

Annual Report 2024

Centre for Sustainable Subsurface Resources



Centre for Sustainable
Subsurface Resources

Table of Contents

Preface	3	International conference contributions	36
Message from the Chair (SAC)	4	In the Spotlight	38
Research Strategy	6	New PostDocs and PhD in 2024.....	40
Energy security and climate commitments	8	Earth Science Analytics AS	42
Vision for integrated research.....	10	Industry collaboration on advanced imaging.....	44
Insight Article	12	Radial Flow Lab	46
Role of AI and machine learning in reservoir simulation	14	CSSR Facts	48
Highlights 2024	16	Governance Structure.....	50
CSSR Annual Conference 2024	18	Operation Centre.....	52
Robust methodology for sustainable reservoir management.....	20	CSSR Research Partners	54
Experimental studies of microbial hydrogen consumption rates in porous media.....	22	Key figures.....	56
New prototype tool for screening CO ₂ storage potential of NCS fields	24	Education and training	58
Earth Science in CSSR.....	26	Publications	60
Stakeholder engagement.....	28	Outlook	66
Success in EU projects.....	30		
Summer schools.....	32		
Dissemination at industry events.....	34		

Kirabo Erimas Mugwanyana and Eda Önal, PhD students.

FRONT PAGE PHOTO ANDREAS GRAVEN | NORCE
DESIGN HALTENBANKEN, MODIFIED BY NORCE



“*Industry and academia should have brave, common visions.*”

Dear Readers,

I am very happy to write my first address to the CSSR annual report for 2024 as the Chair of the Executive Board.

I have been involved with CSSR from before the official start in 2022, so the centre is very special to me. To read about the plans for CSSR was exciting back then, and I am very pleased to see what has been achieved so far and how so much has been materialised since then. Last year was a very productive year – which I hope this report shows.

Recently, I read several memoirs from oil pioneers of Norway. The success stories are numerous, but there are also stories where the results were not as planned. Such learnings are crucial for future success. Some of the most important developments – what we would now call successes on NCS today - were also very challenging; both during the development and in their start phase.

This points me to a message that I want to convey: a centre like CSSR has a responsibility – and privilege – to pave the way with innovation and research where the end results might be used to manage resources that are very important for our society. And in doing so we need to be bold. The road that has to be travelled for true energy transition will be challenging, but I believe that a centre like CSSR becomes even more relevant and important in such a setting.

Lastly, I would like to state my true gratitude to the centre management and to all researchers, members, partners, stakeholders, students and supporters. Let us all work towards making 2025 a brilliant year.

Sincerely,
Geir Terje Eigestad
Subsurface Manager at Harbour Energy Norge,
Chair of the CSSR Executive Board

Message from the Chair of the Scientific Advisory Committee

AUTHOR EVA HALLAND

On behalf of the Scientific Advisory Committee (SAC) for CSSR, I am pleased to present highlights from our second evaluation. SAC's mandate is to advise on the relevance of centre activities and provide recommendations, guidance and feedback on the effectiveness of intermediate and final results.

SAC operates independently as an advisory body to the entire consortium and reports annually to the Board.

We are pleased to see that the research output is impressive and has not slowed since the last evaluation. We want to highlight the annual conferences as well as the centre organised workshops and seminars which provide excellent networking and collaboration possibilities. The overlap we observe between students graduating and beginning on every project in the centre is excellent. Analysis of the subjectivity of expert

assessments and interaction dynamics in the context of FluidFlower is elucidating and helpful. And we are also pleased to observe a good strategy for AI.

SAC will encourage the team and leadership to carry on their excellent research, laboratory experimentation and software development, as well as the strategic objectives between the activities.

The SAC feels confident that we will see significant scientific and technological advances during the duration of this centre given the high-quality and multidisciplinary nature of these research teams. We look forward to continuing the collaboration of the SAC with CSSR.

SAC Members



Eva Halland
SAC chair
Managing Director,
CarbonGeo Consulting

Eva Halland worked in the Norwegian Petroleum Directorate until mid-2022, and now as an independent consultant and strategic advisor in CCUS. She has led several industrial collaborations such as FORCE and the CO₂ storage forum. She was project manager for the Norwegian CO₂ Storage Atlas and led the CCS work with regulation and professional assessment for the authorities.



Maša Prodanović
Professor and Associate
Department Chair,
Frank W. Jessen Professorship
in Petroleum Engineering,
University of Texas at Austin



Stephan Matthai
Professor,
Chair of Reservoir
Engineering,
University of Melbourne

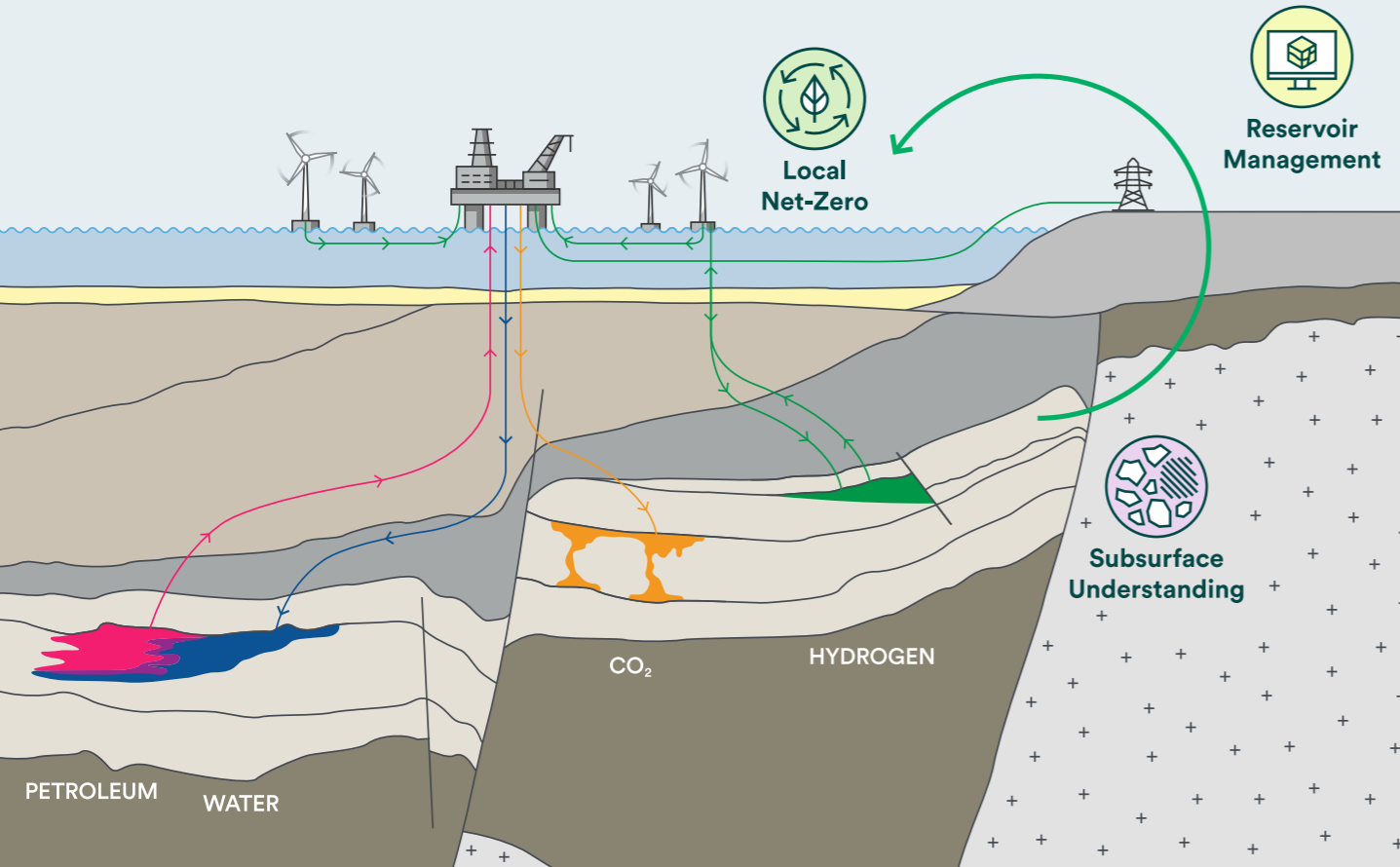


Vahid J. Niasar
Professor,
Chemical Engineering,
University of Manchester

Research Strategy



Energy security and climate commitments



CSSR strives for research results and solutions that are industry-compatible and societally-positive. For us, this means developing groundbreaking concepts that can make emissions reductions on the NCS compatible with the rest of society.

Since CSSR’s start in 2022, the backdrop that motivates our research is ever more complicated. The continuously developing situation in Europe since Russia’s full-scale invasion of Ukraine still influences the energy debate. Norway has solidified its role as a crucial supplier of energy to Europe following the disruptions in Russian gas supply. Investments in renewables that initially increased in 2022 appear to be waning, and the USA election will put more pressure to deprioritise the green transition. The call to eliminate production emissions on the NCS still stands, while CO₂ storage licences have increased at a record pace. The sense of urgency still looms.

Challenge of net-zero on the NCS

Electrification of the NCS is a complicated topic with several intertwined technical, economic and societal challenges. With the exception of HyWind Tampen, the vast majority of electrification projects involve tiebacks to hydropower from shore. The next best approach is often shutting down CO₂-intensive fields.

In the context of persistently high electricity prices, the pushback from society for sending clean energy to power-hungry offshore installations is understandable. Hydropower is a limited resource and offshore wind development has come to a near standstill. Thus, the

competition between industry and consumers for access to clean energy is difficult to solve.

From energy-islands to energy-neighbours

The NCS will produce oil and gas for decades to come, and it is highly unlikely that industry can expect guaranteed on-demand access to power with each new electrification project. Regular consumers have already become accustomed to spot pricing, smart meters, and adjusting life’s patterns to reduce energy consumption at peak demand. The question thus remains, what can industry do to adjust their own energy consumption in an analogous way?

A societal-positive approach to energy efficiency

As a national petroleum research centre, CSSR strives for long-term research that benefit both industry and society. We research how power consumption can be adapted to peak or seasonal energy demand from consumers; how innovative concepts for production optimisation can account for uncertainty in intermittent wind energy; and how the subsurface responds to these new tactics, both good and bad. CSSR integrates this research into a holistic understanding of the trade-offs of electrification, which is important for evaluating next generation ideas within the broader industry and societal context.

Vision for integrated research

CSSR continues to grow a robust research programme with focus on end users. In 2024, a total of 10 PhDs and postdoctoral fellows combined with 15 individual researcher projects to deliver a strong output of high-quality research results. The breadth of subsurface research topics covered by the centre reflects the broad challenges facing society and industry as we move towards net-zero emissions on the Norwegian continental shelf and the energy transition by 2050.

Greater than the sum of its parts

Amidst these impressive numbers, a high priority for CSSR continues to be ensuring individual projects work in concert towards a common goal, thus enabling a cumulative impact whose total is greater than the sum of its parts. There are several ways we take action to meet this goal, for example data exchange between experimental and modelling work packages or developing a common field case around which to apply and test concepts.

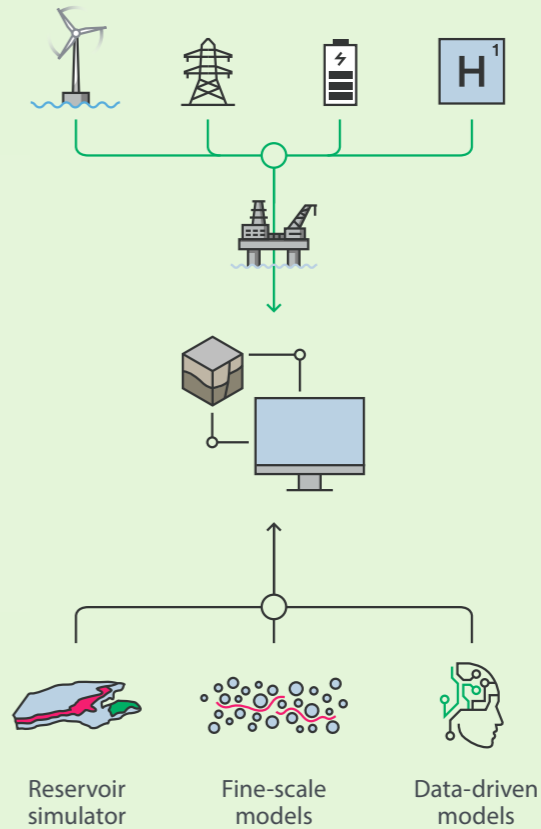
Innovative research ideas

The perfect illustration of CSSR’s research strategy can be found in one of our PhD projects “Wind-powered oil production”, where Mathias Methlie Nilsen (NORCE) is working

on new optimisation algorithms that improve the ability to integrate available wind energy with gas power when balancing oil production with CO₂ intensity. The preliminary results are intriguing – by using 30-day wind forecasts to fine-tune production forecasts, platform emissions can be cut significantly while still maximising value from the field. There is one critical innovation – allowing the water injection to fluctuate with daily wind power. This flexibility is important as it allows the platform to use much more of the available wind energy. This in turn reduces the reliance on back-up gas power in periods of low wind. A win-win!

