIRECTORATE · petoro

TABLE OF CONTENT

THE MANAGEMENT

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Randi Valestrand
Director Of Research

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Director Of Academia

Sissel Opsahl Viig
Director Of Field Implementation

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SCIENTIFIC ADVISORY COMMITTEE

Professor Ann Muggeridge, Imperial College, London
Professor William R. Rossen, TU Delft
Professor Yu-Shu Wu, Colorado School of Mines
Professor Stephan Herminghaus, Max-Planck-Gesellschaft

THE CENTRE BACKGROUND

The world needs energy. Up to present day oil and gas have contributed to the primary energy by more than 80 %, and even in the 2-degree scenario of the United Nations more than 50 % of the total energy needs to come from oil and gas. On the Norwegian Continental Shelf, more than 50 % of the total discovered resources are still left in the ground. There is a great environmental benefit of extracting most of the discovered resources, as existing infrastructure can be used.

The National IOR Centre of Norway provides cost efficient and environmentally friendly solutions for improved oil recovery on the Norwegian Continental Shelf through academic excellence and close cooperation with the industry.

The Centre was awarded by the Research Council of Norway after a national competition.

University of Stavanger is the host of The National IOR Centre of Norway, the research institutes IRIS (now NORCE after merger on 1 January 2018) and IFE are research partners. Several other national, international research groups, and 12 oil and service companies, complete the Centre's list of partners and collaborators.

The researchers in the Centre work actively in order to improve the recovery, whilst reducing costs and mitigating environmental impact. To achieve this goal, it is important that all stakeholders work together, and The National IOR Centre of Norway is an important arena for doing exactly this.

OVERALL AIM

The Centre will contribute to the implementation of cost efficient and environmentally friendly technologies for improving oil recovery on the Norwegian Continental Shelf.

SECONDARY OBJECTIVES

- Robust upscaling of recovery mechanism observed on pore and core scale to field scale.
- Optimal injection strategies based on total oil recovered, economic and environmental impact.
- Education of 20 PhD students and 8 postdocs during the lifetime of the Centre.

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The National IOR Centre of Norway

Tijana Livada

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Laura Borromeo

Remya Nair

Aojie Hong

Message from the director

Looking back at 2017, there are many milestones I could have listed. It is almost impossible to select only some of the highlights. However, first of all I am proud to say that we set a record number of 400 participants for our IOR NORWAY conference. We did not do that on our own – with us we had EAGE (European Association of Geoscientists and Engineers), a professional organisation. Together we organized the 19th edition of the European Symposium on Improved Oil Recovery with the theme «Sustainable IOR in a Low Oil Price World».

At the conference the participants got to hear 175 scientific presentations. Around 70 of these were from PhD students and postdocs. This is a result of targeted work at the Centre. Our students have participated in monthly presentation skills seminars in 2017, thus their ability to disseminate their research has become even better.

Another milestone in 2017 was the graduation of the first PhD student at the Centre, Aojie Hong. He defended his doctoral degree 14 December at the best possible way. The committee was impressed with his work, and praised the young student for his commitment and hard work.

Finally, I want to mention the midterm evaluation of the Centre. An international expert panel and representatives from RCN came to visit us in September. The panel met the management team, task leaders, doctoral students, industry partners, and visited our labs. We enjoyed the visit and the possibility to present our research and highly appreciate the in-depth work and useful recommendations given by the international evaluators. Even though we still wait for the final decision to be taken whether the Centre will receive funding or not for the last three years; I would like to quote a statement in the evaluation report: " (…) it could be said that the Centre is now a focal point for IOR internationally."

Photo: Carina Johansen

Photo: Kjersti Riiber

Message from the chairman

2017 was the year of graduation for the National IOR Centre, as it passed the Research Council of Norway mid-term evaluation. It has been a productive year with full focus on deliverables needed to facilitate future decisions on EOR pilots. To bridge the gap between core scale testing and full-scale field pilots more emphasis have been on intermediate to large scale (decametres) testing and realistic upscaling. In this aspect continued development of the IORSim and use of Open Porous Media simulation model is considered key to success.

The methods of smart water injection in chalk and polymer injection in sandstone have been selected as case studies. Advances on 4D seismology statistical methods, with implementation of Ensemble Kalman Filter techniques, for improved reservoir history matching and predictions is very encouraging and expected to become a vital tool for reservoir management decisions going forward.

An accession agreement was signed with DEA in June to join the consortium, while DONG elected to leave by year end. Additional changes in the partnership can be expected as Wintershall and DEA is entering a merger process and Mærsk oil has been sold to Total. Consequently, attraction of new industry partners will continue to be on the agenda going forward.

MANAGEMENT

MERETE VADLA MADLAND is professor in reservoir technology at the University of Stavanger. In autumn 2013 she was appointed Director of The National IOR Centre of Norway. She holds a Dr. ing.-degree in geomechanics from the University of Stavanger and has been supervising more than 150 undergraduate and graduate students. The last 17 years she has worked on developing new methods for effective extraction of oil from reservoir rocks. She has been heading several research projects funded by the Research Council of Norway as well as a number of industry funded projects. Her research focuses on understanding the physical and chemical interactions between rocks and fluids on the pore and core (nano/micro) scale and how these can be transferred to the field (macro) scale. Her work has led to SR Bank's Innovation Award in 2010, the Norwegian Petroleum Directorate's IOR prize in 2010 as part of the COREC team, Lyse's Research Award in 2013, and her research is presented in more than 100 scientific publications. She has given several keynote presentations at national and international conferences/symposiums. Madland has served on numerous boards. She has been member of the Programme Board/Expert Committee for FRINATEK since 2014 and the OG21 Board representing the University sector since 2017.

AKSEL HIORTH is Chief research scientist within enhanced oil recovery (EOR) at IRIS and professor within reservoir technology at the University of Stavanger. Currently he is research director for Theme 1 at The National IOR Centre of Norway. He has a PhD within theoretical physics from University of Oslo, and has been principal investigator within several large research projects supported by the industry and the Research Council of Norway. In the last decade he has mainly worked with developing simulation models that can describe the physical and chemical processes taking place during multiphase flow in porous rocks. He has published more than 75 scientific papers. The work has led to SR Bank's Innovation Award in 2010, the Norwegian Petroleum Directorate's IOR prize in 2010 as part of the COREC team and Lyse's Research Award in 2013.

RANDI VALESTRAND is the Research Director at IRIS heading the Reservoir group located in Bergen. Valestrand is research director for Theme 2 in The National IOR Centre of Norway. She holds a PhD degree in physics from University of Bergen. Since 1999 she has worked with research within the petroleum sector with main focus on parameter estimation, history matching, reservoir characterization and data assimilation. She has worked in IRIS since 2002 and has frequently worked as project leader for large projects sponsored by the industry and the Research Council of Norway.

SISSEL OPSAHL VIIG is holding a position as a senior scientist with the Petroleum Technology Division at Institute for Energy Technology (IFE). Viig is director of Field Implementation in The National IOR Centre of Norway. She has a master degree in nuclear chemistry from the University of Oslo. Since 2003 she has worked with research within tracer technology with main focus on development of tracer methods for reservoir evaluation, tracer methods for determination of residual oil saturation and analytical chemistry. She is frequently working as project leader for several research projects with national and international industry partners.

SVEIN M. SKJÆVELAND is a reservoir engineering professor at the University of Stavanger (UiS) with a PhD from the Norwegian University of Science and Technology in engineering physics and a PhD in petroleum engineering from Texas A&M University. He is director of Academia at The National IOR Centre of Norway. At UiS (Rogaland Regional College) he worked to establish the master and PhD programs in petroleum engineering and geoscience and to develop the research organization IRIS (Rogaland Research). He is an appointed «Oil Man of the Year», and has won many prizes. During 1992-94 he was an elected rector and has held many adminstrative positions in academia. He enjoys teaching and has published many papers in the fields of physics, reservoir engineering, and multiphase flow in porous media.

The Management Team of The National IOR Centre of Norway. From the left: Sissel Opsahl Viig (IFE), director of field implementation, Aksel Hiorth (UiS/IRIS), research director of Theme 1, Merete Vadla Madland (UiS), centre director, Randi Valestrand (IRIS), research director of Theme 2 and Svein Magne Skjæveland (UiS), director of academia.   Photo: Kjersti Riiber

SCIENTIFIC ADVISORY COMMITTEE

The main task of the Scientific Advisory Committee (SAC) is to advise and evaluate the scientific performance of The National IOR Centre of Norway in relation to the Centre's vision, objective and research plans including PhD projects. The next SAC meeting will be held 26 April, right after IOR NORWAY 2018, where both Bill Rossen and Ann Muggeridge will attend as key note speakers.

YU-SHU WU

Professor, Foundation CMG Reservoir Modeling Chair, and the Director of Energy Modeling Group (EMG) Research Center in the Petroleum Engineering Department at The Colorado School Of Mines (CSM)

He is a fellow of the Geological Society of America. At CSM, he teaches and carries out research in reservoir engineering, multiphase fluid and heat flow, geomechanics, unconventional oil and gas reservoir dynamics, CO_2 geosequestration and EOR, geothermal engineering, and numerical reservoir simulation. He leads the EMG in its research effort in (1) flow dynamics in unconventional oil and gas reservoirs; (2) coupled processes of multiphase fluid and heat flow, geomechanics, and chemical transport in porous and fractured media; (3) CO_2 sequestration and EOR application; (4) improved formation stimulation/cryogenic fracturing technologies; and (5) advanced reservoir-simulation technologies. Previously, he was a staff scientist with the Earth Sciences Division of Lawrence Berkeley National Laboratory for 14 years (1995–2008). During his career, he has authored or coauthored 110+ peer-reviewed journal papers and 17 peer-reviewed books/chapters as well as 62 SPE papers.

STEPHAN HERMINGHAUS

Director at the Max Planck Institute for Dynamics and Self-Organization

Studies in physics and fine arts, PhD in Physics University of Mainz (1989), in 1990 postdoctoral stay at the IBM Research Center, San José, California (USA), German Habilitation at the Faculty of Physics, University of Konstanz (1994), head of an independent research group at the Max Planck Institute for Colloids and Interfaces, Berlin (1996-1999), Professor at the University of Ulm (1999-2003), Director and Scientific Member at the Max Planck Institute for Dynamics and Self-Organization (since 2003) (formerly MPI for Flow Research), Honorary Professor of Physics, University of Göttingen (since 2005).

WILLIAM R. ROSSEN

Professor in Reservoir Engineering, Department of Geoscience and Engineering, Delft University of Technology

He was formerly Professor at The University of Texas at Austin, and before that a research engineer at Chevron Oil Field Research Co. He has more than 90 peer-reviewed journal publications. Professor Rossen's current research concerns use of foams for diverting fluid flow in porous media, modeling complex transport processes in networks, and understanding flow in naturally fractured geological formations. In 2012 he was named an IOR Pioneer at the SPE/DOE Symposium on Improved Oil Recovery, Tulsa, OK, and he is a Distinguished Member of SPE.

ANN MUGGERIDGE

Professor of Reservoir Physics and EOR, Dept. of Earth Science and Engineering, Imperial College London

Professor Muggeridge's research focuses on methods for improving oil recovery. Following her DPhil she worked at the then BP Research Centre, followed by a service company (SSI (UK) Ltd) before joining Imperial College in 1995. From 2006-08 she was a Technology Fellow at BP. She is the chair of the organizing committee for the EAGE IOR Symposium 2017 (held in conjunction with IOR NORWAY) and sits on the technical committee for the SPE Reservoir Simulation Symposium. She has published more than 100 papers.

TECHNICAL COMMITTEE SENDS THEIR REGARDS

The Technical Committee (TC) provides an excellent forum for the industry partners of The National IOR Centre to meet and engage with the researchers and the management of the Centre. In particular it is a forum to provide feedback on technical topics and the scientific scope of the Centre.

The opportunity to engage actively is very much appreciated by us in the industry, as evidenced also by the high level of participation both in the TC meetings and in conferences and workshops organized by the Centre.

The workplan and roadmap developed by the Centre provides a structured framework for these engagements. 2017 was a good year in terms of engagement and active participation from the various industry partners and we have had many good opportunities to influence the work-scope of the Centre. The next phase of the large scale tests and the inclusion of 4D seismic data from selected fields on the Norwegian Continental Shelf in the modeling work being planned for the coming year are good example of such activities.

2017 was also the year where the Centre went through the mandatory mid-term evaluation by the Norwegian Research Council, with positive feedback from the evaluation team. The participation and support from the members of the TC is highly appreciated. It was very clear from the feedback that the active engagement from industry is encouraged and emphasized as an area of constant focus for the Research Council of Norway. The comments from the evaluation team also included suggestions for how we as industry partners could be doing even more to engage with the Centre and in particular with the students and young researchers being trained within the Centre. We will be taking this input on board for our discussions in the TC going forward.

A number of the current PhD and postdoc projects will come to successful completion during 2018 and as a consequence the Centre will be defining a number of new project activities in the coming year. The input from the industry partners with respect to the content and scope of these new activities will be very important and we look forward to participating in some engaging and active workshops to help defining the future studies in the Centre. NIELS LINDELOFF
Corporate Technology and Innovation, Maersk
TC leader, The National IOR Centre of Norway

Photo: Marius Vervik

THE RESEARCH THEMES

The research in the Centre is organised in two R&D themes with seven main Tasks, which are specified by a research plan covering deliverables, milestones and methodologies.

Researchers from UiS, IRIS, and IFE serve as task leaders. As an overall strategy in these tasks, we involve researchers from different research environments (Improved Oil Recovery / Enhanced Oil Recovery, reservoir, chemistry, geology, geochemistry, geophysics, mathematics, physics, nano- science/ technology, biochemistry, environmental, industrial economy) from the partners as well as national and international collaborators.

1: MOBILE AND IMMOBILE OIL AND EOR METHODS

Aksel Hiorth,
research director theme 1

In theme 1 the main goal is to understand, model, and upscale the microscopic and macroscopic displacement efficiency when various EOR fluids are injected into a porous rock. The environmental impact is addressed through a fundamental understanding of the amount of chemicals needed to efficiently displace the oil and the fate of the chemicals from the injector to the producer.

EOR fluids interacts with the rock, alters primary mineral phases, and their surface properties. Many EOR fluids are non-Newtonian (e.g. polymeric fluids), which behaves highly non-linear in complex and time dependent flow which is relevant for porous media. To solve these challenges we work at the submicron to characterize the rock before and after flooding, and quantify the changes induced by the pore water. The dynamic of polymeric liquids are investigated experimentally by performing experiments in porous rocks, capillary tubes, and

Anton Paar Rheometer. The experiments are interpreted using molecular dynamic simulations, methods based on statistical physics, and by extending Darcy law. A multi scale understanding of the EOR processes secures that the reservoir scale models we develop are consistent with the underlying physical and chemical processes taking place in the pore space. This in turns allow us in a robust way to evaluate the potential of EOR operations for realistic cases, and the environmental impact.

2: MOBILE OIL – RESERVOIR CHARACTERISATION TO IMPROVE VOLUMETRIC SWEEP

Randi Valestrand,
research director theme 2

In theme 2 we focus on improved reservoir modelling by improved simulation, optimization, and prediction, of IOR methods. This is done by; integration of all types of data (such as pressure data, production data, seismic data, tracer data, geophysical data, and geological data into the field scale simulation models; by developing improved simulation tools capable of handle/simulate the complexity of different IOR methods; and by developing new and improved tracers.

