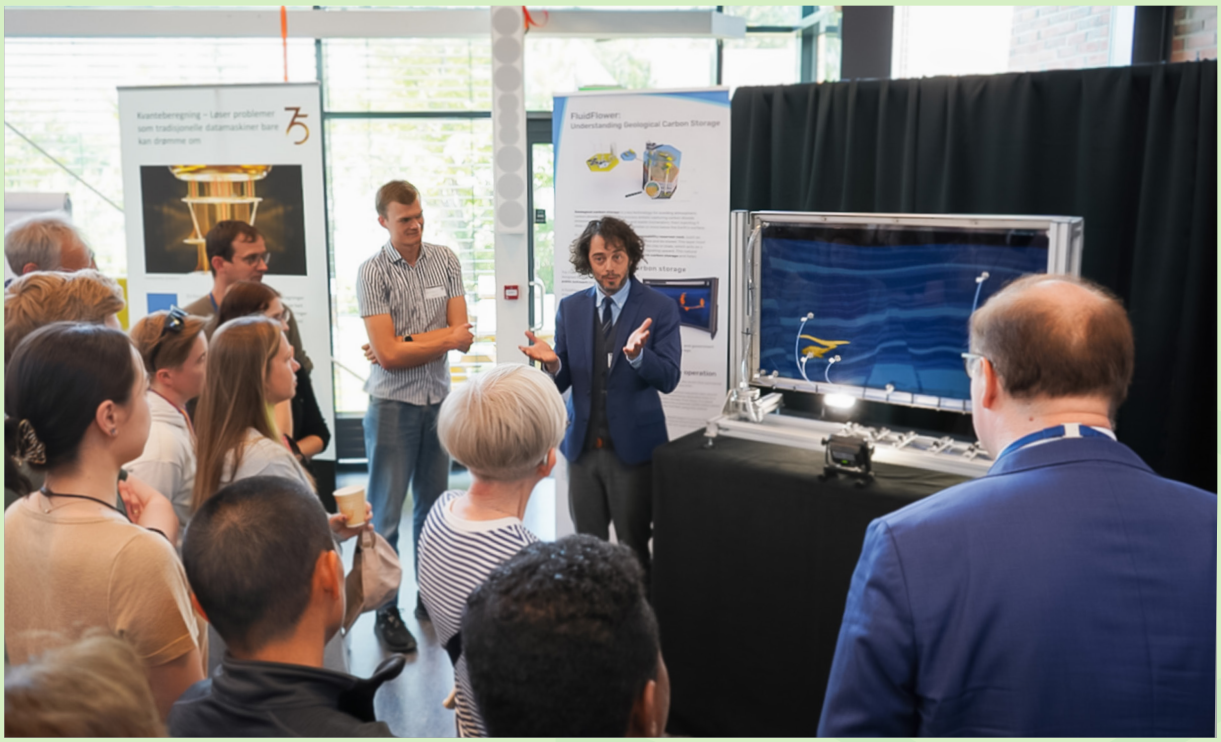
Annual Report 2025

Centre for Sustainable Subsurface Resources



Centre for Sustainable
Subsurface Resources

Table of contents

FRONT PAGE PHOTO **WILLIAM HUSBY HOVEN | SINTEF**

DESIGN **HALTENBANKEN,** MODIFIED BY **NORCE**

Dear readers

"We work together" is one of Harbour Energy's core values—and my personal motto. In today's geopolitical climate, I value this principle even more and believe it is something we should never take for granted.

The time I spend at CSSR events is always a highlight of my work. These gatherings bring perspectives I rarely encounter in my daily tasks. The first PetroCentre conference in Oslo this April was a clear example—an inspiring meeting place showing the contributions and achievements from all three centres. They are visible, relevant, and complementary, and communicating their results to the public—and to those who rely on them—is essential, even when that means engaging with people who may not share our views.

As my career has progressed, I have learned to value diverse perspectives deeply. In my team, I welcome when colleagues challenge assumptions or introduce new angles. I encourage everyone to share their views openly, even if they differ from mine or from the group's. Working together means exchanging ideas, challenging each other constructively, seeking clarity, discovering opportunities—and engaging respectfully with critics. When done well, this benefits everyone involved.

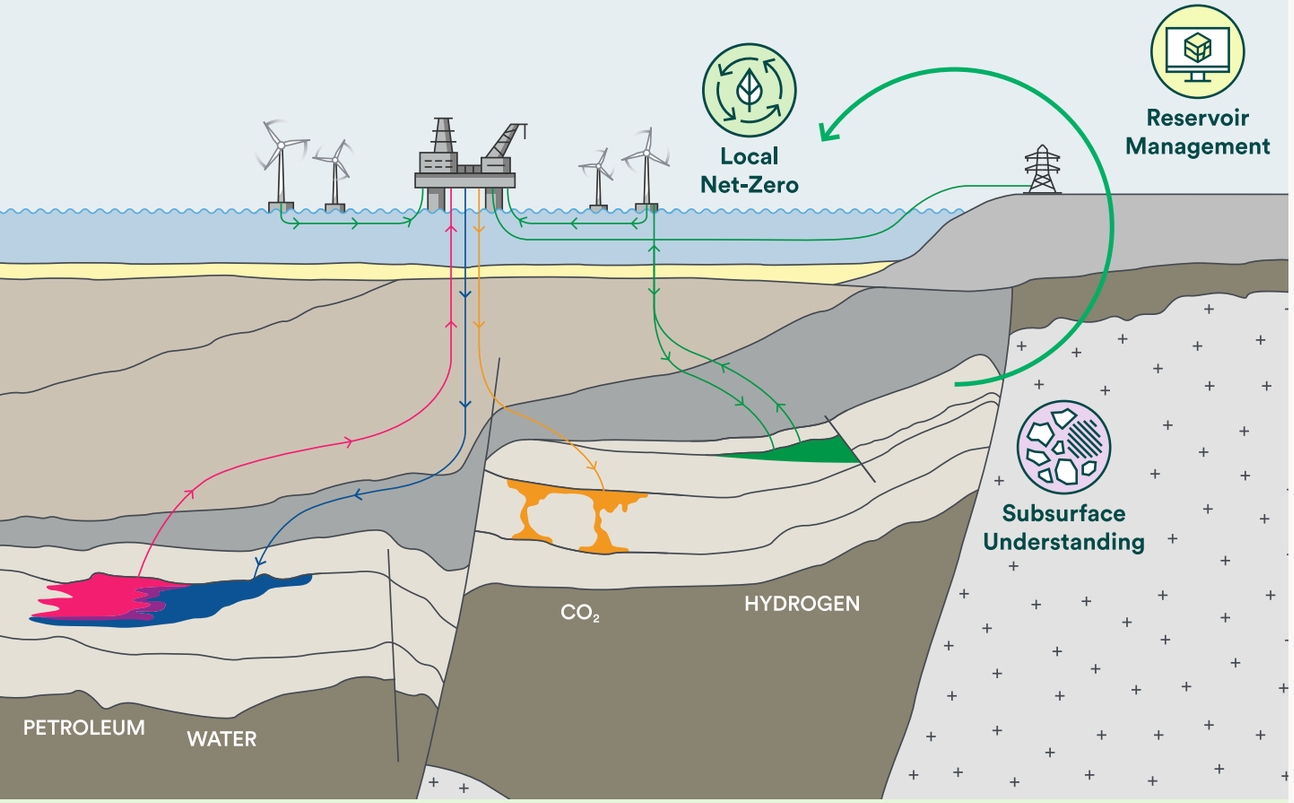
Hans Christen Rønnevik, one of the pioneers of Norway's oil and gas industry, often said he valued open offices because they allowed him to hear more of what others were thinking. His message was that each of us sees only fragments of the bigger picture—and that only together can we see the whole.
This is something I believe strongly. I am proud of the collaborative spirit within CSSR. Let us continue to use that shared arena—and keep up the good work of working together.

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

Research Strategy

Centre for Sustainable
Subsurface Resources

The impact of slow science



We may never see the fruits of our labour or win a Nobel Prize, but passion for science, patience and persistence will one day lead to technological achievements beyond our imagination.

The world moves at a fast pace. Events unfolding around us seem to occur at breakneck speed, and challenges are multiplying in size and number. There is increasing demand to deliver more quickly, to be disruptive, to break things, to make new discoveries. The media celebrates earth-shattering breakthroughs and is hungry for the next big thing. In the end, we are hard-wired to believe that innovation only happens in an instantaneous burst of creativity.

Standing on the shoulders of giants

It is true that many important breakthroughs with immediate impact, such as penicillin or LLMs, appear to come nearly out of the blue. In fact, most breakthroughs result from decades of research that span generations – a methodical march towards technology that changes our lives, often in ways unimaginable by the scientists who performed the foundational studies. The 2025 Nobel prizes in Physics, Medicine, and Chemistry are examples of the impact of slow science. It was obscure research in quantum tunnelling 40 years ago that laid a foundation that eventually culminated in today's mobile phone technology, but it is difficult to pinpoint any one specific result or experiment that was a game-changer.

What is CSSR's slow science?

We recognise that it takes a healthy dose of both slow and fast science to solve the greatest challenges facing society. For CSSR, the balance is clearly tilted more towards slow, basic science – a natural preference for an 8-year research centre. We see a good example in the long-term collaboration between NORCE and Equinor studying injectivity of reservoir rocks in the lab, work that has continued by PhD student Tongtong Yu with her contribution on cycling flows (see page 22). The red thread twists and turns through these studies, with many failed experiments along the way, and is being picked up by pore- and core-scale modelling activities in CSSR and beyond. Where exactly this line will terminate is hard to predict, but the solid foundation being laid today will certainly be indispensable.

How to quantify the impact of slow science?

A hard question even for Nobel laureates. CSSR has a goal to deliver research that increases value for Norwegian industry and society. CSSR's 14 PhDs and postdoctoral researchers – the next generation of experts, thought leaders, and decision makers – are a clear investment that will pay off many times in return. Research also creates indirect value for industry, with analysis showing that public funding for petroleum research provides a 30 times return on investment to the state. These numbers are heartening and help us evaluate the high-quality datasets, foundational models, and a suite of software prototypes produced by CSSR year after year.

RCN interim evaluation

2025 marks four years in operation for CSSR and the halfway point of the centre's lifetime. The mid-point is also the time when the Research Council of Norway (RCN) requires an Interim Evaluation ("Underveisevaluering") by an outside Assessment Committee. CSSR prepared a comprehensive information package for the Committee, which also carried out a digital site visit in October before submitting its evaluation to RCN in November.

The evaluation process offered a unique opportunity to reflect on our accomplishments and chart a way forward. In its first years, CSSR has delivered high-quality scientific results across all thematic areas, validating our original concept and positioning the centre as a key knowledge hub for sustainable subsurface energy systems. The centre has moved beyond proof-of-concept in several areas, delivering functional prototypes, advancing scientific understanding, and establishing open benchmarking platforms. International visibility has increased through new EU collaborations and the global recognition of FluidFlower.

Looking ahead, the final three years will focus on consolidating CSSR's role as a leading national and international centre of excellence for zero-emission subsurface research. This includes deeper integration of research, innovation, and field-relevant application, and accelerating the maturation of technologies toward scalable deployment. The updated objectives (see table) reflect a deliberate shift from foundational exploration to practical implementation, consistent with the centre's mission and evolving societal needs.

