National Centre for Sustainable Subsurface Utilization of the Norwegian Continental Shelf

Annual report
2024

Contents

Introduction

The National Centre for Sustainable Utilization of the Norwegian Continental Shelf was granted by the Research Council of Norway (RCN) in 2021, started in 2022 and will last up to eight years. The University of Stavanger is the host, and NORCE, IFE and the University of Bergen are research partners. The centre is funded by RCN, six oil and energy companies, and in-kind from the four academic partners and two technology suppliers. NCS2030 will contribute to solving the sustainability dilemma - utilization of the nation's resources to ensure stable energy access, while at the same time reducing emissions of greenhouse gases. More than 70 researchers, including 7 PhDs and one Post.doc, with a broad interdisciplinary background are linked to the centre. To increase the value of research for industry and society, the centre collaborates with related projects and Ph.Ds., and with the other petrocentres; CSSR and LowEmission. In the coming years, the Centre will hire three more Postdocs. and ten PhDs.

In 2024, we begin to see good results of the one-to-one meetings with the industry partners in 2023. The good dialogue and increased cooperation have led to the completion of courses, access to field data and samples, and the employment of summer students who have worked with the industry on specific issues. Calculation tools, such as eCalc, which can quantify the reduction in CO_2 emissions achievable by using the centre's research, is central to several of our projects. In the summer of 2024, the Centre and Equinor arranged a two-day course in eCalc where students, own researchers, and employees from Okea and LowEmission participated.

The centre's annual conference "Energy Norway" took place 15-17 April in Stavanger. A workshop on Digitalization was followed by two days of talks on energy security and the development of the Norwegian continental shelf in the context of society, politics, and the economy.

An important activity is to educate future experts on sustainable utilisation of the Norwegian continental shelf. The picture is from Energy Norway 2024. PhD student Veronika Abdulina is presenting her research in a 1-minute stand-up session. Photo: Kjersti Riiber

Partners

Academic partners

University of Stavanger

IFE

NORCE

UNIVERSITAS BERGENSIS

User partners

equinor

OKEA

vår energi

AkerBP

HALLIBURTON | Landmark

DNO EST - 1971

Harbour Energy

slb

Observers

Funded by The Research Council of Norway

petoro

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University of Stavanger

Ying Guo
Assistant director &
Innovation director
NORCE

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(Christian Dye -Oct. 2024)
Representative, centre mangement
IFE

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(Zachary Alcorn -Oct. 2024)
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University of Bergen

Siv Marie Åsen
Project coordinator
University of Stavanger

Kjersti Riiber
Communications adviser
University of Stavanger

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Objectives

The primary objective of NCS2030 is to fill knowledge gaps and provide solutions for maximizing value creation of subsurface resources to reach the net-zero emission goals on the Norwegian Continental Shelf (NCS).

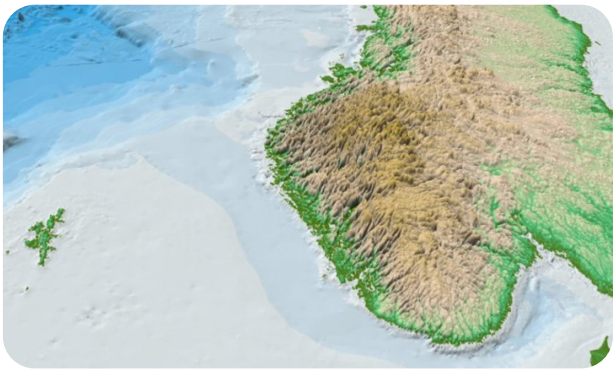
The vision of the NCS2030 centre is to facilitate an energy-efficient, multi-purpose utilization of the subsurface into a "Sustainable Subsurface Value Chain" to reach the net-zero emission goals on the Norwegian Continental Shelf. Four main research areas are identified, namely **Subsurface energy systems, Net-zero emission production, Digitalization and Society**. The research activities are organized into eight work packages (WPs): six WPs in research, one WP in education and outreach and one WP in management.

Norway is one of the most important and secure providers of energy to Europe. We have major opportunities to become a frontrunner in the sustainable energy transition to renewable energy and NZE hydrocarbon production. To transform the Norwegian Continental Shelf into sustainable utilization, a new way of thinking across disciplines and societal acceptance is required. Therefore, it is important to integrate research, education, and innovation to build knowledge and develop technologies towards the optimal utilization of the Norwegian Continental Shelf.