Cross-centre synergies

Mathias’ work is producing cutting-edge mathematical formulations – important academic contributions in their own right – but also new insights that help spur investigations in other parts of the centre. For instance, CSSR laboratory and geological studies are looking into the consequences of fluctuating water injection on the near-well fluid system. While new developments in reservoir simulation are helping resolve technical limitations to facilitate using even more wind energy. And it is certain that many new project ideas will be spurred by this and other groundbreaking work.



CSSR aims for improved methods for production optimisation that select the right fuel source to balance production and emissions targets. To achieve this goal, CSSR works to integrate results from other research activities in the centre, e.g. faster simulation tools and fine-scale subsurface data or models.



Dr. Sarah Gasda is a research director at NORCE and adjunct professor in Physics and Technology at the University of Bergen. She holds a PhD in civil and environmental engineering from Princeton University. Her expertise is in modelling and simulation of fluid flow in porous media, focusing on CO₂ and underground energy storage. She is the centre director for CSSR.

Insight Article



Role of AI and machine learning in reservoir simulation

AUTHOR **BIRANE KANE** AND **SARAH GASDA**

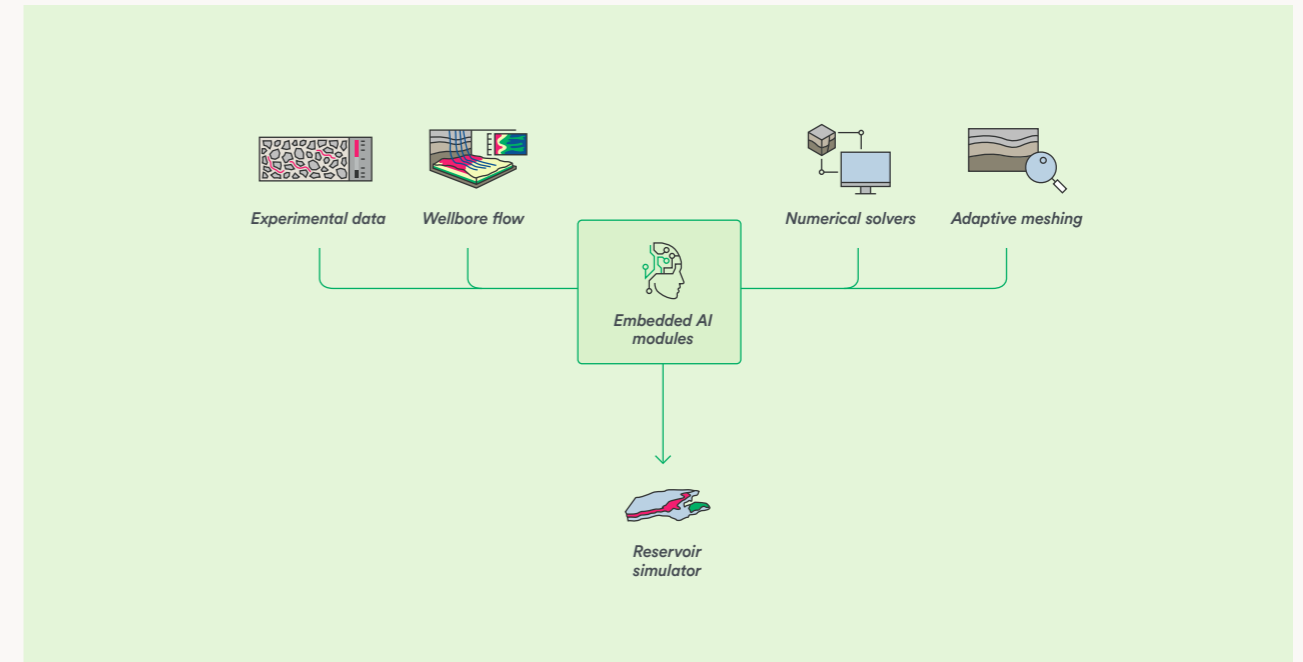
CSSR is dedicated to advancing research in computational methods for reservoir management, with a focus on developing a toolbox of models that accelerate simulations in optimisation and data assimilation. The goal is to understand how lower-complexity, low-fidelity models can provide reliable solutions at reduced computational cost. A key long-term outcome is to establish guidelines for incorporating simpler models into ensemble-based workflows.

Machine learning (ML) and artificial intelligence (AI) are integral to achieving this goal. CSSR adopts a unique approach whereby trained ML models are embedded within rather than instead of classical reservoir simulation. In this way, AI is used as a tool to alleviate classic bottlenecks in reservoir simulation without sacrificing physical accuracy. Examples include ML to improve solver performance or replace cumbersome constitutive models (see figure).

This line of thinking grew out of the CEMRACS summer school in 2023, where CSSR researchers and PhD students first embedded neural networks (KERAS) into the open-source OPM Flow simulator. This event laid the foundation for ongoing work in scientific machine learning, leading to the development of the WP4/5 workplan.

CSSR's focus on ML and AI reflects the growing impact of these technologies in subsurface resource management. Over 30% of abstracts at the recent EAGE European Conference of Mathematics for Geological Reservoirs (ECMOR) featured AI-related topics, underscoring the significance of data-driven modelling in reservoir simulation. CSSR contributed two papers at ECMOR involving ML integration into reservoir simulation.

ML is a broad and fast-developing field. For CSSR it is important to be clear on the scientific questions to be addressed when



CSSR develops a variety of data-driven modules that are embedded with a classic reservoir simulator to relieve computational bottlenecks without sacrificing physics-based modelling at the core.

seeking to gain benefits of ML technology while navigating pitfalls. For example, easily accessible ML tools can be trained on high-fidelity data that is otherwise challenging to model, but this process must be handled by domain experts to ensure predictive capability of the end result.

CSSR will continue along the selected research path of integrating ML methods to relieve the computationally intensive components of classical simulators. This research path is complementary to associated projects involving many of the same researchers, including the Porotwin project run by UiB.



Birane Kane is a researcher at NORCE. His research interests are in scientific machine learning, adaptive mesh refinement and reservoir simulation. In CSSR, Kane contributes to work package 4.

Highlights 2024



CSSR Annual Conference 2024

CSSR gathered for our annual conference in September, sharing research from the centre and discussing how research and industry can work together towards the green transition on the Norwegian Continental Shelf.

How do we measure success within research? Is it a question of how much money we make? If it gave PhD-students a job? How many papers we got published? All relevant questions, but the most important one is – did we make an impact? Collaboration with industry forces you to look at real problems. It keeps you real as a researcher, said Martin Blunt, from Imperial College London, when he partook in a panel discussion on interactions, approaches, options, and challenges between academia and industry.

The ecosystem within renewable energy is immensely big. The research communities help us understand that ecosystem, and where things are moving. Many things we take for granted in the industry today came from collaboration between industry and research, said Fredrik Varpe from Equinor. It featured keynote speakers addressing net-zero ambitions and the green transition

on the NCS, providing valuable insights from policy, industry, and scientific perspectives on electrification and the green transition, both nationally and internationally.

“
Our overall objective is to perform research that is useful for companies looking to reduce production emissions. Therefore, we are researching energy efficiency, modernising digital workflows for reservoir management, and working to optimise subsurface use towards net-zero.”
”
Sarah Gasda | Centre Director



From the left: Martin Blunt, professor at Imperial College London, Ingrid Anne Munz from the Norwegian Research Council, Fredrik Varpe, Vice President Renewable & Low Carbon Energy Systems, Equinor (in the back), Kristin Flornes, Executive vice president Energy and Technology NORCE, Ketil Djurhuus Research Director Subsurface Energy Solutions at NORCE and centre deputy at CSSR.



Professor Jan Martin Nordbotten from UiB had a live demonstration of the FluidFlower, as part of the annual conference



Tom Jönsthövel, CCS Programme Software Architect, SLB and **Fredrik Varpe, Vice President Renewable & Low Carbon Energy Systems, Equinor**

PHOTOS RUNE ROLVSJORD | NORCE



Robust methodology for sustainable reservoir management

AUTHOR MATHIAS METHLIE NILSEN

My research focuses on optimisation and sustainable reservoir management, and is divided into two areas: general development of optimisation algorithms and methodology development for optimised offshore oil and gas production using power from offshore windfarms.

For the development of optimisation algorithms, my main work has been on improving the accuracy of the ensemble gradient for bounded controls [1], and the use of optimisation techniques from machine learning for reservoir optimisation [2].

On the topic of sustainable reservoir management we developed a mathematical model for creating an ensemble of daily wind speed series over a period of 4.5 years [3]. The wind speed ensemble was then used in multi-objective optimisation, where the two objective functions were NPV (Net Present Value) and CO₂ emissions. For this application, the Drogon reservoir model (Figure 1) and the emission calculator eCalc (both developed by Equinor) were used.

In [3], sustainable reservoir management is based on optimisation with uncertain wind resources. Our latest developments extend this approach to optimisation with uncertainty in the geological properties of the reservoir, such as permeability and porosity. The uncertainty is represented by an ensemble of model realisations of these properties, and the average objective function is optimised. Two sets of solutions for multi-objective optimisation are performed: one with combined wind and gas power and one where only gas power is available.

These scenarios are shown as two curves in Figure 2. Each curve is a Pareto curve,

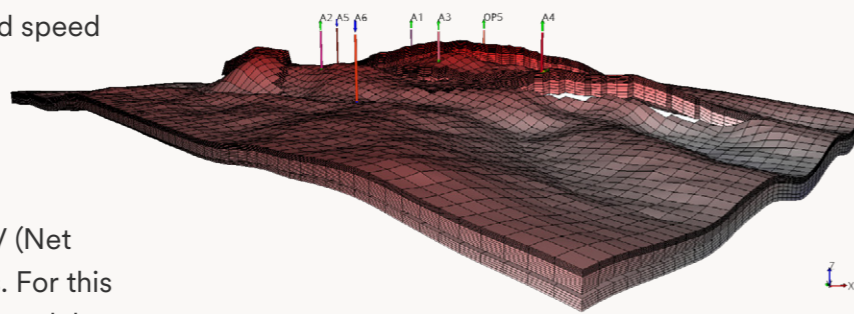


Figure 1: The geometry of the Drogon reservoir model, and the different production (A1-A4 and OP5) and injection (A5 and A6) wells.

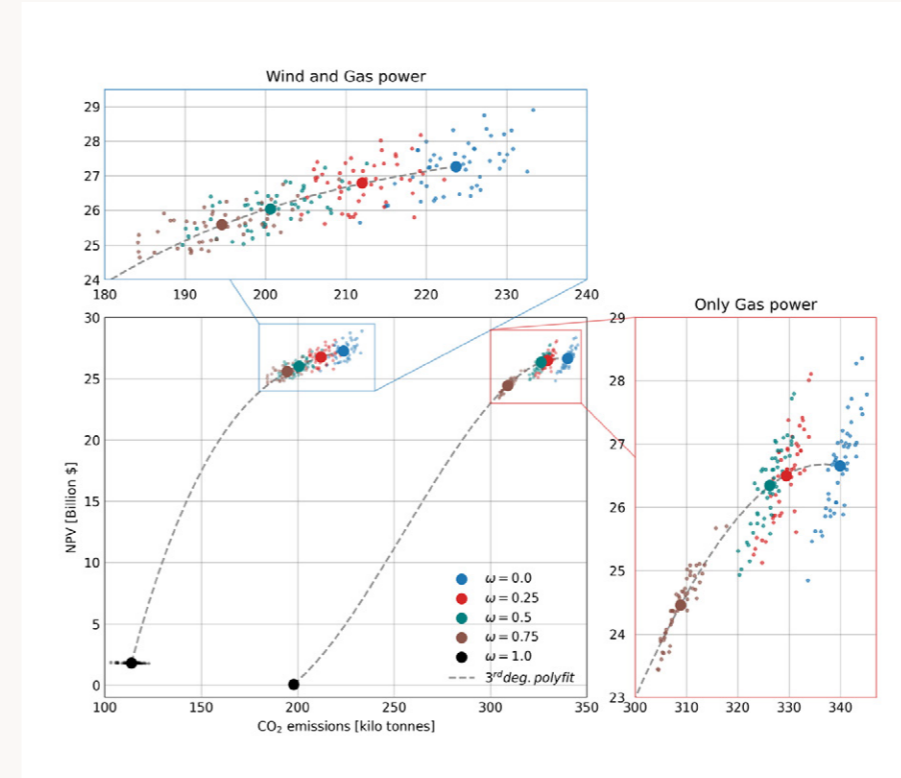


Figure 2: Two solution sets for the multi-objective optimisation. Each colour represents a weight (denoted with ω) between NPV and CO₂ emissions. When $\omega=0$, only NPV is maximised, and when $\omega=1$, only CO₂ emissions are minimised. Smaller points indicate one realisation of wind power and geological properties, and the big dots represent the ensemble means. The uncertainty in wind power and geological properties are reflected in the spread of the small points.

generated by varying the weight, ω , between NPV and CO₂ emissions. One key finding is that when only gas power is used, it is not possible to achieve a 40% reduction in emissions, which is the goal of the Norwegian oil

and gas industry by 2030. However, when wind power is included, this goal can be reached with only a 2.3% reduction in NPV (by selecting the solution when $\omega=0.5$).