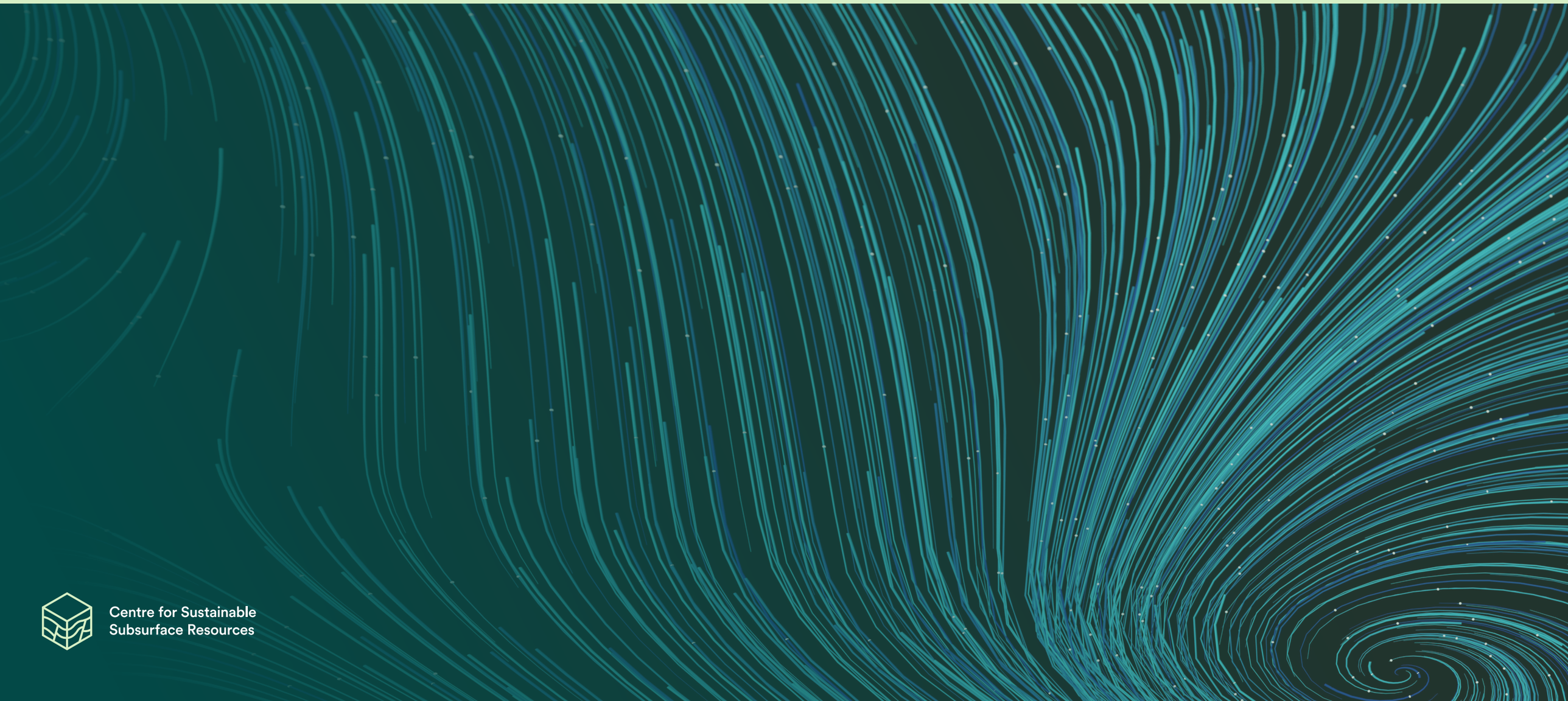
The Assessment Committee acknowledged CSSR's impressive achievements in the first period, including our established track record in multidisciplinary energy research, a productive pipeline of PhDs, strong international collaborations, and our proactive approach to optimising our research programme. We are encouraged by the Committee's assessment of our final three-year plan, described as "robust and well-aligned with industry and society's demand for practical, scalable energy solutions."

In December, RCN formally approved funding for the final three years. We extend our appreciation to the Assessment Committee for their thorough evaluation and constructive insights.

> ***" I am very pleased with the mid-term evaluation. It recognises the centre, its management, the work being done, and the people who contribute to CSSR. Behind such a strong evaluation lies hard work, excellent expertise, dedication—and people. In short, a well-run centre. "***
>
> Geir Terje Eigestad | Chair CSSR Executive Board

Final three-year objectives:	
1	Advance mechanistic understanding of subsurface flow dynamics under fluctuating operational conditions
2	Strengthen the integration between experimental data, data-driven models, and full-physics simulation
3	Develop transferable, predictive tools and workflows
4	Expand the centre's contribution to hydrogen storage, electrification, and low-emission reservoir operations
5	Ensure that research outcomes support innovation and uptake
6	Reinforce CSSR's role as a training arena and knowledge hub

Insight Article



Centre for Sustainable
Subsurface Resources

From instruments to insight

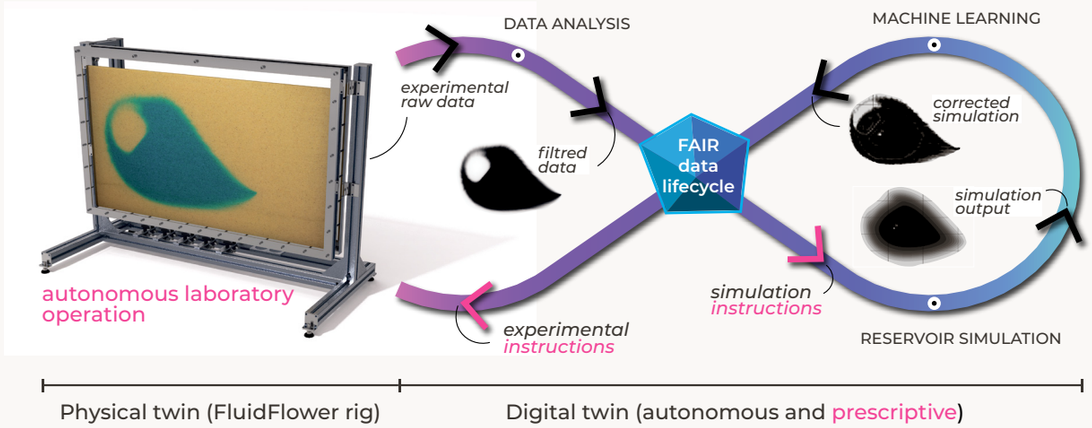
Building Norway's next-generation subsurface research infrastructure

AUTHOR **KETIL DJURHUUS**

A large part of the CSSR work programme is grounded in the close interaction between experimental work and computational methodologies. To further strengthen this integration, the **NRG Infrastructure** proposal envisions a transformative platform that bridges the physical and digital worlds to accelerate innovation in energy transition. At its core is a **closed-loop research ecosystem** where laboratory experiments, real-time data streams, and advanced models interact seamlessly within a **digital twin framework**. This means experiments do not just produce data—they actively inform simulations, which in turn prescribe new experimental conditions. By coupling physical rigs with predictive models, researchers can explore complex processes such as CO_2 storage or hydrogen injection under realistic conditions, reducing uncertainty and speeding up technology development.

A key stepping stone for this concept is the **PoroTwin project**, a pioneering prototype that demonstrated real-time, two-way coupling between a physical laboratory (FluidFlower) and digital models. PoroTwin streams live data to the cloud, assimilates it into simulations, corrects predictions using machine learning, and autonomously adjusts experimental settings. This breakthrough proves that "experiment-in-the-loop" workflows are feasible and impactful, laying the blueprint for scaling up to a national infrastructure spanning multiple laboratories and modelling environments.

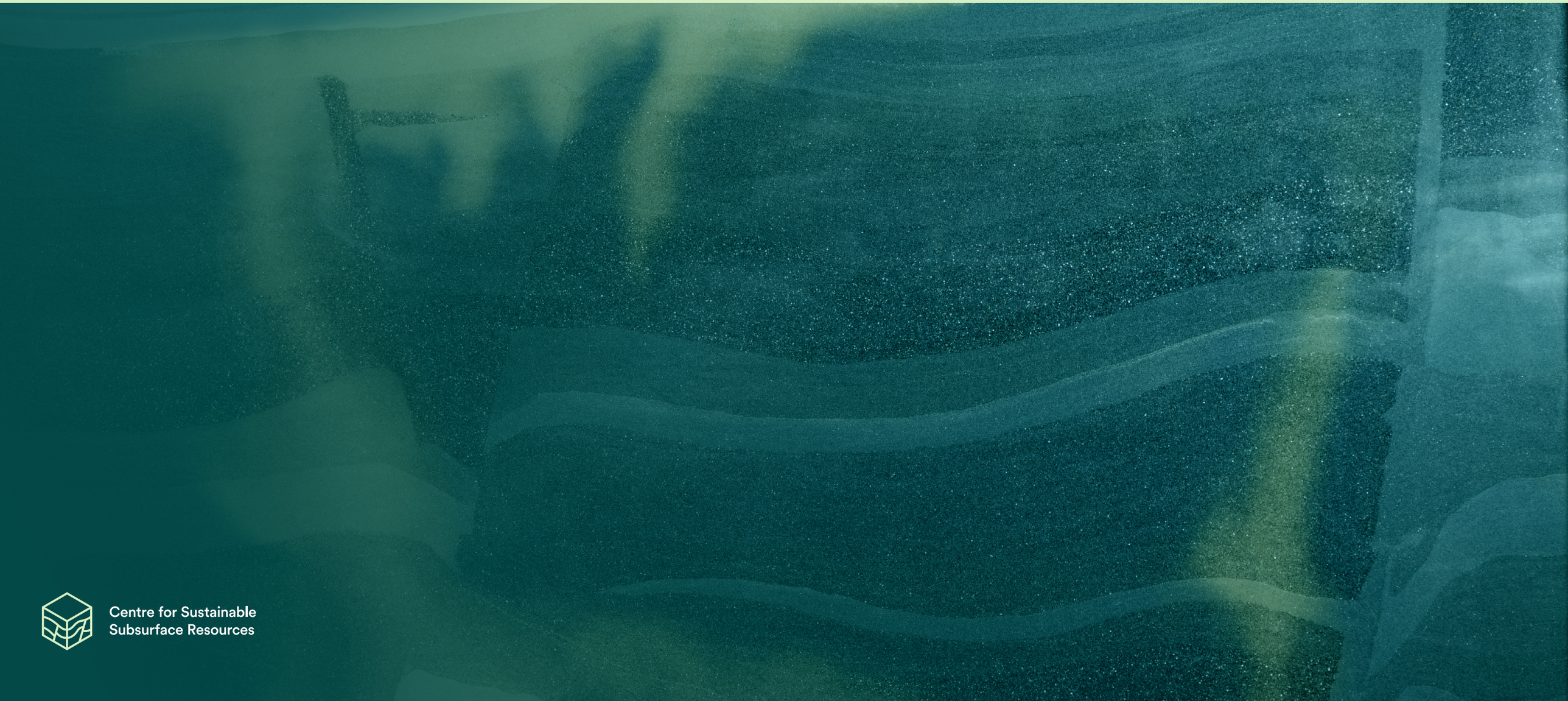
Equally important is NRG's commitment to **FAIR data principles**—making all data **Findable, Accessible, Interoperable, and Reusable** from the outset. Instead of treating FAIR compliance as an afterthought, NRG embeds it into every workflow: persistent identifiers, rich metadata, standardised formats, and versioned pipelines ensure transparency and reproducibility. Automated metadata capture and community-driven standards will lower barriers for researchers, enabling seamless integration across disciplines and institutions. This approach turns fragmented data practices into a coherent, open ecosystem that fosters collaboration and accelerates discovery.



From rig to cloud and back again: real-time feedback loops between experiment, data analytics, and simulation.

Ketil Djurhuus is a research director of the Subsurface Energy Solutions group at NORCE. His research interests are experimental approaches to understanding the coupling between flow physics, bulk and interfacial processes in subsurface fluid flow. Djurhuus is one of the centre deputies of CSSR.

Highlights 2025



Centre for Sustainable
Subsurface Resources

Joint National Petrocentre Energy Research Conference (JNPC)

In April, CSSR, NCS2030 and LowEmission jointly hosted the first national Petrocentre Energy Research Conference. The event gathered researchers, industry leaders and policymakers at the Research Council of Norway's premises. The participants met to discuss how technology and collaboration can drive a sustainable transformation of the Norwegian continental shelf towards 2050.