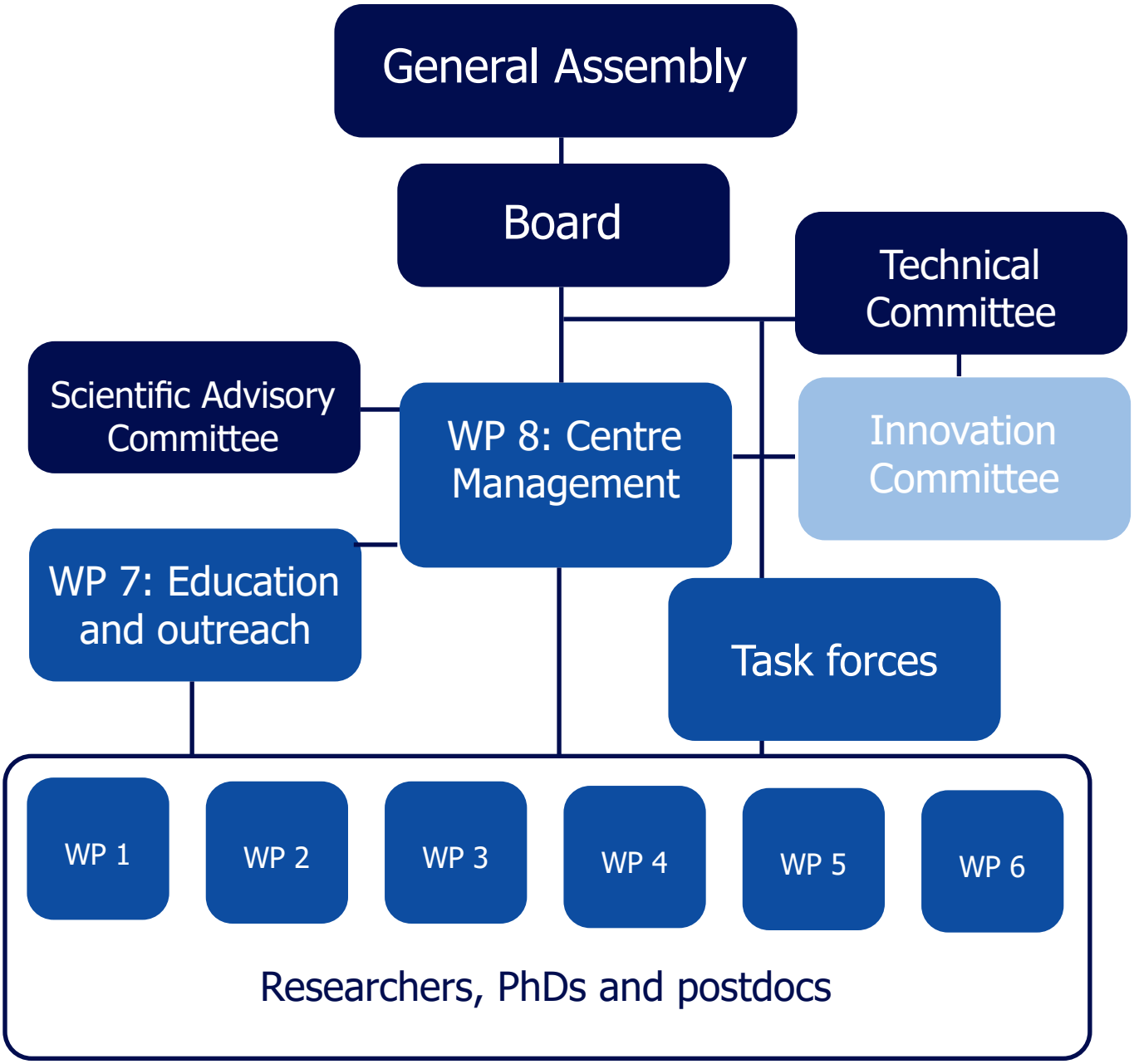
CENTRE OBJECTIVES

- Build integrated near field subsurface holistic models for increasing reserve base and evaluate the potential of geological CO_2 and H_2 storage;
- Develop new improved oil recovery solutions for improved and accelerated hydrocarbon production at low environmental footprint;
- Develop data-driven and machine learning approaches to integrate subsurface characterization, uncertainty quantification and management workflows;
- Recommend field cases with high potential for NZE production;
- Create awareness and acceptance of NCS2030 activities;
- Establish an innovation platform for technology development with industry;
- Attract and train future scientists and skilled professionals for the energy transition and disseminate results.

The centre will collaborate broadly with academia and hands-on with industry partners and innovation companies.



Governance structure



Message from Chair of Board

Dear readers,

It is my pleasure to present to you the third annual report from the NCS2030 Petrocentre!

Another year of remarkable achievements and research progress at the National Centre for Sustainable Subsurface Utilization of the Norwegian Continental Shelf. An impressive number of scientific publications and disseminations have been delivered, and important results and insights have been achieved. There has been high activity level regarding collaboration and interaction - with many joint workshops, task forces, conferences and one-to-one meetings being arranged. It's great to see all engagement happening in the centre.

At the NCS2030 Petrocentre, we aim to educate a new generation of professionals, build expertise, and find solutions to key challenges in the energy transition. The centre's goal stays firm and ambitious - to maximize the value creation of energy resources on the Norwegian Continental Shelf while simultaneously achieving net-zero emissions. It's a tough goal requiring top notch competence, commitment, collaboration, hard work, and pushing of boundaries of scientific and technological innovation to succeed.

I extend my heartfelt thanks especially to all the NCS2030 dedicated researchers, students and the centre management. Your hard work and commitment, together with the members' interactions are the driving forces to success. I am confident that the centre will continue to thrive and deliver remarkable achievements in the years to come.

On a personal note, this message marks my final communication as Chair of NCS2030. It has been an honor and a privilege to serve in this role for this important Petrocentre over the last two years. I am deeply grateful for the support and dedication of all the members of the 'NCS2030 family'. I am looking forward to the continuation!

Camilla Vavik Pedersen (Equinor)
Chair of Board (-October 2024)

Director’s view

The year 2024 has been exceptionally successful for the centre. As we continue to progress and mature, we have diligently followed our roadmap, initiated key deliveries, and deepened interdisciplinary discussions. Our online presence has expanded through research webinars and short films featuring our PhD candidates.

Energy Norway and Task Forces 2024 saw significant participation and valuable contributions from both research and industry participants. These activities were well-received by our scientific, technical, and board committees, as well as the Research Council of Norway, which provided positive feedback and acknowledged the importance of the centre’s research and progress.

Our pool of PhD and Postdoctoral researchers, directly and indirectly associated with the centre, continues to grow, now totaling 15 individuals who form the core of our research activities. Master students also play a crucial role, contributing through eight thesis projects. A notable highlight was winning the Laurie Dake EAGE international student competition, where our team evaluated sustainable solutions for the development of an oil field in the North Sea, demonstrating the practical application of our research.

We are also adapting to new challenges, with a growing focus on energy management and the integration of surface and subsurface efforts to achieve net zero CO_2 emissions during production. Collaboration with other petrocentres and industry has become increasingly important, and we are acquiring case studies and datasets that will be vital for testing our research and creating innovation projects in 2025. Our international collaborations are also maturing, with joint applications in various areas from education to innovation.

Looking ahead, 2025 promises to be a year of significant activities and collaborations. We extend our gratitude to all members for their dedication and support, which has brought us to our current position.

Alejandro Escalona
Centre Director

Results and highlights

In 2024, the centre in collaboration with industry has further developed and sharpened the activities, with the following highlights and results.

2024 has been a year of increased cooperation between the centre's partners with focus on building research awareness, identify case studies and spin-off projects.

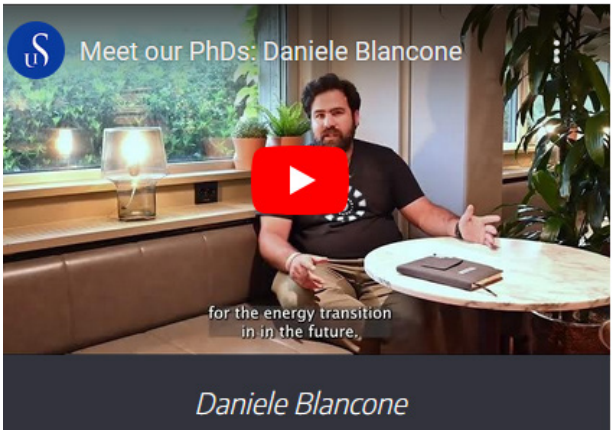
During the year, 8 master's students have graduated, and one Ph.D. scholarship holder and one Post.doc. have been employed. A total of nine fellows are thus starting their research projects and delivering results.

The "Energy Norway" conference took place at the University of Stavanger on 15-17 April with more than 180 participants spread over the three days. The conference consisted of a one day of workshop on digitization followed by demonstrations of software from our two technology suppliers and one of our PhD students. A mixture of results from the centre's own research, external research that sheds light on the same themes, and insights that put research on energy security and the development of the Norwegian continental shelf in the context of society, politics and the economy were presented.

In 2024, we saw good results from the one-to-one meetings we held with the industry partners in 2023. The good dialogue and increased cooperation have led to the completion of courses, access to field data and samples, employment of summer students who have worked closely with the industry on industry-specific issues, and inspiring targeting of our projects.

Based on the centre's project description, the centre's management, in collaboration with the work package managers, has drawn up a road map showing the timeline for milestones and deliveries. The specific deliveries, in the form of reports, procedures, software etc. are made available to the partners via an access-controlled Teams channel.