References

- [1] M. M. Nilsen, et al., "Non-Gaussian Ensemble Optimisation," *Mathematical Geosciences*, vol. 56, 2024.
- [2] M. M. Nilsen, et al., "Accelerated ensemble optimisation using momentum methods," *Scientific Reports*, vol. 14, 2024.
- [3] M. M. Nilsen, et al., "Wind-Powered Reservoir Management," in *ECMOR2024*, Oslo, 2024.



Mathias Methlie Nilsen is a CSSR PhD student in WP3 and is employed at NORCE. Before starting his PhD in CSSR, he studied at the University of Bergen, where he completed a master's degree in theoretical atomic, nuclear and particle physics.



Experimental studies of microbial hydrogen consumption rates in porous media

AUTHOR RAYMOND MUSHABE, NA LIU, NICOLE DOPFFEL, GEIR ERSLAND, AND MARTIN A. FERNØ

Underground hydrogen storage (UHS) is emerging as a promising solution to address the supply-demand imbalance of renewable energy sources. For efficient operation, it is crucial to understand the microbial processes that may initiate or accelerate in the presence of hydrogen within the porous storage sites. New experimental core-scale data is essential to accurately quantify microbial hydrogen consumption and its interaction with the porous media. This data is vital for both potential reservoir characterisation and providing high-quality input for numerical models.

Experimental findings

To address the existing knowledge gap in core-scale studies, my research has focused on understanding and quantifying anaerobic microbial hydrogen consumption in porous media. Sand pack experiments were conducted using bacteria-containing brine as the aqueous phase and hydrogen as the gaseous phase. State-of-the-art medical imaging techniques (Figure 1) were employed to explicitly

study local hydrogen flows and distribution within the opaque porous media.

By simulating cyclic hydrogen storage site operations in the laboratory, microbial hydrogen consumption rates were precisely determined during shut-in periods. We observed an exponential decay in consumption between storage cycles (Figure 2), with a total cumulative hydrogen loss across the three cycles amounting to 15%. The reduction in hydrogen consumption after the first storage cycle was attributed to an increase in brine pH (from 7.5 to 8.4) due to microbial activity. We noted an improvement in the average hydrogen in-place saturations after the first non-sterile storage cycle. The observed consumption rates in porous media were two orders of magnitude higher than those in batch bottle tests with short-lived microbial activity. This higher rate in porous media was correlated with the larger surface area, which directly accelerates the pH increase and, over time, could reduce the overall microbial risks.

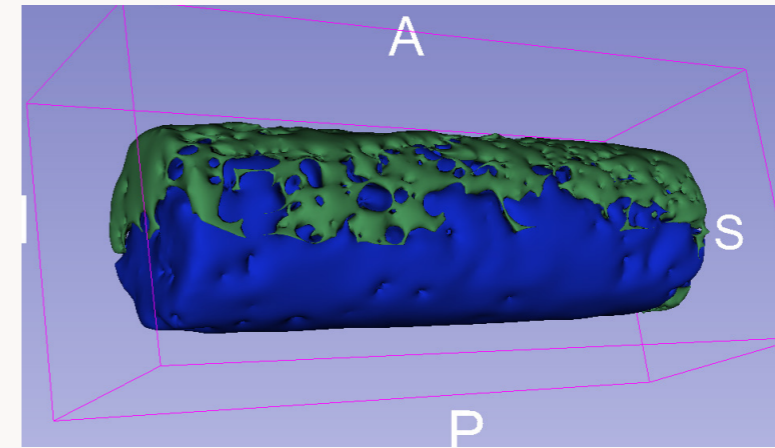


Figure 1: MRI image of hydrogen injection into a brine-filled sand pack. Shown is a segmented 3D image showing regions saturated by hydrogen (green) and brine (blue). A publication of methodology and results is under preparation.

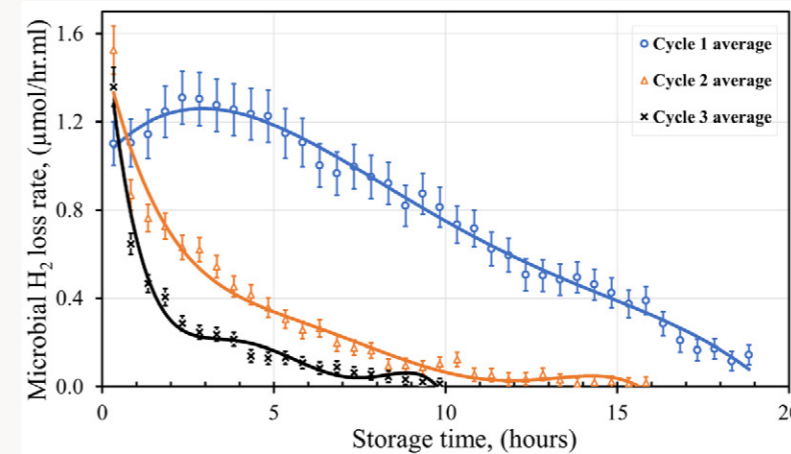


Figure 2: Average microbial consumption rates in three storage cycles based on eight experimental repetitions. Microbial hydrogen consumption was most dominant in the first storage cycle and continuously decreased in the second and third storage cycles. The cumulative loss across the three cycles amounted to 15 ± 6%.



Raymond Mushabe is a third-year PhD student (WP2) specialising in experimental reservoir physics, with a particular focus on underground hydrogen storage in porous media. His research is concentrated on understanding hydrogen loss due to microbial activity and how this phenomenon impacts recovery efficiency.



New prototype tool for screening CO₂ storage potential of NCS fields

AUTHOR TRINE MYKKELTVEDT AND ALEXEY KHRULENKO

According to the Norwegian Offshore Directorate (NOD), by the end of 2023, 55% of the total resources on the NCS had been produced, implying huge pore volumes that can be repurposed for CO₂ and hydrogen storage. Through decades of petroleum activities on the NCS, a large amount of data has been gathered and can also be reused, which was the subject of one of the studies within CSSR in 2024.

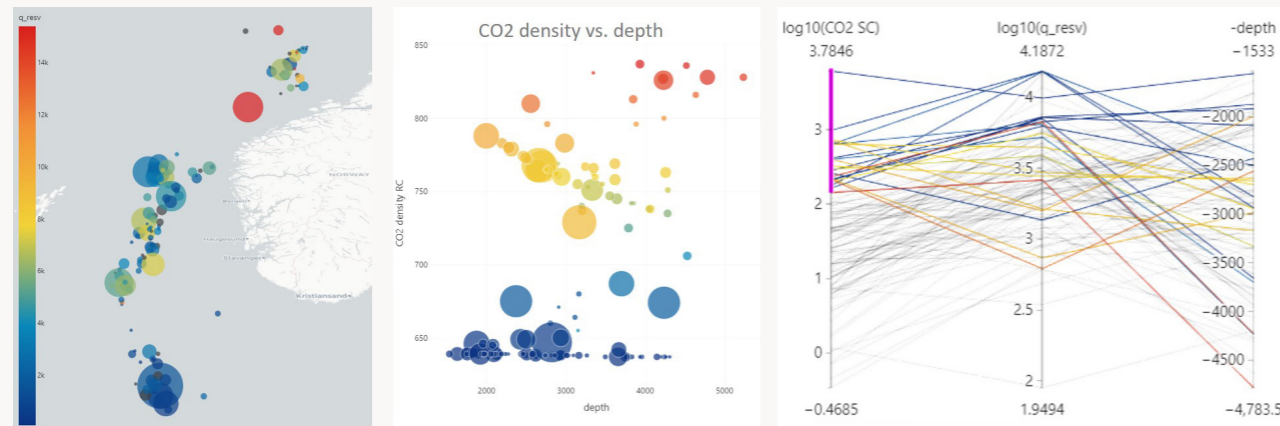
The study utilised well, and reservoir data made publicly available by the NOD. The data have been gathered, processed, and enriched to fill missing values and facilitate further analysis for nearly all fields on the NCS.

A set of indicators has been proposed to assess capacity, injectivity, and other aspects of CO₂ storage in depleted petroleum fields. These

indicators allow for consistent comparison of different reservoirs and can be combined with other parameters into a single score to rank candidates based on user preferences. While the methodology does not resolve all uncertainties, it can be used for screening purposes to narrow down possible options, address essential questions, and identify areas that require detailed studies.

The data and methodology have been implemented in a web application for visualisation and screening at <https://subcset-35e143428f88>.

herokuapp.com/. The data and codes are available on the centre's GitHub repository at <https://github.com/cssr-tools/SubCSeT>. The results were presented at the Greenhouse Gas Control Technologies Conference in Calgary, October 20–24, 2024. The e-poster can be viewed at <https://api.ltb.io/show/ACGES>. The conference paper is available at <https://dx.doi.org/10.2139/ssrn.5069175>.



Plots generated using the screening tool, from left to right: map of fields indicating capacity (size) and injectivity (colour), depth and density of CO₂ for each field, paraplot for some selected fields and properties, and total score of fields for selected properties.



Trine Mykkeltvedt is a senior researcher at NORCE and leader of work package 6. She holds a PhD in applied Mathematics from the University of Bergen, and her research interests include computational methods and modelling of multiphase flow in porous media with a speciality in CO₂ storage and underground energy storage.



Alexey Khrulenko is a senior researcher at NORCE. He holds a PhD in Engineering and has been with IRIS/NORCE since 2012, contributing to various projects in reservoir engineering, modelling, assisted history matching, model-based optimisation, data analysis, code development, and CCS.



Earth Science in CSSR

AUTHOR CHRISTIAN HAUG EIDE

Geoscience plays a crucial role in achieving net-zero targets by understanding reservoir structures, seals, and potential leakage pathways for subsurface storage. It predicts properties beyond measurement points and assesses how reservoir heterogeneities affect performance. It also elucidates subsurface "plumbing systems" and the size and geometry of traps for storage.

At the Department of Earth Science, PhD candidates Kirabo Mugwanya and Catherine Amusugut are advancing geoscience projects affiliated with CSSR. The CSSR PhD projects explore: 1) the properties and storage potential of the Triassic succession on the Horda Platform, and 2) how sedimentary heterogeneity impacts reservoir performance under intermittent production.