We put emphasis on real fields and aim to develop methodologies that ease the decision making of a petroleum producing reservoir. The aim is to develop new and improved methodologies that will support the evaluation and decision making with regards to IOR/EOR pilots at the Norwegian Continental Shelf (NCS). This addresses the potential of producing the resources in unswept areas as well as mobilizing the trapped resources in swept areas. The research is focusing on challenges for the entire NCS while demonstrating the improved methodologies on real field cases.

THE RESEARCH TASKS

TASK 1: CORE SCALE

The aim of this task is to design novel experiments on core scale and develop models that capture the transport mechanisms observed. The deliverables of this task will be chemical systems that can improve the microscopic and microscopic sweep on clastic and chalk fields.

LEADER: ARNE STAVLAND, IRIS: Chief scientist at IRIS where he has worked for 30 years. His main interests are in enhanced oil recovery and chemical water control. He holds an MS degree in physics from the University of Trondheim.

TASK 2: MINERAL FLUID REACTIONS AT NANO / SUBMICRON SCALE

The research is focused on rock-fluid interactions when injecting fluids into rock formations either clastic or chemical sedimentary rocks. We deliver methods in the field of electron microscopy, Raman spectroscopy, specific surface area measurements and X-Ray Diffraction for further investigations of EOR related experiments in the future. The geology of the hydrocarbon bearing formations plays a significant role in task 2.

LEADER: UDO ZIMMERMANN, UIS: Professor at UiS. His research has focused on provenance techniques and reservoir characterization using petrography, heavy minerals and geochemical and isotope geochemical methods in clastic and chemical sedimentary rocks of Archean to Phanerozoic ages.

TASK 3: PORE SCALE

The focus in this task is to study the interplay between fluid transport, mineral reactions and oil recovery in reservoir rocks at pore scale. The main aspects are to identify the mechanisms that influence transport and reactions on the pore scale using experiments and numerical modeling, and then to evaluate if these mechanisms are important on the core scale.

LEADER: ESPEN JETTESTUEN, IRIS: Senior researcher at IRIS. His main interests are in rock fluid interactions and how these influence the properties of reservoir rock on the microscopic scales. He holds a PhD in physics from the University of Oslo.

TASK 4: UPSCALING AND ENVIRONMENTAL IMPACT

The main objective is to translate the knowledge we have about EOR processes on core scale to field scale. The deliverables from this task will be simulation models and work flows that can be used to design IOR operations and interpret IOR implementations.

LEADER: AKSEL HIORTH, UIS/IRIS: Chief research scientist at IRIS and Professor within reservoir technology at the University of Stavanger. His main interest is developing simulation models that describe the physical and chemical processes during multiphase flow in porous rocks.

TASK 5: TRACER TECHNOLOGY

The objective is the development of tracer technology to measure reservoir properties and (changing) conditions during production. The most important condition is the (remaining) oil saturation, either in the flooded volume between wells (interwell examinations) or in the near-well region out to some 10 m from the well (single-well huff-and-puff examinations).

LEADER: TOR BJØRNSTAD, IFE: Special Advisor at IFE within reservoir technology, and Prof. em. in Nuclear Chemistry at University of Oslo. Main interests: Tracer technology, IOR and flow assurance. He holds a PhD (Dr. Philos.) in Nuclear Chemistry from UiO.

TASK 6: RESERVOIR SIMULATION TOOLS

The primary objective of this task is to advance the state-of-the-art of modeling and simulation in context of reservoirs. Such advance is needed to cope with the challenges arising from scientific questions and targets of The National IOR Centre of Norway.

LEADER: ROBERT KLÖFKORN, IRIS: Senior Researcher at IRIS. He holds a Dr. rer. nat. in Applied Mathematics from the University of Freiburg. His research interests are scientic computing and software development with focus on computational methods for partial differential equations and it's applications.

TASK 7: FIELD SCALE EVALUATION AND HISTORY MATCHING

We are focusing on history matching, optimization and economical evaluation for improved decision making. In 2017 a large focus has been on history matching using 4D seismic data, which means that we are tuning reservoir parameters to obtain reservoir models that are matching the actual observations. We are using ensemble based methods to this. That means that we are running with a set (an ensemble) of different realizations of the parameter set and use statistical methods to tune the parameters. The outcome is then a set of reservoir simulation models that are better aligned with the actual observations from the field.

LEADER: GEIR NÆVDAL, IRIS: Chief scientist at IRIS. His research interests include reservoir characterization, data assimilation and production optimization, and his main research focus the last decade has been the use of ensemble based methods for updating reservoir models. He holds a PhD in mathematics from NTNU.

Arne Stavland   Udo Zimmermann   Espen Jettestuen   Aksel Hiorth   Tor Bjørnstad   Robert Klöfkorn   Geir Nævdal

THE ROADMAP

	2014	2015	2016	2017

Theme 1

Development of IOR methods
1

IOR mechanism
3

Upscaling, simulation and interpretation tools

Both themes

EOR Screening → Demonstrate potential and prepare for pilots

2 **4**

Field performanc

5 **6** **7**

Economic potent

Monitoring

Theme 2

Fiscal framework and investment decis

	2014	2015	2016	2017

12

8

15

Full Field prediction

2

Business cases

Prepare for full field pilots

Field tests

13

ce

tial and environmental impact

9 11

tools and history matching

10

14

16

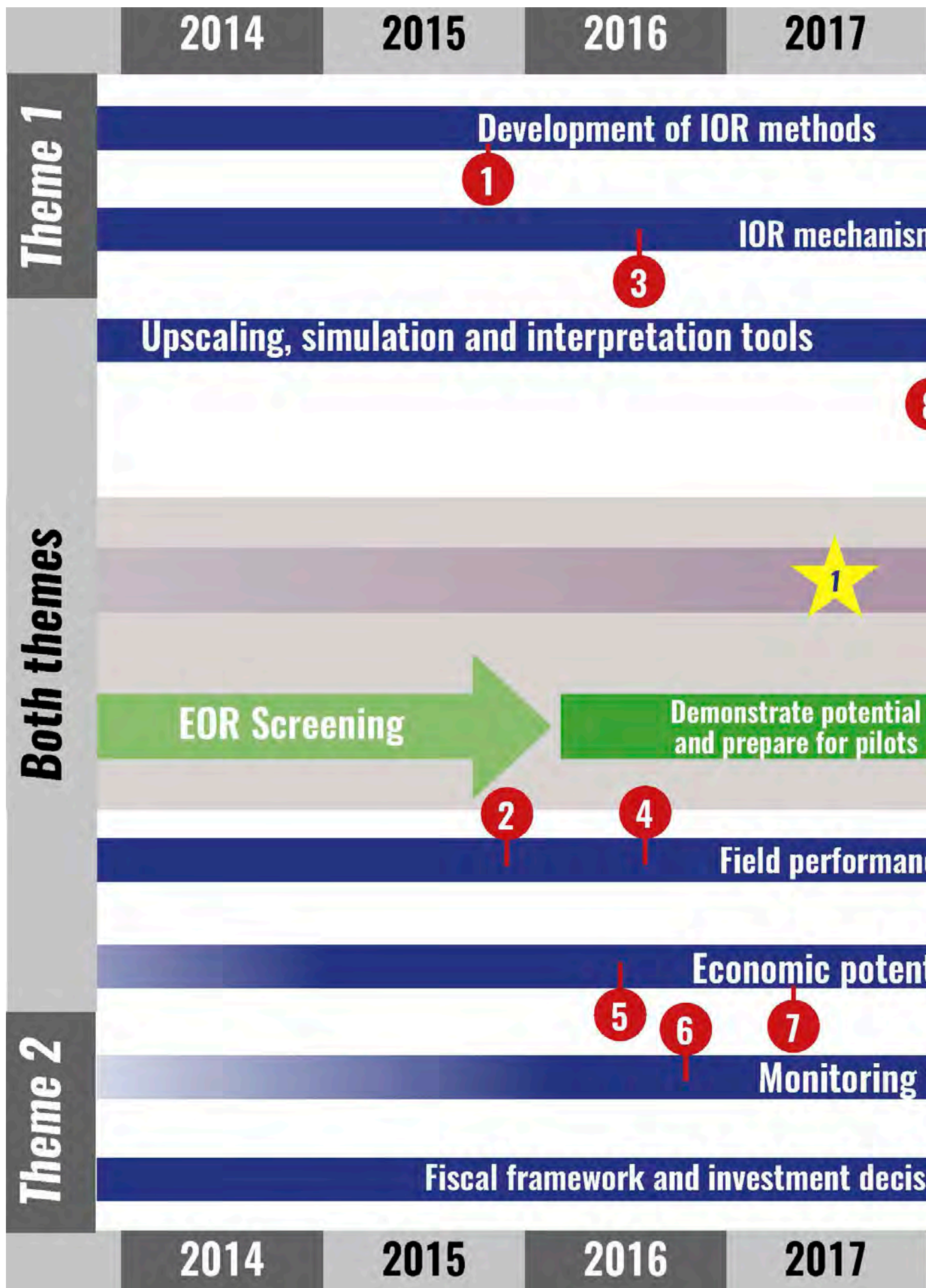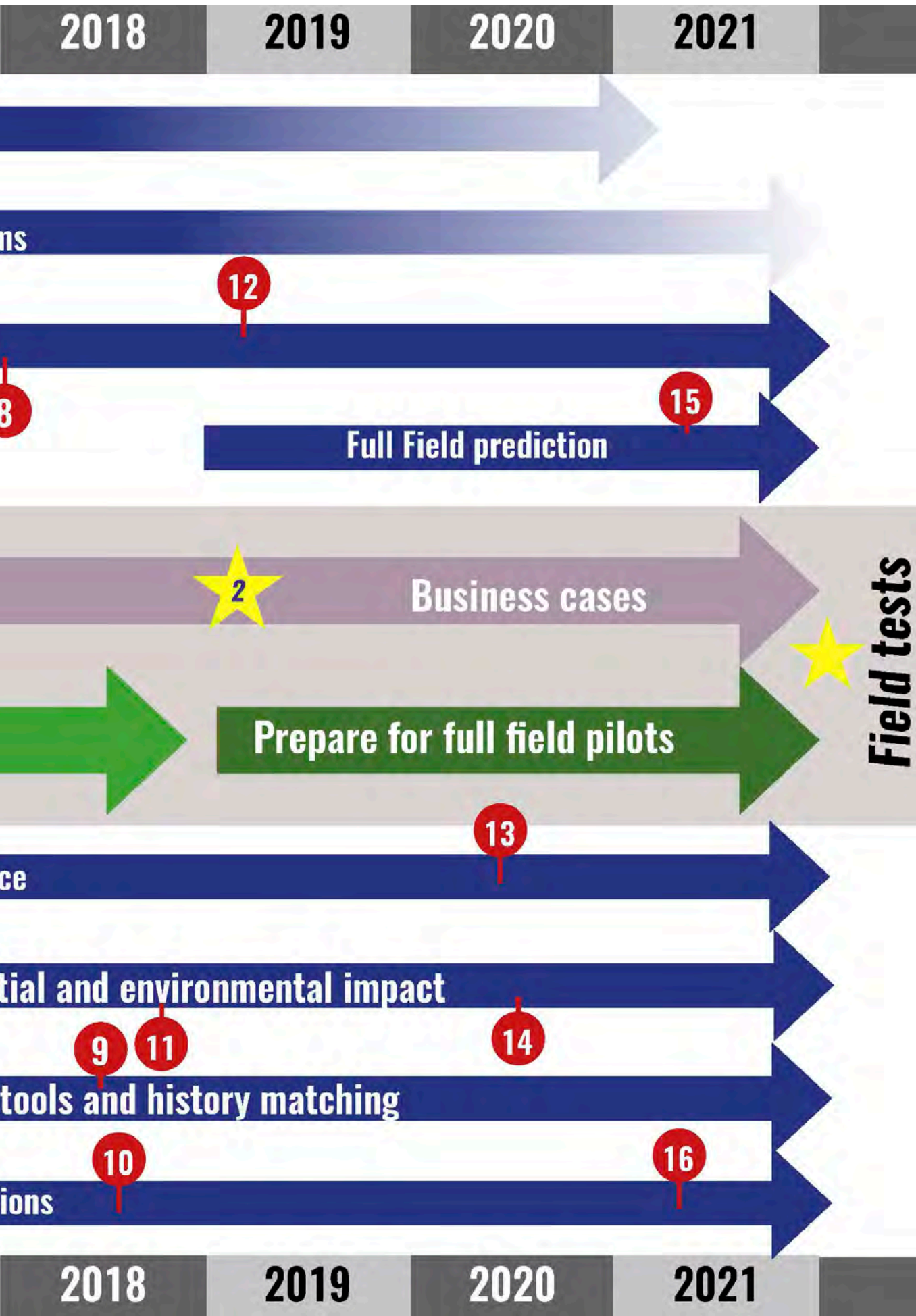ions

EXPLAINING THE ROADMAP

The roadmap was established to set the direction of R&D activities in the Centre. This is important so that everyone gets the same understanding of the goals and milestones we have in the Centre. It guides us so that we can more easily focus the research that is being done, and establish good cooperation between the projects. The roadmap is an important tool to evaluate new ideas and project proposals within the timeframes. The map will as such visualize any gaps and be of help prioritizing the R&D projects.

The roadmap is a guiding tool, used to lead the way towards a use case. However, the research in the Centre is not limited to only the roadmap, and in some cases projects will submit valuable input to earlier stages of the map, resulting in better background and understanding for further progress.

THE R&D ARROWS

The blue arrows show the main activities we wish to focus on. All projects should deliver to one or more of these arrows in order to be relevant for The National IOR Centre of Norway. These arrows can include projects from several different tasks, across both research themes; however, some of the arrows are naturally more directed towards projects in one of the two themes.

The green arrows represent overall themes in the research at various times in the lifetime of the Centre: EOR Screening, Demonstrate potential and prepare for pilots and Prepare for full field pilots. It is important to note that The National IOR Centre of Norway will not perform pilots, but contribute with research and results towards this.

THE STARS
1. Selection of suited field for single-well tests (access to field data)
2. Single-well pilot tests:
- Smart water injection
- Polymer injection

THE RED MILESTONES

1. Selected IOR methods
2. Field data in place (injection, production and tracer data, 4D seismic and reservoir model/geo-model/geomechanical model)
3. Input model parameters (from pore, core, sub-micron experimental and modeling R&D activities)
4. Large scale polymer shear degradation test
5. Economic potential of IOR methods
6. Monitoring tools: 4D seismic (front detection), tracer data (residual oil saturation)
7. Conditioning of injection fluids
8. Reservoir simulation, geomechanics (e.g. Eclipse, Visage), tracer and IOR fluid simulation (IORSim)
9. Full field history matching with 4D seismic and tracer data
10. Viability of methods (fiscal framework and taxation)
11. Environmental impact of selected IOR methods
12. Tool-box for interpretation of pilot-tests
13. Pilot-tests conclusions (Volumetric sweep/injection and production strategy, residual oil saturation, compaction impact, economic potential)
14. Economic potential of pilot-tests
15. Recommendation for comprehensive and full-field tests
16. Economic potential of full-field tests at NCS

EXPLAINING THE MILESTONES
The milestones are important developments in our research that we rely on in order to reach our goal. Each year we will reach several of these milestones, and take one step further towards improved oil recovery. It is important to notice that the milestones do not limit other projects in their progress, even if they do not deliver to a specific milestone at all times. The stars represent use cases that are relying on progress made from reaching the milestones.

We have per 2017 reached a total of seven milestones, with another ten to go. These are the milestones we have reached:
- Selected IOR methods
- Field data in place (injection, production and tracer data, 4D seismic and reservoir model/geo-model/geomechanical model)
- Input model parameters (from pore, core, sub-micron experimental and modeling R&D activities)
- Large scale polymer shear degradation test
- Economic potential of IOR methods
- Monitoring tools: 4D seismic (front detection), tracer data (residual oil saturation)
- Conditioning of injection fluids

PLANS FOR THE FINAL 3 YEARS

As part of the midterm evaluation, The National IOR Centre of Norway has developed research plans for the final three years. This has been an ongoing process in collaboration with the industry experts.