The first day focused on strategic perspectives, featuring contributions from the Ministry of Energy, Offshore Norway and members of the Norwegian Parliament on the role of CCS, offshore wind, and hydrogen in Norway's energy transition. The three centre directors also presented recent achievements and discussed the importance of collaboration across institutions.

The second day highlighted technical advances in energy efficiency, reservoir management, digitalisation and alternative energy solutions. At a dedicated PhD breakfast session, young researchers from all three centres presented their work, and engaged directly with industry representatives, fostering valuable dialogue between research and practice.

The conference marked an important step in strengthening collaboration across Norway's petroleum research centres and underscored the shared commitment to a sustainable and knowledge-driven energy transition.

> *It was great to see the three Petrocentres collaborate and align at the joint energy research event. By merging the intelligence across the centres, the conference became a living network — a place where ideas connected and insights flowed. Truly inspiring to be a part of."*
>
> Camilla Vavik Pedersen | CSSR Board Member, Equinor

> *It is essential to study how the use of renewable power will affect operations on the continental shelf — from surface-level activities to deep in the subsurface and the reservoirs."*
>
> Camilla Stoltenberg | CEO, NORCE

Catherine Padde Amusugut, a PhD student at CSSR, presenting her research during PhD breakfast session with industry stakeholders.

The three Petrocentre directors presented an overview of their centre's goals and key highlights. From left: Alejandro Escalona Varela (NCS2030), Professor at University of Stavanger; Stefania Gardarsdottir (LowEmission), Senior Researcher at SINTEF Energy; and Sarah Gasda (CSSR), Research Director at NORCE.

PHOTOS **INGVILD AURSLAND | SINTEF ENERGY**

CSSR milestones

Successful PhD defence

Mathias Methlie Nilsen successfully defended his PhD thesis, “Optimisation Methodology for Sustainable Reservoir Management” on 10 November, becoming the centre’s first PhD graduate. Mathias was employed at NORCE in 2022 within the Data Assimilation and Optimisation group and enrolled as a PhD fellow in the Department of Mathematics at the University of Bergen.

During his PhD, Dr. Nilsen developed advanced optimisation strategies for reservoir management and explored ways to integrate offshore wind power into production. A key focus was managing the variability and uncertainty of wind energy through new optimisation routines. His thesis shows how to balance emissions and economic performance for reservoir fields—with and without offshore wind.

Mathias engaging with the audience during his session at the Joint National Petrocentre Energy Conference in April 2025

PHOTO **INGVILD AURSLAND | SINTEF ENERGY**

As a candidate, Mathias set a high standard, publishing four peer-reviewed articles and contributing to several international conferences. Congratulations to Dr. Nilsen on a job well done!

New grant to support education and collaboration activities

CSSR is happy to announce the International Cluster of Excellence in Sustainable Subsurface Research (ICE-SSR), one of 20 new projects awarded within the competitive International Partnerships for Excellent Education, Research and Innovation (INTPART) programme by the Research Council of Norway. The grant entails NOK 5 million over four years to create a global platform for integrated research and education in physics-based subsurface simulations. ICE-SSR will form an international cluster of excellence that directly links to CSSR’s educational and international collaboration with new courses, winter schools, and researcher exchange.

ICE-SSR is spearheaded by the Reservoir Physics group at UiB with Professors Sarah Gasda, Martin Fernø, Kundan Kumar and Jan Martin Nordbotten in the project team. The extended partnership includes NORCE and nine leading institutions worldwide from the USA, UK, Germany, the Netherlands, Brazil, China, South Korea, and Canada.

H.R.H. Crown Prince Haakon of Norway engaging with Prof. Martin Fernø on the FluidFlower project.

PHOTO **WILLIAM HUSBY HOVEN | SINTEF**

> *The INTPART grant gives us a unique opportunity to strengthen interdisciplinary and international collaboration in sustainable energy and carbon storage in the subsurface. For our interdisciplinary academic community at the Faculty of Science and Technology, it means we can offer our students access to a global network of leading researchers, innovative courses, and training in the green transition.”*
>
> Martin Fernø | Centre deputy

Homotopy continuation solvers for challenging nonlinear problems in porous media flow

AUTHOR PETER VON SCHULTZENDORFF

Fluid flow in subsurface reservoirs involves complex fluid interactions and constitutive equations that add significant nonlinearity to the model equations. This is seen, for example, in highly heterogeneous geometries or flow regimes that feature coupling between viscous, capillary, and buoyancy forces. As a result, the standard nonlinear solution algorithms commonly employed in reservoir simulation may struggle or even fail to converge, causing poor computational efficiency.

In this project, the homotopy continuation (HC) method is investigated as a mathematical means to improve the robustness and flexibility of the nonlinear solver. The key idea behind HC is to continuously deform a simple-to-solve auxiliary problem into the complex target problem. The continuous path between the auxiliary and target problems forms a so-called HC solution curve. The curve is iteratively traced towards the target problem with a predictor-corrector algorithm by solving intermediate nonlinear problems along the curve.

Our work focuses on the design of algorithms for tracing the HC curve. We employ mathematically stringent a posteriori error estimates to derive stopping criteria for the tracing algorithm to improve computational efficiency. The algorithm is tested on models derived from the SPE10 and SPE11 benchmark problems. In addition, we also investigate the impact of the choice of the simple auxiliary problem on the performance of the iterative HC method. This is done through numerical experiments on 1D hyperbolic transport problems.

References

von Schultzendorff, P.; Both, J.W.; Nordbotten, J.M.; Sandve, T.H.; Vohralík, M.; An adaptive homotopy continuation solver for incompressible two-phase flow in porous media (in preparation).

von Schultzendorff, P.; Both, J.W.; Nordbotten, J.M.; Sandve, T.H.; Efficient design of continuation methods for hyperbolic transport problems in porous media (in preparation).

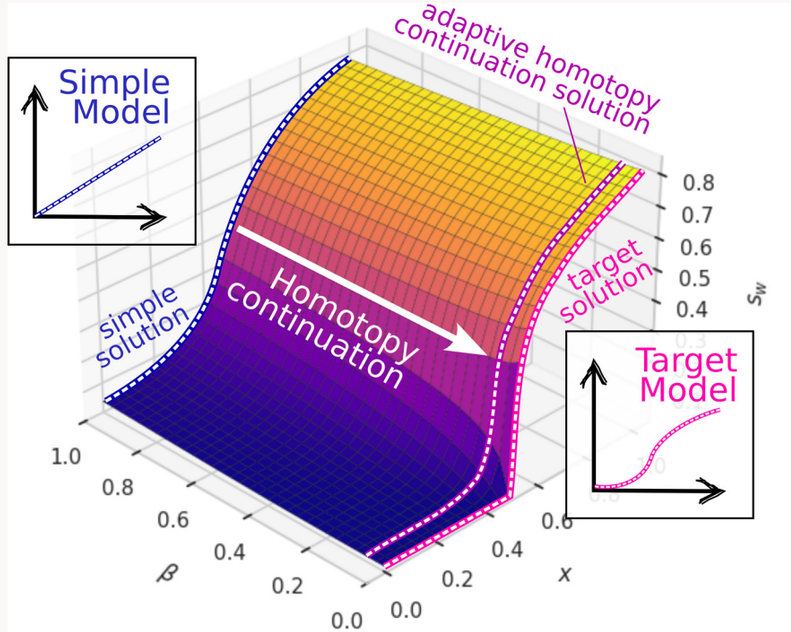


Figure: The auxiliary problem is deformed into the target problem, creating a continuous solution curve. A solution to the target problem is obtained by iteratively solving intermediate problems along the curve.

In 2025, PhD student Peter von Schultzendorff visited Professor Martin Vohralík and the SERENA research group at Inria Paris for a research stay. The collaboration focused on advanced numerical methods for reservoir simulation, drawing on SERENA's internationally recognised expertise in a posteriori error estimation and adaptive algorithms. During the stay, Peter contributed to the development of the Adaptive Homotopy Continuation (AHC) method, strengthening the methodological foundation of his PhD project.

Peter von Schultzendorff is a PhD student in the Porous Media Group at UiB. In his PhD, he investigates nonlinear solvers for coupled problems in porous media. His special interest is in the coupling of classical physics-based models for reservoir simulations with new data-driven methods.

Dynamics of particle deposition in reinjection processes

AUTHOR **TONGTONG YU**

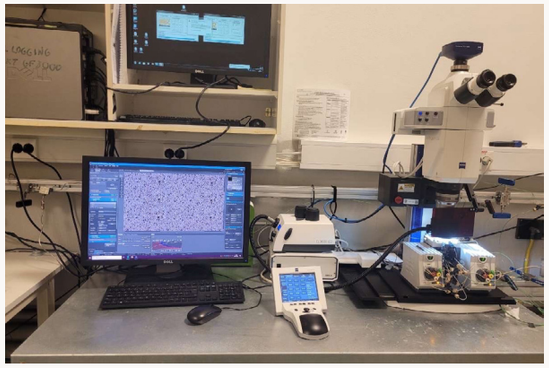
Re-injecting produced water into reservoirs offers an environmentally friendly approach to water management, but the suspended impurities—particularly solid particles—can cause formation damage and decrease injectivity. A concern is the balance between particles filtered off at the sandface and particles penetrating deeper, which are more difficult to remediate.

This study investigates particle transport and retention in porous media by injecting synthetic produced water through a heterogeneous microfluidic chip—which mimics reservoir pore structure—under different conditions. Real-time visualisation across sections with identical pore structure reveals that higher flow rates and smaller particle sizes enhance penetration, while larger particles and lower rates promote early retention near the inlet. Particle accumulation is closely linked to local flow conditions and pore geometry: narrow pore throats discourage settling due to higher velocities, while wider ones promote retention. The early stage of internal filter cake formation is observed near the inlet, and pore-scale heterogeneity disperses particles away from the main flow path, resulting in a broader spatial distribution.

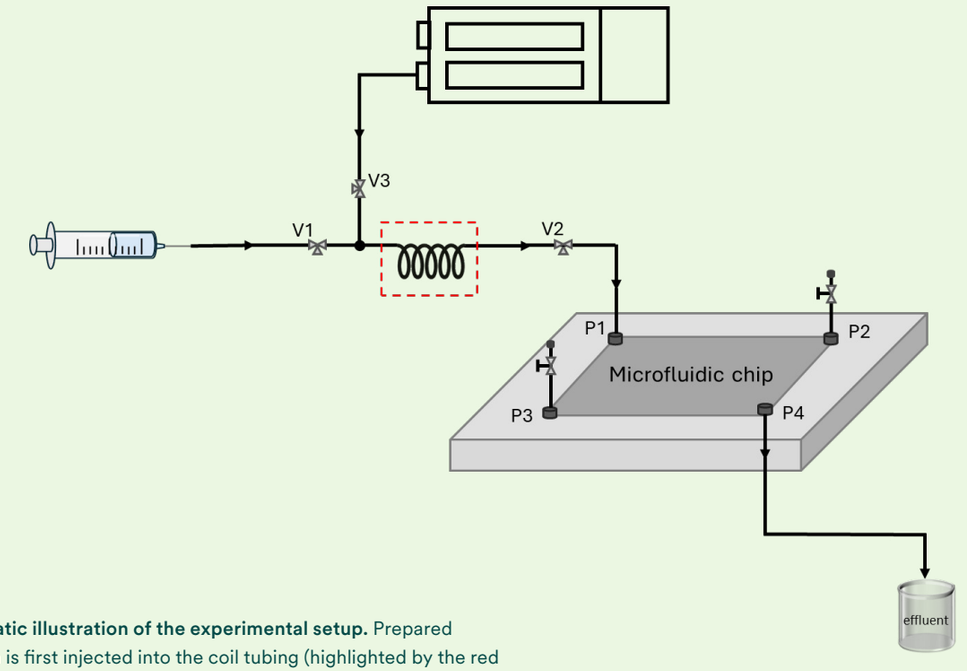
These findings highlight the complex interplay between hydrodynamic forces and pore structure in governing particle behaviour, offering insights into optimising water management strategies and minimising formation damage in porous media.