The centre's website, [uis.no/en/ncs2030](uis.no/en/ncs2030), is regularly updated with news, webinars, vacancies, completed master's degrees and results. New this year are short film clips in which the doctoral students explain their research and its role in the centre's work.



In this section you will find highlights from last year's research in each work package.

The last year's research has provided increased understanding of how fluids move in the subsurface, and its implications for temporary storage of hydrogen (H_2), permanent storage of CO_2, and petroleum production.

NEAR FIELD RESOURCE EVALUATION

In the work package "Near field resource evaluation", studies of seismic data from the southern North Sea have shown that by washing out cavities in salt structures in the underground, hydrogen can be stored there. Furthermore, it has been verified that the method that uses naturally occurring isotopes to determine whether the fluids in the subsurface are in contact can also be used on drilling cuttings, which will expand the area of use for and the applicability of the method.

RESERVOIR UTILISATION

During 2024, the work package "Reservoir utilisation for energy transition" developed a numerical model for viscoelastic deformation where graphics processors are used for more efficient calculation techniques. A new group of tracers, relevant for CO_2 storage and use, has been identified. For hydrogen, simulations have been used to investigate which chemical and biological processes should be avoided in order to limit the loss of hydrogen while it is stored in porous rock.

IMPROVED OIL RECOVERY

Within improved oil recovery (IOR/EOR), further research is being done on the injection of carbonated water, which can both capture CO_2 and reduce the amount of water needed in oil fields. In some cases, this will have a beneficial effect where the water is sucked in and can push the oil out of a larger area of the oil field. Another method we are developing further is smart water. This year it was discovered that a dense reservoir (diatomite) with large oil reserves in the North Sea has the ability to absorb water. This shows that smart water such as carbonated water may have the potential for this type of reservoir. Another method to increase oil recovery and to reduce energy consumption is water desalination. A simulation study of two different water delineation methods simulated on an oil field shows a reduction in water injected.

DIGITAL SUBSURFACE

In the work package dealing with digitalisation, work is being done with confederated knowledge clouds, ensemble-based methods for modelling, and how digitalisation can be used to increase collaboration between different subject areas and work packages in the centre.

In confederated knowledge systems, one has extended the design by including fe-

From the Board meeting March 2024. Chair of Board Camilla Vavik Pedersen to the right. Photo: Kjersti Riiber

derated learning, large language model for automating workflow, Blockchain, and protocols for decentralized social networks (”ActivityPub”). Methods for evaluating multiple probability scenarios are demonstrated on a model of a real oil reservoir. Furthermore, continuous improvements are made in existing methods for reservoir evaluation for better decisions. Simulation studies on the model of a real oil field have shown that it is also possible to store significant amounts of hydrogen in both the water zone and the oil zone, with respectively 96% and 90% recovery, and that there can be synergy effects by combining hydrogen storage and CO_2 injection in producing fields.

ECONOMY AND SOCIETY

In the work package for energy policy, economy and society, new results show a connection between oil revenues and the quality of democracies in non-OECD (Organisation for Economic Co-operation and Development countries), and how different tax regimes affect and lead to uneven distribution of investments.

Near-field resource evaluation

The growth in energy demand, combined with climate change, requires the use of new integrated strategies and multi-disciplinary methods for the long-term sustainable exploration and exploitation of subsurface energy resources and storage capacity to reach the Net Zero Emissions goals by 2050. The aim is:

- Build integrated near-field holistic models for increasing both energy reserves and potential from H_2/CO_2 storage, and evaluate renewable energy production

ACHIEVEMENTS 2024

Research activities in the work package on near-field resource evaluation focused on developing and validating techniques to analyze the internal facies and fracture zones of salt diapirs.

Other highlights:

Underground storage of hydrogen

- Ensemble-based workflows for characterization and monitoring in saline aquifers
- Regional interpretation and velocity model of Zechstein salt
- Evaluation of storage potential in salt caverns

Cloud computing solutions of near-field resource evaluation

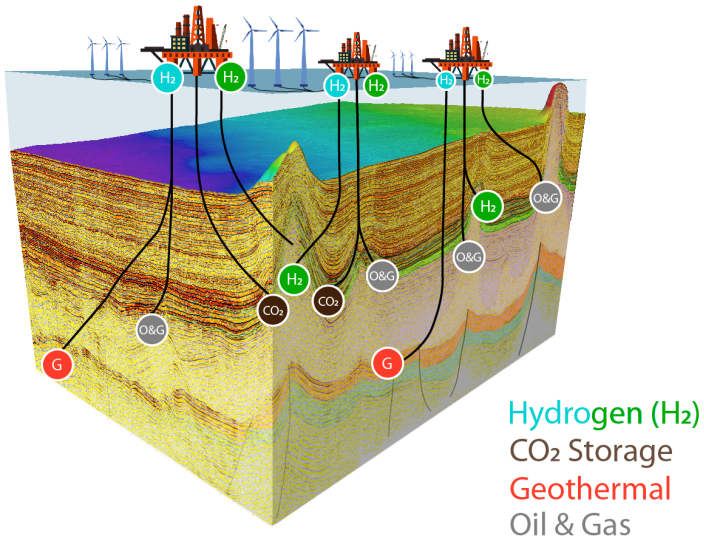
- Deployment of Permedia, Decision Space ongoing (Landmark)
- Dataroom with Delfi Petrotechnical Suite up and running (Slb)
- New postdoc on reservoir characterization at a regional level

Basin-scale fluid communication

- Strontium method on core cuttings completed
- Interaction between producing field and CO_2 injection to be developed into a spin-off project

Next generation of scientists

- Training of PhD and MSc on Landmark and SLB tools
- 2 ongoing PhD projects
- Several ongoing and completed MSc projects



Leader: Stéphane Polteau (IFE)

Reservoir utilization for energy transition

The project aims to enhance CO_2 and H_2 storage capacity and geothermal energy production on the Norwegian continental shelf by developing methods to optimize reservoir management and understand storage mechanisms.

ACHIEVEMENTS 2024

Physics of focused fluid flow

We did a multidisciplinary study on CO_2 injection in sedimentary basins using analog and numerical modeling. Our findings identify six phases of fluid flow in soft sediments, influenced by injection rate, pressure, and permeability. We demonstrate that beyond diffusion and brittle failure, porosity waves can form, potentially enhancing injectivity and storage capacity in compartmentalized reservoirs but also presenting a potential leakage risk if pierced through the storage seal.

Modeling of Geomechanical behavior

We developed a Graphics Processing Unit (GPU) optimized numerical model integrating porous flow and poro-(visco)-elastoplastic deformation to study fluid injection-induced seismicity. Using discretization with pseudo-transient solvers, we analyze seismic moment tensors to assess fault reactivation and cap rock integrity. Our primary focus is identifying conditions favoring macroscale seismicity and discerning indicators of critical pre-failure states. We tested and validated our model on synthetic cross-sections, covering important endmember cases of the reservoir geometry and of the in-situ stress field. A key trend in geo-computing is developing self-consistent thermo-hydromechanical models. We show that finite-difference discretization with pseudo-transient solvers effectively handles nonlinear complexities.