Each year the research and user partners in the Centre provide a detailed work plan, which is approved by the Board. Work plans are available on our website (www.uis.no/ior). In 2017, we also summed up our status and relevance, new research methodologies that has evolved in the Centre but was not in the original plan, and we made updated plans for the final three years of the Centre. In this report we would like to describe new research methodologies that where not in our original proposal have evolved in the Centre, and, we would like to describe the new activities we have planned for in the last three years of the Centre.

NEW RESEARCH ACTIVITIES

We would like to highlight two new research methodologies that where not in our original proposal: i) Large scale testing and ii) The IOR integration activities.

Large scale testing

Large scale testing was proposed after discussions between Halliburton, IRIS, UiS and the oil companies (in particular Statoil). The first test was successful and provided high quality data that has already been presented both at conferences and in scientific journals. The Centre, due to its national and international visibility, was able to attract interest from international chemical vendors (e.g. SNF) and service companies (e.g. Matek-Samson) to contribute with both chemical systems and equipment to be tested at IRIS. The test was successful and produced high quality data that are already presented at EAGE/IOR NORWAY and which will be published in peer-reviewed

journals. Tests of this kind are very hard and expensive to run and would not have been initiated without the Centre and its 14 partners. The Centre is independent and have no commercial interests in the equipment nor in the chemical systems tested, and the results are made available for all 11 user partners. Thus it is attractive for service companies and chemical vendors to demonstrate the potential of their sophisticated methods and unique equipment. In the following years we will continue large scale testing to investigate the IOR potential and the behaviour of chemical systems at a mesoscale. In some cases it is possible to scale down experiments, and to investigate the transport properties of chemical systems at the lab scale. But in most cases it is not; one example is when both diffusive and advective processes are important on a large scale (e.g. stability of viscous fingering, transport of nanoparticles, interactions between the injected and formation water). To advance our knowledge of these processes, we are confident that controlled, larger scale testing is crucial and the intermediate step towards pilot testing in the field.

Integration of IOR

To enable proper integration of research results from the Centre, initiatives have been taken to investigate the relationship between different IOR research projects. It appears to be difficult to obtain all relevant data for a single field, but there is still a need for testing the numerical and analytical methods on the same field. As a result of this, we have defined (and are currently in the process of defining) use cases, and one of the aims is that all PhD

Foto: Marius Vervik

students and Post docs contribute to these case studies. Thereby we can demonstrate the full potential of our methods on realistic cases.

We believe the latter is a very important step in the innovation strategy of the Centre which in turn will lead to promoting future value creation using the developed tools.

UPDATED PLANS FOR THE FINAL THREE YEARS

There are several changes to the original application when it comes to specific details, however, the main objectives within each task are unaltered. This is natural because the specific projects within each task are developed in close collaboration with the researchers involved in the projects and the TC.

Focus on chemical IOR

There is more activity on polymer and silicate than specified in the original project description. Using silicate for water shutoff and improved sweep was particularly attractive as Statoil had performed two pilots on the Snorre field, and the field data and lab work (performed at IRIS) were made available to the Centre. Both silicate and polymer solutions are non-Newtonian fluids, and there have been an increased activity at the pore scale to also investigate these fluids in more detail. Starting up this summer, a master student will analyze cores flooded with sodium silicate to quantify the degree of trapping of silicate particles in the pore space, and the effect of divalent ions (formation of Mg-, and Ca-silicates). Thus the silicate system for water shutoff will most likely be the first EOR system that involves all seven tasks in the Centre all the way from submicron to field scale. We will increase the focus on two-phase flows and the electro-chemical surface effects between different fluid phases, and between the fluid and the solid. This will expand the work on wettability effects and target the stated goals of the pore scale activity, i.e. to understanding capillary effects and multiphase flow properties. In addition, this work can give valuable insights to the effects of chemical EOR on rock mechanical properties. Dissipative Particle Dynamics (DPD) is a pore scale modelling tool not described in the original application, but it is now an integral part of the pore scale activities due to collaboration with IFE. The pre-existing DPD model has been further developed in the Centre in the project «Improved oil recovery molecular processes» with special focus on the depletion layer in polymer flows.

Large scale testing continues

There will be an even higher focus on larger scale testing than described in the original application. During discussions with TC we really see the need for testing on larger scale to bridge the gap between advanced laboratory core scale testing and EOR pilots.

IORSim development

IORSim may be coupled to any existing reservoir simulator, commercial or not. Up till now, IORSim has been coupled to ECLIPSE. The reason for this is that most oil companies use ECLIPSE as the standard tool for reservoir modelling. Hence, IORSim is able to fill a large gap for the oil companies, who have invested a lot of resources in building reservoir cases for ECLIPSE. Through IORSim, advanced modelling of geochemistry and polymer/silicate processes can be added to existing reservoir tools of the oil companies. We are also seeking other options, such as OPM. There are many advantages of coupling IORSim to OPM. Firstly, having access to the OPM source code makes the coupling easier to perform. Secondly, the coupling may have better functionality and contain more physical features, since IORSim can be coupled more directly to the OPM code.

Thirdly, the performance of the coupled codes can be more efficient with regard to computing time.

Tracer technology development

Plans for technical development of tracer technologies described in the original application have been followed closely, and the original defined plans will be followed also in the time to come. It is highly probable that these efforts will result in new field-applicable technologies, and we are planning to test our developed tracers in pilots.

Tor Bjørnstad (IFE), leader of task 5, is preparing for the site visit from the evaluation panel.

Photo: Marius Vervik

We are aware that real pilot tests generally cannot be carried out within the normal budget of the Centre. However, data from real pilots will be very important to demonstrate the potential for users and to integrate more with the other tasks in the Centre. One major addition to the original plans has occurred: As R&D proceed, new ideas and opportunities tend to emerge, and this idea, not specifically defined in the original application, has been included in IFE's experimental program: Synthesis, characterization and testing of nano-sized particles, more specifically so-called C-dots, for application as passive and/or interacting tracers in interwell flow examinations. This activity has resulted in an interesting cooperation with Cornell University (CU) in USA. Apart from the originally proposed ideas, we have focused on the development and application of modern numerical techniques for full field simulation to ensure that predictions based on simulation tools deliver correct results. This diverts from the original plan but has been identified as an important topic.

Aksel Hiorth

Improved numerical models, OPM

Many studies have shown that less accurate low order numerical methods which are typically used in commercial but also other research simulators provide inaccurate results in the representation of fronts and mixing will significantly improve prediction results for IOR studies and thus improve decision making for the NCS. In the remaining time of the Centre we will focus on completion of ongoing integration of such improved discretisation into the Open Porous Media (OPM) simulation framework. In addition, a detailed study on impact of discretization methods for evaluation of IOR potential estimation for oil fields will be carried out in collaboration with the history matching and optimization researchers. For single well tracer tests such techniques will also be available and applied in collaboration with IFE. Together with IORSim researchers we will engage in direct simulation of polymers on the microscopic level to validate the mathematical models developed in IORSim.

Robust optimization

The natural continuation of ensemble based history matching is ensemble based optimization which is often referred to as robust production optimization. Within robust production optimization we have been focusing on 1) further development of ensemble based methods for production optimization and 2) the use of proxy models to reduce the number of full field reservoir simulation to reduce the computational burden of the problem. Until now the focus has been on methodological development, but this will change towards actual use of the developed methodology to address the challenges that will be defined by the full field tests.

Ensemble-based history matching

For the research on data assimilation and history matching, the focus has been on including 4D seismic data in the workflow. This is a very challenging task, due to many reasons such as; big-data, big-models, uncertainty quantification and upscaling/downscaling. For the research on «Improved history matching under compaction» we have started out by first doing investigations more adapted to the workflows used in the industry, utilizing a data set provided by one of the industrial participants. The integration between the reservoir and the geomechanical model will be conducted.

Summing up

Together with TC we have made decisions on the selection of fields that will be used in further studies. The willingness of the companies to provide data for real studies depends on several internal factors, including the availability of personnel resources to follow up work that is done within the Centre utilizing the provided data.

Besides continuation of the ongoing work there is a number of more integrated studies that would be natural to do during the coming three years. In particular there is a scope for evaluating economic benefits using injection of polymers or other chemicals changing the wettability by performing ensemble based production optimization utilizing state of the art reservoir simulation technologies. It would be natural to define such a study together with industrial participants and key personnel from Theme 1. Data assimilation for full field pilots combining the use of production, tracer and other available data is suitable for collaboration within Theme 2. It might be beneficial to do synthetic studies ahead of the actual pilot evaluating the ef- fect of including different data types to ensure that enough data is collected while performing the pilot study.

Merete Vadla Madland, centre director at The National IOR Centre of Norway.
Photo: Marius Vervik

USING FIELD DATA IN OUR RESEARCH

Together with data from the laboratory, real field data provide the opportunity to predict field performance in a generic manner. This information is used together with the modelling tools developed at the Centre to provide recommendations for full field tests. At the Centre, experimental data from laboratory tests and large scale tests, together with real field data delivered from industry partners, generate information of generic importance, which allow us to predict field performance. Here we list projects where we use real field data in parts of each project's research activities.

Adding more physics, chemistry, and geological realism into the reservoir simulator (Norne)

This project addresses forward simulation of IOR methods. Moreover, in this project we aim to contribute in providing a tailor made simulator which includes necessary modeling methodologies and simulation capabilities for simulating IOR pilots on the Norwegian Continental Shelf. The main objective of this project is to provide modelling methodology and simulation capabilities for IOR. This includes the following research topics:
- Field scale simulation of «modified water» injection.
- Representation of brine-dependent behavior in terms of mathematical models.
- Transfer lab-scale mechanism to field scale.
- Field scale simulation of fracture systems.
- Include imbibition effects controlled by water-rock chemistry on field scale.
- Implement the results from the above within the Open Porous Media (OPM) framework.

Data assimilation using 4D seismic data (Norne)

This project is the main project addressing history matching at the Centre. Work is in progress using data from Norne. The project focuses on being able to meet the target of full field history matching using 4D seismic and tracer data. A part of this project has also been carried out by a postdoc at TNO (the Netherlands Organisation for applied scientific research). The primary objective of this project is to include 4D seismic data in ensemble-based history matching for full fields. Secondary objectives include:
- Establishing real field(s) and gathering the data required.
- Investigating which form of 4D seismic data is most suitable for inclusion.
- Developing suitable rock physic model(s).
- Uncertainty quantification of the seismic data.
- Adapting the ensemble based methods to work with the large amount of seismic data.

Interpretation of 4D seismic for compacting reservoirs (Ekofisk)

This project aims to improve the interpretation of 4D seismic data for the location of gas, water and pressure fronts in compacting reservoirs. The methods developed will further contribute towards improving history matching using 4D seismic data for compacting reservoirs. The main objective of this project is to address the extra complexity of compacting reservoirs when including 4D seismic data in history matching. The secondary objectives are:

- Working towards solving this problem with a data set from ConocoPhillips (Ekofisk). Initially we will focus on interpreting 4D AVO seismic data for updating saturations, pressures and porosities.
- In the second step we will use the interpreted data for ensemble-based history matching.

4D seismic and tracer data for coupled geomechanical / reservoir flow models (Ekofisk)

This project is investigating the coupling between fluid flow and geomechanics for improved oil recovery and the use of 4D seismic data in history matching of coupled models. The project also brings geomechanics into the history matching picture and links lab results on rock strength to field scale modelling. The main objective of the project is to investigate rational methods for building and updating coupled fluid flow / geomechanical models. This includes

- Linking 4D seismic observations to stress exchange in the reservoir and surrounding rock.
- Incorporating faults and fractures interpreted from seismic in history matching.

IORSim development project (Snorre)

The purpose of this project is to develop a simulator, IORSim, which improves the capabilities of industry standard reservoir simulators to simulate IOR processes. This is done by letting the industry standard reservoir simulator carry out the fluid flow predictions, while IORSim simulates the transportation of chemicals, interactions and effects on the flow parameters (relative permeability and capillary pressure). This allows us to take advantage of the improved pore- and core-scale models developed in Tasks 1, 2 and 3 directly in realistic field cases. The objective of the project is to develop a simulator that uses industry standard reservoir models and the important physio-chemical mechanism from the lab scale to predict the impact of an IOR strategy.

EVALUATION OF THE CENTRE

Four years have passed since the birth of the National IOR Centre of Norway. In September 2017 it was time for the mid-term evaluation of the Centre. Needless to say the expert panel were pleased with our work. The evaluation report concludes that The National IOR Centre of Norway is strong and result oriented.

September 19th an expert panel and representatives from the Research Council of Norway (RCN) visited the Centre. During the day, the panel got to meet both the management team, industry partners, PhD students and postdocs and other collaborators.

The panel who is evaluating the Centre consists of five experts within different fields of academia:

- Generalist: Alison McKay (professor in engineering design), University of Leeds
- Geology: Fridtjof Riis, Norwegian Petroleum Directorate
- Reservoir technology: Craig Smalley, Imperial College
- Geophysics: Angus Best, National Oceanography Center
- Environmental risks: Ingela Dahllöf, University of Gothenburg

The purpose of the mid-term evaluation was to make sure that the Centre is producing relevant research and that the collaboration within the Centre including all partners and national/international collaborators is well functioning. The evaluation will form the basis for determining whether funding from the Research Council will be continued for an additional three years following the initial five-year period.

On the agenda this day were two different interview sessions. In the first session the panel asked questions about research, internationalization, researcher training and recruitment, and plans for the final three years and beyond. In the second interview session the topics were organization, partners and funding, relevance and utility for user partners and relevance to the call and special stipulations.

In between these sessions the panel met ten of the Centre's PhD students and postdocs. They had all prepared for a one minute stand up about their research. Dissemination and presenting skills are priorities at the Centre, therefore the students have attended several seminars on this subject.

September 21st the same panel was visiting our sister centre, Arcex in Tromsø. After the site visits, the panel went through both centres' self evaluations, plans for the last three years and other relevant docu-

ments, in addition to the information they got at the site visits. In December we got the «verdict»; the evaluation report. A consensus expert panel gave their recommendations. The evaluation concludes that The National IOR Centre of Norway is a strong and result oriented centre. «In the first period, the Centre has conducted high-quality research that has been recognized externally with international prizes,» is the RCN conclusion on their website. The evaluation states that the collaboration between research communities within the Centre and the industry is excellent. The panel highlights the importance of this cooperation for both industry partners and society as a whole. We were especially pleased to find this statement in the report: *«The open working environment and good results of the research has made it possible for the Centre to build up a wide network of collaborating institutions, and it could be said that the Centre is now a focal point for IOR internationally.»*

«Cooperation between research and industry is essential to reaching successful solutions to the challenges associated with the efficient utilization of petroleum resources,» says Fridtjof Unander, Division Director for Energy, Resources and Environment at the RCN website.

Spring 2018, the Centre will submit plans for the last three years. In these plans, the Centre must come up with its own recommendations for the guidelines the expert panel has given. RCN will make a final decision on the financing of the last three years in April 2018.

The Research Council of Norway

Midterm evaluation of research centres for petroleum activities

Research centres for petroleum activities – PETROSENTER
Division for Energy, Resources and the Environment

Foto: Kjersti Riiber

PREPARING FOR SITE VISIT

Director of field implementation Sissel Opsahl Viig and PhD student Samuel Erzuah.