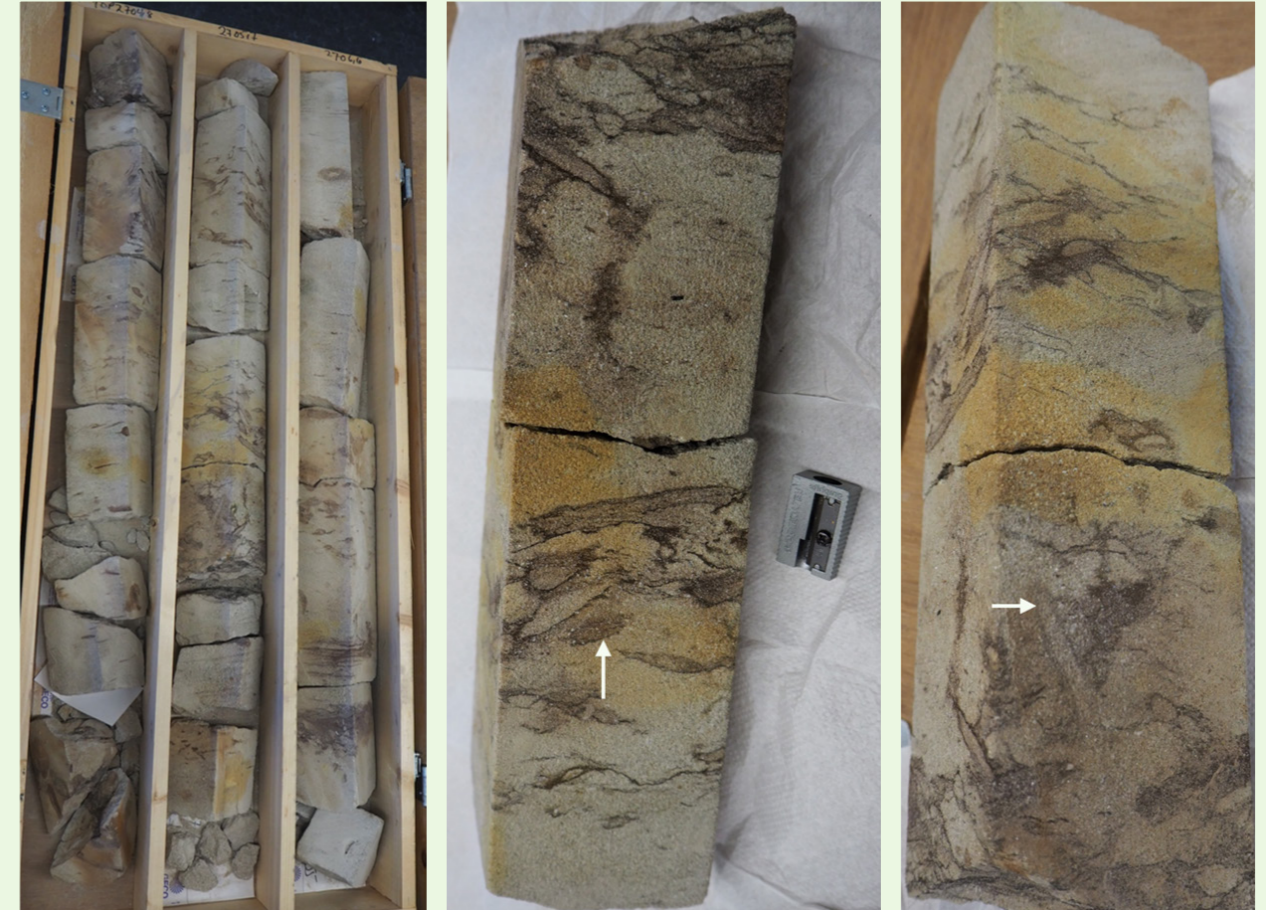
Project 1: Reservoir properties of the Triassic Succession on the Horda Platform

Kirabo Erismas Mugwanya, midway through his PhD, investigates the Triassic succession on the Horda Platform. This interval lies just below the Northern Lights project storage intervals and could significantly enhance storage capacity. His research addresses

the currently poorly understood aspects of reservoir quality and connectivity. Kirabo is finalising his subsurface interpretations and beginning to write his PhD papers, focusing on sedimentary facies, reservoir properties, and sandbody connectivity in the Triassic interval of the Horda Platform.

Project 2: Influence of sedimentary heterogeneity on intermittent production

Six months into her PhD, Catherine Amusugut explores the impact of sedimentary heterogeneity on intermittent production in hydrocarbon reservoirs—a strategy to reduce carbon emissions by aligning hydrocarbon infrastructure operations with renewable or grid power availability. Catherine's initial work involves data assembly, modelling strategies, and understanding relevant stratigraphy. Her forthcoming models will conceptually test how sedimentary geometries and properties of various clastic reservoirs affect intermittent production. Future phases will simulate intermittent production in North Sea fields using real data.



Core data from the Triassic of the Horda Platform under investigation by CSSR PhD student Kirabo Erismas Mugwanya.



Christian Haug Eide is a professor of sedimentology at the Department of Earth Science. He works on using diverse datasets to solve broad and applied problems, especially in the subsurface in sedimentary basins.

Stakeholder engagement

Joint Industry events

Engaging with CSSR industry partners is crucial for enhancing collaboration and ensuring that the centre's research aligns with industry priorities. Close interactions help identify knowledge gaps, update work plans, and develop new projects. A key venue for partner interactions is the yearly partner workshop, which was held on May 7-8, 2024, in Bergen. The event combined scientific presentations with breakout group sessions, providing valuable insights on aligning multiscale modelling and simulations with laboratory work and driving digital innovations forward to ensure industry adoption.

CSSR hosted a hybrid Joint Industry Workshop in Bergen on April 16, 2024, focusing on data-driven approaches for improving modelling, simulation, and optimisation. With nearly 40 participants, including researchers, operators, and service providers, the workshop facilitated fruitful exchanges between industry leaders and CSSR's machine learning experts. Feedback was overwhelmingly positive, and the event concluded with a social gathering, leaving participants inspired and satisfied.



From left: Carl-Jörg Petersen (WDEA), Tor Harald Sandve (NORCE), Martin Fernø (UiB), Sarah Gasda (NORCE), Peter von Schultendorff (UiB), Kristine Spildo (UiB), Ketil Djurhuus (NORCE), Ingrid Anne Munz (NFR), Aina Berg (NORCE), Tongtong Yu (NORCE), Rune Volla (NFR). Photo by Maya Havre (NORCE)



Participants at the CSSR Partner workshop engaged in productive discussions during breakout group sessions. Photo by Apoorva Bharadwaj.

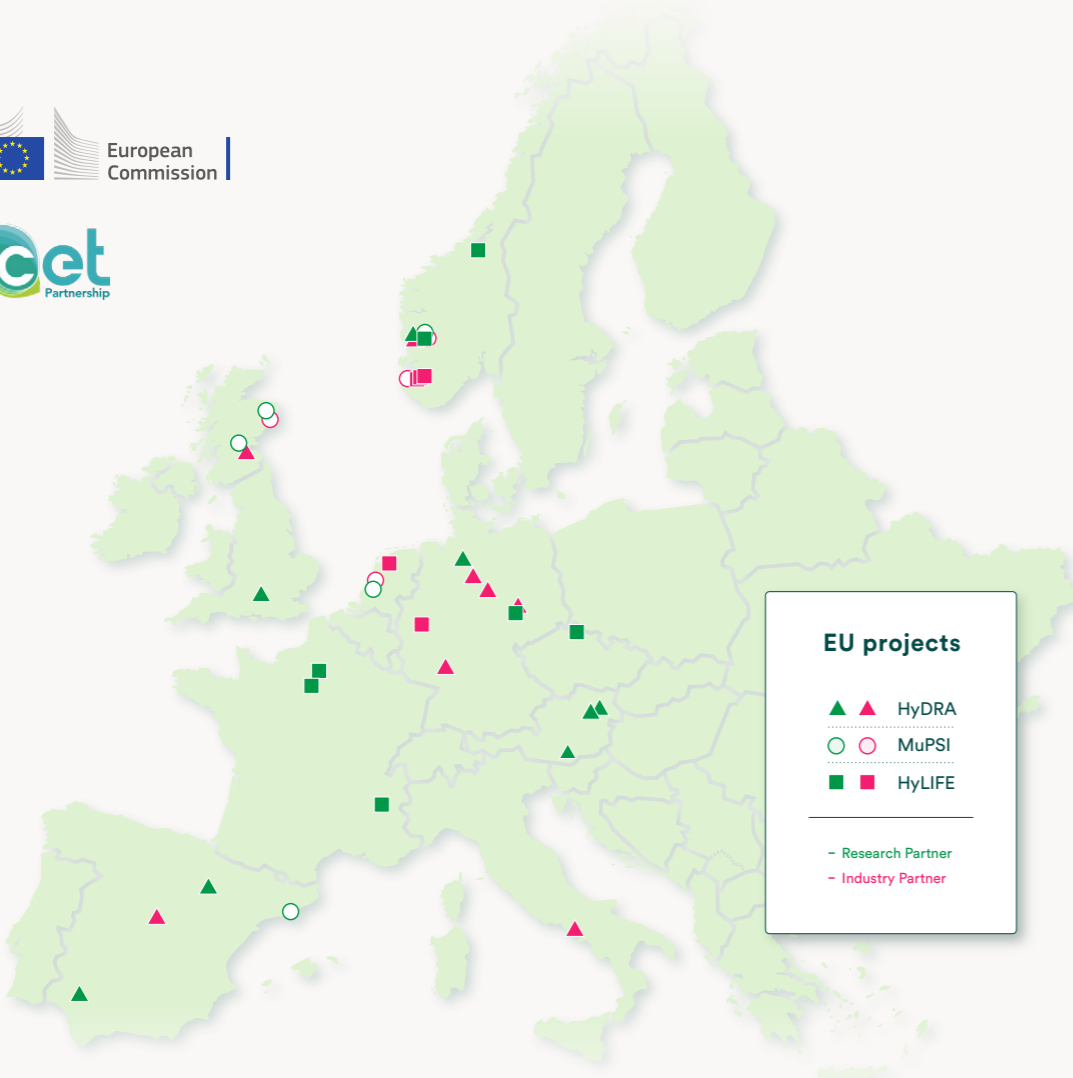
Engagement with government agencies

In 2024, CSSR also engaged with key stakeholders. In March, CSSR hosted a site visit with Ingrid Anne Munz and Rune Volla from the Research Council. Centre Management highlighted CSSR's achievements, and the CSSR Chairman emphasised the significant contributions of the centre's results to the industry. The visit included a tour of the FluidFlower facilities and a poster session where PhD students showcased their work.

CSSR management and key researchers met with Norwegian Offshore Directorate and Petoro to discuss ongoing projects. These meetings are invaluable for obtaining expert feedback and ensuring alignment with industry standards. Their insights help refine our research and development efforts, contributing to the success of our energy and environmental initiatives.

Success in EU projects

AUTHOR MARTIN FERNØ



CSSR is excited to announce the acquisition of competitive EU research funding, highlighting our commitment to advancing crucial topics for Norway, industry partners, and collaborators. This funding will support innovative projects in underground hydrogen storage, microbial activity related to hydrogen storage, and multi-site regional CO₂ storage integrity.

Securing EU funding validates the innovative nature of our research and bolsters our impact on global climate change mitigation and energy transition efforts. These projects align with CSSR's mission to develop sustainable subsurface solutions, keeping Norway at the forefront of scientific and technological advancements. Collaboration with industry and research partners will enhance the practical applications and societal benefits of our work, driving progress toward a sustainable future.

The HyDRA project (Horizon Europe)

The HyDRA project addresses the need for comprehensive knowledge of microbial, geochemical, and flow dynamics to develop guidelines and regulations for underground hydrogen storage (UHS). By characterising hydrogen-consuming microbial activity and interactions with storage formations, and developing methodologies, ISO standards, and science-based recommendations for UHS, the project will support acceleration of European UHS deployment.

The MuPSI project (CETP)

Large-scale CO₂ storage involves several projects sharing a single regional aquifer, where one site's decisions can increase fault-related risk for the other projects. The MuPSI-CETP project aims to develop advanced tools to analyse and simulate pressure-stress dynamics across regional-, project- and fault- scales. NORCE and UiB are collaborating on education and open-source software development. The consortium includes CSSR partner Equinor who collaborates on fault characterisation experiments and modelling.

The HyLIFE project (CETP)

To reduce risks and improve decision-making for UHS, the HyLife-CETP project has successfully processed over 40 samples from reservoirs and salt caverns across 8 European countries in the first year, aligning sampling and analytical methods between partners. These results are used to assess geochemical relationships, test microbial-mitigation strategies and inform risk-related economic business model in collaboration with industry partners.



Martin Fernø is professor at the Department of Physics and Technology at the University of Bergen and an experimental researcher working on multiphase flow in porous media, currently focusing on CCS and hydrogen. Fernø is one of the centre deputies of CSSR and leads Focus Area 1.

Summer schools

Research stay at TNO

PhD student Mathias Mathlie Nilsen (WP3) was hosted by TNO in Utrecht in the fall 2024. He collaborated with Dr. Olwijn Leeuwenburgh on developing workflows for integrating wind power variability into reservoir management, where upscaled reservoir models are used to accelerate the optimisation. The results are promising and will be presented at the 2025 EAGE Annual Conference in Toulouse, France.



Mathias Methlie Nilsen with his girlfriend in the Netherlands



“

I am grateful to the Petroleum Research School of Norway (NFiP) for the travel grant that helped support my three-month collaboration visit at TNO. This experience has been incredibly fruitful in advancing my PhD research. I was also lucky enough to bring my girlfriend with me on my trip.

During our time in the Netherlands, we stayed in the beautiful city of Amersfoort. In the weekends we got to explore all the major cities of the country and even spent a weekend in Brussels.”