Tracers and tracing methods

A high-pressure cell is being tested to study phase-partitioning tracers under various conditions, along with optimizing analytical methods for CO_2 tracer detection and quantification.

Hydrogen storage in salt caverns

We investigated geomechanical response of salt caverns in hypersaline environments, focusing on salt containing anhydrite and clay impurities. Triaxial creep tests on salt samples revealed that lower anhydrite content increases ductility and strength, while anhydrite enhances creep tendency. All samples showed that unloading does not lead to any additional creep. Our findings suggest preloading caverns to maximum pressures before operations.

Hydrogen storage in porous media

We studied the effect of density-driven convection mixing and geochemical reactions on hydrogen storage in porous media. Key findings include reduced H_2S formation in pyrite-free environments, temperature-dependent H_2 solubility shifts, and salinity-driven density changes impacting convection. Higher reservoir pressure decreases H_2S in the gas phase. Our analysis of the Northern Light site in the Cook Formation improves hydrogen storage stability assessments.

Recruitment

Our project trained two PhD students at UiS, one PhD student at IFE, three MSc students from UiS and the University of Florence, and one summer student at IFE.

Leader: Viktoriya Yarushina (IFE)

Net-zero emission (NZE) production

In work package 3 one of the goals is to develop improved oil recovery concepts for improved, accelerated, profitable and sustainable hydrocarbon production at low environmental footprint.

ACHIEVEMENTS 2024

WP3.1 Tight reservoir solutions:

- Spontaneous imbibition oil recovery tests on diatomite samples resulted in 40-75% Original Oil in Place (OOIP) production efficiency using formation water as imbibing brine.
- Both outcrop Fur and Lark reservoir diatomites behaved water-wet producing oil by capillary forces.

WP3.2 CO_2 utilization:

- CO_2 foam: Experimental results show a detrimental effect of oil (n-Decane and Troll crude) on foam strength. However, foam was still generated in the presence of both oils at a low surfactant concentration (0.1wt%). Troll crude had a larger impact on foam strength compared to n-Decane.
- Carbonated water (CW): Injection found to change permeability and porosity of two sandstone rocks with different mineral compositions.
  - At low rate, rock was more reactive than high rate.
  - CW with higher CO_2 concentration was more reactive.
  - During injection of CW to sandstone with high dolomite content, Mg and Fe effluent peaks were observed and this confirmed reactions of CW with Fe-dolomite.

WP3.3 Improved tracing:

- $^{22}Na+$ (ideal sorbing tracer candidate) were included in flow experiments on sand packed columns to study possible reversible interaction with rock material.
  - Separation of passive and sorbing tracer were observed in experiments with Berea sandstone indicating that $^{22}Na+$ interacts with rock surface.
  - Separation depended on the clay content in the rock material.

Leader: Tina Puntervold (UiS)

Efficient water management

The amount of water injected, produced and discharged to sea in aging fields on the NCS is increasing. Water handling is energy-intensive and costly, and represents about 50% of the total energy for field operation. Therefore, efficient water management is crucial for field economics and emission reduction. Specific aims of WP4 are:

- To further investigate solutions for improved macroscopic sweep of reservoirs.
- To minimize injection water recirculation with reduced energy needs, thus reducing CO_2 emissions.

ACHIEVEMENTS 2024

WP4.1 Deep water diversion for minimizing CO_2 footprint

- LCA analysis framework has been tried for comparing the Snorre and Alvheim field water shut-off cases as demonstrated. Results presented at the Energy Norway conference.
- Looking for field trial for optimization of near- or in-depth water shut-off (Snorre, Ula can be used if no other candidate proposed)
- eCalc from Equinor has been released as OpenSource code, a training course was organized with nine participants from NCS2030, one engineer from OKEA, one Phd candidate from LowEmission Petrocenter and one MSc student from NTNU. Two summer job students from UiS have worked on eCalc with field data to understand its capabilities and functionalities. Two GEO680 students are continuing the same work in autumn semester at NORCE, potentially also lead to two MSc theses.

WP4.2 Optimization of injection water for IOR

- New lab data re-confirming the significant effect of CO_2 in produced water (CPW) for accelerating oil production - looking for reservoir cores to test for realistic EOR potential
- New ECO-Clay tested for high salinity and high temperature for gelation with higher Ca^{2+} concentration

WP4.3 IORSim modelling for near wellbore geochemistry and geomechanics

- Visualization of mineralogical changes has been implemented, working on a field sector model to demonstrate it.
- Model multiphase flow from near well outer boundary, through near well zone, through well equipment and through base-pipe up to the wellhead
- NORCE PhD hiring is postponed to 2024-2027
- IORSim field test studies:
  1. Snorre silicate simulation with good match of oil, water production and well pressures.
  2. Modelling of a large chalk field with good match of ionic composition of produced water.

Leader: Ying Guo (NORCE)

Digital subsurface for decisions

Large volumes of subsurface data exist, but current workflows for subsurface understanding are suboptimal, resulting in inadequate utilization of datasets. Using an ensemble of model predictions to support robust decision-making is in its infancy; thus, we must establish consistent methods for robust decision-making. Digitalization and machine learning are required components of a Sustainable Subsurface Value Chain, and we must integrate knowledge and competence building to make more informed decisions. We will establish a digital infrastructure, i.e., Subsurface Knowledge Cloud (SKC), to provide readily usable data, high-performance computing power, and visualization tools.

ACHIEVEMENTS 2024

In work package 5, we conduct industry-relevant methodology developments and apply these to the industry's problems. In 2024, we focused on developing data-driven and machine learning approaches to integrate subsurface characterization, uncertainty quantification, and management workflows for better decisions.

The main deliverable has been new digitalization workflows with improved functionalities and computational efficiencies.

We will use the work package 5 deliverables in applications, education, and dissemination throughout the NCS2030 centre.

In 2024, we have focused on work relevant for the industry future use:

- Federated Large Domain Model System (2024). Initial system design of Federated Knowledge Cloud using decentralized identity (DID), ActivityPub, LLM, Smart Contract and Blockchain.
- Scenario evaluation: Theory was developed and tested on synthetic cases in 2023. In 2024 the development and testing has advanced to real fields: Norne.
- We have included eCalc in the reservoir workflows PET and ERT.
- We have developed a synthetic 3D case study on underground hydrogen storage (UHS).
- Improved implementations:
  1. Seek minimum update to match data
  2. Improved correlation-based localization
  3. Cross validation procedure inspired by supervised machine learning
- SLB and Halliburton software made available for students (master and PhD)

Other:

- Work package 5 arranged the Energy Norway workshop on digitalization in April 2024
- Many new journal papers published in 2024
- PhD candidates are hired and producing on time

Leader: Geir Evensen (NORCE)
Deputy leader: Randi Valestrand (NORCE)

Energy policy, economy and society

The role of the Norwegian Continental Shelf (NCS) in the future energy system depends on the national and international business regulations, societal acceptance and licence to operate.