All photos: Marius Vervik

From the top: Aksel Hiorth, Niels Lindeloff, Merete Vadla Madland, Mona Wetrhus Minde and Ying Guo.

Master student Shijia Ma and PhD student Tijana Voake.

Phd student Anna Kvashchuk, task leader Tor Bjørnstad and research director Randi Valestrand.

To the right: The winning team Irene Ringen, Ola Ketil Siqveland, Tijana Voake and Aksel Hiorth.

PhD students and postdocs contributing to the research projects at The National IOR Centre of Norway in 2017: Laura Borromeo, Oddbjørn M. Nødland, Bergit Brattekås, Mona Wetrhus Minde, Irene Ringen, Teresa Palmer, Dmitry Shogin, Remya Nair, Emanuela Iedida Kallesten, Kun Guo, Samuel Erzuah, Aruoture Voke Omekeh, Jaspreet Singh Sachdeva, Shaghayegh Javadi, Tijana Voake, Mohan Sharma, Anna Kvashchuk, Mario Silva, Mahmoud Ould Metidji, Thomas Brichart, Trine Solberg Mykkeltvedt, Tuhin Bhakta, Kjersti Solberg Eikrem, Karen Synnøve Ohm, Aojie Hong, Eystein Opsahl, Yiteng Zhang, Pål Østebø Andersen and Yanhui Zhang.

At the midterm evaluation it was time for our PhD students and postdocs to shine.

An evaluation panel consisting of five experts within diffe- rent fields of academia met up with both management, industry partners and PhD students and postdocs at the site visit 19 September 2017. The quotes below are from the evaluation report written after the site visit:

«The evaluation team met an impressive spectrum of enthusiastic and capable PhD students, postdocs and early career academics who were most appreciative of the opportunities they gained from being members of their (…) Centre. It was noticeable that the PhD stu- dent and post-doc scientific training and experience was outstanding (…).»

The panel also highlighted our students opportunities to travel abroad:

«There are numerous examples of international resear- cher exchanges and PhD students were positive about the international experience they were able to gain from their membership of the Centre.»

Before the site visit, the PhD students had placed them- selves in the Centre's roadmap. At the site visit they repeated this challenge in front of the panel.

«It was excellent that the 26 PhD students and post- docs were able to explain how their projects fitted

into the roadmap and contributed to the overall ob- jectives. The dynamic and multi-disciplinary research environment at the Centre provides an excellent training ground for this cohort of PhD students and exposure to industry-facing problems and methods. Currently, the students' main access to the industrial partners is through discussions in seminars, workshops and other gatherings.»

Also the dissemination skills seminars, hosted by pro- fossor emerita Aud Berggraf Sæbø, was mentioned in the report:

«The management team is proactive in establishing a positive working environment for PhD students that recognises their contributions to the Centre: for example, by arranging activities for the whole student cohort to develop soft skills, facilitate cross-discipline learning and social networks. This enhances the students' experience and is building social capital for their future careers. The future plan, including the STEP (Students & Partners) programme, where all students will contribute to the use cases, is likely to be an effective way of further de- veloping cross-disciplinary synergies between students, tasks and projects.»

Dmitry Shogin and Irene Ringen

Bergit Brattekås

Mario Silva presenting

Aud Berggraf Sæbø

Mahmoud Ould Metidji

Yiteng Zhang

Mario Silva

IORCoreSim: «THIS IS INNOVATION»

A new tool for our industry partners was released late June 2017. All partners were invited to a «release party» / user course for the new simulator.

In the course the attendees, representatives from our industry partners, learned how to run the simulator on core and small field cases. They also got to visualize the results with software from ResInsight.

The new simulator allows the companies to interpret SCAL experiments, correct for capillary end effects. Representatives from several of the Centre's industry partners attended the short course / release party; ConocoPhillips, Maersk, Statoil, Eni, Halliburton and Aker BP were all present at the course which took place at IRIS, one of the research partners of the Centre.

It was initially the companies who asked for this course. «They saw the potential and wanted to use the core scale / sector scale simulator we now have developed,» centre director Merete Vadla Madland says.

Madland adds that this was just meant as an introduction course.

«The companies will most likely need a follow-up course. In the next course we hope to give them more details about how to use the simulator,» Madland said.

She is very proud of the core scale simulator, and especially the work done by PhD student Oddbjørn Nødland. «This is innovation – a new tool for our industry partners.»

FACTS IORCoreSim
- Has been developed in the Centre
- Was previously known as BugSim, a simulator for predicting the behavior of microbes during water flooding
- Is unique in the sense that it can simulate the combined effect of low salinity water injection and polymer flooding on oil recovery
- Senior scientist Arild Lohne has been the main developer. During the Centre lifetime Lohne has added functionality to simulate the injection of non-Newtonian fluids, such as polymers
- Professor Aksel Hiorth has added functionality to simulate geochemical interactions
- Lohne's and Hiorth's PhD student Oddbjørn Nødland has improved the numerical codes and tested the simulator against core scale experiments

Researcher Arild Lohne from IRIS/The National IOR Centre of Norway and Arve Oftedal from Halliburton.

PhD student Oddbjørn Nødland has been essential in developing the core scale simulator.

The Centre at Wintershall's main office in Barnstorf. From the left: Luis Genolet, Merete Vadla Madland, Steinar Kristiansen, Jan Ludvig Vinningland, Kjell Gunnar Pettersen, Ana Todosijevic, Aksel Hiorth, Sissel Opsahl Viig, Tor Bjørnstad, Arne Stavland, Randi Valestrand, Ingebret Fjelde, Aron Behr and Meindert Dillen.   Photo: Wintershall

VISITING THE INDUSTRY PARTNERS

Collaboration is one of the key elements to success in the Centre. The user partners from the industry provide a valuable entrance to important data and expertise needed in order to succeed. In 2017 we visited Wintershall in Barnstorf, Statoil in Trondheim and Aker BP in Stavanger.

The oil company Wintershall, one of the industry partners of The National IOR Centre of Norway, is owned by BASF, one of the largest chemical producers in the world. A delegation from The National IOR Centre of Norway visited both Wintershall and BASF to learn more especially about their work on Schizophyllan, but also to share knowledge from some of the research projects at The Centre.

Discussed future innovations
During the stay at Wintershall and BASF the researchers got to visit the BASF compound with EOR laboratories and production facilities. An important part of the visit was to hear more about the EOR projects, like the low salinity program and surfactant portfolio, and to learn more about the progress in application of synthetic polymers. «Most of all we are delighted to meet up with our colleagues in Germany and discuss future innovations to implement cost efficient and environmentally friendly technologies for improving oil recovery,» centre director Merete Vadla Madland said after the trip to Germany. «Developing innovative technologies and better solutions for the industry will not be possible solely by sitting in our offices in different parts of the world. We need to get out of our home environment, we need to meet our user partners in person and have those important one-to-one

talks over the dinner table,» Merete Vadla Madland claims.

Statoil and Aker BP visits
Centre director Merete Vadla Madland and research director Aksel Hiorth attended an IOR workshop in Trondheim, 8 June. Since the workshop took place at Statoil's research centre at Rotvoll, it was only natural to pay them a visit as well. 7 September research director Randi Valestrand, task leader Geir Nævdal and researcher Xiaodong Luo (see picture below) visited Aker BP at Forus.
The visits performed by representatives of The National IOR Centre of Norway are not limited to the user partners, but also involves collaborators and other interested parties.

Xiaodong Luo, Geir Nævdal, Mark Shahly and Randi Valestrand

THE INSPIRE PROJECT

In 2017 the Centre and partners were awarded an Research Council of Norway project from the programme: International Partnership for Excellent Education, Research and Innovation (INTPART). INTPART will fund partnerships between Norwegian higher education and research institutions and excellent partners in prioritized counties. Special emphasis is on integrating higher education- and research, and may include business partners.

We were awarded the InSPiRE project: International Open Source Simulation Software Partnership in Research and Education (InSPiRE).

InSPiRE aims to boost the the development of open-source simulation software. Institutes and universities in Norway, Germany and France are to collaborate closely – also in order to integrate relevant industrial partners.

Senior Research Scientist at IRIS and task leader at The National IOR Centre of Norway, Robert Klöfkorn is leading the project and explains that the main goal of InSPiRE is to establish a partnership in research and education. This will result in a joint workshop and summer school series and a joint course at the Universities of Stavanger and Bergen in collaboration with the International Research Institute of Stavanger, and the Universities Heidelberg and Stuttgart, Universite Cote d'Azur as well as the French Geological Survey (BRGM).

The primary intention of the project is to establish research and education based software platforms that are closely linked together and will greatly benefit all involved partners for future joint project proposals. Secondarily, the project also aims to:

- Strengthen collaborative networks between industry and academia
- Increased value creation by superior simulation capabilities
- Facilitate education and knowledge sharing through better mobility
- Create an arena for generation of research and innovation projects especially towards EU programs
- Increased utilization of research e-infrastructure in Norway, Germany, and France.

Text: Søren Arentsen / IRIS

OPEN POROUS MEDIA SEMINAR

The National IOR Centre of Norway, in cooperation with a CLIMIT-Demo project for improved simulation tools for CO_2-EOR, and IRIS hosted an OPM introduction course and a two-day OPM workshop at IRIS' offices in Bergen. Tuesday October 17th The National IOR Centre of Norway did an OPM introduction course for invited members. The day started with a brief introduction to the Open Porous Media (OPM) initiative, given by Robert Klöfkorn (IRIS). The course continued with installation of OPM-Flow, the OPM Black-oil simulator, on laptops of all participants. And finally, field test cases were run, and the results were visualized with the free 3D visualization tool RESINSIGHT (fast and free 3D visualization of simulation results in Eclipse binary format.) The following days, 18th-19th of October,

Tor Harald Sandve from IRIS conducted a two-day OPM workshop. The workshop was open to all, and the first day attracted almost 40 attendees from various companies/research environments all interested in modeling and simulating porous media processes.

Alf Birger Rustad from Statoil gave an opening speech emphasizing how far we have come during the last year, and that the main reason for this success is that we work together. According to Rustad, 90 percent of functionalities are implemented in OPM-Flow, and what's within the remaining 10 percent might be different for different users. This is the key value of open source: You have the ability to implement the functionalities you need to meet your needs. *Text: Søren Arentsen / IRIS*

THE CENTRE AND IRIS AT SIAM

Eleven scientists from IRIS and the Centre arranged a mini-symposium at the SIAM conference on mathematical and computational issues in the geosciences.

The conference took place 11–14 September, 2017 in Erlangen, Germany. Trine S. Mykkeltvedt (see picture) from the reservoir group at IRIS was one of the eleven IRIS scientists who presented in Erlangen. Mykkeltvedt is also working for The National IOR Centre of Norway.

She explains that the SIAM conference is an excellent arena to learn about the latest research within advanced modeling and simulation.

«And not the least, it was great for IRIS to arrange a mini-symposium with three sessions where we could present some of our latest research results,» Mykkeltvedt says. *Text: Søren Arentsen / IRIS*
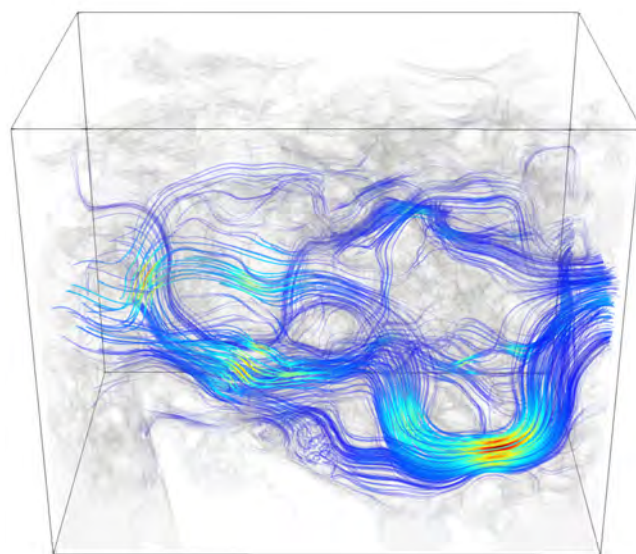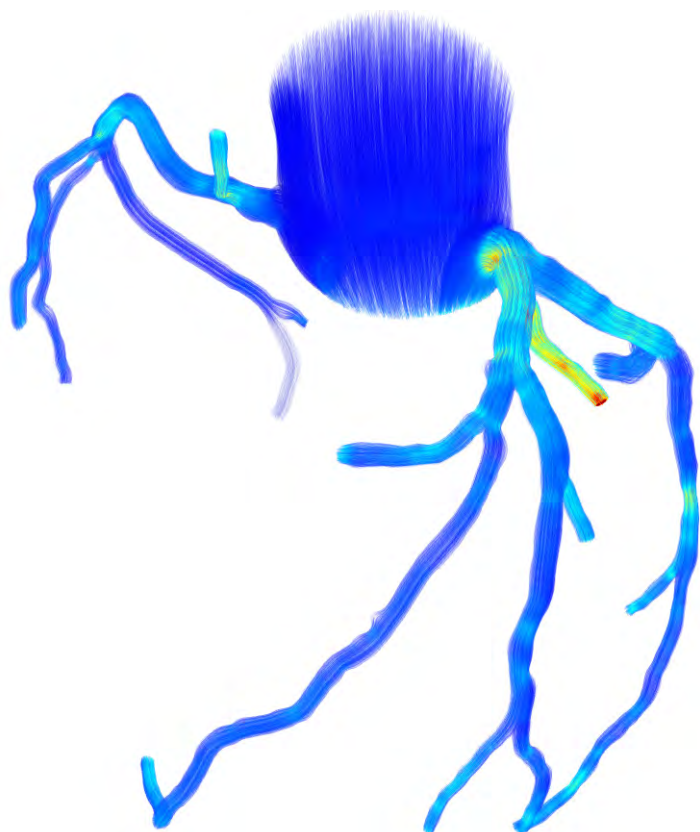
The figures show a flow model of the coronary arteries (left) and a flow model from an oil reservoir.

OIL TECHNOLOGY HELPS HEART PATIENTS

The aim of the IRIS project Pumps and Pipes is to allow doctors to examine the arteries of the heart non-invasively. The Centre's research director Aksel Hiorth and senior researcher Jan Ludvig Vinningland are both contributing to the project.

Restricted blood flow in the coronary arteries can result in a heart attack. A narrowing in the arteries providing oxygen to the heart can therefore be deadly. Today, doctors examine patients using a catheter to determine whether an obstructive coronary artery disease is present or not. New technology can make it possible to evaluate the severity of blood vessel narrowings without inserting a catheter.

«Even though blood is different from oil, and blood vessels differ from pipes, there are several similarities,» says Jan Ludvig Vinningland at IRIS (International research Institute of Stavanger). This means that blood supply to the heart can be calculated in much the same way as oil flowing through reservoirs and pipes.

«Mathematically it's very similar – more or less identical in fact,» says Aksel Hiorth at The National IOR centre of Norway at the University of Stavanger. Together with medical doctors from Stavanger University hospital, the two physicists are adapting oil technology to medicine.

Risky examination

The coronary arteries provide critical blood and oxygen supply to the heart. If one or several coronary arteries are narrowed, the heart might not receive enough oxygen. These blockages develop to cause a heart attack. Cardiologists use a catheter to investigate the narrowing of coronary artery. The catheter is inserted into an artery, usually in the patient's arm, and from there directed to the coronary artery supply of the heart. A sensor at the end of pressure measuring wire registers drop of pressure over the narrowing. This indicates how severe the narrowing is.

«The problem is that a catheter based measurement is potentially both risky and painful for the patient. For instance, the catheter might damage the arteries," explains interventional cardiologist Nigussie Bogale at a gathering of petroleum researchers and hospital doctors.