Mathias Methlie Nilsen | PhD student

Summer School Participation

CSSR PhD students, postdocs and early-career researchers have many opportunities to increase their competence at research schools and present their work at major international conferences and national industry-oriented events. Their contributions and achievements highlight the strong support for research and professional development at CSSR.

These prestigious programmes provided invaluable learning experiences and networking opportunities for our students, significantly contributing to their academic and professional development.

NORA Summer School on AI methods (University of Agder): Kirabo Erismas Mugwanya (WP1)

CCS Summer School (TU Delft): Eda Önal (ExpReCCS PhD)

Adaptive Computational Methods Summer School (Hasselt University): Peter von Schultendorff WP 5

UiB Porous Media Group Study Tour (multiple locations): Peter von Schultendorff (WP5) and Eda Önal (ExpReCCS PhD)



Kirabo Erismas Mugwanya at the NORA summer school in UoA.



From Left (PhD and Master students at PMG): Yuhe Zhan, Simon Strandenes, Ruben Tjore Wespestad, Tor Erik Wollmann, Daniel Førland Holmen, Jakob Seierstad Stokke, Marius Nevland, Ingrid Kristine Jacobsen and finally CSSR Phd Students Eda Önal (Associated) and Peter von Schultendorff (WP5).

Dissemination at industry events

CSSR participation and contributions at industry-oriented events in Norway is an important means of encouraging knowledge sharing and promoting implementation of key results, methods, and products beyond the centre. CSSR focused efforts towards several key events hosted by industry associations: Society of Petroleum Engineers, FORCE network, and Norwegian Petroleum Society (NPF).

SPE Norway Subsurface Conference

CSSR and associated projects ExpReCCS and PoroTwin contributed with five papers at this highly relevant industry conference hosted annually in Bergen, Norway. The presented results included digital rock physics simulations of intermittent injection (WP1), salt precipitation in cyclical CO₂ storage (WP2), and data-driven modelling of CO₂-EOR (WP2). Conference proceedings are available for all SPE members, further encouraging broad dissemination of CSSR results.

FORCE: Joining Forces - Solving the Energy Challenges Together

FORCE is a cooperating forum conducted by oil and gas companies and authorities in Norway. It hosts a biannual one-day seminar at the Norwegian Offshore Directorate's locale in Stavanger aimed at enhancing collaboration between the energy industry and academic institutions. Eleven participants, including several NORCE PhD students, presented posters on improved exploration, sustainable recovery, and energy efficiency. The event fostered valuable R&D discussions. Centre director Sarah Gasda served on the programme committee.



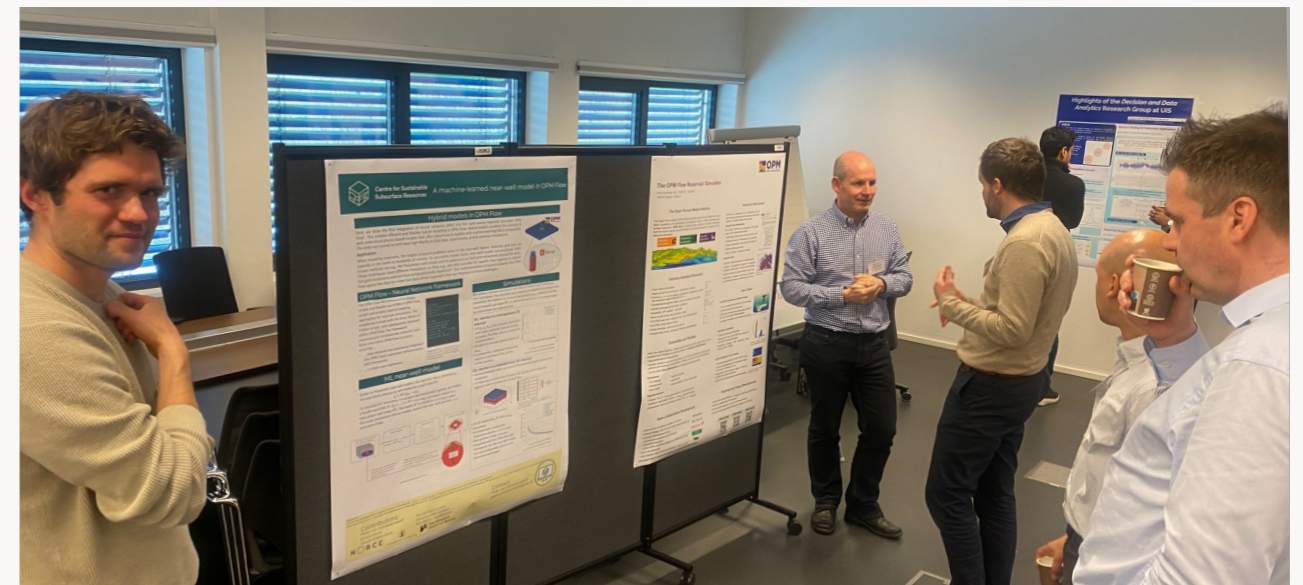
CSSR WP1 leader Espen Jettestuen chatting in the break at SPE Norway conference. He presented new results on pore-scale simulation workflow for improved characterisation of hysteresis in saturation functions at low capillary numbers.

NPF conference on Reservoir and Production Management

The three Petrocentres LowEmision, NCS2030 and CSSR were invited to Sola to give presentations at the bi-annual industry conference. Centre director Sarah Gasda presented on “Wind-power oil production” which is the work in WP3 of PhD student Mathias Methlie Nilsen, NORCE researchers Rolf Johan Lorentzen and Andreas Stordal, and TNO collaborators Olwijn Leeuwenburgh, Eduardo Barros. The presentation presented a new strategy to fine-tune short-term production optimisation using 30-day wind forecasts to substantially reduce emissions without significant NPV reduction.



NCS2030 and CSSR meet at NPF: Geir Evensen and Ying Guo represented NCS2030 and NORCE at the NPF conference, pictured here together with Centre director Sarah Gasda.



CSSR had several posters at the Joining Forces conference hosted by the FORCE network and NOD Photo: Sarah Gasda

International conference contributions

CSSR contributed to 15 international conferences and workshops in 2024, providing valuable opportunities for researchers and students to communicate results to the wider academic community. Notable events included the 16th Annual Meeting of InterPore in Qingdao, China, the EAGE European Conference on the Mathematics of Geological Reservoirs (ECMOR) in Oslo, Norway, and the 17th International

Conference on Greenhouse Gas Control Technologies (GHGT-17) in Calgary, Canada.

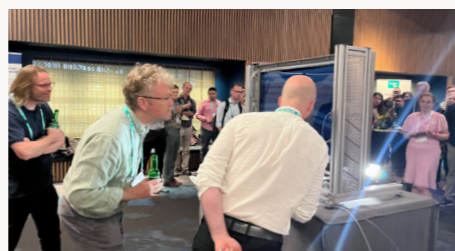
ECMOR 2024 featured numerous CSSR contributions: four conference papers, two invited speakers, and a FluidFlower live CO₂ demonstration. CSSR SAC member Stephan Matthai was the ECMOR conference co-chair and was instrumental in organising the popular topical workshop on CCS.



NORCE researchers at GHGT-17: Trine Mykkeltvedt, Kirsti Midttømme, Alexey Khrulenko, Roman Berenblyum, Sarah Gasda, and Arvid Nøttveit.

Travel Grants awarded

Our early career researchers and PhD students are proactive in seeking additional grants outside of CSSR to support and enhance their research endeavors. Notable recipients include Peter von Schultzendorff (UiB) receiving grants from **UiB's Meltzer Fund Norwegian Formation Evaluation Society** and David Landa Marbán (NORCE) InterPore2024 Travel Grant.



Expert panelists and invited speakers: Jan Martin Nordbotten (UiB), Philip Ringrose (NTNU), Odd Andersen (SINTEF), David Pauling (OGS), Stephan Matthai (Uni Melbourne), Sarah Gasda (NORCE). Top right: ECMOR attendees getting a closer look at the FluidFlower. Bottom right: Kristoffer Eikehaug (UiB), Jan Martin Nordbotten and Arne Skorstad (Halliburton) engaged in mathematical discussions.

“ I am extremely appreciative of additional funding from UiB's Meltzer Fund, Climate and Energy Transition Fund, and the Norwegian Formation Evaluation Society's student travel grant. This support enabled me to attend conferences and workshops to present my research, learn about the latest advancements, and connect with other researchers.”

Peter von Schultzendorff | UiB



Peter von Schultzendorff WP5 PhD student presenting at the ECMOR 2024 conference in Oslo.

In the Spotlight



New PostDocs and PhD in 2024



Name | Antoine Lechevallier
Affiliation | Computational Geosciences and Modelling, NORCE
Nationality | French
PostDoc period | 2024–2026
Project | Enhancement of reservoir simulations through data-driven approaches

How is it to be a Postdoctoral researcher in NORCE/CSSR?

Being a Postdoctoral researcher in NORCE/CSSR means advancing your expertise, building independence, and contributing impactful research that bridges your Ph.D. to the next stage of your career.

Any plans for the future? Where do you see yourself in 5 years career-wise?

Ideally, I envision myself as a researcher in a research institute, developing collaborative projects with academia and industry to advance scientific machine learning, particularly in reservoir simulation. I also aspire to supervise students, including both PhD and Master's students.



Name | Verena Nikeleit (Associate Postdoc)
Affiliation | Subsurface Energy Solutions, NORCE
Nationality | German
PostDoc period | 2024-2026
Project | MOCHyS, Microbial Opportunities and Challenges in Underground Hydrogen Storage

What sparked your interest in geomicrobiology?

I am fascinated what those little guys are able to do. Have you seen a microbe under the microscope? They are so tiny, and still, they are able to shape our world, play important roles in geochemical reaction and can use a lot of different things to grow on.

How is the relation to CSSR?

Potential underground hydrogen storage reservoirs are found on the Norwegian Continental Shelf in porous reservoirs. They are defined by a variety of chemical, physical properties and diverse microbial community. The project MOCHyS uses field brine samples provided by Equinor and Total Energies and examines how active these microbes are in consuming hydrogen.



Name | Catherine Padde Amusugut
Affiliation | Department of Earth Science, University of Bergen
Nationality | Ugandan
Period | 2024–2027
Project | Investigating the Influence of Geological Heterogeneity on Multiphase Fluid Flow During Intermittent fluid flow

What is your thesis focused on?

My thesis investigates the influence of geological heterogeneity on multiphase fluid flow during intermittent production and injection. It aims to model multi-scale heterogeneity and simulate fluid flow under fluctuating flow conditions in key Jurassic and Palaeocene reservoirs in the Norwegian North Sea to understand their response to intermittency introduced when using renewable energy sources to power petroleum operations.

What effect could the results of your thesis have on the field of which you are researching?

The results could significantly improve the understanding of reservoir behaviour under intermittent injection and production, providing insights to optimise energy-efficient petroleum strategies. This research aligns with the broader goal of achieving near-zero greenhouse gas emissions for operations on the Norwegian continental shelf by 2050.

CSSR Industry Partner

Earth Science Analytics AS

Earth Science Analytics (ESA) is an innovative software company with proven technology and solutions that enables and accelerates the ongoing digitalisation of the energy industry. It was formed in 2016 to create the next generation of subsurface technologies and workflows.

AUTHOR DR. BEHZAD ALAEI

As one of the pioneers in implementing data liberation and AI-assisted studies in subsurface geoscience, ESA has collaborated with different stakeholders including regulators and global energy companies. Its expertise spans digitalisation, data liberation and management, carbon capture storage (site selection and monitoring), and aiding exploration and field development. ESA has managed data from regions worldwide, including the Gulf of Mexico, the Middle East, Norway, UK and Asia Pacific.