The targets of work package 6 are to:

- Address the competitiveness of the NCS in national and international contexts.
- Contribute to sound climate mitigation policies.
- Understand and explain the risk and uncertainty of investments related to work packages 1-5.

ACHIEVEMENTS 2024

Recent findings/results WP6.1/6.2:

- Policies have high impacts on investments, especially tax design.
- Expected positive profitability built into Norwegian licencing system.
- Companies from OECD countries had global outlook historically.
- Revenues from companies from OECD countries have effects on quality of democracies in Non-OECD countries.
- The capital allocation of oil companies across countries are affected by barriers, such as taxes.

Recent findings/results WP6.3:

- Rate of electrification and supply source (from offshore wind, power from shore or gas) largely depends on political, societal and technological developments.
- Emission reduction target of 50% by 2030 is not achievable in any of the scenarios analyzed.
- Electrification towards 2040 largely depends on energy imports due to long lead time of renewable energy investments in Norway.
- Electrification through power from shore occurs faster if competition for electricity from other energy intensive industry in Norway is low.

Leader: Torfinn Harding (UiS)

Education and outreach

The diversification in the energy sector requires skilled professionals with subsurface competences, knowledge in multiple energy sources, storage options, and digitalization, and an understanding of the Norwegian Continental Shelf. However, the number of students in energy related topics at universities in Norway has dramatically declined, and the supply of people with subsurface competence is approaching a critically low level.

To address these challenges, the specific targets are to:

- Attract the next generation of scientists and skilled professionals for the energy transition; and
- Educate new professionals at MSc and PhD levels in the future energy competences in collaboration with the industry.

ACHIEVEMENTS 2024

The main objective of this work package is bridging communication between academia, industry, the general public, and students at secondary and tertiary education levels.

Recent progress of note:

- Researcher Standup at ONS (Offshore Northern Seas) in August 2024.
- Internal knowledge and skills development 3-year workshop plan, includes planned workshop for understanding funding sources, writing and using artifical intelligence, and introductory programming.
- Assembly of NCS2030 Energy Box.
- Popular science blog preparation – launch in March 2025.
- More PhD videos: [uis.no/en/ncs2030](uis.no/en/ncs2030).

Path forward:

- Maintain good systems established in 2023 and 2024.
- Continue with successful outreach activities.

Leader: Lisa Watson (UiS)

To show our partners some glimpses from the research conducted at the centre, a Task Force Seminar was held in May.

The goal of the seminar was to show highlights on relevant results and progress of the different work packages, but also to build awareness among the participants of the different research areas. The meeting was an opportunity for all partners to be updated on the progress of the NCS2030 centre.

Other goals:

- Identify areas of cross-cooperation between different work packages, industry partners and researchers
- An opportunity for the Technical Committee (TC) to get more in-depth insight in our activities

In 2024, we begun to see good results of the one-to-one meetings with the industry partners in 2023. The good dialogue and increased cooperation have led to the completion of courses, access to field data and samples, and the employment of summer students who have worked with the industry on specific issues.

VISIT FROM THE RESEARCH COUNCIL

The Task Force Seminar was combined with a visit from the Research Council of Norway (RCN). Special adviser Ingrid Anne Munz and department director Rune Volla spent a day at Universty of Stavanger. The visit included lab tour and presentations from the PhD candidates in the centre. Six PhD students gave presentations during the visit:

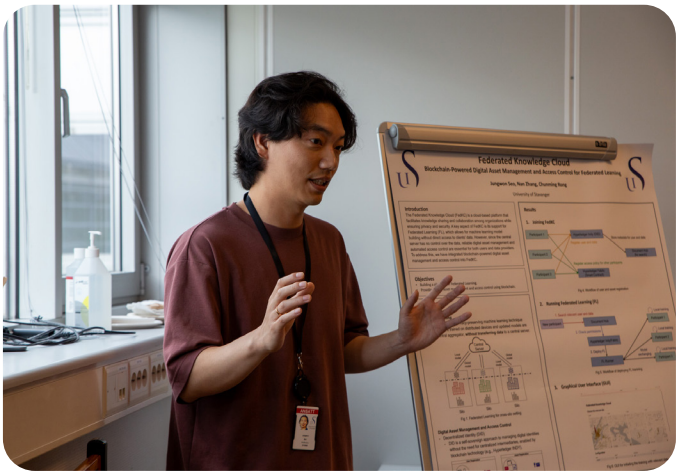
- Jungwon Seo
- Anaëlle Guillevic
- Mostafa Mohammadi
- Veronika Abdulina
- Mahmood Fani
- Donald Minougou

Ingrid Anne Munz and Rune Volla study the work of Anaëlle Guillevic. Photos: Kjersti Riiber

Task Force Seminar and visit from the Research Council

Centre director Alejandro Escalona

From left: Rob Berendsen (Halliburton) and Egil B. Petersen (Aker BP).



PhD student Jungwon Seo.

Photos: Kjersti Riiber

PhD student Donald Minougou, Rune Volla and Ingrid Anne Munz.

PhD student Veronika Abdulina.

Randi Valestrand (NORCE), Viktoriya Yarushina (IFE) and Sissel Viig (IFE).

Energy Norway 2024

Energy Norway was arranged 15-17 April 2024. Theme: Subsurface opportunities for the future energy mix.

The Energy Norway conference is an annual meeting place for subsurface professionals in Norway and international communities, policy makers, regulatory bodies, and students. The theme for the 2024 edition was «Subsurface opportunities for the future energy mix». The global energy situation has significantly impacted us, making the research focus at the NCS2030 centre on energy security and climate goals even more pertinent. How can we best utilize our energy resources? Is Carbon Capture and Storage (CCS) a viable option for Norway? At Energy Norway 2024, we brought together researchers, government agencies and industry experts to discuss sustainability and subsurface opportunities.

THE SKJÆVELAND AWARD

An important part of the Energy Norway conference is to involve our students, from master to PhD level. Each year we arrange a poster competition, the Skjæveland Award, where students are encouraged to participate with a scientific poster as well as a one-minute stand-up to present their research. The award is given to a young researcher who shows excellence, courage and innovation in his or her research, and should motivate for further research towards optimizing oil and gas production.

In the 2024 edition of the conference, Yan Wu won the Skjæveland Award. For the first time, a master student was awarded the prize. Yan Wu, at the time a final year master student at the study programme Energy, Reservoir and Earth Sciences, was awarded the prize for her innovative research and dedication to advancing practices in the master project ”Generic variations in subsurface aquifer models and their impact on simulated subsurface CO_2 storage”.

CONFERENCE TOPICS

Our aim is that Energy Norway will continue to be an important meeting place in the years to come. To ensure scientific relevance for our network of researchers, the first day of the conference was dedicated to a workshop. The theme for the workshop was ”Navigating challenges and solutions in digital transformation on the NCS”. What is digital transformation? Why do we need digitalization transformation? For companies it is important to achieve strategic goals and to enhance the efficiency in cost and the value delivered to both customers and to society. Thus, the main objective for the workshop was to strengthen the industry and academia collaboration for digital advancement on the Norwegian Continental Shelf.