Reference

Yu, T.; Liu, N.; Djurhuus, K.; "Pore-Scale Experimental Study of Particle Dynamics and Filter Cake Formation in Porous Media During Produced Water Reinjection," ADIPEC, 2025.



Microfluidic experimental setup at the University of Bergen.



Schematic illustration of the experimental setup. Prepared solution is first injected into the coil tubing (highlighted by the red dashed square) using a syringe. The solution is then introduced into the microfluidic chip via a precision pump. Throughout the experiment, the microfluidic chip is placed horizontally.

Tongtong Yu is a PhD student in WP1–Reservoir Physics with a background in petroleum engineering. Her current research at NORCE focuses on experimental studies of particle transport in porous media at both core scale and pore scale.

Incremental machine learning for faster history matching

AUTHOR ANTOINE LECHEVALLIER

History matching involves adjusting model parameters to improve the agreement between observed and simulated reservoir data. Conventional ensemble-based methods are inherently computationally intensive workflows, a challenge which is further aggravated by complex reservoir behaviour and non-linearity that slows convergence of the reservoir simulator. This study presents an innovative methodology that integrates machine learning models to speed up convergence of the non-linear solver, improving the overall performance of ensemble-based history matching.

One common source of computational complexity arises from operational changes in the simulation model, e.g. well rate adjustments that induce rapid changes in near-well reservoir behaviour. Such events force the solver to take smaller time steps to maintain stability. However, well behaviour also tends to show consistent patterns across space and time. We exploit this by using incremental learning to predict near-well solutions and supplying these predictions as improved initial guesses for Newton's method. After each history matching ensemble iteration, a deep learning model is trained or fine-tuned for each well's local region.

The advantage to this method is twofold. First, because this training uses existing simulation data and is restricted to a small spatial domain, it remains cost-effective and computationally affordable. These near-well models then act as localised non-linear preconditioners for subsequent ensembles, taking advantage of nested parameter distributions and progressively refined model states. Second, the physics of the converged solution is not impacted by the quality of the initial guess provided by the deep learning module.

Our methodology, implemented with the open-source Python Ensemble Toolbox and the OPM simulator, is validated on the Drogon field dataset. Results show a clear, event-dependent reduction in non-linear iterations, with training easily parallelised on CPUs. Altogether, this framework accelerates history matching, enhances robustness, and integrates seamlessly with existing workflows, providing a scalable path for broader machine learning adoption in reservoir engineering.

Finally, this data-driven non-linear preconditioning strategy is the first officially supported machine learning approach within OPM Flow. Current work focuses on further maturing the technology by testing it on more complex cases provided by partners and by quantifying the impact of the preconditioning, not only in terms of solver iterations but also in total end-to-end runtime, with the goal of achieving measurable real-world impact.

This work was presented at SPE-RSC-25. https://doi.org/10.2118/223843-MS.

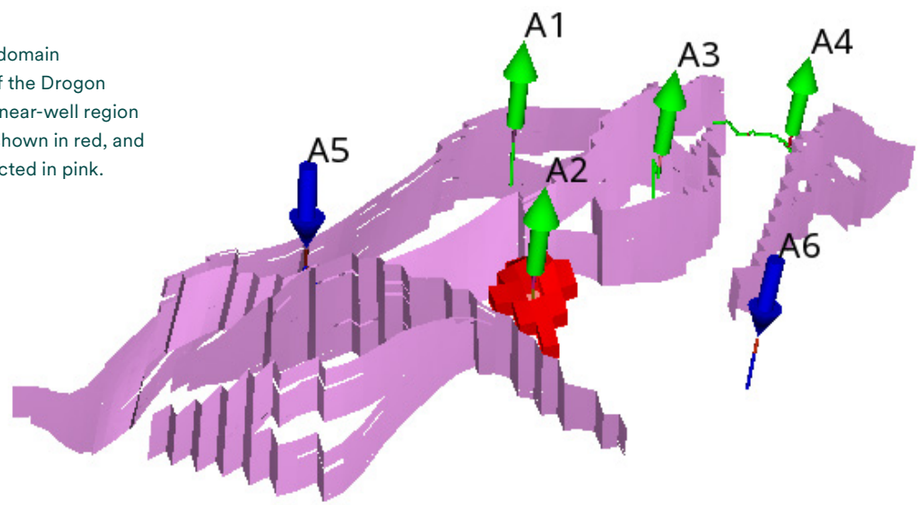


Figure: Local domain visualisation of the Drogon reservoir. The near-well region for well A2 is shown in red, and faults are depicted in pink.

Antoine Lechevallier is a geoscientist and applied mathematician specialising in scientific machine learning for reservoir simulation. His work at NORCE as a postdoctoral researcher in WP4 builds on a PhD from Sorbonne Université and IFPEN, focusing on applying practical ML methods in industrial workflows.

SPE11: Benchmarking CO_2-storage simulators at scale

AUTHOR **MARTIN FERNØ**

The 11th Society of Petroleum Engineers Comparative Solution Project (SPE11) set a new standard for benchmarking numerical simulators for geological carbon storage. Spearheaded by CSSR researchers Jan Nordbotten and Martin Fernø, the SPE11 study was finalised in 2025. The international study attracted 45 participating groups, with 18 submitting results to the final comparison.

SPE11 probed three levels of complexity: a lab-scale 2D case (11A), a rescaled field-scale 2D transect (11B), and a full 3D field model (11C) – all sharing a common geometry to make cross-case learning transparent. The **open-access summary**, published in the International Journal of Greenhouse Gas Control (2025), introduced a global distance metric to compare submissions and performed a quantitative analysis of why results diverge. The analysis highlights three dominant drivers of variation – thermal effects, dissolution-driven convective mixing, and how simulators resolve facies discontinuities – along with a clear dependence on grid resolution. Importantly, unreported "human-choice" factors in model setup were found to be at least as impactful as the documented numerical settings.

Beyond the science, SPE11 leaves a practical open-access legacy for regulators and practitioners: benchmark definitions, a curated dataset, and reproducible analysis/visualisation scripts. These resources let teams benchmark their own tools, reproduce published figures, and stress-test decision workflows for site selection and permitting—exactly the trust-building steps needed for safe, long-term CO_2 storage at scale.

Online resources

Official SPE11 page (overview & cases) – benchmark description, A/B/C cases, and links to data. **https://www.spe.org/csp/spe11/**

Open-access SPE11 Problem Statement (Nordbotten, Fernø et al. 2024) The 11th Society of Petroleum Engineers Comparative Solution Project: Problem Definition. **https://doi.org/10.2118/218015-PA**

Open-access peer-reviewed summary (Nordbotten, Fernø et al. 2025) Benchmarking CO_2 storage simulations: Results from the 11th Society of Petroleum Engineers Comparative Solution Project **https://doi.org/10.1016/j.ijggc.2025.104519**

Open-access curated SPE11 dataset (Flemisch, Nordbotten et al. 2025) The 11th SPE Comparative Solution Project: Submitted Data **https://doi.org/10.18419/DARUS-4750**

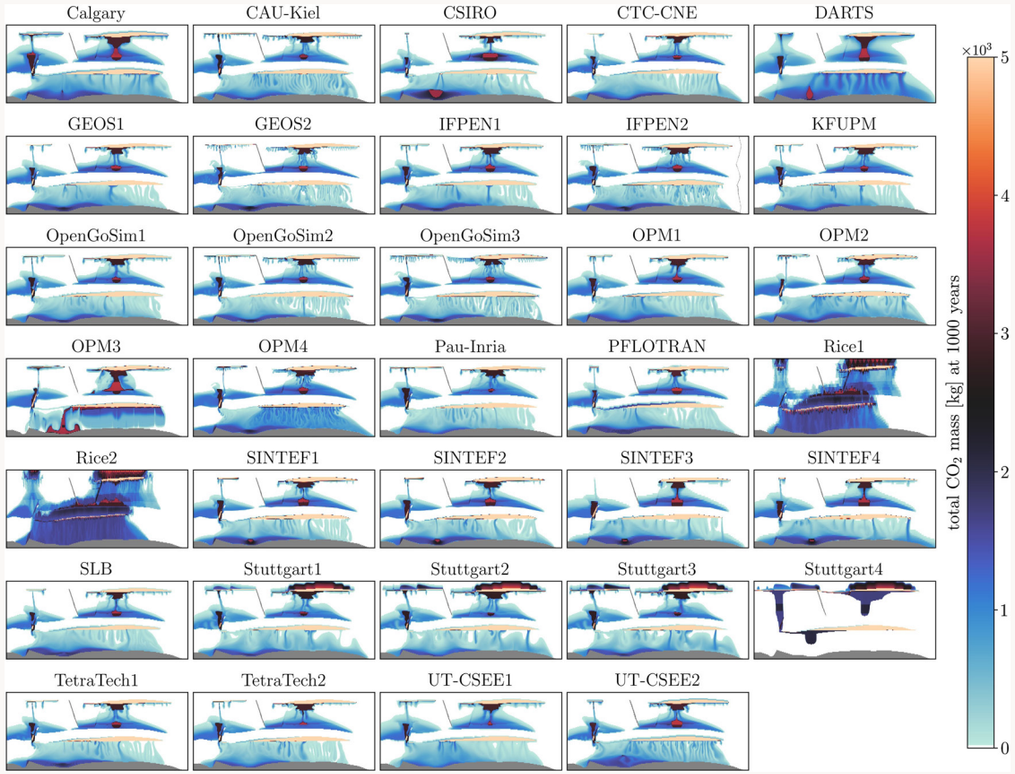


Figure: An overview of the SPE11B submissions, in terms of distribution of CO_2 at the end of the simulation period.

Additional resources

Interactive results gallery – explore submissions across cases. **https://olavmoyner.com/SPE11-plot-test-deploy**

Analysis & tools (GitHub) – scripts, input decks, notebooks to reproduce figures and compute the SPE11 distance metric. **https://github.com/Simulation-Benchmarks/11thSPE-CSP**

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.

Synergies with associated projects

AUTHOR **MARTIN FERNØ**

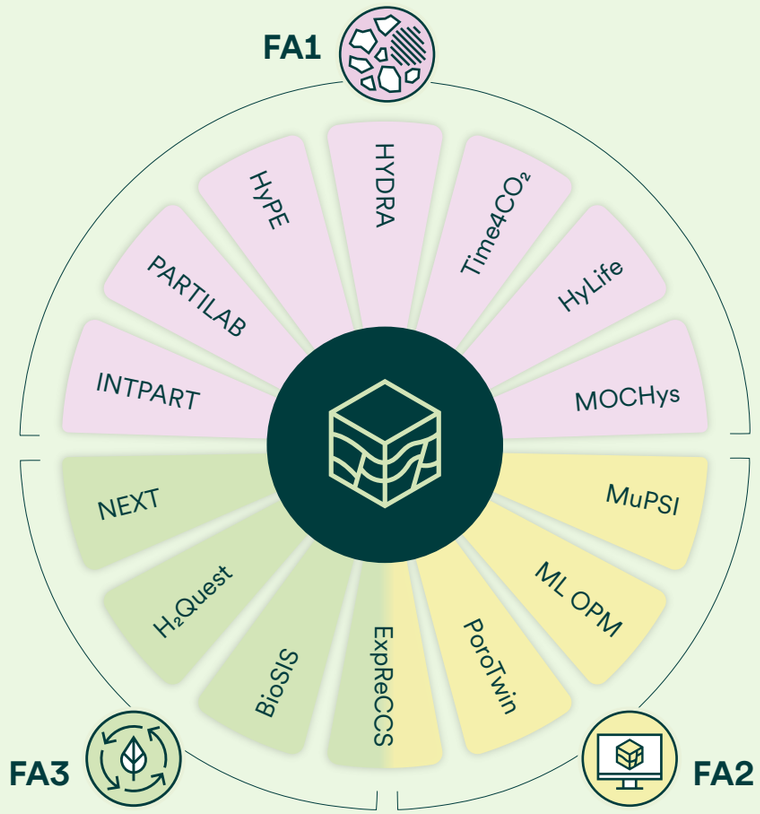
CSSR's associated projects (see Figure) strengthen the Centre's ability to translate subsurface science into decision-ready tools for industry and regulators by linking laboratory observations, field data, and advanced simulation. Together, they reinforce the feedback loop in which experiments refine models, models guide measurements, and both support safer and more efficient storage strategies.