From oil to blood

According to Vinningland and Hiorth, the human body can be compared to porous rock.

«In the same way as oil is spread in a network consisting of gaps and pores in porous rock, blood spreads through a very fine network of veins and arteries in our body,» Hiorth explains.

Fluid dynamics describe the flow of liquids and gases. By applying the basic laws of fluid dynamics, physicists and other researchers are able to simulate several real-life situations. For instance, this can be used to simulate airflow round the blades on a windmill. Or how water flows round a propeller. Or how oil, gas and water flow through a reservoir. Petroleum researchers at UiS and IRIS have spent decades developing flow models, and these are now tested on blood veins.

Text: Karen Anne Okstad / UiS
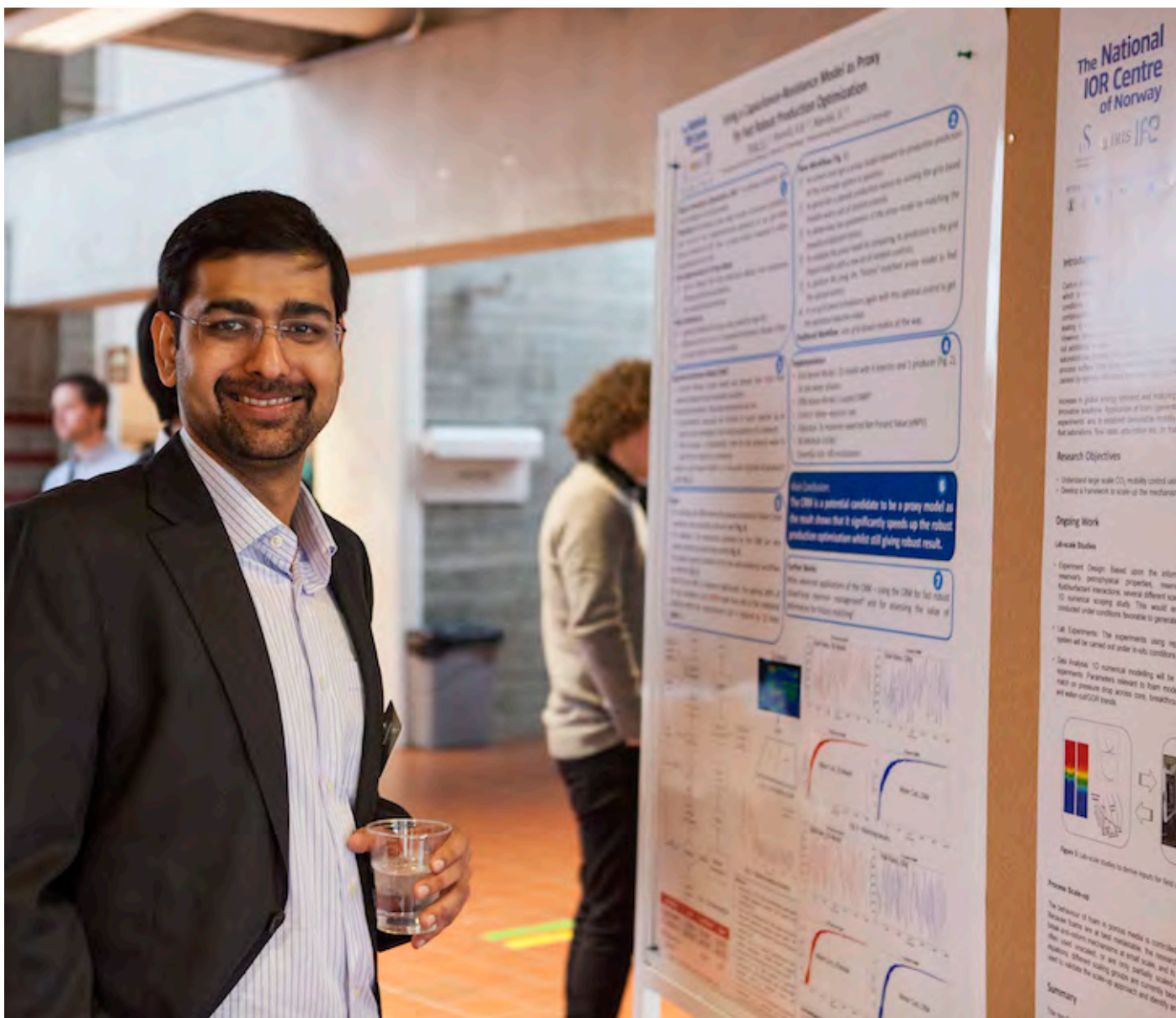
Centre PhD student Mohan Sharma is investigating the mechanisms on small and large scales for CO2 Foam EOR. On this picture Sharma is standing in front of the poster he presented at IOR NORWAY 2016.   Photo: Mari Løvås / UiS

CO₂ FOAM EOR FIELD PILOTS

CO₂ injection is a proven technique to tap residual oil, but suffers from phenomena like gravity segregation, viscous fingering and channelling; eventually leading to poor sweep. Foam has been proven as a solution for mobility control based on studies done at core scale in laboratories. The displacement mechanism with foam, however, is less understood at large scale. So, field pilots for both carbonate and sandstone reservoir were planned at two onshore fields in USA, to demonstrate the scalability of the technology, before it can be adopted by companies operating on Norwegian Continental Shelf.

The pilot for one of the selected fields, with carbonate reservoir, will start in March this year. A rapid SAG (Surfactant-alternating-Gas) injection with six cycles lasting over six months will be implemented, followed by chase fluid injection. Extensive work has been done in laboratories at UiB over last two years, to screen an appropriate surfactant, establish additional recovery with foam using reservoir core and fluids, and obtain

parameters for reservoir simulation. A 3D geologic model was established, which was history matched to previous waterflood and ongoing CO₂ injection, subject to uncertainties in static and dynamic models. This model acts as a vehicle to derive the injection strategy, and will be used to understand the large scale displacement mechanisms by integrating findings from data acquired during different stages of the pilot. An interwell tracer study is ongoing, which will be supplemented by injection fall-off test and injection profiling to establish baseline connectivity and reservoir dynamics. Flow profiling and pressure transient tests will be repeated to understand the effect of foam on CO₂ mobility. The pilot for the other field will start later this year, with plans to complete the laboratory studies and numerical modelling, including baseline data acquisition by the third quarter.

Text: PhD student Mohan Sharma
The National IOR Centre of NORWAY

THE NEED FOR LARGE SCALE TESTS

Many large and legacy fields at the Norwegian Continental Shelf are already mature with rapid production decline and the time is critical to implement IOR/EOR technology. According to the Research Council of Norway (RCN) there will be significant future demand for infrastructure that provides facilities for value-adding research to corroborate and test new technologies in the petroleum sector. The National IOR Centre of Norway sees research on IOR as one of the areas where huge technological advances and added value can be created if facilitated by improved research infrastructure. Some of the key factors to future success are developing new technology and improving competencies to maximise resource utilisation and minimise environmental impact.

Not a trivial task

Even though we have already a good understanding of IOR and EOR mechanisms, only a few field pilots have been put into play, and no field-scale implementations at the NCS have been sanctioned so far. Laboratory measurements on core plugs (~cm scale) have repeatedly demonstrated the potential for IOR, where usually more than 90% of the oil is produced. Translating the lab results to field scale (~km) is not a trivial task. There are many challenges, such as complex geology, large well distances and limited knowledge about the transport properties of IOR chemicals at larger scales. Therefore, bridging the gap between spatial scales can be achieved by performing experiments at small, medium, and large scale, and by building models that can interpret these experiments. New research results from large scale tests will contribute to field implementation of existing, new and improved IOR methods, reducing costs and the environmental impact, and maximising hydrocarbon recovery from the mature fields on the NCS.

High quality data

The first large scale test at The National IOR Centre of Norway (October 2016) was successful and provided high quality data. Tests of this type are very difficult to implement. They are also expensive. Large scale testing in this format had not been possible if there were no cooperation between the research partners and the industry partners at the Centre. The IOR Centre is independent and has no commercial interests. For us the most important thing is that the results are made available to all user partners. In the coming years, the Centre will continue large scale testing to investigate the IOR potential and properties of mesoscale chemicals.

Amare Mebratu from Halliburton led the participants through the yard test at IRIS October 2016. Even though the Centre did not organize for any large scale tests in 2017, this is of great importance for our research. Hopefully we'll arrange a new test in 2018. Photo: Mari Løvås / UiS

«One of the highlights have been how well the PhD students have been integrated in the Centre activities, both in house, but also included in industry visits, presentations and discussions. The possibilities to present and discuss one's work internally and with industry has enabled me to get a better understanding of how my work impact others' research and which questions the industry want answered.»

Mona Wetrhus Minde

«The IOR Centre encourages their students to visit abroad universities, which is a very good opportunity for the students to broaden their horizon and collaborate with other excellent researchers.»

Aojie Hong

«The IOR Centre inspires their PhD students to get insights about what the industry requires from them and how to present our work in the most efficient way. The Centre encourages to have a creative working environment for their students and helps to integrate with other researchers in the Centre.»

Remya Nair

«The social environment at the Centre is wonderful. It is a pleasure for me to work amongst the leading intellectuals and researchers from the oil and gas industry with everyone aiming one common goal: optimizing and increasing the oil recovery from the Norwegian Continental Shelf.»

Jaspreet Singh Sachdeeva

Top left: Dmitry Shogin, Ma
Middle left: Samuel Erzuah, Bergit Brattekås, Oddbjø
Bottom left: Anna Kvashchuk, Irene Ringen,

«The management team puts a big emphasis on the social environment and regularly promotes team building activities. In particular for me, being stationed in Oslo at IFE, this is a great attitude. It allows me to get to know everyone, what they're doing, and even developing personal relationships with some people. It's very easy to talk to everyone affiliated with the Centre, from fellow PhD candidates to its head. It's a healthy and motivating environment.»

Mario Silva

«My project aims to scale-up the technology of using foam for mobility control for CO2 EOR, from Lab to Field. This is a collaboration project involving seven universities from Europe and the USA, and six oil companies. The journey so far has been really exciting with the laboratory studies, reservoir simulation, and baseline data acquisition in field, acting as precursor to the pilot in a heterogeneous carbonate reservoir which is scheduled to start in March this year.»

Mohan Sharma

«I am fortunate to work with the best! I highly respect my supervisors, both as scientists and as persons. They are supportive and at the same time acknowledge, challenge and champion initiative, new approaches and creativity. »

Emanuela Kallesten

hmoud Ould Metidji, Mario Silva
ørn M. Nødland, Emanuela Kallesten, Shaghayegh Javadi
Mona Wetrhus Minde, Remya Nair, Yiteng Zhang

Aojie Hong with celebrates graduation with his wife Wei Zhao and their son Keen Zhao Hong (15 months).   Photos: Kjersti Riiber

WELL DONE, AOJIE HONG!

Aojie Hong spent five months at the University of Texas in Austin spring/summer 2017. Here he worked closely with Professor Larry Lake, one of the world's foremost researchers in his field (EOR and Decision Analysis).

When UiS was awarded The National IOR Centre of Norway in December 2013, it was required that the Centre should educate at least 13 PhDs in the first five years. Now the Centre has been in operation for four years, and already 20 PhD students have joined us. The first to defend his doctoral degree was Aojie Hong. December 14 he defended the thesis «Managing geological uncertainty with decision analysis in reservoir management».

Aojie Hong's research field is optimization of oil production. Despite his young age (29 years), he has already published several scientific articles. He has also contributed greatly to the cooperation between the academic communities at the University of Stavanger and the University of Texas, UT Austin. Hong's contribution to The National IOR Centre of Norway is also of great importance, especially for how our 12 industry partners will think optimization in the years to come.

Professor of Investment and Decision Analysis, Reidar Bratvold, is the main supervisor for Hong. He is impressed with what the student has done during his time at UiS. «During my work with him, he has demonstrated professional skills, expertise and behaviour. I have learned a lot from our joint work and have tremendous respect for his abilities. Aojie has published several papers in international journals of high standings and this demonstrates his scientific potential. He is ambitious and hard-working and continue to add research results and publications even as his PhD work is in the finishing stages,» Bratvold says about his student.

In 2018 several of our PhD candidates will graduate. Laura Borromeo, who is working on a project on Raman spectroscopy applications, is due 6 June. Also Kun Guo and Shaghayegh Javadi is defendig their doctoral degrees spring 2018.

Meet our newest PhD candidate, Siv Marie Åsen. After working in the Improved Oil Recovery group at IRIS since 2002, she is now working on a PhD degree in the Centre; Polymer rheology at micro- and Darcy scale.

«What is your role in The National IOR Centre of Norway?»

«I have been working in projects in the IOR Centre since the start, but recently I started working as a PhD student on a project called "Polymer rheology at micro- and Darcy scale".»

«What is your background?»

«I have a master in organic chemistry from the University of Oslo and have been working as a researcher within enhanced oil recovery (EOR) at IRIS since 2002.»

«How will you contribute to The National IOR Centre of Norway in the future?»

«Hopefully I will be contributing with valuable research and interesting publications, and maybe also to further improve the cooperation between IRIS and UiS.»

«Why is IOR important?»

«It is (of course) because it leads to more oil being produced from the same oil field which leads to more energy for the world, more income for Norway and more people working.»

«In what way is IOR environmentally friendly?»

«In the same way as you do not slaughter an ox and eat only the tenderloin. If you have put energy and money into finding and devolving an oilfield, you should get as much energy out of it as possible (of course without putting more energy into it than you get out).»

In addition to Siv Marie Åsen, the Centre will employ yet another PhD candidate spring 2018.

MEET SIV MARIE

Siv Marie Åsen and her supervisor Aksel Hiorth.   Photo: Mari Løvås / UiS

# TRAINING DISSEMINATION SKILLS

The students at The National IOR Centre of Norway have had several presentation seminars during 2017. In april they were gathered with professor emerita Aud Berggraf Sæbø. Her field of study is drama and learning processes, and she taught the PhD students how to get the attention from the audience when they're giving their presentations for instance at big conferences such as IOR NORWAY.

Presenting your research in front of about 300 people is not everyday life for the PhD students.

«Never forget to look at the audience with a blink or a smile,» Berggraf Sæbø advised the students.

«'Now I will take you through a very exciting story'. That's what you should tell yourself when you're doing your presentation,» the professor continued.

Also in the beginning of September the students had a seminar with Sæbø, this time to prepare for the Research Council of Norway's expert panel site visit. At the site visit the panel had interview sessions with the students. Sæbø's job was to drill the students in how to answer in front of an expert panel who might ask questions you are not prepared to answer. Needless to say, our PhD students did great both at IOR NORWAY 2017 and at the site visit in September.
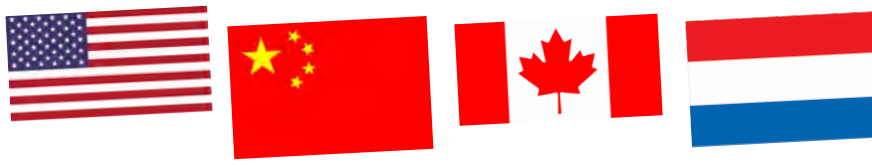
Panorama of Prexy's Pasture at the University of Wyoming during winter time. This is a large grassy area located within a ring of classroom and administrative buildings.

Private photos

MY STAY IN WYOMING, LARAMIE

Pleasant, cheerful, enjoyable and off-course intriguing stay! That I can say all about my visit at University of Wyoming, Laramie during Sep-Nov, 2017. The city, Laramie, is itself very beautiful and scenic; and located on eastern side of the Laramie river. It is surrounded by the Snowy mountain and the Laramie mountain ranges. The population is just above 30,000 here. The city is home to the University of Wyoming, the only university of the state Wyoming, USA. I visited Dr. Dario Grana and his group in the department of Geology and Geophysics during my stay. The visit was very fruitful and adds new dimension to our current research activities at IOR center.