Main topics for the 2024 conference:

- On our way to net-zero emissions
- Energy security and reduced emissions
- Public acceptance and recruitment of the young generation
- The role of the subsurface towards net-zero emission
- Pathways and obstacles for achieving 2030 emission reduction goals

Lunch time for the workshop participants. Photos: Kjersti Riiber

Associate professor Lisa Watson on the SUBSET project.

Host Tor Øyvind Skeiseid and Maria Flesjå Sivertsen.

Winner of the Skjæveland Award 2024, master student Yan Wu.

Master students Syed Ali and Solmøy Austbø gave the students' perspective on the future. What are their thoughts on the transition to a low-carbon energy future? Is it even possible?

Communication, conferences and collaboration

NCS2030 researchers have been present and/or given presentations at the following events and meetings in 2024, including internal events for PhD students and industry partners.

VISIT FROM FRANCE

Frederic Bessat and Frederic Choblet from the Institut Francais visited the centre in January 2024. The purpose of their visit was to learn more about Norwegian energy policy and energy research. The visit was also beneficial for the center's management. The French delegation shared their perspectives on the energy situation in Europe, and how we can collaborate to change course and ensure stable and clean energy for all European countries.

EAGE 2024

In June in Lillestrøm, 15 of the centre students and researchers participated in the annual EAGE conference through scientific presentations and an exhibition stand. Four UiS master's students co-supervised by centre director Alejandro Escalona won the prestigious Laurie Dake challenge for their sustainable development plan for the Volve field in the North Sea.

CALCULATING EMISSIONS

In June Equinor gave centre researchers a crash course in eCalc, a tool to estimate emissions. eCalc is a software tool for calculation of energy demand and greenhouse gas emissions from oil and gas production and processing. It allows integration of subsurface and operational knowledge and calculates emission forecasts directly relating drainage strategy to operational strategies and equipment. Frode Martinsen from Equinor and Ketil Wik from Bouvet gave the course. Participants were researchers and PhD students from UiS, Low Emission Centre (Sintef), Norce, NTNU, and OKEA.

EDUCATIONAL OUTREACH

Several of our PhDs presented their work to the collaboration forum FORCE during the spring and summer. In September, master's students led educational activities at the Petroleum Museum as part of the NGF Geologiensdag and at the University of Stavanger Forskningsløype as part of Forskningsdagene. The website, uis.no/en/ncs2030, acts as a platform for dissemination to the public. The site is regularly updated with news, webinars, videos, vacancies, and links to publications. For school-aged youths between the ages of 10 and 13, a physical and web-based "toolbox" is being finalized. It will be complete in the first half of 2025 and distributed to schools to raise awareness of climate-friendly energy and promote interest in geology and energy.

ARENDALSUKA & ONS

PhD students Daniele Blancone and Behzad Amiri gave talks at Arendalsuka. The theme was energy security and transition. The NCS2030 centre was also represented at ONS 2024. One of the events, a popular science night at the pub Gnu in Vågen, gave several of our PhDs an opportunity to present their research to the general public.

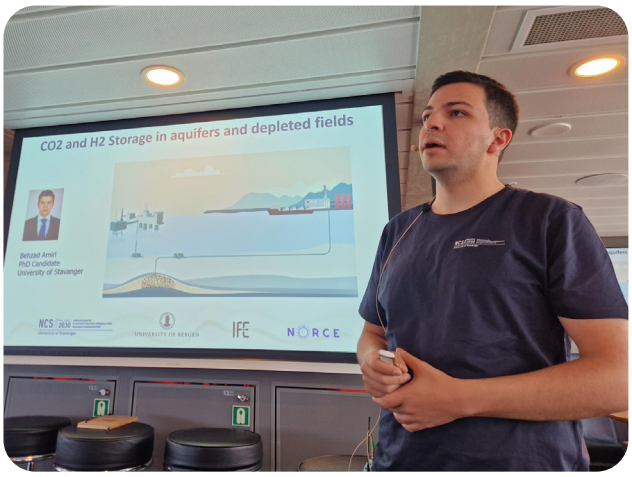
NOVEMBER CONFERENCE IN RIO

Ying Guo and Ingebret Fjelde participated in the November Conference in Rio De Janeiro in Brazil. The November Conference is viewed as the most important networking and knowledge-sharing arena for Norwegian and Brazilian research institutions involved in energy transition.

Frederic Bessat and Frederic Choblet from the Institut Francais visited the centre. Alejandro Escalona to the left. Photo: Kjersti Riiber

UiS master's students co-supervised by the Centre's director won the prestigious Laurie Dake challenge at EAGE. Photo: Private

Tina Puntervold and Ying Guo at the eCalc course in June. Photo: Kjersti Riiber



PhD student Behzad Amiri presenting at Arendalsuka in August. Photo: Private

From left Alejandro Escalona, Daniele Blancone, Veronika Abdulina, Mahmood Fani and Hamed Vaseghnia at ONS+, August 2024. Photo: Siv Marie Åsen

Collaboration

In 2024, the Centre has strengthened national and international cooperation through associated projects, new project applications, exchanges, and mentoring.

PhD candidate Jungwon Seo gives a talk for a delegation from FORTH in Greece the day after Energy Norway. Photo: Kjersti Riiber

This year has been pivotal in maturing and expanding our collaborations. The ”Energy Norway” conference once again served as a catalyst for building new networks and reinforcing existing ones. Key participants included the Low Emission Centre in Trondheim, the Twinn2set project with FORTH in Greece and IFPEN in France (EU twinning programme), the Intpart project with the University of Campinas (Unicamp) in Brazil (focused on IOR), and our scientific advisory committee.

NATIONAL COLLABORATION

Together with the other two petrocentres (Low Emission Centre and CSSR), we are planning a joint Petrocentre Conference in Oslo in 2025 at the Research Council facilities. The main goal is to highlight the importance of our research activities to decision-makers. We are also closely collaborating with the Low Emission Centre in energy management and the Well Fate project from the Research Council of Norway.

INTERNATIONAL COLLABORATION

The centre visited the Universities of Leeds and Teesside in the UK, engaging in discussions with their energy transition centres on potential areas of cooperation, which we hope will materialize in 2025. PhD candidate exchanges continue with The University of Texas at Austin and Rice University in Houston, USA, focusing on hydrogen storage and CO_2 foam for IOR purposes.

An Utforsk project with the University of Campinas in Brazil has been granted to strengthen our collaboration, this time focusing on student exchange within energy transition. Additionally, we contribute to another Utforsk project with Johannes Gu-

tenberg University in Mainz, Germany, in the area of hydrogen. Our collaborations also continue with DTU (Denmark), the University Technology of Petronas (Malaysia), Kwame Nkrumah University (Ghana), Stanford University (USA), University of Stuttgart (Germany), University of St. Andrews (Scotland), University of Glasgow (Scotland), and University of Helsinki (Finland). Through the spin-off project StoreH2Safe with Equinor and Teeside University in England, we are in dialogue about extended collaboration. Two researchers visited the new Net Zero Center in Teeside and discussed collaboration opportunities.