FA1 brings together projects that clarify the physical, chemical, and biological behaviour of hydrogen and CO_2 in the subsurface. Hydrogen-focused initiatives—HyPE, HyDRA, MOCHys, and HyLIFE—build the scientific basis for underground hydrogen storage, addressing multiphase flow, gas trapping, and microbial processes influencing site suitability. NEXT and H_2Quest extend this to natural hydrogen through studies of generation, migration, microbial modification, and exploration workflows. BIOSIS contributes insight into environmentally friendly biofilm disruption relevant for well integrity. PARTILAB strengthens model–experiment integration through optimal-transport-based parameter estimation for high-resolution flow data.

FA2 focuses on modelling and computational scale-up. MuPSI develops tools for assessing geomechanical risks and pressure interactions. ML-OPM enhances simulation performance using machine-learning modules. ExpReCCS delivers regional-to-site modelling frameworks for pressure communication, capacity limits, and coordinated multi-licence storage. PoroTwin extends digital-twin workflows by linking detailed physics to efficient computation.

FA3 lifts these developments to system-level planning. ExpReCCS is central here, showing how regional modelling and pressure budgeting support licensing, operator collaboration, and portfolio management.

Together, FA1–FA3 ensure that CSSR's research is cross-validated from pore scale to basin scale, enabling credible hydrogen and CO_2 storage solutions.



FRIPRO project

UiB researcher and CSSR WP deputy **Jakub Both** has been awarded an RCN FRIPRO Researcher Project for Early Career Scientists (2025–2029). His project, $TIME_4CO_2$, advances CCS simulation technology by combining mathematical modelling, image-based data analysis, and laboratory experiments. As Both notes, it "builds on the CSSR spirit of collaboration between NORCE and UiB" and strengthens CSSR's role in climate-solution innovation and interdisciplinary research.

Students abroad

Throughout 2025, CSSR PhD students engaged with the international research community through conference participation and extended research stays. These activities enabled the exchange of ideas, the development of academic collaborations, and the dissemination of research that contributes to the transition towards a more sustainable energy future.

Peter von Schultzendorff – Research stay at Inria, Paris

> *Collaborating with the SERENA group was highly productive. Their expertise in a posteriori error estimation and adaptive methods provided a fresh perspective and gave me new ideas for tackling the challenges in my PhD.”*
>
> Peter von Schultzendorff | PhD student

Peter von Schultzendorff pictured in front of the Eiffel Tower during his 2025 visit to the SERENA research group at Inria.

Kirabo E. Mugwanya during the poster session in Spain.

PHOTO ALINA SHCHEPETKINA

Kirabo E. Mugwanya – 38th International Meeting of Sedimentology, Huelva, Spain (26–28 June 2025)

Kirabo Erismas Mugwanya presenting his poster on sedimentary signals of climate change. His research explores how geological processes shape fluvial sediments on the Horda Platform and how these systems responded to changing environmental conditions, providing valuable insights for subsurface modelling and carbon storage.

Tongtong Yu – ADIPEC 2025, Abu Dhabi (3–6 November)

Tongtong presented her research at ADIPEC, entitled “Pore-scale Experimental Study of Particle Dynamics and Filter Cake Formation in Porous Media During Produced Water Reinjection” with the aim of improving how water is managed and reused during oil production. This research supports more efficient and sustainable field operations.

Tongtong Yu at ADIPEC 2025, Abu Dhabi

Raymond Mushabe – InterPore 2025, Albuquerque, USA (19-22 May)

Raymond Mushabe attended InterPore 2025 in Albuquerque, where he delivered an in-person presentation and co-chaired session MSO5 with David Landa-Marbán. His presentation focused on quantifying microbial hydrogen consumption and microbial impacts on multiphase flow during short-cycle cyclic underground hydrogen storage in porous media. The results were obtained using MRI visualisation on sand-pack columns as rock analogues, contributing to improved understanding and quantification of microbial risks in subsurface hydrogen storage.

Raymond Mushabe at InterPore 2025, Albuquerque, USA

PHOTO DAVID LANDA-MARBÁN | NORCE

Science meets industry

Throughout the year CSSR prioritises events and workshops where we can contribute to shared learning and stronger partnerships with industry. These arenas help induce dialogue, co-creation, and research closer to industrial, regulatory, and societal needs.

CSSR partner workshop

The CSSR Partner Workshop 2025 brought together academia and industry to discuss the future of subsurface energy systems. Over one and a half days, participants from companies including Equinor, Harbour Energy, and Sumitomo Corporation engaged in presentations, breakout sessions, and discussions. The workshop generated valuable input on aligning research with operational needs, strengthening co-creation, and developing PhD and postdoc competencies. The event reaffirmed the importance of research–industry collaboration and laid a foundation for continued innovation and impact.

Vestland CCUS

In November Vestland CCUS 2025 brought together around 100 participants in Bergen as a key meeting place between research, industry, and public authorities. The event was organised by NORCE and the University of Bergen, highlighting their central role in facilitating dialogue and collaboration on carbon capture and storage (CCS). Representatives from industry and public authorities actively contributed through presentations and panel discussions. Key themes included aligning research with industrial needs, accelerating CO_2 storage, reducing costs, and addressing financing and coordination challenges. The strong industry presence underlined the importance of sustained research–industry collaboration for advancing CCS in Norway and Europe.

Right: Sveinung Hagen, Equinor, in front of the fireplace telling a fairytale about CCS during the conference dinner.

PHOTO **TRINE MYKKELTVEDT | NORCE**

Participants at the CSSR Partner Workshop 2025.

PHOTO **RUNE ROLVSJORD | NORCE**

From left: Melito Soares (CSSR PhD student), Ketil Djurhuus, and Roman Berenblyum talking together during the break.

PHOTO **RUNE ROLVSJORD | NORCE**

NPF CCS

In December the Annual International Carbon Capture and Storage Conference (CCS 2025), organised by Norwegian Society of Petroleum, gathered over 100 participants from government, industry, and research. The programme covered the full CCS value chain, with emphasis on scaling CCS on the Norwegian Continental Shelf. CSSR was well represented through contributions to the programme committee, moderation, and research presentations. CSSR and NORCE shared results on CO_2 transport and multi-actor storage hubs, strengthening dialogue between research, industry, and policymakers.

Participants at Vestland CCUS.

PHOTO **IDA SOLLESNES | NORCE**

International events and recognition

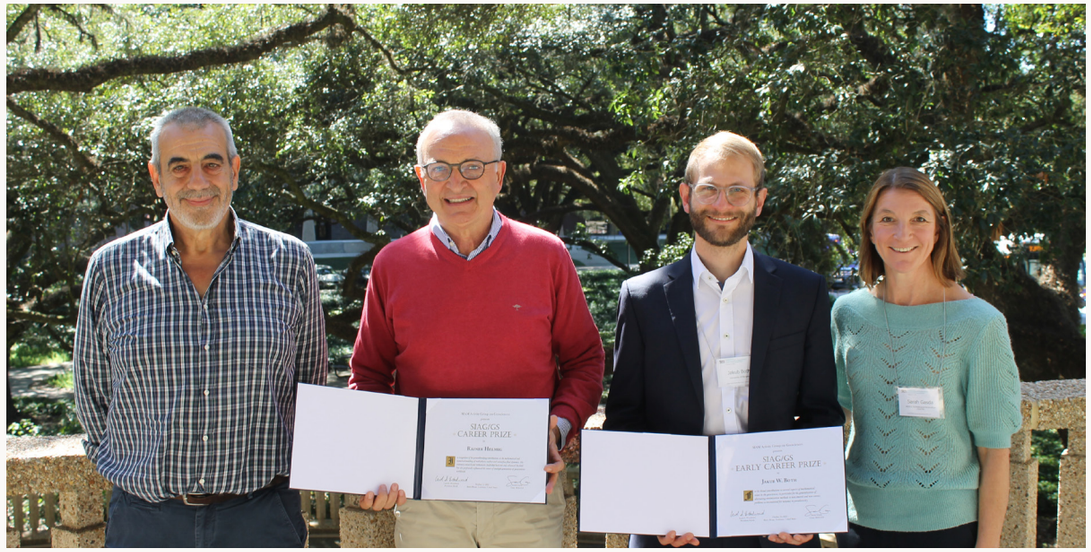
SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS25), Baton Rouge, USA
The biennial SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS25), organised by the Society for Industrial and Applied Mathematics, is a leading international forum for computational mathematics in the geosciences. The 2025 conference marked a particularly strong year for CSSR-associated researchers.

UiB researcher and CSSR WP deputy Jakub W. Both received the **SIAM Activity Group on Geosciences Early Career Prize**. SIAM highlighted his "outstanding contributions to several aspects of mathematical issues in the geosciences, in particular for his generalisation of alternating minimisation methods to non-smooth and non-convex problems, as encountered for instance in poroelasticity." His prize lecture was very well received.

Long-time CSSR collaborator Rainer Helmig (University of Stuttgart) received the **SIAM-GS Career Prize**. CSSR Centre Director Sarah Gasda, Chair of the SIAM Activity Group on Geosciences, presented the awards and delivered a plenary lecture on CO_2 storage simulation. WP6 leader Trine Mykkeltvedt also presented results from the ExpReCCS project.

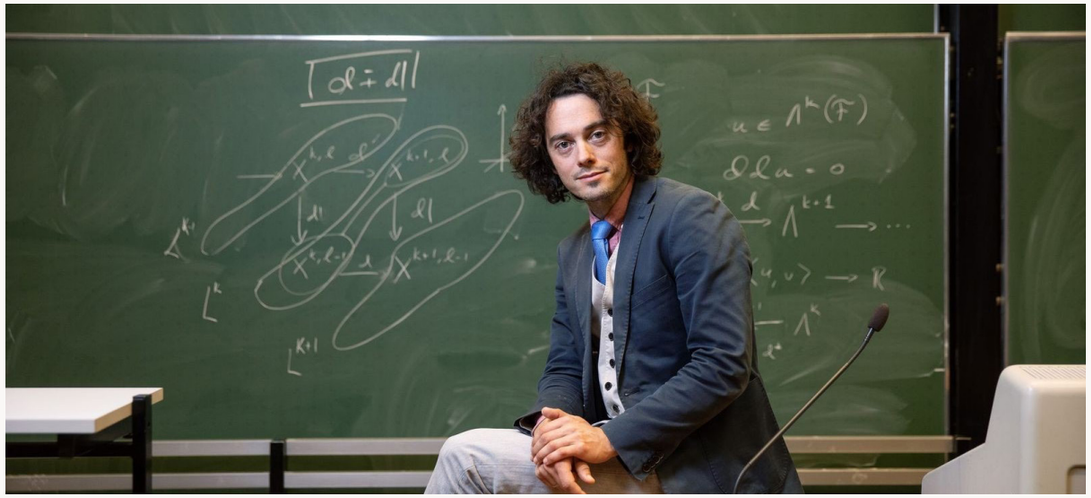
InterPore 2025, Albuquerque, USA
CSSR continued to make a strong impact at the annual InterPore meeting. Researchers Na Liu (UiB) and David Landa-Marbán (NORCE) co-organised a mini-symposium on Microbial Dynamics in Porous Media. Johan Olav Helland (NORCE), Raymond Mushabe (PhD), and Sarah Gasda (NORCE) also gave oral presentations.