The research

Currently, we have been working on seismic history matching. The main objective of this work is to integrate seismic data more efficiently in the history matching workflow. Seismic data is one of the most important tools used for reservoir exploration, monitoring, characterization and management in the petroleum industry. Compared to conventional production data used in history matching, seismic data is less frequent in time, but much denser in space. Therefore, complementary to production data, seismic data provide valuable additional information for reservoir characterization. There are different types of seismic data that one can use in history matching and they are essentially coming from various levels. For example, we can perform seismic inversion for seismic parameters (i.e. velocities and density) or reservoir/ petrophysical parameters (i.e. saturations, pore pressure etc.). However, inversion and integration of seismic data in the history matching workflow itself has challenges due to the inversion procedures, lack of uncertainty quantification, time to depth conversion etc. Therefore, in this work, we tried to investigate and improve various aspects.

The collaboration helped us to obtain hands-on experience on performing Bayesian seismic inversion which has emerged as one of the promising geophysical data inversion technologies in recent years. Further, I have gathered the preliminary knowledge to prepare the inverted seismic data for the history matching workflow, such as time to depth conversion and seismic to reservoir upscaling etc.

The staying

Well, this was the first time I stayed in USA for a period of three months. The students at the university are very welcoming and always ready to help. The campus itself is very organized. I was amazed by the free transportation within the campus as well as through/from city. The university further provides free transportation to its students over the weekend nights. This helps students to be in campus even after the university working hours as well as during weekends. I stayed at Spanish Walk apartment. I really loved its proximity to various restaurants and cafeterias. Moreover, the presence of a grocery store near to the apartment was an added advantage. The weather was almost stable during my stay. Most of the time, I enjoyed very bright and sunny days. However, for a couple of days I experienced heavy snow fall and low temperature (- 8ºC) which is quite normal during November. Fortunately, it didn't rain much during my stay. First time in my life, I witnessed so called "American football" at War Memorial stadium. I was amazed to see the craze among the Americans about this game. The stay also provided me the opportunity to meet new people and live the university life once again. Altogether, this visit was enjoyable and fruitful both professionally and personally.

Tuhin Bhakta

Tuhin Bhakta, a research scientist from IRIS, works in Task 7 in Theme 2 in The National IOR Centre of Norway. Last year, he spent three months (Sep-Nov, 2017) in the department of Geology and Geophysics at the University of Wyoming, USA. (Widescreen photo)

Watching American football at War Memorial stadium.

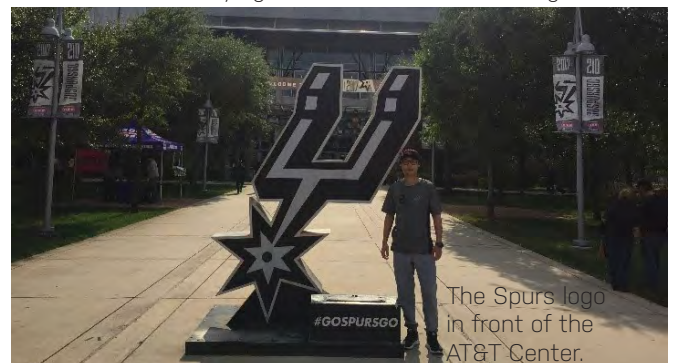Geological Museum in front of the department of Geology and Geophysics, University of Wyoming.

Me and my baby son watching a monkey in the Austin Zoo.   Private photos

People gathering on the Congress Avenue Bridge in Austin, Texas to see bats flying out from beneath the bridge.

The Spurs logo in front of the AT&T Center.

The sunshine and warmness in Austin was a treasure! I arrived there in February when the temperature was perfectly around 20 °C. Austin is the capital of the state of Texas with a population of 967.000. Because it is close to Mexico, there are many Mexicans speaking Spanish and Mexican culture and food are dominating. Compared to Houston and San Antonio, it is quite small. However, it is very big compared to Stavanger. Austin is very famous because of its titles such as «Live Music Capital of the World» and «the No. 1 Place to Live in the US». The University of Texas at Austin (UT Austin) is a public university founded in 1881. By the fall of 2016, there were 3000 academic staff and 51.000 students. UT Austin is one of world's best universities for petroleum engineering. It is one of the reasons why I decided to visit there.

I conducted my research there collaborating with Prof. Larry Lake who is a world leading expert in Improved Oil Recovery (IOR). The research was focusing on reservoir management in a decision analysis framework, including looking for approaches to better quantifying the uncertainty in future production and to making better IOR related decisions. Two projects would not be conducted successfully without the discussions with and the insights from Prof. Lake and other professors and researchers. All the students I met were professional and friendly. We discussed our researches during working and shared our lives in spare time. I made many friends there.

The first project was on fast analysis of optimal IOR start time. A particular decision for development design is: when is optimal to start an IOR process such as water-flooding or gasflooding? This decision relates to the plan of manufacturing, transporting and installing the equipment, allocating both financial and human resources and licensing for production. We proposed a method

for performing a fast analysis of the optimal IOR start time using a decline curve based production model and least-squares Monte Carlo (LSM) algorithm and found that the LSM algorithm can significantly improve the decisions and lead to a significant increase in a field's economic performance and that using the decline curve based model combined with the LSM algorithm can provide useful insight in the problem of deciding the optimal IOR start time with limited computational resource.

The second project was on integrating model uncertainty in probabilistic decline curve analysis for unconventional oil production forecasting. Decline curve analysis is an industry-accepted and extensively used method in the oil and gas industry. However, several models have been developed to capture the characteristics of different flow regimes in unconventional plays. Thus, which model should be used for forecasting is still in question. No one model is best in all circumstances, so instead of identifying a single «best» model for unconventional production, we proposed to regard any model as a potentially good model whose goodness is described by a probability representation. The model probabilities are calculated using a Bayesian framework. These probabilities are further used to weight the model forecasts. We believe that considering model uncertainty gives a more complete estimate of uncertainty in a production forecast.

Besides intensive research, I visited many interesting places for relaxing, including the Congress Avenue Bridge, the Graffiti Park and the rescue zoo in Austin, the NASA Johnson Space Center in Houston and the AT&T Center – the home of NBA team Spurs – in San Antonio (it was a dream-come-true moment for me as a basketball lover). All in all, I had wonderful time of combining doing research and having fun.

Aojie Hong

Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS) instrument.

GOING BACK TO MY HOMELAND

Thanks to the financial support from Petroleum Research School of Norway (NFiP), I was granted the opportunity to spend one and a half months research stay in Professor Quan Shi's group at State Key Laboratory of Heavy Oil Processing, China University of Petroleum, Beijing. This Laboratory is the first and only state key laboratory in China that focuses on the research of heavy oil, and has been equipped with extensive and advanced instruments, making it a perfect place for me to conduct the component characterization of my heavy oil samples.

I was deeply impressed by the professionalism and expertise of the staff at the Laboratory from day one. With their guidance, sixteen oil samples were thoroughly analyzed using simulated distillation (SimDis), Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS) and elemental analysis. The results have been published as a journal paper Energy & Fuels, 2017, 31 (6), 6045–6055. I really appreciate the excellent support from Prof. Shi's group.

Besides the work, it was also special for me to be back to Beijing because I lived in Beijing for the first year of my master study. The capital is a mega city known for its importance in politics, economy, history, culture, and technology. Visiting Beijing could not be a better choice to experience the eastern world. Several world heritage sites are situated in the city. In my opinion, it would never be enough to climb the symbolistic Great Wall so I did it again with one of my friends.

In all, this research exchange has been a great memory for me for being productive and meaningful. I am very grateful for those who have made this possible. *Kun Guo*

The Great Wall
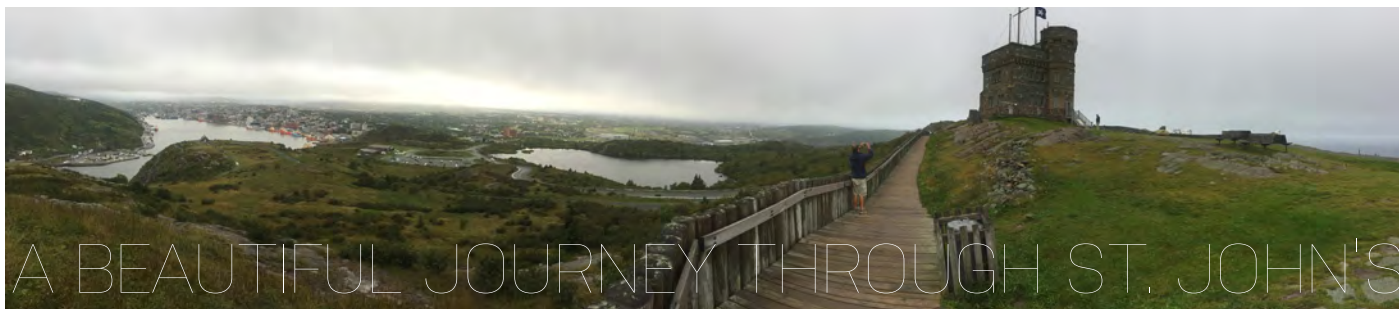
A BEAUTIFUL JOURNEY THROUGH ST. JOHN'S

PhD student Jaspreet Singh Sachdeva with The National IOR Centre of Norway spent two months working with wettability in chalk in St. John's, Canada.

To understand how chalk reservoirs deform during the injection of seawater-like brines has been the topic of discussion since quite a long time now. Considerable research has been carried out on the chemically indu-ced compaction in chalk reservoirs. This research has primarily focused on water wet chalk and has shown how seawater and other simplified seawater-like brines alter stiffness, strength and time-dependent mechanical parameters. My work involves evaluating the effect of presence of oil in the pore spaces on mechanical stability of chalk, i.e. how different wettabilities dictate chalk me-chanics. The overall mechanical behavior measured over a approximately equal to 0.1 m scale core arise from a sum of grain-grain contact behaviors. It is assumed that if grain-grain contacts, that dictate mechanics of the frame work, remain water wet, the wettability is inconsequen-tial to the mechanical parameters describing chalk core behavior, and vice versa. To understand these effects in more detail, it was of paramount importance to evaluate as to what degree the wettability of chalk cores can be controlled in the lab.

I got the opportunity to carry out wettability estimation studies over a duration of two months during Fall 2017 at the Hibernia Enhanced Oil Recovery Laboratory at Memo-rial University of Newfoundland (MUN) in St. John's, Cana-da under Dr. Lesley James. Her research group focuses on sustainable oil production by increasing oil recovery rates through enhanced oil recovery.

The main objective of my work, as stated above, was to follow a systematic approach to evaluate the degree to which wettability estimation is possible in chalk cores. The brine composition, oil composition and aging tem-perature were kept constant, and aging time was the laboratory control variable. Three different methods were used to evaluate wettability, viz. contact angle measu-rement, Amott-USBM test, and SEM-MLA analysis. The repeatability of the WI estimate was also tested, i.e. how experimental controls led to repeatable wettability de-terminations. The work also included using a structured approach with the abovementioned different methods to quantify the degree of uncertainty linked to WI estimation and the aging procedure to control wettability of chalk. With a comprehensive suite of samples, we were able to reproduce the conditions required to restore the chalk cores to the desired wettability. The results of this work will be presented at the Society of Core Analysts Annual Symposium in Trondheim, Norway in August 2018. Besides working at MUN, I got to enjoy the natural sce-nery and landscape in and around St. John's as well. St. John's is the capital and largest city in Newfo-

undland and Labrador. The easternmost point of North America, Cape Spear, is only 15 kilometers away from St. John's and provides great opportunities to take breath-taking pictures during the sunset with the grand North Atlantic Ocean in the backdrop. Signal Hill, in the heart of the city, provides beautiful panorama view of the whole city. There is a lot of diversity in St. John's like the rest of Canada, and the city has so many restaurants and food joints with a wide range of cuisines to enjoy a good meal anytime of the day. Canadians are very enthusiastic about two things: hockey and maple syrup. I had some interesting conversations with the local people on these topics as well. Canadians are known to be calm, down-to-earth and well-mannered people and I found it to be true during my interactions with the locals.

I can describe my trip to Canada in one sentence: You cannot buy happiness, but you can visit Canada and that is pretty much the same thing.

I met so many people and made quite a few friends within a short span of two months that I will cherish forever. The people I met made my stay a very pleasant and an unforgettable one. I felt sad while leaving, but had this happy feeling to finally been able to go back home in Norway before the super-cold winters of Canada set in. I miss everyone I met back in St. John's and wish everyone good luck with their studies, jobs and lives in general! We will meet again sometime somewhere around the globe! Au revoir.
Jaspreet Singh Sachdeva

From left: Jaspreet Singh Sachdeeva, Lesley James and Edison Sripal.

MY STAY AT TU DELFT

«More than half remains» says the Petroleum Resource Report from the Norwegian Petroleum Directorate for 2017. It also says that large oil resources on the Norwegian continental shelf cannot be produced with current plans and technology, and these call for enhanced oil recovery (EOR) techniques. To put this in perspective, Norway has more than 23 mature waterflooded reservoirs, both sandstone and chalk, of significant size with 2400 million Sm3 residual oil after water injection as EOR target. Developing and applying new improved recovery methods within a reasonable time is required to ensure that substantial oil volumes on the NCS are not lost. Foam for mobility control has the potential to overcome the challenge of unstable displacement during CO_2 injection that limits the EOR potential. A lot of work has been done over a decade in laboratories at UiB and IRIS - collaborators of the National IOR Centre. It's time to take a leap of faith and go out in field. CO_2 foam systems for mobility control have been designed, and will be tested in two inexpensive onshore US field pilots, in both clastic and carbonate reservoirs. Assisted by field experience from these pilots, it is planned to develop CO_2 Foam EOR field implementation on NCS. Sounds cool!

In the fall last year, I got an opportunity to work with Prof. William R. Rossen from TU Delft, who is one of the project collaborators. His research group is involved in studying almost all aspects of foam displacement at core scale, and modelling the response analytically. The pilot in one of the field will start by March this year, so during my stay I was involved in calibrating the numerical model for the pilot area to historical production data and getting first pass pilot simulation results. However, it is not as straightforward as it sounds. While scaling up from lab to field, it becomes imperative to link EOR performance parameters to uncertainties to ensure that decisions made for pilot design yield maximum value from entire process including data acquisition. I learned a few tricks to setup modelling workflow so that it can digest uncertainty surrounding lab and field data we have available with us. The other existing part of exchange program was that I got to meet with the members of DARSim (Delft Advanced Reservoir Simulation) especially, Prof. Jan-Dirk Jansen and Dr. Denis Voskov, who are working on development of advanced modelling and simulation methods for flow in porous media. We know that numerical models fail to replicate the analytical findings for SAG (Surfactant-Alternating-Gas) injection, which will be our main strategy for pilots given other operational constraints; and we cannot completely rely on simulation results. But having said that, numerical modelling is a necessary evil if we need to account for reservoir heterogeneity, and capture flow beyond one dimension. So, as a possibility for further research collaboration, we discussed to develop functionalities for front tracking in large-scale simulators to serve as a workaround.

That's not all! The life outside of work was equally exciting in the canal-ringed college town. The town boasts of a large number of monumental buildings and Delft Blue pottery. The last year was quite happening for the residents for one more reason. The Delft University of Technology celebrated its 175th anniversary. A whole range of events were organised to celebrate this milestone, and I managed to get into a couple of them.