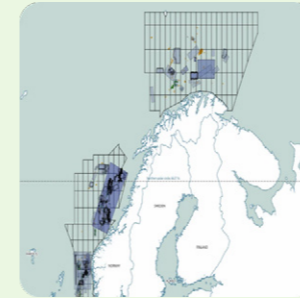
The solutions and Implementation Services

are offered in the form of consultancy, multiclient products and software licensing. Examples of work that can benefit from ESA's expertise and technology:

- Data ingestion to the OSDUTM Data Platform
- Predicting overlooked hydrocarbons

- Optimising production from existing fields
- CCS site screening
- CCS characterisation and de-risking
- Offshore wind farm placement
- Integrated E&P studies

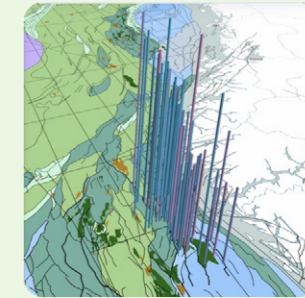
EarthNET by Earth Science Analytics offers a fully integrated cloud-native, suite of AI-driven geoscience tools. It is more than just a geoscience software. It is designed to revolutionise the way you work. Using cloud technology, high-performance computing, and artificial intelligence EarthNET helps you leverage the power of subsurface data to drive innovation and accelerate your geoscience workflows, it includes:



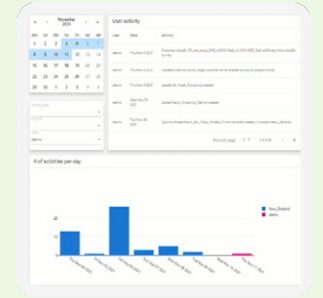
Data Lake



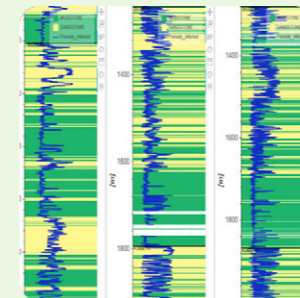
Viewer



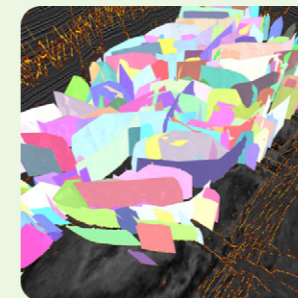
Insights



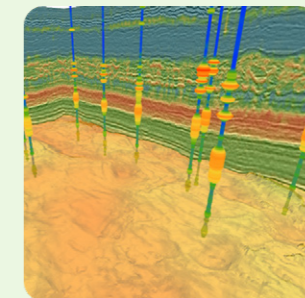
Dashboard



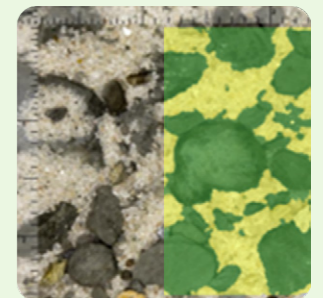
AI Wells



AI Seismic Interpretation



AI Seismic Properties



AI Images



Behzad Alaei is the co-founder and CPO at ESA, has 30+ years experience in the E&P industry and research. He holds a Ph.D. in Geophysics from the University of Bergen and specializes in leveraging data science to optimise key processes in geosciences.



Industry collaboration on advanced imaging

AUTHOR GEIR ERSLAND

Prof. Geir Ersland at UiB and Equinor have closely collaborated for several years on advanced imaging of fluid rock interactions using Magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR). Raymond Mushabe is the fourth PhD that will take advantage of the very sophisticated instrument to study underground hydrogen (H₂) flow and storage and the role of microbial activity. Storing hydrogen in porous geological formations underground leverages technology developed from natural gas storage in old natural gas fields and aquifers. However, since H₂ and natural gas have different properties, new knowledge is required. The remedy lies in the capable hands of Raymond and a 4.7 Tesla MRI at Equinor.

MRI is a technique using strong magnetic fields, magnetic gradients, and radio waves to create detailed 3D images. The radiofrequency coil (RF-coil) located inside the MRI-scanner uses radio waves to excite protons to a higher energy state. The re-emitted energy is detected, and the signal decay or relaxation time is used to identify the density, location

and molecular structure and environment of the H₂ atom. Applications of MRI in clinical studies of water or fat in the human body has been key in the development of medical imaging and diagnostics. State-of-the-art medical MRI can map blood flow in veins and spatially resolve oxygen transport and activity in the brain. Adapting these techniques for flow and transport of fluids in sedimentary systems can provide valuable data, especially to characterise development of biomass that



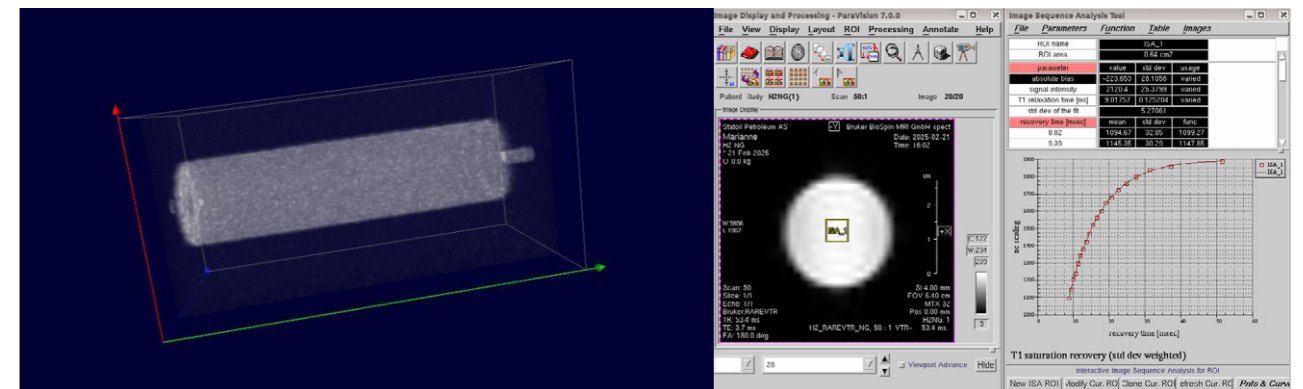
CSSR PhD student **Raymond Mushabe** running tests at the Equinor MRI-lab in Sandsli, Bergen.

thrives on H₂ gas. However, it is more challenging with mineral grains present.

MRI for H₂ gas has been more of a curiosity with very few scientific studies available in the open literature. The high self-diffusion coefficient and short-lived signal makes it challenging, but with tuned MRI protocols we have captured a high-quality signal from H₂ gas at moderate pressures. These measurements will be very helpful to study diffusive transport of H₂ and gas mixing in storage reservoirs but can also help closing knowledge gaps across the H₂ value chain.

“This collaboration is of mutual benefit, it is very valuable for Equinor to have access to expertise from UiB and CSSR, and valuable for students and staff to use advanced imaging in their research.”

Dr. Marianne Steinsbø | MRI-lab at Sandsli



H₂ gas was scanned in the MRI-lab at Sandsli. High quality signal showing 3D image of hydrogen gas at 100 bar (upper) and high precision measurements of NMR fluid properties.



Geir Ersland is a Professor at the Department of Physics and Technology, University of Bergen. His research encompasses experimental and some numerical studies of flow and phase transitions in porous media applied to Gas hydrates, CO₂ storage, CCUS, hydrogen, and energy storage.



Radial Flow Lab

AUTHORS KETIL DJURHUUS, ABDULJELIL KEDIR AND BEHRUZ SHAKER SHIRAN

At CSSR, a central part of our research aim is to improve our understanding of how increasingly dynamic flow regimes impact multiphase fluid flow. A key part of this is exploring how the reinjection of produced water and the resulting changes in water quality and injection patterns affect reservoir injectivity. We approach this by combining novel and traditional experimental techniques with multiscale modelling and numerical simulation.

On a real field, the flow out of the injection well follows a radial flow pattern. To improve our understanding of how particle filtration and deposition influence the continuously

decreasing flow rate in the near-well region, we apply a unique radial flow model for experimental verification. The model employs cylindrical discs of core material embedded in epoxy coating to contain fluids, with up to 10 pressure ports typically spaced logarithmically away from a central injection point representing the injection well. Closely spaced pressure monitoring near the injection well allows us to pinpoint the depth of penetration for particles of different sizes. Using the full distribution of sensors, we can apply the Darcy equation in radial form to determine both local and overall permeabilities.

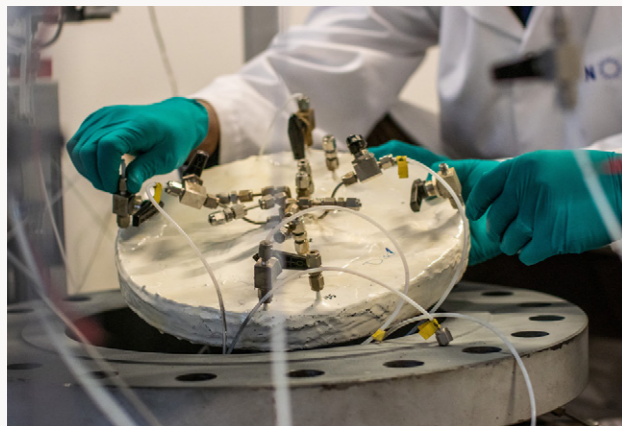
The radial models offer unique insights into the effects of pressure transients on near-well behavior. In addition to particle settling and clogging, this applies to all processes influenced by the balance between hydrodynamics, kinetics, and equilibrium processes, including all aspects of non-Newtonian flow, such as polymer flow or gel treatments.

To achieve flow rates representative of real well conditions, the radial models can be placed in a large, pressurised chamber. This chamber allows us to apply overburden pressure up to 40 bars.

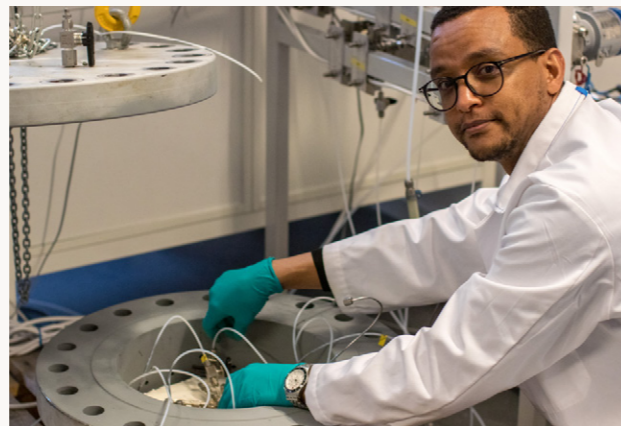


Behruz Shaker Shiran and Abduljelil Kedir prepare sample for the radial model.

PHOTOS RUNE ROLVSJORD | NORCE



The radial model allows 10 independent pressure ports to capture the logarithmic pressure distribution.



Abduljelil Kedir secures the sample in the pressure chamber.



Abduljelil Kedir is a senior researcher at NORCE and holds a PhD in Chemistry. His current research interests focus on experimental studies of microbial risk during underground hydrogen storage, CO₂ storage, and development of analytical/physical methods for material characterisation. He is a project member of work package 1.

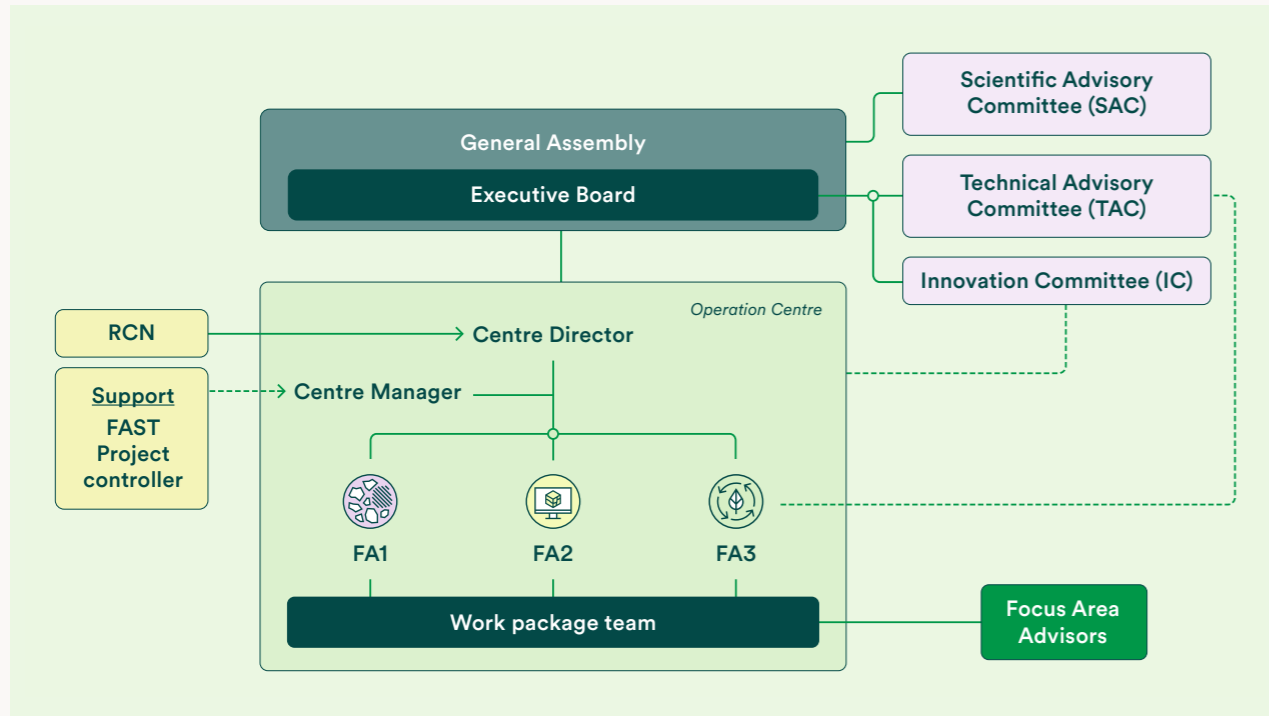


Behruz Shaker Shiran is a senior researcher at NORCE. He holds an MSc in Petroleum Engineering from the University of Kansas, and a PhD in Petroleum Technology from the University of Bergen. He has been with Uni Research/NORCE since 2010, focusing on experimental studies of fluid flow in porous media, enhanced oil recovery and subsurface hydrogen storage.