UiB professor Jan Martin Nordbotten received the prestigious **InterPore Medal for Excellence in Porous Media Research**, recognising his outstanding theoretical and modelling contributions to porous media research over the past decade.



UiB researcher Jakub Both and Professor Rainer Helmig, University of Stuttgart, received the Early Career and Career prizes at SIAM GS25 in Baton Rouge, USA. Mario Putti (University of Padua) represented the prize committee and Sarah Gasda (CSSR) is the Chair of SIAM Activity Group on Geosciences.

PHOTO **SIAM GS**



Professor Jan Martin Nordbotten (UiB) received the InterPore Medal for Excellence in Porous Media Research.

PHOTO **EIVIND SENNESET | UiB**

Launch of CSSR webinar series

In 2025, CSSR launched a monthly Open Webinar Series to strengthen scientific exchange and make research from across the centre more accessible. The series offers a regular forum for researchers at all career stages to present ongoing work, share new findings, and receive feedback from colleagues within and beyond the consortium. Opening the webinars to national and international participants has broadened CSSR's academic reach, increased visibility for early-career researchers, and supported interdisciplinary dialogue. The series is now a stable part of CSSR's research culture, promoting transparency and linking subsurface research with emerging needs in the energy transition. Recordings and summaries of all webinars are available at cssr.no, each accompanied by a short, non-technical summary to ensure accessibility for wider audiences.

Understanding data and simulations for flows in porous media- Jan Martin Nordbotten, UiB

CSSR also hosted a standalone webinar by Jan Martin Nordbotten in collaboration with InterPore. Although separate from the Open Webinar Series, it is included here to provide a full picture of the 2025 webinar activities. The presentation examined how understanding CO_2 storage improves when experimental insights from the FluidFlower rig are combined with large-scale simulations such as the SPE11 Comparative Solution Project. It outlined current validation work and the use of regularisation, Wasserstein-based comparison, and clustering to strengthen analysis. Viewed through the FAIR principles, the talk showed that initiatives like SPE11 and FluidFlower remain only partly FAIR, with reproducibility still limited. The webinar concluded with a vision for a real-time, FAIR, automated laboratory and a next-generation digital twin for porous-media experiments.

> *"The CSSR partner workshop was an excellent arena, with a mix of talks and break-out groups that encouraged both knowledge sharing and creative discussions."*
>
> Jan Martin Nordbotten | UiB

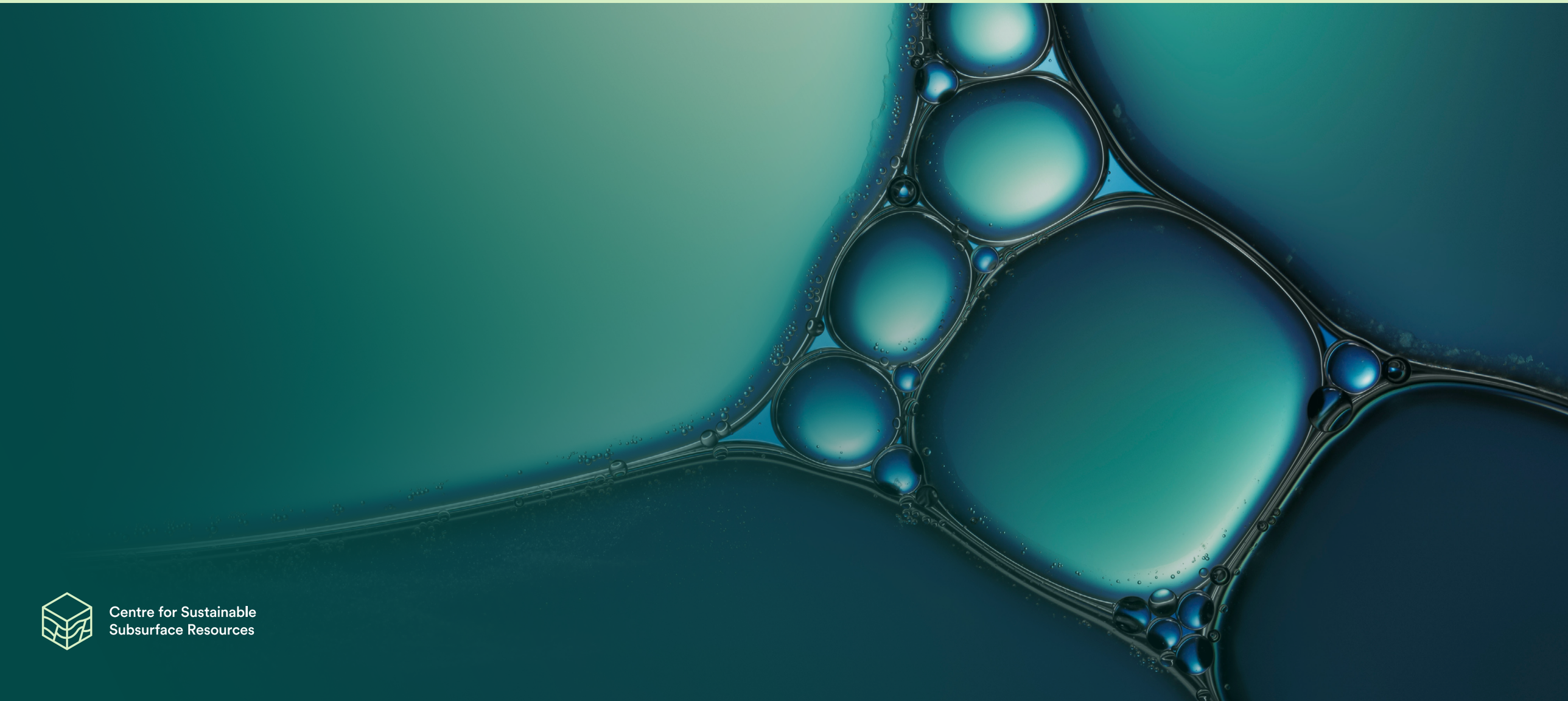
CSSR webinar series 2025*

Presenter	Webinar Title
Trine Solberg Mykkeltvedt	CO_2 storage potential on the Norwegian continental shelf
Mathias Methlie Nilsen	Closed-loop workflow for short-term optimisation of wind-powered reservoir management
Raymond Mushabe	Underground hydrogen storage in porous media: Microbial controls and multiphase flow
Antoine Lechevallier	Efficient nonlinear preconditioning for reservoir simulation history matching using random features learning
Jan Martin Nordbotten	Understanding data and simulations for flows in porous media

*Recordings of all past webinars can be found at **https://cssr.no/cssr-webinar-series/**

Snapshots of participants at the CSSR partner workshop 2025.
PHOTOS **RUNE ROLVSJORD | NORCE**

In the Spotlight



Centre for Sustainable
Subsurface Resources

New PhDs in 2025

Name | Trygve Johan Kjellemo Tegnander

Affiliation | Department of Mathematics, UiB

Nationality | Norwegian

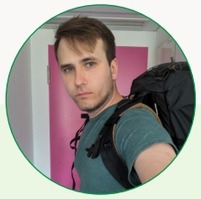
PhD period | 2025–2029

Project | Efficient solution strategies for heterogeneous Wasserstein distances approaches

My thesis is focused on finding efficient ways to solve the optimal transport problem. This will provide a new method to compare both numerical and experimental results, offering a quantitative measure of differences in results.

What sparked your interest in mathematics, physics, or geology?

I have always been fascinated by the beautiful patterns and puzzles of mathematics, and have developed an increasing interest in how the physical world works through physics. Applied mathematics lets me combine the two interests, which is why I find it so rewarding.



Name | Claudius Holeksa

Affiliation | Computational Geoscience and Modelling, NORCE

Nationality | German

PhD period | 2025-2028

Project | Computational modelling of flow and transport in porous media under variable energy input conditions

My thesis focuses on analysing clogging behaviour of sediments in porous rock structures, comparing different approaches using the Lattice-Boltzmann method including consideration of multiphase fluids. Since pore throats are often found in complex geometrical structures, variations in the boundary conditions are also analysed.

What made you choose CSSR, or what made you decide to move to Bergen?

Bergen is a city that offers everything I am looking for. The mountains are close, outdoor bouldering is available nearby, and the sea is right at your doorstep. It combines the charm of a small community with easy access to a range of amenities.

Name | Melito Espírito Santo Do Rosário Soares

Affiliation | Department of Physics and Technology, UiB

Nationality | Timorese

PhD period | 2025-2029

Project | Numerical modelling and simulation of underground hydrogen storage: Capturing multiphase flow hysteresis and operational dynamics in porous media

My thesis focuses on numerical modelling and simulation of underground hydrogen storage, with emphasis on multiphase flow hysteresis and operational behaviour. The work aims to improve modelling approaches through a multiscale framework that captures key physical, geochemical and microbial processes.

What effect could the results of your thesis have on your research field?

I hope this work will help make underground hydrogen storage more reliable and easier to scale. By improving how we model flow behaviour and coupled subsurface processes, the results could support safer, more efficient storage design and contribute to hydrogen's role in the energy transition.

Name | Stefano Galati

Affiliation | Department of Mathematics, UiB

Nationality | Italian

PhD period | 2025–2028

Project | gigaCCS – Analysis and numerical methods for two-scale models of poroelasticity

As part of the gigaCCS project, my thesis aims to develop mathematical models and numerical methods for large-scale carbon storage operations, with a particular focus on the geomechanical response at the basin scale. Mathematical homogenisation will be extensively employed to derive the upscaled models.

How is it to be a PhD student in UiB?

It is absolutely great! It is rewarding to be part of a large research group such as the Porous Media Group and to work in such a positive environment. I enjoy the many activities organised by the Department, and as an Italian, I particularly appreciate the strong international atmosphere at UiB.

New PhDs in 2025

Name | Frank Viveros Acosta
Affiliation | Department of Physics and Technology, UiB
Nationality | Colombian
PhD Period | 2025–2029
Project | HyDRA – Biogeochemical interactions in multiphase systems (Bacteria–Rock–Gas–Water): Implications for underground hydrogen storage

It focuses on biogeochemical interactions occurring during underground hydrogen storage (UHS), with particular attention to the interactions between H_2, microorganisms, fluids, and surrounding minerals within a coupled system. It investigates how these interactions influence storage integrity, hydrogen loss, and long-term storage performance.

What sparked your interest in reservoir physics?

My interest in these areas stems from the need to contribute to the renewable energy value chain from the storage side, where geological structures represent an excellent alternative for combating climate change when they are used as natural batteries.

Name | Åsmund van Brussel Synnevåg
Affiliation | Department of Mathematics, UiB
Nationality | Norwegian
PhD period | 2025-2028
Project | MuPSI – Multiscale coupling strategies for multiphase poroelasticity

As part of the MuPSI project, my thesis focuses on creating coupling strategies that capture pressure propagation across flow and no-flow regions. In particular, I work on developing models that describe how pressure build-up affects co-located CCS projects with shared subsurface storage infrastructure.

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

In five years, I see myself continuing a career in research, either within academia or in an applied research environment. I hope to contribute to the development of robust mathematical models and simulation tools that have real-world impact, particularly within CCS or other climate-related applications.

Participants at the partner workshop 2025.
PHOTOS RUNE ROLVSJORD | NORCE

CSSR international partner

Building confidence in subsurface storage

Delft University of Technology, The Netherlands

AUTHOR LOT VAN DER GRAAF

The **Subsurface Storage Theme** within the Department of Geoscience and Engineering at TU Delft integrates reservoir engineering, geological and geophysical monitoring to build confidence in underground storage of carbon dioxide and energy carriers such as hydrogen, hot water and compressed air. We combine laboratory experiments with modelling and simulation across scales to address thermodynamics, hydromechanics and biogeochemistry of storage in different in-situ settings.