3 months flew quicker than I expected, but the stay was undoubtedly a fruitful one. Hoping to visit Delft again in near future!

Mohan Sharma

IOR NORWAY 2017

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GEOSCIENTISTS &
ENGINEERS

Stavanger IOR
NORWAY

19TH EUROPEAN SYMPOSIUM ON
IMPROVED OIL RECOVERY

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IOR NORWAY SUMMED UP

Lars Høier (from the left), Shawket Ghedan, David Puckett and Arvid Østhus.

In total close to 400 delegates from both industry, academia and national authorities attended last year's IOR conference hosted by The National IOR Centre of Norway and EAGE (European Association of Geoscientists and Engineers). As a final wrap, four well known experts summed up the theme – sustainability – in a panel debate. Lars Høier (Statoil), Shawket Ghedan (Computer Modelling Group), David Puckett (UK Oil and Gas Authority) and Arvid Østhus (Norwegian Petroleum Directorate) gave their views on different topics.

Keeping the talents
«I'm very glad that the Norwegian Petroleum Directorate are pushing us when it comes to research and development. In a cyclic industry as ours, it's crucial to continue developing new methods and keeping the talents,» Lars Høier said.

«Things are picking up slowly. In Statoil there will be a need for a lot of people in a few years. We need young talents. We need ideas,» he continued. Arvid Østhus in the Norwegian Petroleum Directo-

rate shared this view. «We must transfer our knowledge to the next generation,» Østhus said.
So, what does sustainability mean to the experts?
«The most sustainable action is to reduce costs in the industry. We must continue that journey,» Høier said.

Boosting the Centre
The National IOR Centre of Norway was highlighted as a success by the experts. Lars Høier in Statoil claimed that centres like this is a key factor to maintain high quality on research and development.
David Puckett from the UK Oil and Gas Authority used the phrase «Early Or Regret», playing on the abbreviation EOR (enhanced oil recovery).
«In the UK we don't have centres like yours. We need to recognize what you do here,» Puckett said.
Arvid Østhus got the last words in the debate.
«At conferences like this we can motivate each other, but we must also take the next step; we need to get out of the labs and do the field tests,» he said.

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N O R W A Y

State secretary Ingvil Smines Tybring-Gjedde opened the conference.

Aina and Arild Schiøld performed during the opening of the conference. Aina, being a midwife, performed a song about a normal day at work for her, helping babies into this world.

PhD student Remya Nair opened the Low Salinity session day one.

PhD student Tijana Voake presents her research. Almost 100 posters were presented during the three-day conference.

EAGE's Ann Muggeridge (to the left) and centre director Merete Vadla Madland hosted the conference.   Photos: Kjersti Riiber

Centre postdoc
Pål Ø. Andersen

The threeday conference had double sessions each day.
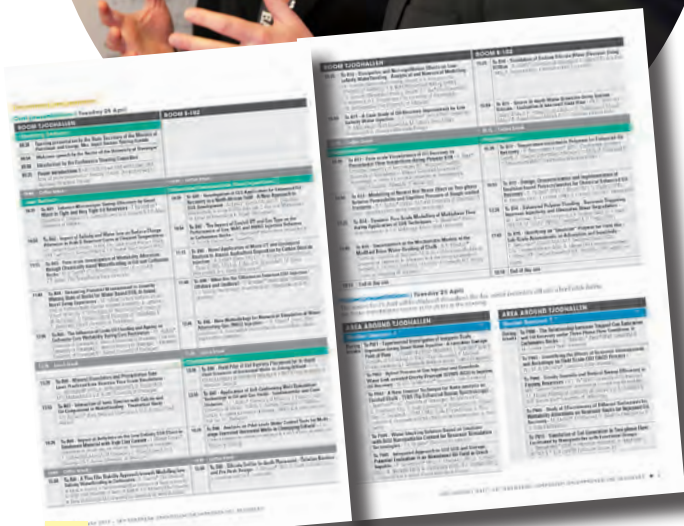
Chief Engineer Reidar Inge Korsnes
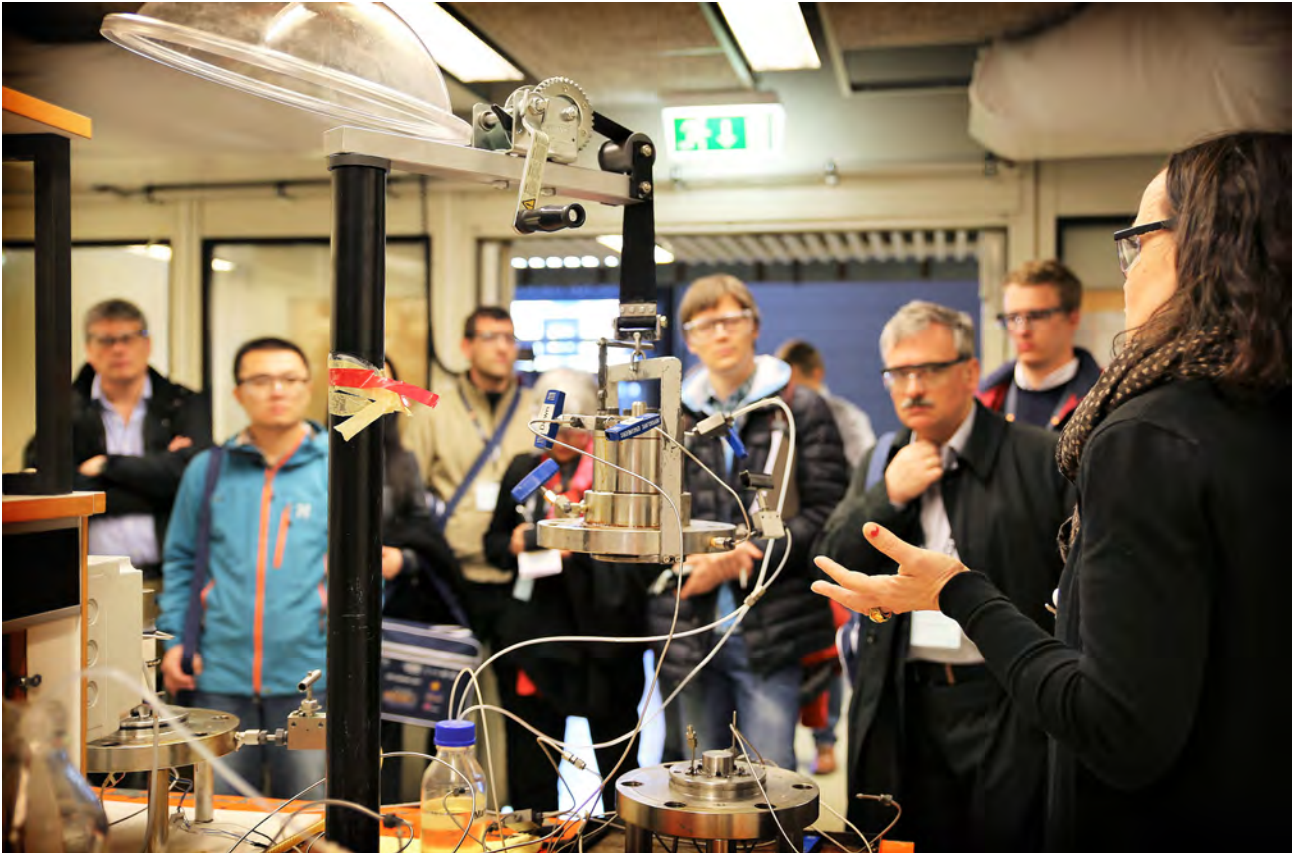
Centre director Merete Vadla Madland shows the visitors the geomechanic lab at the lab walk the day prior to the conference. The participants also got to see the SEM (Scanning Electron Microscope) lab and the environmental technology lab.

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Sustainable IOR in a Low Oil Price World

The National
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Visibility in the local media is crucial for The National IOR Centre of Norway. Here journalist Arne Birkemo in Dagsavisen Rogalands Avis is taking photos at the environmental technology lab.   Photos: Kjersti Riiber

IOR NORWAY 2017

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Stavanger *IOR*
NORWAY

19TH EUROPEAN SYMPOSIUM ON
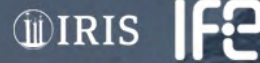IMPROVED OIL RECOVERY

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- 3 days + 1 day workshop
- 2 parallelle sessions
- 400 participants
- 100 posters
- 100 stand up presentations
- 75 scientific presentations
- 175 scientific papers*

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Oddbjørn M. Nødland, Mona Wetrhus Minde from The National IOR Centre of Norway and Han Byal Kim from Memorial University of Newfoundland got respectively The Skjæveland Award and the prize for «Best Young Presenter under 30».   Photo: Kjersti Riiber

AND THE WINNERS ARE ...

Oddbjørn M. Nødland and Mona Wetrhus Minde were awarded with the Skjæveland Award on the last day of the IOR NORWAY 2017 conference. Han Byal Kim from Memorial University of Newfoundland won «Best young presenter under 30».

Nødland and Minde were given the Skjæveland Awards respectively fo their presentation and poster. Nødland for his presentation on «Mechanical Degradation of Polymers at the Field Scale – A Simulation Study», and Minde for her poster introduction on «Comparative Studies of Mineralogical Alterations of Three Ultra-long-term Tests of Onshore Chalk at Reservoir Conditions». Both Nødland and Minde are PhD students at The National IOR Centre of Norway.

The third prize handed out this day went to Han Byal Kim for best young presenter under 30 – based on her talk on «Experimental Investigation of EOR by Injecting SiO2 Nanoparticles as Water Additive with Application to the Hebron Field».

Excellence, courage and innovation
The Skjæveland award is given to young researchers who show excellence and innovation in his or her research. The award should motivate for further bold moves towards optimizing oil and gas production. «Nødland and Minde both show excellence and courage in their research,» director Merete Vadla Madland at The National IOR Centre of Norway said in the justification.

Both Nødland and Minde received a diploma and a sculpture made by the artist Anu Allikas.

EAGE prizes
Since IOR NORWAY 2017 was arranged in collaboration with EAGE, they also awarded some of the young talents. As mentioned above Han Byal Kim got the award for best presenter under 30. Secondly Nikola Gaillard from SNF was awarded for the best presentation – on «Advanced Selection of Polymers for EOR Considering Shear and Hardness Tolerance Properties».

The prizes were given based on forms handed out to six members of the audience during each presentation. The rest of the forms were written by the two Chairs in each session. The Steering Committee of the conference made the final decision. The two conference Chairs and the Steering Committee consisted of Ann Muggeridge, Merete V. Madland, Samir Békri, Dane Cantwell, Emma Chapman, Torsten Clemens, Helber Cubillos, Mariann Dalland, Inna Edelman, Øivind Fevang, Raymond Anderson Haas, Sunil Kokal, Bernd Leonhardt, Franco Masserano, Danielle Morel, David Puckett, Bill Rossen, Leonid Surguchev, Janos Szelényi and Diederik van Batenburg.

HONOUR TO THE IOR CENTRE

Director Merete Vadla Madland (in the middle) represented the National IOR Centre of Norway as one of the ambassadors of Region Stavanger at the ceremony 16 March 2017. The Centre got the prize for the collaboration with EAGE.   Photo: Marie von Krogh

The Director of the National IOR Centre of Norway, Professor Merete Vadla Madland was awarded the Ambassador prize by Region Stavanger in a ceremony held in Stavanger Concert Hall on March 16.

Professor Madland received the prize for her efforts to attract the "The 19th European Symposium on Improved Oil Recovery" to Stavanger in April this year.

The conference is arranged in collaboration with the European Association for Geoscientists and Engineers –

EAGE and has previously been held in the Hague, Paris, Cambridge and St. Petersburg.

«I am honoured to receive this prize and I am confident that the conference will be a success – we expect at least 300 participants from all over the world. The Centre itself is represented with 28 papers and posters and we see this event as a great opportunity to put our research on display,» says Professor Madland.

Text: Leiv Gunnar Lie / UiS

AWARDED SPE PRIZE

Reidar Bratvold, professor at the Department of Petroleum Engineering at University of Stavanger, was awarded with the SPE Management and Information Award for 2017. The prize was given at the SPE Annual Awards Banquet in Texas October 2017.

SPE (Society of Petroleum Engineers) is the largest individual-member organization serving managers, engineers, scientists and other professionals worldwide in the upstream segment of the oil and gas industry.

In addition to his work at Department of Petroleum Engineering, Bratvold has been the supervisor for one of the PhD students at The National IOR Centre of Norway, Aojie Hong – the first Centre PhD candidate to graduate. Bratvold has also been project manager at one of the Centre's research projects.

LUNCH & LEARN AT CoP

In a packed hall, the Centre's PhD students Emanuela Kallesten and Mona Wetrhus Minde (picture) gave ConocoPhillips employees a Lunch and Learn session on permeability and EOR mechanisms.

While around 150 CoP employees had their pizza lunch, Kallesten and Minde gave their presentations on respectively «Permeability and Stress State» and «Understanding EOR Mechanisms». At the CoP offices in Tananger, around 1000 people have their work place, but this Lunch and Learn session was mainly aimed at the geologists and physicists in the company.

Popular science vs. akademia
As PhD students at The National IOR Centre of Norway, both Kallesten and Minde are trained in presenting their work for different audiences. «At presentations like this it is important not to get too hung up in the scientific details. At the same time, the presentation should not be held in a strictly popular scientific manner. It should be somewhere inbetween,» Minde says.

Curious audience
Both Kallesten and Minde are thankful to CoP and the other industry partners. Kallesten took the opportunity to thank both the user partners and her supervisors at the Centre. After the presentations, the audience asked questions on the topics – useful input for the PhDs. Hopefully both parties left the Lunch and Learn session a little bit wiser.

MAERSK: 20 % INCREASE IN OIL RECOVERY

At The National IOR Centre of Norway we were happy to see this Tweet from Maersk Oil: «Together with @IOR_Norway, we're using new tech to improve the #oil recovery rate for Norway's #NorthSea.»
Further: «20%: The increase in oil recovery for the Norwegian Continental Shelf due to polymer and "smart water" tech.»

OG21-FORUM: THEY ARE THE FUTURE

The students got questions from the audience. From the left Mariann Forsberg, Magnus Nystad, Yiteng Zhang, Knut Ringen Viten and Adriaen Verheyleweghen. In front Terje Svabø.
Photo: Kjersti Riiber

These five students, amongst them Centre PhD Yiteng Zhang, showed the OG21 participants that they need not worry about the future of the industry.

The theme for this year's OG21-forum was:«Collaboration for a technological change of pace». Collaboration on the use of new technology strengthen the industry's competitive position, but collaboration also has its challenges. How will alliances and new collaboration models impact your company? This was one of the questions presented and discussed at OG21-forum in Oslo, November 8th.

To represent The National IOR Centre of Norway was Yiteng Zhang with the presentation «Production Optimization for the Digital Subsurface».

All five students that presented was asked about their expectations for the future of the petroleum industry and what the industry can do to motivate the students to continue in this business. Several of the students mentioned a closer involvement from the industry at an early stage. Also, the petroleum industry needs to strenghten its reputation.

Zhang was very grateful for the opportunity to present at OG21. During the conference he got the chance to meet several high level technology decision makers in the petroleum industry.

Minister of Petroleum and Energy, Terje Søviknes emphasized in his opening speech that the petroleum industry will exist in Norway for decades to come, and that this industry delivers important technology for the future. The minister also communicated that we need research on both renewable and petroleum in the future, and that he will work actively to ensure that the petroleum research programs are not cut.

IEA GOT VISITED

Jaspreet Singh Sachdeva, Merete Vadla Madland and Andy Lingenfelter.