CSSR Facts



Governance Structure



CSSR strengthened its routines for monitoring and managing progress in its third year of operation and fostered good cooperation between the centre management team (CMT), the governing bodies, GA and EB, and advisory bodies.

- SAC second external review of the centre’s scientific strategy and output was approved by the GA. The CMT will work to implement SAC recommendations in 2025.

- TAC reviewed the 2025 CSSR Annual Working Plan to ensure industry relevance and impact was incorporated in the final plan approved by the board and RCN.
- IC created the CSSR Idea Pool, an online platform for collecting innovative proposals from the WP team. The IC assesses submissions and assists in the next steps.
- CMT publishes a biannual newsletter to keep consortium partners informed about centre activities and developments.

In 2024

Executive Board

Geir Terje Eigestad Chair Harbour Energy	Camilla Vavik Pedersen Equinor	Aina Berg NORCE
	Øyvind Frette University of Bergen	Maria Eide* The Research Council of Norway (RCN)

* observer

EB update

We welcome Geir Terje Eigestad as the new chair and Harbour Energy representative on the Executive Board from June 2024, and Maria Eide as Observer from the Research Council of Norway. Thank you Carl Jörg Petersen and Ingrid Anne Munz for your valuable contributions since CSSR's inception.

TAC update

In September 2024, Pit Arnold (Harbour Energy) became TAC Chair, with Bastian Koehrer (Harbour Energy) as Deputy Chair. CSSR deeply appreciates their valuable contributions.

Technical Advisory Committee (TAC)



Pit Arnold is a simulation engineer in Digital Rocks with a PhD in Petroleum Engineering. He joined Harbour Energy in 2023 at their Technology and Service Centre in Germany. His research focuses on pore scale physics, multiphase flow modelling, and multiscale imaging in porous media. He also serves as a visiting lecturer at Montanuniversität in Leoben.

Operation Centre



From left: Martin Fernø (Centre Deputy), Biwen An-Stepec (WP2 leader), Ketil Djurhuus (Centre Deputy), Espen Jettestuen (WP1 leader), Tor Harald Sandve (WP4 leader), Sarah Gasda (Centre Director), Trine Mykkeltvedt (WP6 Leader), and Jakub Wiktor Both (WP4 Deputy).

PHOTO RUNE ROLVSJORD | NORCE

Centre Management Team

Role	
Centre Director	Sarah Gasda
Deputy Director	Martin Fernø
Deputy Director	Ketil Djurhuus
Centre Manager	Maya Havre
Financial officer	Alexander Isaksen
Communications advisor	Ida Sollesnes

In 2024, CSSR has streamlined its management structure to secure optimal efficiency and progress. Building on experiences from the first years of operation, work packages 4 and 5 have been merged to allow closer scientific interactions while reducing overhead costs. Moreover, the Centre management team (CMT) has been reduced to two Deputy directors.

Work Package Team

	Work package	Lead	Deputy
1	Energy-efficient and effective reservoir drainage	Espen Jettestuen	Kundan Kumar
2	Short-cycle energy storage efficiency	Biwen An-Stepec	Geir Ersland
3	Optimisation and data assimilation	Rolf Lorentzen	Kjersti Solberg Eikrem
4/5	Data-driven models in reservoir simulation	Tor Harald Sandve	Jakub Wiktor Both
6	Sustainable re-use of depleted fields	Trine Mykkeltvedt	Roman Berenblyum

CSSR Research Partners

The CSSR consortium is led by NORCE and the University of Bergen (UoB), both of which are prominent in subsurface resource research. The consortium also includes five internationally recognised research and development institutes from Europe and the United States, in addition to six Norwegian industry partners. The centre fosters collaboration

with international and industrial partners. Its research activities encompass experiments and modelling studies that produce co-authored publications. CSSR facilitates collaboration through regular workshops, joint supervision of PhD students, invited lectures, and researcher exchange programmes.

Norwegian Research Partners



International Research Partners



Norwegian and International Industry Partners

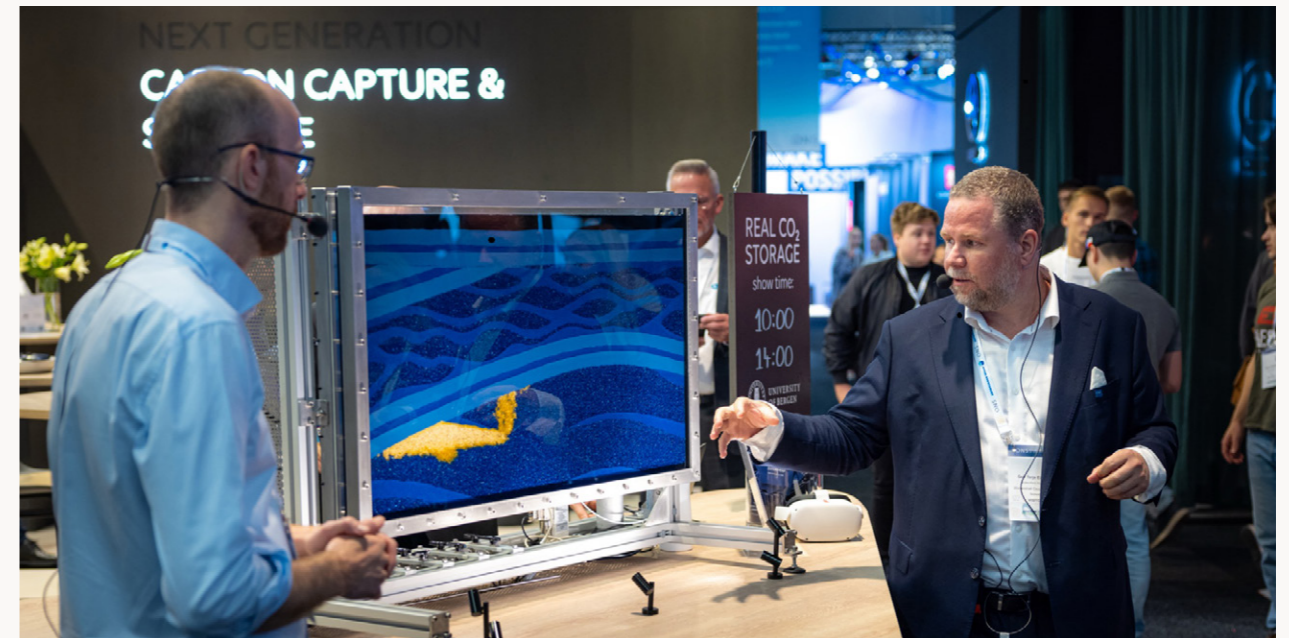


CSSR is financed through the Research Centre for Petroleum Programme of the Research Council of Norway (Grant Number #331841)

FluidFlower Travels in 2024

FluidFlower continues to captivate audiences worldwide with its innovative approach to fluid dynamics and geological carbon storage. This year, our journey includes participation in several prestigious events. We are proud to have the support of CSSR, which bolsters our efforts in advancing research and dissemination. Join us as we showcase the remarkable impact of FluidFlower and its contributions to sustainable carbon storage solutions!

- Teacher's Day @ UiB (Jan 26)
- EFTA house Brussels (Jan 30)
- Hannover Messe (April 22-26)
- EAGE Annual Conference & Exhibition (June 9-14)
- ONS (August 26-29)
- ECMOR (September 2-5)
- Annual CSSR meeting (September 18-19)
- NPF Carbon Capture and Storage Conference (December 4-5)



Martin Fernø (Centre Deputy) and Geir Terje Eigestad (CSSR Chair of the Board) giving a live demonstration of the FluidFlower at the Harbour Energy stand at ONS in Stavanger.

Key figures

The 2024 Annual Work Plan was ambitious, featuring dozens of deliverables across all work packages. The CSSR team successfully achieved its milestones and goals, demonstrating significant progress towards our planned objectives. The collective efforts and dedication of the team played a crucial role in fulfilling our commitments and advancing our mission.

In 2024, CSSR experienced a notable increase in reported costs, reflecting the expanded scope of our research and operational activities. A new PhD and postdoctoral fellow were hired during this year. Laboratory activities and associated expenditures increased, underscoring our commitment to cutting-edge research.

Researcher engagement intensified, with increased time dedicated to implementing the workplan.

Conference participation reached new heights in 2024, with CSSR researchers and

students presenting at over a dozen major international conferences. This includes a variety of academic presentations, guest lectures at partner institutions, and participation in high-profile panels, further establishing our presence and influence in the global research community.



Collaboration visit with Oregon State University. Back row: Espen Jettestuen (WP1 leader), Raymond Mushabe (PhD), Johan Olav Helland (NORCE), Ketil Djurhuus (Centre Deputy), Martin Fernø (Centre Deputy). Front row: Tongtong Yu (PhD), Hasan Gürsel (PhD), Dorthe Wildenschild (OSU), Na Liu (UiB).

Dissemination

Category	2024
Journal publications	2
Conference proceedings	10
Book or book chapter	2
Presentation and posters	26
Theses	4
Products	4
Media, public outreach	2

For further details on publications, please visit cssr.no

CSSR Cost*

Cost	Amount
The Research Council of Norway	0
NORCE (Host Institution)	13 334
University of Bergen (Research Partner)	7957
Industry Partners	287
International Academic Partners	113
Total	21 691

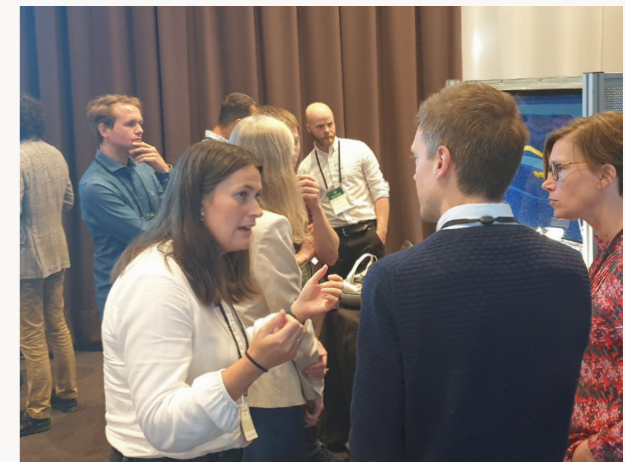
CSSR Funding*

Funding	Amount
The Research Council of Norway	11 352
NORCE (Host Institution)	1 870
University of Bergen (Research Partner)	2 636
Industry Partners	5 833
International Academic Partners	0
Total	21 691

* Figures in kNOK



Martin Blunt from Imperial College London, alongside Eda Önal (UoB), engaged in a pleasant exchange at the CSSR annual conference.



Trine Mykkeltvedt engaged in a lively exchange with attendees at the Annual Conference 2024.

Education and training

A total of eight (8) PhD and postdoctoral fellowships are financed through CSSR, while associated projects ExpReCCS and HyLife support two (2) PhD and postdoctoral researchers, respectively. The fellows are

engaged in various research areas including production optimisation, reservoir physics, hydrogen storage, geosciences, and reservoir simulation. A monthly seminar series is aimed at building presentation skills.