Thermodynamics of storage is investigated to provide the correct physiochemical properties for technical feasibility and performance optimisation. For example, analysis of Jule-Thompson effects is important for CCS in depleted gas fields such as PORTHOS (Netherlands 2026). Furthermore, our **RICH-ID** consortium investigates hydrate formation and wellbore clogging upon expansion and cooling of the CO_2 plume, and our **H_2ToolBox** project addresses the thermodynamic properties of hydrogen and its mixtures, combining Molecular Dynamics and Laboratory experiments.

Hydromechanics of storage focuses on multiscale experiments for coupled flow and mechanics under cyclic loading for CCS and UHS. This includes near wellbore integrity, injectivity, and CO_2 and H_2 exposure tests. Flow experiments are conducted using micro-chips, micro-CT, and medical CT scanners in many projects (**NWO-ADMIRE, CO_2Well, EU-SHARP**, etc).

Biogeochemical studies investigate the impact of microbial activity on the safety and efficiency of subsurface storage. For example, in our **MOCHYs** project with NORCE we investigate microbial H_2 consumption at elevated pressures, and in collaboration with **ADMIRE & CSSR** we study the impact of microbial activity on the wettability of hydrogen.

Finally, **advanced simulation** of complex subsurface processes, especially for CCS, UHS, Geothermal, is performed across different scales with in-house open-source simulators. With our research-based multiscale DARSim simulator we analyse UHS and CCS performance (**EU-ITN SHINE** and **ADMIRE**). For commercial-grade simulations required e.g. in our **H_2Screen**, **CO_2Up**, and **GPU$_2$CO$_2$** projects, as well as for our own TU Delft geothermal well, we use our scalable in-house open-source DARTS simulator, optimised for complex physics and high performance.

Core-flood experiments for Underground Hydrogen Storage, an example of many mCT & CT-based hydromechanics research conducted in our lab.

(left) Some of our PhD & Postdocs. (right - top) Lot van der Graaf conducting UHS microbiology experiment together with (right-bottom) Denis Voskov & Hadi Hajibeygi (modelling & sim.)

CSSR industry partner

SLB, a global technology company driving energy innovation for a balanced planet

AUTHOR **TORMOD SLETTEMEAS**

SLB (formerly Schlumberger) is the world's leading technology-focused energy services company, delivering solutions across exploration and production, reservoir characterisation, and well construction. The company emphasises digital integration, decarbonisation, and accelerating the energy transition. Operating in more than 100 countries and employing people from 160 nationalities, SLB develops technologies that help reduce emissions while meeting growing global energy demand.

Following its rebranding, SLB defined four strategic focus areas:

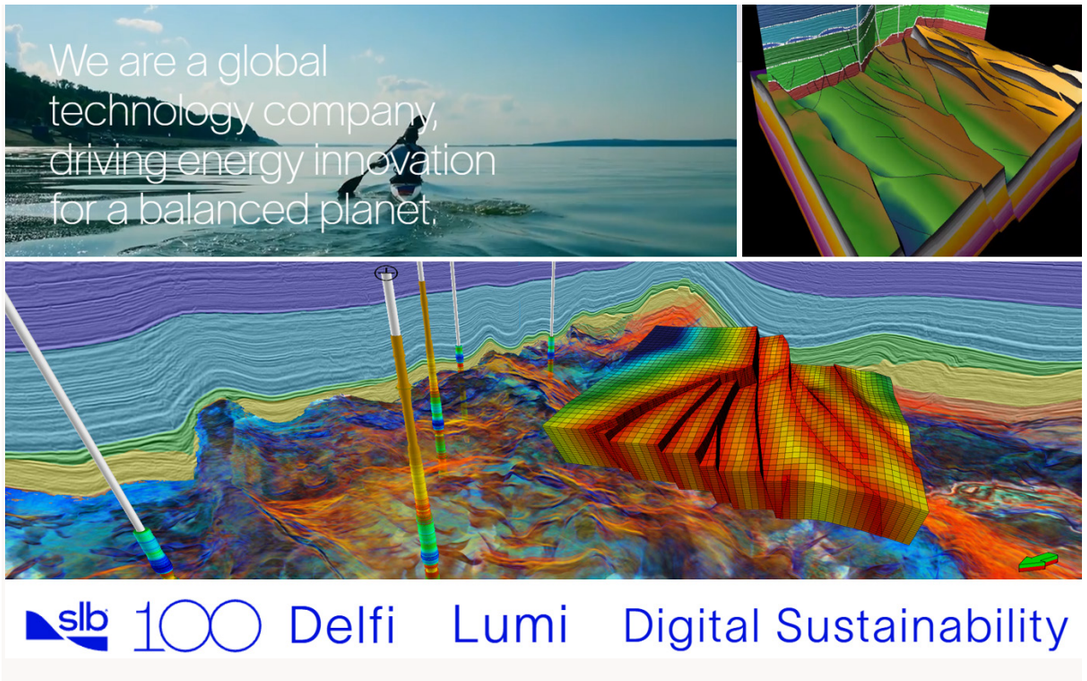
- Decarbonising industry
- Innovating in oil and gas
- Scaling new energy systems
- Delivering digital at scale

100 years of innovation, 60 years in Scandinavia

SLB celebrates its 100-year anniversary in 2026, with nearly six decades of activity in Scandinavia. The region has produced several technologies now used globally.
In Norway, SLB's operations include offshore services, programming, manufacturing, and R&D, with locations in Stavanger, Oslo, Bergen, Kristiansand, Gjøvik, and Trondheim. The SLB Norway Technology Centre and the INNOVATION FACTORI sites develop digital solutions for geoscience, drilling, and flow assurance. SLB Capturi—the joint venture with Aker Carbon Capture—also draws on Norwegian research. In Denmark, SLB operates workshops in Esbjerg and a sales office in Copenhagen.

Why SLB collaborates with CSSR

Accelerating decarbonisation and innovating across the energy landscape are central to SLB's strategy. Scandinavia's long-standing leadership in technology and digital development aligns strongly with these ambitions. SLB contributes advanced software and digital capabilities—including Petrel, OLGA, GEOX, and cloud-based machine-learning technologies through the Delfi platform. Through Petrocentre and CSSR, SLB shares expertise while learning from Norwegian research, helping identify, prototype, and scale new energy solutions through both local collaboration and its global footprint.



Tormod Slettemeas holds a Master's degree in structural geology from East Greenland. He began his career as a Wireline field engineer in the Middle East, before joining Technoguide (the founders of Petrel). After two decades in software training, consulting, and product development, Tormod now manages the Digital Subsurface, Data, and AI domain business for SLB in Scandinavia.

Subsurface modelling using open-source tools

AUTHOR THOM VAN DER HEIJDEN, MARGRETE HÅNES

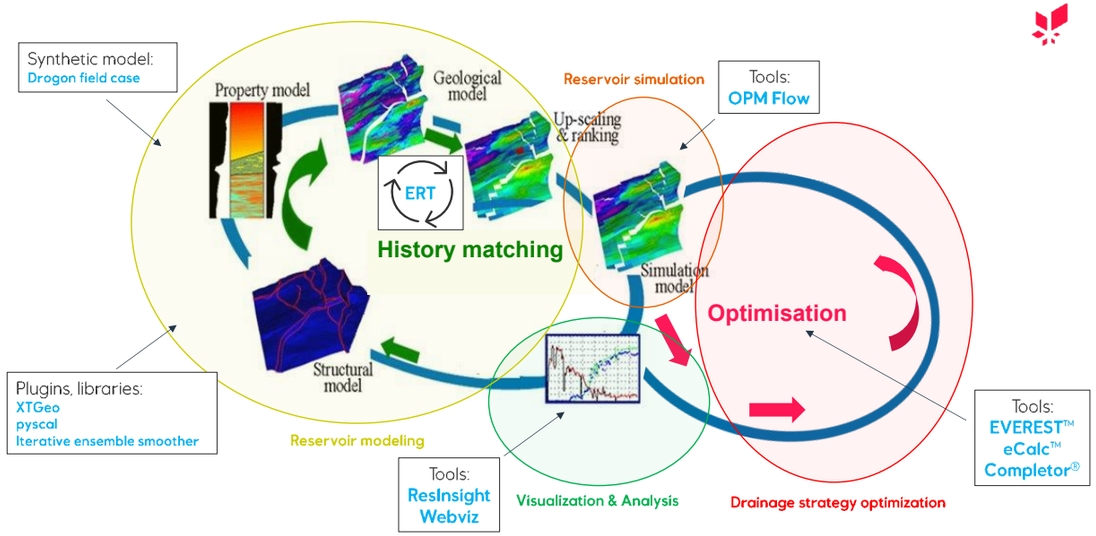
CSSR relies heavily on open-source software tools for subsurface modelling – all the way from reservoir modelling to simulation, optimisation and visualisation/analysis.

Many of these tools were developed in, or with support from, Equinor. In Equinor there is a strong drive for developing and deploying open-source software tools, both for subsurface and for other purposes. Open source is chosen as a strategic direction for software development in Equinor based on the belief in the many benefits that this offers in terms of collaboration, increased user interaction, receiving contributions, R&D progress, hands-on participation by projects, flexibility, cost-sharing, reducing the risk of vendor lock-in and more (ref. **https://opensource.equinor.com**).

For subsurface specifically, the software toolbox and workflows are centred around the principles of uncertainty quantification and ensemble-based modelling. Naturally, this does not apply to every situation, asset, project or stage, but the general principle is that ensemble-based modelling shall be used for field development projects of a certain maturity and for fields in production. For this, Equinor uses the Fast Model Update™ (FMU) integrated and automated workflow for reservoir modelling and characterization.

The various elements of the FMU workflow are flexible and so are the software tools used. Many of them are published open source (indicated in blue). Connecting it all together, one can use the open Drogon field case. This is a synthetic reservoir model which includes a complete FMU set-up, all the way from input data to production and emission profiles. This way, one can get more familiar with the (ensemble-based) subsurface modelling workflow in general and various software tools specifically.

Equinor thanks CSSR for the cooperation in general and for the possibility to showcase some of its open-source subsurface software tools. We hope that this will be useful in further CSSR work – providing new subsurface knowledge and digital solutions to significantly reduce Norway's offshore emissions.