The 4th of April 2017 a delegation from IEA GOT visited the Centre. Evert Everts from the Dutch Energy Department, Andy Lingenfelter from GE Oil & Gas and Jostein Dahl Karlsen in the Norwegian Ministry of Petroleum and Energy got «the grand tour» in the Centre's labs.

Both Everts and Lingenfelter said that the oil industry in their respective countries could harvest from the knowledge and competence at the Centre.

The three visitors also got to meet some of the young scientists. PhD student Jaspreet Singh Sachdeva showed the delegation the geomechanic lab, and talked about his project on determining and evaluating the effect of wettability alteration on the mechanical properties of chalk.

Centre director Merete Vadla Madland participated in a climate debate at the university library together with professor Oluf Langhelle, dean Øystein Lund Bø and leader of the Research Network for Sustainable Energy, Siri Kalvig.

At Research Square both young and old curious people visited our stand. Maria Ganska (11) (bottom left) was one of them.

When the pupils from 8B at Gosen school visited the Centre, the day consisted of both freezing cold nitrogen and a cool ice cream lunch. Here PhD student Mona Wetrhus Minde does experiments with liquid nitrogen.

PhD student Sanne Lorentzen shows the pupils how chalk looks like in a microscope. 　　　　Photos: Kjersti Riiber

SHARING OUR RESULTS

The researchers at The National IOR Centre of Norway travel all over the world, and they bring their results with them. In 2017 representatives from the Centre have been present at, among others, Eni Norge Reservoir Seminar, FORCE Seminars, The Energy Year 2017, SPE OKC Oil & Gas Symposium, TNO Workshop: Mature Fields in the North Sea: Searching for Synergies, IOR NORWAY 2017, IEA-GOT Mature Fields, Trondheim, SPWLA Annual Symposium, SIAM GS 2017, Science Week, SEG Annual Meeting, ENUMATH 2017 Conference, Reservoir & Production Management – NPF, OPM Meeting, The November Conference, OG21-forum, SETAC, Adipec, Short Course on Solvent Flooding and Enhanced Oil Recovery, NFiP Annual PhD Seminar and Colloids and Complex fluids for Energies.

LUNCH & LEARN
In addition to all the dissemination done off campus, the Lunch & Learn events have been very popular back on campus at University of Stavanger. After a total of 11 Lunch & Learn events in 2016, he Centre only arranged two sessions at UiS in 2017 – with Lesley James, Associate professor and Chevron Chair in Petroleum Engineering at Memorial University and postdoc Pål Østebø Andersen from The National IOR Centre of Norway/UiS. In addition to this, PhD students Emanuela Kallesten and Mona Wetrhus Minde gave a Lunch & Learn for 150 employees at ConocoPhillips in Tananger.

IOR NORWAY 2017
The most important event, and one of the main arenas for dissemination for The National IOR Centre of Norway is of course the IOR NORWAY conference. A total of 400 participants joined in on this three-day conference and the workshop before the main conference.

OG21
The National IOR Centre of Norway was well represented at OG21 in November 2017. PhD student Yiteng Zhang gave a presentation in the student session. It should also be mentioned that centre director Merete Vadla Madland was appointed to the OG21 board by Minister of Petroleum and Energy, Terje Søviknes, summer 2017.

DISSEMINATION IN NUMBERS
2017 was a very productive year for the researchers at the Centre. Here are some statistics from CRIStin (Current Research Information SysTem in Norway):
- Journal article: 31
- Conference contribution or scholarly presentation: 117
- Book: 2
- Report/dissertation: 49
- Part of a book/report: 46
- Media contribution: 30
- Commercialisation: 1
- Information materials: 2

From left: Anders Matheson, Yiteng Zhang, Rolf Johan Lorentzen, Xiaodong Luo, Tor Harald Sandve, Sergey Alyaev, Geir Evensen, Robert Klöfkorn, Anna Kvashchuk, Trine Mykkeltvedt and Yuqing Chang.
Photo: Søren Arentsen / IRIS

Research director Randi Valestrand

PhD student Eystein Opsahl

MEDIA CONTRIBUTIONS 2017

COLLABORATION

UNIVERSITY OF BERGEN
KEY CONTACTS: Professor Arne Graue, Associate Professor Martin Fernø at the Department of Physics and Technology, Professor Morten Jakobsen at the Department of Earth Science, UiB.
PHD / POSTDOC: PhD Mohan Sharma: Displacement mechanisms in heterogeneous reservoirs with CO_2 foam for mobility control; upscaling for field applications. Researcher: Dr. Bergit Brattekås: Integrated EOR for heterogeneous reservoirs.

UNIVERSITY OF OSLO
KEY CONTACTS: Professor Dag Dysthe, Dr. Anja Røyne, Professor Anders Malthe-Sørenssen, MSc Sigve Skattum. PhD: Shaghayegh Javadi: Experimental investigation of the effect of fluid chemistry on the adhesive properties of calcite grains.
Bahareh Zareeipolgardani, PhD student at Université de Lyon, has been spending several weeks at the Centre autumn 2016, studying the influence of stress and temperature conditions on calcite powder – a part of the NanoHeal project at UiO.

NTNU / UGELSTAD LABORATORY
KEY CONTACTS: Professor Johan Sjøblom, chief engineer Camilla Dagsgård. Various project cooperation.

SINTEF
KEY CONTACTS: Dr. Knut-Andreas Lie, Dr. Atgeirr Flø Rasmussen, Dr. Xavier Raynaud. IRIS and SINTEF collaborate to develop the open reservoir simulator OPM. Further work is now in testing and research is being done on numerical methods that can be implemented in this simulator.

DTU / GEO / GEUS
KEY CONTACTS: Professor Ida Lykke Fabricius, Chief Engineer Helle Foged Christensen and Dr. Claus Kjøller. PHD: Tijana Voake Professor Fabricius is also employed as Professor II at the University of Stavanger and is supervisor for one of the PhD students in The National IOR Centre of Norway, as well as several MSc students.

TNO
KEY CONTACTS: Olwijn Leeuwenburgh, Philippe Steeghs, Rahul Fonseca
POSTDOC: Yanhui Zhang
TNO has a 2-year postdoc research project as official contribution to The National IOR Centre of Norway and which project ceased in spring 2017.

TU DELFT
KEY CONTACTS: Professor Jan Dirk Jansen (TU Delft), Rafael Moraes (TU Delft / Petrobras)
Professor Jan Dirk Jansen is the head of department of Geoscience & Engineering and professor of Reservoir Systems and Control at the University TU Delft. IRIS is engaged in a research collaboration with TU Delft in production optimization. PhD student Mohan Sharma had a research stay at TU Delft fall 2017.

CORNELL UNIVERSITY
KEY CONTACTS: Professor Lawrence M. Cathles III
IFE has a partnership with Lawrence M. Cathles at Cornell University on the use of C-dots as tracers in porous media.

UT AUSTIN
KEY CONTACTS: Professor Larry Lake
Project Collaboration: Robust Production Optimization. Included in this collaboration is the use of less detailed models (CRM – Capacitance Resistance Model) for reservoir simula-tion for use in optimization. One of the PhD students and a professor in The National IOR Centre of Norway are invol-

ved in this, and both are planning to spend a semester at UT in 2016/17. PhD student Aojie Hong stayed at UT summer 2017.

INSTITUTE FOR THE STUDY OF THE EARTH'S INTERIOR (ISEI)
KEY CONTACTS: Professor Eizo Nakamura
Project: Quantification of chemical changes in flooded chalk on homogenized and natural samples with FE-TEM.
Research Assistant: MSc. Nina Egeland, has been on a research stay in Japan during the period January-June 2016.

TU BERGAKADEMIE FREIBERG, INSTITUTE FÜR MINERALOGIE
KEY CONTACTS: Bernhard Schulz and Jens Gutzmer
TU Bergakademie Freiberg is one of Task 2's main partners and several students have been here for analyzing rock samples.

ECOLE POLYTECHNIQUE PARIS, FRANCE
KEY CONTACTS: Razvigor Ossikovski and Chiara Toccafondi. At this collaborating laboratory in Paris, the Centre researchers use nanoRaman to identify the mineralogy of the surface of thin section samples.

UNIVERSITÉ DE LYON, FRANCE
KEY CONTACTS: Olivier Tillement
IFE cooperates with Olivier Tillement at Université de Lyon. The cooperation involves characterisation of various characteristics of nanoparticles and complexes. These are components being tested as possible new tracers to determine the oil saturation in a flooded area of a reservoir.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR)
KEY CONTACTS: Senior researchers Dorit Hammerling and Ram Nair. NCAR's Computing Lab consists of specialists in mathematical and statistical methods to simu-late and predict complex stochastic phenomena.

UNIVERSITY OF STUTTGART
KEY CONTACTS: Birane Kane
PhD student Birane Kane visited IRIS for 3 months during spring 2016. Kane is working on development of discontinuous Galerkin methods for flow in porous media with Robert Klöfkorn and other researchers on simulator development at IRIS Bergen.

UNIVERSITY OF WYOMING
KEY CONTACTS: Assistant Professor in Rock Physics and Reservoir Modeling, Dario Grana. Postdoc Tuhin Bhakta had a research stay in Wyoming fall 2017, working on a 4D seismic project.

MEMORIAL UNIVERSITY OF NEWFOUNDLAND (MUNF)
KEY CONTACTS: Lesley James, Dr. Chemical and Petroleum Engineering. PhD student Jaspreet Singh Sachdeva stayed at MUNF fall 2017. He got the opportunity to carry out wettability estimation studies over a duration of two months at the Hibernia Enhanced Oil Recovery Laboratory at Memorial University.

CHINA UNIVERSITY OF PETROLEUM, BEIJING
KEY CONTACTS: Professor Quan Shi. PhD student Kun Guo stayed with his group at State Key Laboratory of Heavy Oil Processing, the first and only laboratory in China that focuses on the research of heavy oil. It has been equipped with extensive and advanced instruments, making it a good place to conduct the component characterization of heavy oil samples.

The National IOR Centre of Norway believes in transparency. The best results are found through cooperation. Therefore, it is vital to form a good network. This network helps to ensure the quality of the research, while it also aids in making the Centre stand out as when it comes to IOR research worldwide.

MEET OUR NEW PARTNER – DEA

DEA staff at a rig inspection in Norway.

Photo: Rolf Estensen / DEA Norge

On the General Assembly June 19 2017, the members decided to say yes to making DEA Norge partner of the Centre.

The following was decided:

«The General Assembly welcomes the inclusion of DEA as industry partner in The National IOR Centre of Norway under the current terms and conditions, and grants the University of Stavanger permission to sign the Agreement to the accession of a new party to the Consortium Agreement on behalf of the Consortium participants.»

Since DEA is joining the Consortium later than the rest of the partners, the company will pay a late participant fee in accordance with decisions made by the General Assembly last year.

When DEA signed the agreement, The National IOR Centre of Norway had 12 partners from the industry. With DONG Energy now working solely with electrical energy, the Centre has 11 partners from January 1 2018.

The other 10 partners are Engie (now Neptune Energy), Maersk (now a part of TOTAL), Wintershall, Eni Norge, Halliburton, Schlumberger, ConocoPhillips, Lundin Norway, Statoil and AkerBP.

- DEA Norge is part of the international DEA Group. The company have been in Norway for more than 40 years.
- Number of employees: 140
- Knowledge-based company that creates value through the exploration, development and production of oil and natural gas resources on the Norwegian Continental Shelf.
- Over the last few years, DEA Norge has made several commercial discoveries on the Norwegian Shelf and will become a development and production operator in the near future. The company is experiencing increased activity across the entire oil and gas value chain as an active partner in licenses, infrastructure and collaboration projects.
- Operating revenues 2016: 7 750 000 000 NOK
- Net income for the year 2016: 575 000 000 NOK
- Production of Crude oil, Cond., LPG, NGL 2016: 12.99 mill barrels O.E.
- Total oil reserves at year end 2016: 20.55 mill m³ O.E.

Kilde: dea-norge.com

ECONOMY 2017

OPERATING INCOME AND OPERATING COSTS 2017
(All numbers in 1000)

Remaining as per 31.12 previous year	-138
UiS – own contribution	13 002
NFR	10 000
User partners	20 000
User partners – in kind	3 496
International – in kind	350
Other income	300
Total operating income	**47 010**
Payroll expenses	20 876
Procurement of R&D services	17 569
R&D services – in kind	3 496
International R&D services – in kind	350
Other operating expenses	2 519
Total operating expenses	**44 810**
Operating profit	**2 200**

Comments to Operating income and expenses in 2017:

- Negative operating profit for NOK 138 was transferred from 2016 to 2017.

- Income from NFR includes NOK 3333 for 2016 and NOK 6666 for 2017. NOK 3333 will be transferred from NFR in 2018 to cover costs for 2017.

- Income includes payments from 10 user partners. They each paid NOK 2000 for 2017.

- Halliburton, Schlumberger, DTU, ISEI and CU each contribute by providing work in kind.

- Other income relates to IOR NORWAY 2017.

- Payroll expenses includes IOR Management, administration, R&D, PhDs and student assistents. Real costs versus NFR rate for PhDs.

- Procurement of R&D services relates to services from IRIS, IFE, TNO and Bureau Veritas Commodites Canada.

- Other operating expenses relates to travel costs, laboratory costs, profiling, IOR Norway 2017 et cetera.

- Positive operating profit for NOK 2200 is transferred to 2018. (Positive profit relates to payment for NOK 2000 from new partner DEA in 2017).

MANAGEMENT TEAM

Merete Vadla Madland
UiS, Centre Director
Project Manager

Kristin Flornes
IRIS, Assistant Centre Director

Aksel Hiorth
UiS/IRIS, Research Director

Randi Valestrand
IRIS, Research Director

Sissel Opsahl Viig
IFE, Director Field Implementation

Sven M. Skjæveland
UiS, Director Academia
Project Manager

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UiS, Communications Advisor

Kjersti Riiber
UiS, Communications Advisor

Iren Lobekk
UiS, Economy Advisor

Inger Johanne Olsen
UiS, Department Engineer

Gro Alstadsæther
IRIS, Finance Coordinator

Mette Skretting
IRIS, Administration Coordinator

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Task 2 / Project Manager

Espen Jettestuen, IRIS
Task 3 / Project Manager

Aksel Hiorth, UiS/IRIS
Task 4 / Project Manager

Tor Bjørnstad, IFE
Task 5 / Project Manager

Robert Klöfkorn, IRIS
Task 6 / Project Manager

Geir Nævdal, IRIS
Task 7 / Project Manager

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Anders Tranberg, UiS
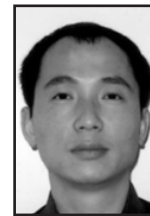
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Anders Nermoen, UiS/IRIS

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Geir Ersland, UiB

Dagfinn Sleveland, IRIS

Sergio Andò,
Università Milano Bicocca

Jan Ludvig Vinningland,
IRIS

Roar Skartlien, IFE

Per Amund Amundsen,
UiS

Anja Røyne, UiO

Jan Sagen, IFE

Roald Kommedal, UiS

Siv Marie Åsen, IRIS

Amare Mebratu, Halliburton

Torleiv Bilstad, UiS

Skule Strand, UiS

Steinar Evje, UiS

Arne Graue, UiB

Reidar Bratvold, UiS

Andreas S. Stordal, IRIS

Philippe Steeghs, TNO

Jarle Haukås, Schlumberger

Wiktor Weibull, UiS

PHD STUDENTS AND POSTDOCS
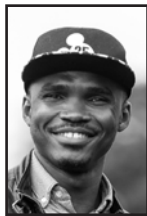
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Kjersti Solberg Eikrem, IRIS
Postdoc

Yanhui Zhanig, UiS/TNO
Postdoc

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