COLLABORATORS

- University of Texas at Austin, USA
- Stanford University, USA
- Virginia Tech, USA
- University of St. Andrews (Scotland)
- University of Glasgow (Scotland)
- University of Aberdeen, Scotland
- Imperial College, England
- Teesside University, England
- University of Basilicata, Italy
- Danish Technical University, Denmark
- RWTH Aachen University, Germany
- University of Stuttgart, Germany
- University of Lausanne, Switzerland
- Memorial University of Newfoundland, Canada
- Center for Petroleum Studies, Brazil
- Federal University Rio de Janeiro, Brazil
- University of Campinas, Brazil
- Edith Cowan University, Australia
- University of New South Wales, Australia
- Forth, Greece
- IFPEN, France
- University of Petroleum in Beijing, China
- Universiti Teknologi Petronas, Malaysia
- Kwame Nkrumah University, Ghana

Daniele Blancone (left) during his exchange stay at the University of Texas at Austin. To the right researcher Nur Schuba.
Photo: Private

Daniele Blancone

The primary objective of the project *Salt Characterization and Modelling for the Future Energy Mix* is to determine the composition, sealing capacity, and thermal properties of the Upper Permian evaporites of the Zechstein Group in the Norwegian North Sea. The goal is to assess the potential of these sedimentary rocks for geological storage (CO_2 and H_2) and their possible applications in geothermal energy production. The key challenge in the energy transition is the seasonal variability of renewable energy sources such as wind and solar power. Storing energy carriers in subsurface formations presents a viable solution, enabling surplus energy to be stored when production exceeds demand and retrieved when needed. Hydrogen storage in underground man-made caverns within salt domes is among the most effective options, as salt has extremely low permeability and reactivity. The first phase of my PhD research focused on assessing the H_2 storage potential of salt domes in the southern Norwegian North Sea, before advancing to a detailed characterization of internal heterogeneities in the most promising areas. We compiled a database of all salt structures in the study area and, in collaboration with The University of Texas at Austin, utilized the GeoH2 Salt Storage and Cycling App to evaluate the storage potential. The results have been groundbreaking, demonstrating that salt caverns in this area have the potential to store enough hydrogen energy to meet Norway's seasonal demand. These findings have been presented at international conferences (Stavanger, Oslo, Austin, and London) and in Norwegian Offshore Directorate meetings, where the topic

Daniele Blancone

generated significant interest, and have also been published in a scientific journal. The ongoing work focuses on applying machine learning tools, in collaboration with NCS2030 partners, to identify intra-salt heterogeneities in the areas classified as "high potential." This approach aims to refine our previous estimates and reduce uncertainty by transitioning to a higher-resolution scale.

Hilde Halsøy

Hilde Halsøy works on the net-zero CO_2 emissions workpackage. She started her PhD in October 2022. Her main supervisor is Zachary Paul Alcorn (UiB). The project *Optimizing CO_2 Foam for EOR and CO_2 Storage* develops a combined CO_2 enhanced oil recovery and CO_2 storage technology using CO_2 foam mobility control. CO_2 foam is a field and laboratory proven technique to mitigate poor CO_2 sweep efficiency for increased oil recovery and CO_2 storage potential. However, all foams are thermodynamically unstable and can easily break. Thus, a thorough understanding of foam stability and the effect of surfactant concentration, presence of oil is required. A more thorough understanding of size-dependent displacement mechanisms is needed to improve predictive modeling of CO_2 foam. The integration of experiments and modeling from the core-level to the field-level will lead to new fundamental knowledge and optimized CO_2 foam EOR and CO_2 storage strategies.

Hilde Halsøy

Jungwon Seo

Jungwon Seo's research focuses on the development of a Federated Knowledge Cloud aimed at fostering a sustainable subsurface value chain as part of the NCS2030 centre. His work explores the training of machine learning models in a privacy-preserving environment without the need for data transfer, utilizing blockchain and federated learning techniques.

The goal is to create a system capable of learning from dispersed data within the NCS2030 network, enabling collaboration among various participants without centralized data storage.

Additionally, Jungwon is investigating the potential of Large Language Models with use cases including managing code distribution, overseeing workflows as a key component of the Federated Knowledge Cloud, detecting malicious code in distributed software, and efficiently managing tacit knowledge in the energy sector and research.

Jungwon Seo is a computer science professional from South Korea with a background in both academia and industry. He completed his bachelor's degree in Seoul and his master's degree at the University of Stavanger (UiS). With several years of experience as a software engineer, he is currently pursuing a PhD under the supervision of Professor Chunming Rong, Associate Professor Ferhat Ozgur Catak and researcher Nan Zhang at University of Stavanger.

Jungwon Seo

Mahmood Fani

Mahmood Fani embarked on his PhD journey in March 2023, delving into enhancing recovery methods while concurrently mitigating emissions, employing innovative hybrid techniques. Among these methods, his primary focus is carbonated water utilisation. This approach involves leveraging CO_2 in Carbon Capture, Utilization, and Storage (CCUS) processes, which can be injected to enhance oil production while simultaneously sequestering CO_2 underground.

However, the injection of CO_2 into aquifers presents a dual challenge. While it aids in storing CO_2, it also induces acidity in the environment. Mahmood's research is multifaceted, as he evaluates the optimal amount of CO_2 safely stored in aquifers. This assessment analyzes the geochemical interactions between the injection fluid and the reservoir minerals. By understanding these interactions, Mahmood aims to enhance the efficiency of subsurface CCS (Carbon Capture and Storage) projects.

This research contributes to the advancement of sustainable energy practices and addresses critical environmental concerns associated with CO_2 sequestration. Mahmood's work holds promise for optimizing CCS/CCUS techniques, thus fostering a greener and more efficient approach to energy production and emissions reduction.

Mahmood Fani

Veronika Abdulina

As conventional reservoirs become increasingly depleted, the focus has shifted toward unconventional formations, such as tight reservoirs, which require advanced recovery methods to achieve sustainable production. Among these, diatomite reservoirs present unique challenges due to their high porosity, low permeability, and complex mineral composition. Their ability to store large volumes of fluids, combined with their fragile structure and low permeability, makes them a promising yet difficult target for hydrocarbon production and CO_2 storage. Understanding how to enhance oil recovery while ensuring sustainable energy practices is key to maximizing the potential of these formations. This project aims to improve enhanced oil recovery methods in tight reservoirs, particularly through Smart Water injection. By optimizing the ionic composition and salinity of injected water, this technique has the potential to modify rock wettability, increase oil displacement efficiency, and support long-term CO_2 storage. Our study focuses on diatomite reservoirs and outcrops from Norway, Greece, Denmark, and the USA to evaluate their wettability, fluid interactions, and storage capabilities. We examine their physicochemical properties using a variety of laboratory techniques to determine how Smart Water can influence oil recovery and CO_2 trapping in these formations. By integrating wettability control, fluid-rock interaction studies, and enhanced recovery techniques, this research aims to determine whether Smart Water can improve oil recovery while supporting carbon storage initiatives. The findings of contribute to the development of low-emission production strategies, bridging the gap between hydrocarbon recovery and environmental sustainability.