PhDs and Postdocs

Name	Grade	WP	Topic	Period
Mathias Methlie Nilsen	PhD	3	Optimisation	9/2022 – 8/2025
Raymond Mushabe	PhD	2	Reservoir physics experimental	8/2022 – 7/2025
Peter von Schultendorff	PhD	4/5	Reservoir simulation	9/2022 – 8/2026
Tongtong Yu	PhD	1	Reservoir physics experimental	1/2023 – 12/2026
Kirabo Erismas Mugwanya	PhD	1	Geosciences	4/2023 – 10/2026
Hasan Gürsel	PhD	1	Reservoir physics modelling	11/2023 – 10/2026
Catherine Padde Amusugut	PhD	1	Geosciences	7/2024 – 6/2027
Antoine Lechevallier	Postdoc	4	Reservoir simulation	4/2024 – 3/2026
Eda Önal	PhD	ExpReCCS	Reservoir simulation	9/2023 – 8/2026
Verena Nikeleit	Postdoc	MOCHyS	Microbiology	6/2024 – 5/2026

Masters theses in 2024

Name	WP	Supervisor	Exam date	Title
Magnus Dønne Moldekleiv	2	Svenn Tveit (NORCE) & Martin Fernø (UiB)	Jun/24	The Open Porous Media (OPM) Flow reservoir simulator for Underground Hydrogen Storage.
Tuva Maria Hovland Graham	2	Sarah Gasda (NORCE) & Martin Fernø (UiB)	Jun/24	The Effect of Near-Well Heterogeneity on Spatial Distribution of Salt Precipitation during CO ₂ Injection.
Espen Tjessheim	1	Rob Gawthorpe & Tim Cullen (UiB)	Jun/24	Insights Into CO ₂ Storage Using the FluidFlower

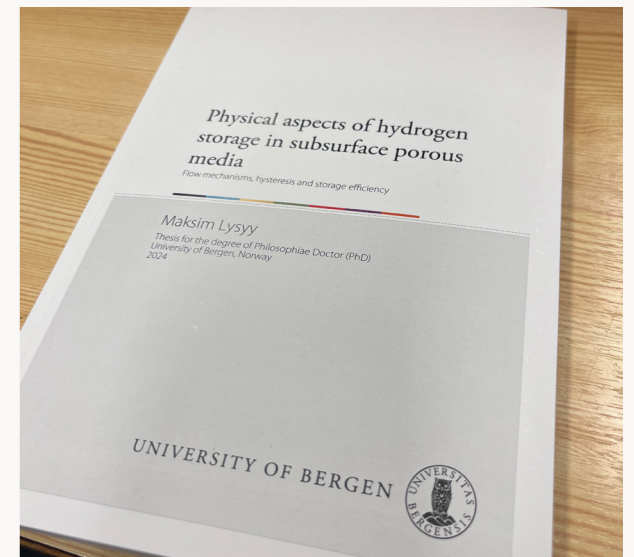


PhD and PostDoc researchers showcased their work through pitches and poster presentations at the CSSR Annual Conference. From left back row: Hasan Gürsel, Antoine Lechevallier, Mathias Methlie Nilsen, Raymond Mushabe. Front row: Tongtong Yu, Kirabo Erismas Mugwanya, Eda Önal, Catherine Padde Amusugu. Not pictured: Peter von Schultendorff and Verena Nikeleit.

The first PhD defense for CSSR associated project marks a milestone achievement. Dr. Maksim Lysyy successfully defended his thesis on underground hydrogen storage at the University of Bergen (UiB). His research, part of the associated project HyPe (NFR grant nr. 325457, characterises flow mechanisms, hysteresis, and storage capacity of hydrogen in porous media. UiB Professors Martin Fernø (CSSR Centre deputy) and Geir Ersland were the main supervisors. Congratulations to Dr. Lysyy on this impressive accomplishment.

Professor Dorthe Wildenschild from Oregon State University, a valued partner, visited Bergen for the annual meeting and conducted a workshop. Her visit focused on strengthening collaboration by integrating experimental work with modelling activities and discussing

potential PhD student exchanges in hydrogen and carbon storage applications. Both her participation in the annual meeting and the NORCE workshop were highly beneficial for CSSR's research initiatives.



First PhD defense for CSSR - Dr. Maksim Lysyy.

Publications

Journal Publications

Boon, M.; Buntic, I.; Ahmad, K.; **Dopffel, N.**; Peters, C.; **Hajibeygi, H.** **Microbial induced wettability alteration with implications for Underground Hydrogen Storage.** *Scientific Reports*, **14**, 8248 (2024).

Benali, B.; **Fernø, M.A.**; Halsøy, H.; Alcorn, Z.P. **A pore-level study of dense-phase CO₂ foam stability in the presence of oil.** *Transport in Porous Media* **151**, 2491–2509 (2024).

***Eikehaug, K.**; Haugen, M.Q.; Folkvord, O.P.; Benali, B.; Bang Larsen, E.; Tinkova, A.V.; **Rotevatn, A.**; **Nordbotten, J.M.**; **Fernø, M.A.** **Engineering meter-scale porous media flow experiments for quantitative studies of geological carbon sequestration.** *Transport in Porous Media*, **151**, 1143-1167 (2024).

*Haugen, M.; Saló-Salgado, L.; **Eikehaug, K.**; Benali, B.; **Both, J.W.**; Storvik, E.; Folkvord, O.P.; Juanes, R.; **Nordbotten, J.M.**; **Fernø, M.A.** **Physical variability in meter-scale laboratory CO₂ injections in faulted geometries.** *Transport in Porous Media*, **151**, 1169-1197 (2024).

*Kovscek, A.R.; **Nordbotten, J.M.**; **Fernø, M.A.** **Scaling up FluidFlower results for carbon dioxide storage in geological media.** *Transport in Porous Media*, **151**, 975-1002 (2024).

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***Gasda, S.E.** How to accelerate towards gigatonne CO₂ storage. *NEXT 2024 - New Energy X Subsurface* (2024).

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***Gasda, S.E.** The role of pressure in deployment of gigatonne CO₂ storage on the NCS. *BRU21 Conference 2024* (2024).

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* Keynotes and invited talks

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An-Stepec, B.; Dopffel, N.; Tveit, S.; Hiorth, A.; Heydolph, B.; Gasda, S.E.; Djurhuus, K. Understanding the role of microorganisms within underground hydrogen storage. *InterPore Norway 2024 Annual Workshop* (2024).

Gasda, S.E. Subsurface H₂ storage simulation tools. *Oslo Hydrogen Seminar* (2024).

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An-Stepec, B.; Wunch, K.; Skovhus, T.L. *Petroleum Microbiology: The Role of Microorganisms in the Transition to Net Zero Energy*. CRC Press (2024).

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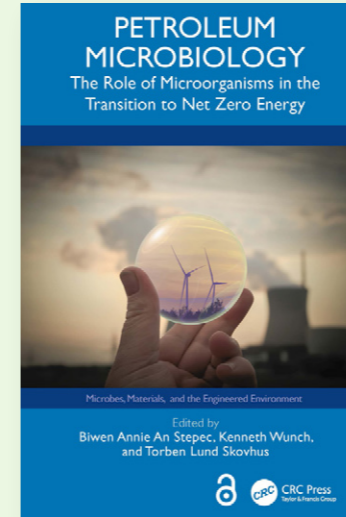
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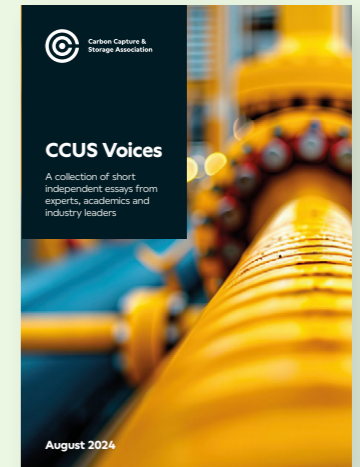
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Lysyy, M. *Physical aspects of hydrogen storage in subsurface porous media*. *University of Bergen* (2024).

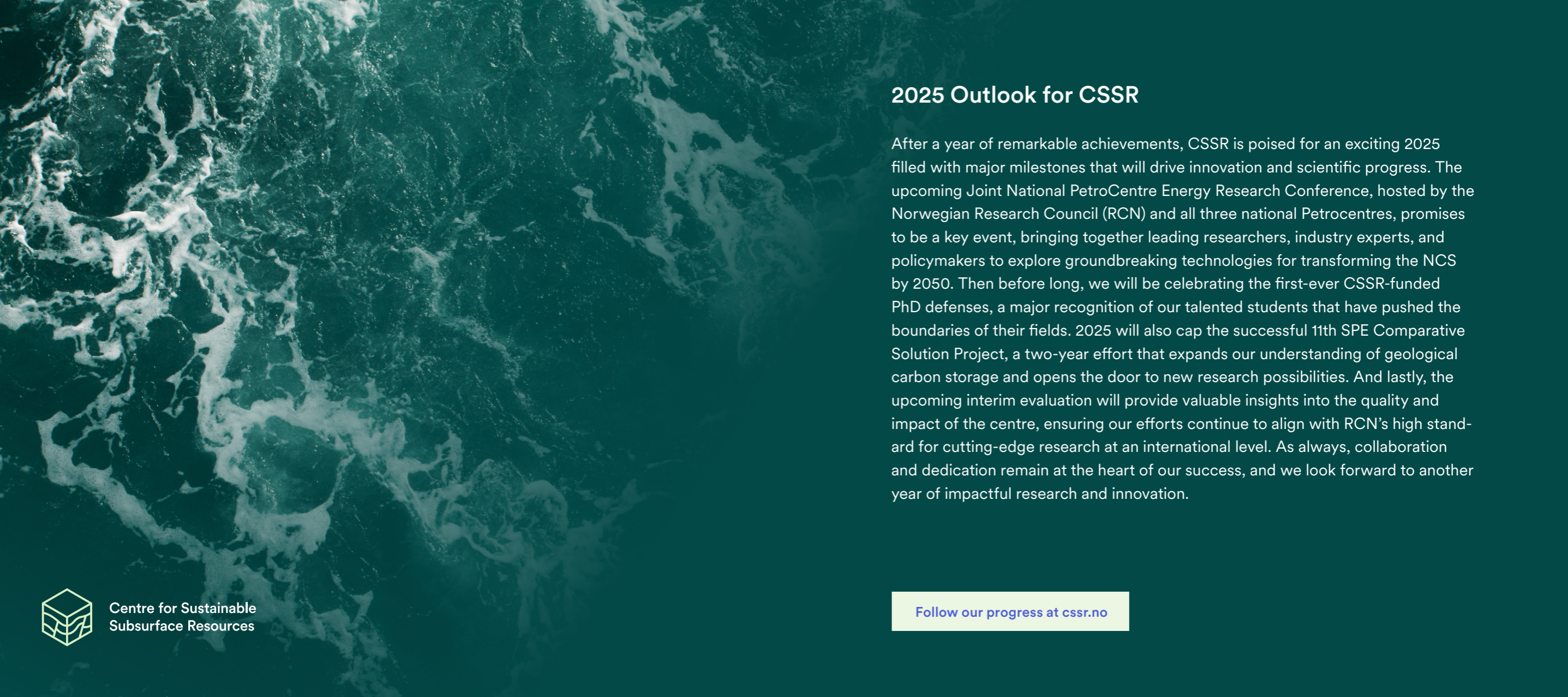


This book explores the pivotal role of microorganisms in transitioning from oil and gas to renewable energy. It delves into advances in applied microbiology addressing issues like oil field souring, corrosion, and biofouling. Highlighting knowledge transfer to renewable systems, including underground hydrogen storage, it underscores microorganisms' critical role in achieving net zero energy goals. Featuring contributions from CSSR experts Sarah E. Gasda, Biwen Annie An Stepec, Nicole Dopffel, and Na Liu, this book aligns with CSSR's key focus areas.

The CCUS Voices publication brings together insights from industry leaders, academics and experts, to underscore the pivotal role of CCUS in the UK and EU's transition to a low carbon economy and the associated economic benefits. Centre director Sarah Gasda shared her long-term vision for CO₂ storage to meet ambitious climate goals – *“A rising tide lifts all boats – sharing and collaborating will ensure a smooth path to gigaton storage.”*



Outlook



2025 Outlook for CSSR

After a year of remarkable achievements, CSSR is poised for an exciting 2025 filled with major milestones that will drive innovation and scientific progress. The upcoming Joint National PetroCentre Energy Research Conference, hosted by the Norwegian Research Council (RCN) and all three national Petrocentres, promises to be a key event, bringing together leading researchers, industry experts, and policymakers to explore groundbreaking technologies for transforming the NCS by 2050. Then before long, we will be celebrating the first-ever CSSR-funded PhD defenses, a major recognition of our talented students that have pushed the boundaries of their fields. 2025 will also cap the successful 11th SPE Comparative Solution Project, a two-year effort that expands our understanding of geological carbon storage and opens the door to new research possibilities. And lastly, the upcoming interim evaluation will provide valuable insights into the quality and impact of the centre, ensuring our efforts continue to align with RCN's high standard for cutting-edge research at an international level. As always, collaboration and dedication remain at the heart of our success, and we look forward to another year of impactful research and innovation.



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