Veronika Abdulina

Behzad Amiri

The energy transition plays a critical role in addressing the challenges posed by global warming. The primary objective is to achieve net-zero emissions, which entails employing strategies such as Carbon Capture and Storage (CCS) and hydrogen-based fuels to counterbalance greenhouse gas emissions effectively. Underground Hydrogen Storage (UHS) is vital in storing green energy over extended periods. Depleted oil and gas reservoirs, as well as saline aquifers, are considered significant alternatives for UHS within the porous media. Using geological porous formations for hydrogen storage will be considered. UHS can bring several challenges that have implications for both efficiency and safety. To address them, reservoir management based on field characterization, uncertainty quantification, model update, optimization and machine learning are utilized. The process entails the optimization of strategies in accordance with the collected information and observed performance of the reservoir, the utilization of real-time monitoring, and the ongoing evaluation of the system. The goal is to maximize effectiveness and minimize environmental impacts.

Numerical reservoir modelling using many realizations for characterizing uncertainty and optimization incurs computational expenses. To manage this, proxy models will be employed to identify the connections between input-output parameters in the fluid flow simulations.


Behzad Amiri

Mostafa Mohammadi

Biased forecasts lead to biased decisions, which, in turn, result in value erosion. In petroleum exploration, key pre-drill inputs for calculating expected monetary value (EMV) and making drilling decisions include the geological probability of success (PoS) and probabilistic volume forecasts. If these forecasts are biased or lack accuracy and reliability, they can lead to suboptimal decisions and financial losses.

Explorers attempt to improve pre-drill forecasts using post-drill PoS analysis, often relying on a limited set of statistical methods focused on forecast reliability. However, high-quality probability forecasts must also satisfy other properties such as resolution, bias, accuracy, and skills. Neglecting these attributes may lead to incomplete forecast verification and misjudgment of forecast quality. To address this, we assess PoS and volume forecasts using various probability forecast verification measures, including the Brier score, skill score, bias assessment, and attribute diagrams.

Our findings indicate that PoS and probabilistic volume forecasts are not well-calibrated, which affects decision-making.

Mostafa Mohammadi

After verification, we apply calibration methods to calibrate forecasts and ultimately evaluate the impact of calibration on exploration decisions.

Fazil Huseynov

The transition to low-carbon energy systems relies on various subsurface processes, including carbon capture and storage (CCS), underground hydrogen storage, and the abandonment of legacy wells. Whether managing CO_2 or H_2 injection or tracking natural fluid migration, these processes are governed by multiphase fluid flow, stress distribution, and rock deformation. A thorough understanding of these coupled mechanisms is essential to ensuring the safety, efficiency, and long-term viability of storage sites.

The project ”Multiphase fluid flow in the subsurface for the energy transition” aims to advance numerical modeling and experimental validation in multiphase flow and geomechanics for subsurface energy applications. The focus is on developing a robust numerical framework to simulate two-phase flow coupled with rock deformation, with particular attention to CO_2 injection for carbon capture and storage (CCS). The model will be calibrated and validated using laboratory experiments, improving predictive accuracy and enhancing the reliability of storage site assessments. By integrating computational modeling with experimental data, the project seeks to optimize geological storage strategies, minimize operational risks, and contribute to net-zero emission goals.

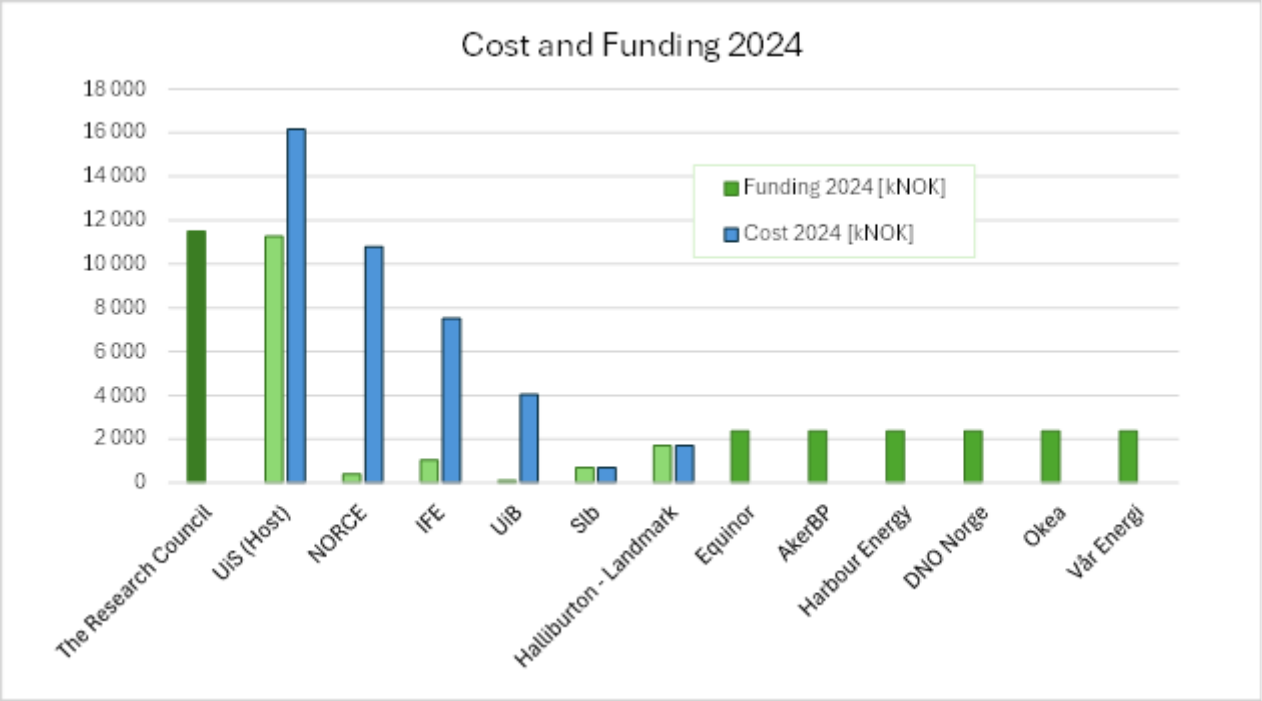
I am a PhD student at the University of Oslo (UiO), originally

Fazil Huseynov

from Azerbaijan. My academic background includes a bachelor’s degree in Geophysical Engineering from Azerbaijan State Oil and Industry University and a master’s degree in Geosciences from the University of Strasbourg.

Economy

	Cost 2024 [kNOK]	Funding 2024 [kNOK]	Funding 2022-2029 [kNOK]
UiS (Host Insititution)	16 157	11 261	78 971
NORCE	10 796	398	6 730
IFE	7 501	1 040	5 744
UiB	4 035	105	9 588
Slb	702	702	10 000
Halliburton - Landmark	1 704	1 704	10 000
User Partners		14 193	120 000
RCN		11 492	80 000
Total Funding	40 895	40 895	321 033



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