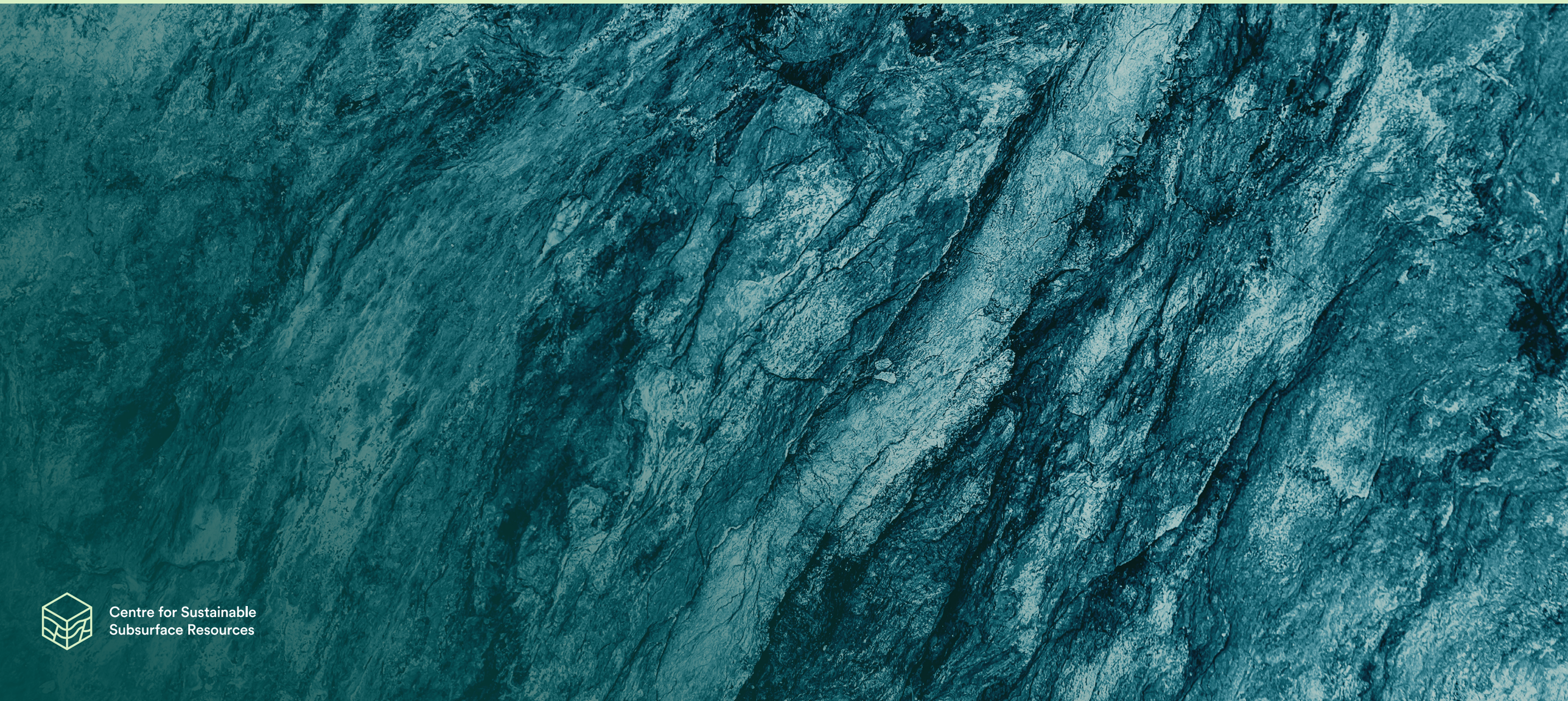
The subsurface modelling & simulation workflow. The Fast Model Update™ (FMU) concept & a selection of open-source software tool.

Thom van der Heijden is responsible for an R&D portfolio focused on subsurface production forecasting and optimisation in Equinor. He has over 15 years of experience from various technical, project-leading and leadership roles – mostly within reservoir/subsurface.

Margrete Hånes leads the R&D portfolio at Equinor delivering energy and emission forecasting tools for O&G installations. Her 28 years' research experience is within chemical reaction engineering and dynamic reservoir simulations, with a PhD in Chemical Engineering.

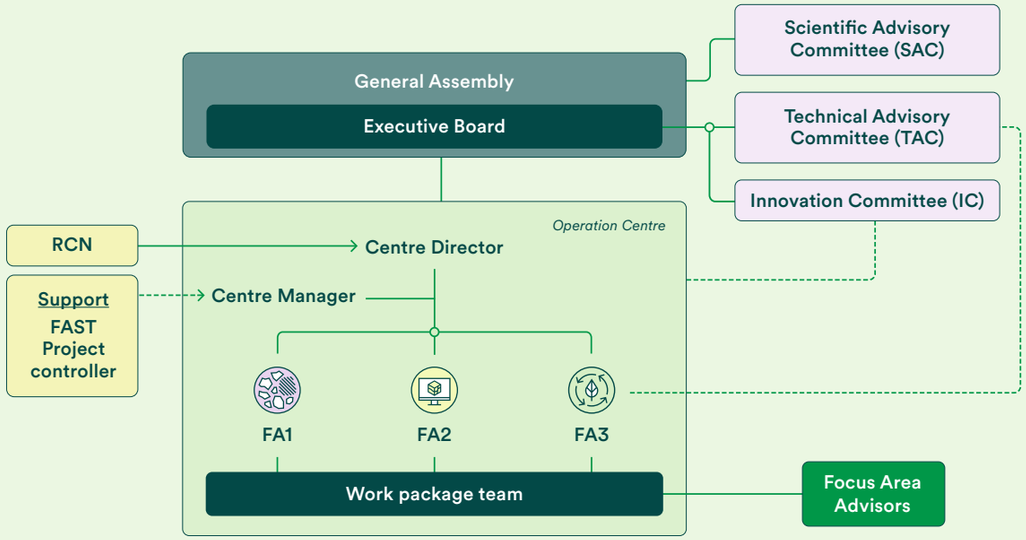
Home

CSSR Facts



Centre for Sustainable
Subsurface Resources

Governance structure



In 2025, CSSR continued to apply established routines for monitoring progress and ensuring effective governance across the Centre. While the General Assembly (GA) maintained its formal oversight role, the Executive Board (EB) remained the primary governing body and met three times during the year to provide strategic direction and approve key decisions.

The year also saw a change in the leadership of the Technical Advisory Committee (TAC). Pit Arnold and Bastian Koehrer stepped down as Chair and Deputy Chair, and CSSR welcomed Martin Haege as the new TAC Chair. The TAC reviewed progress and endorsed the work plan for 2026, while the Innovation Committee continued supporting researchers in refining ideas and strengthening innovation activities.

CSSR management remains satisfied with the advisory structure.

In 2025

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

The Centre values the continued leadership of Geir Terje Eigestad, who was unanimously re-elected as Chair of the Executive Board through 2026, thereby ensuring continuity and providing strong strategic guidance.

Technical Advisory Commitee (TAC) : Insights from outgoing TAC lead and deputy

> ***Thank you for the productive time together — we've really enjoyed the collaboration and the many fruitful discussions and developments."***
>
> Pit Arnold | Harbour Energy

> ***I gained valuable insights into porous media flow and data-driven digital modelling. I'm grateful for the opportunity to contribute to shaping the centre's technical direction."***
>
> Bastian Koehrer | Harbour Energy

Martin Hæge is a Senior Geophysicist at Harbour Energy and brings more than 20 years of experience in geophysics, including microseismic monitoring, 3D/4D seismic interpretation, and static modelling. His expertise is expected to further strengthen CSSR's technical leadership and strategic direction.

Operation centre

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

*Staff changes

CSSR will see changes in its administrative support, as both Ida Sollesnes and Alexander Isaksen are leaving NORCE. The Centre appreciates their contributions and extends its thanks for their professionalism and support. We wish them well in their future endeavours.

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

Work package team

Espen Jettestuen
WP1 leader

Kundan Kumar
WP1 deputy

Biwen An-Stepec
WP2 leader

Geir Ersland
WP2 deputy

Rolf Lorentzen
WP3 leader

Kjersti Solberg Eikrem
WP3 deputy

Tor Harald Sandve
WP4/5 leader

Jakub Both
WP4/5 deputy

Trine Mykkeltvedt
WP6 leader

Roman Berenblyum
WP6 deputy

CSSR research partners

The CSSR consortium brings together a strong research partnership led by NORCE and the University of Bergen (UiB). The collaboration includes five internationally recognised research and development institutes from Europe and the United States, together with six Norwegian industry partners. This broad consortium provides access to complementary expertise, laboratory facilities, and data resources that strengthen the Centre's scientific output.

During 2025, CSSR continued to foster close cooperation across its partners through joint research activities, co-authored publications, workshops, and shared supervision of PhD candidates. The Centre also facilitated invited lectures, researcher exchanges, and collaborative modelling and experimental studies. These activities support an integrated research environment and ensure that CSSR's work remains relevant to both academic and industry needs.

Norwegian Research Partners

NORCE

UNIVERSITAS BERGENSIS

International Research Partners

Oregon State University

Imperial College London

TNO innovation for life

TU Delft

Universität Stuttgart

Norwegian and International Industry Partners

Harbour Energy

equinor

Sumitomo Corporation

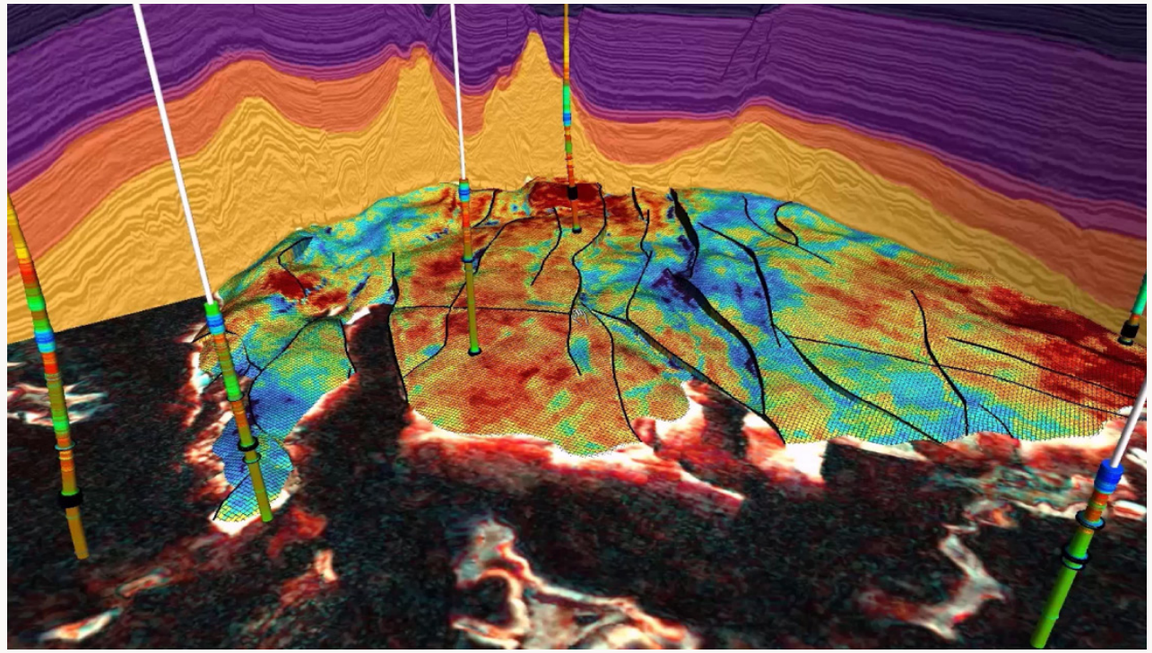
slb

EARTH SCIENCE ANALYTICS

GCE Ocean Technology

The Research Council of Norway

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



SLB representative Tormod Slettemeas provided an update on the DELFI cloud environment for research, highlighting new cloud-native, OSDU-native, and ML/AI capabilities that complement established tools such as Petrel and ECL/IX

Key figures

The 2025 Annual Work Plan set ambitious targets across all work packages, and the CSSR team continued to deliver strong results. Milestones were successfully achieved, demonstrating solid progress toward our strategic objectives. The dedication and collaborative effort of researchers, students and partners were essential in advancing our mission throughout the year.

In 2025, CSSR saw further growth in activity levels, reflected in an increase in reported costs linked to an expanding research portfolio. This year, three new PhD students joined the centre, strengthening our research capacity and ensuring continuity across key scientific themes. Laboratory activity also increased, with higher utilisation of experimental facilities and associated operational spending, reinforcing CSSR's commitment to high-quality, cutting-edge research.

Engagement from researchers intensified, with more time dedicated to implementing the work plan and contributing to collaborative tasks across work packages. CSSR's visibility continued to grow, supported by active participation in national and international conferences. Researchers and students presented at numerous high-profile events, contributed to invited talks at partner institutions, and participated in panel discussions, helping further establish CSSR's presence within the global research community.
To strengthen public outreach, CSSR introduced a monthly open webinar series to share ongoing research and engage a wider audience.

The CSSR chair, Geir Terje Eigestad, in conversation with Professor Jan Martin Nordbotten at the Partner workshop in 2025.

Dissemination

Category	2025
Journal publications	13
Conference proceedings	6
Presentation and posters	40
Theses	3
Products	4
Media, public outreach	7

For further details on publications, please visit **cssr.no**

CSSR Cost*

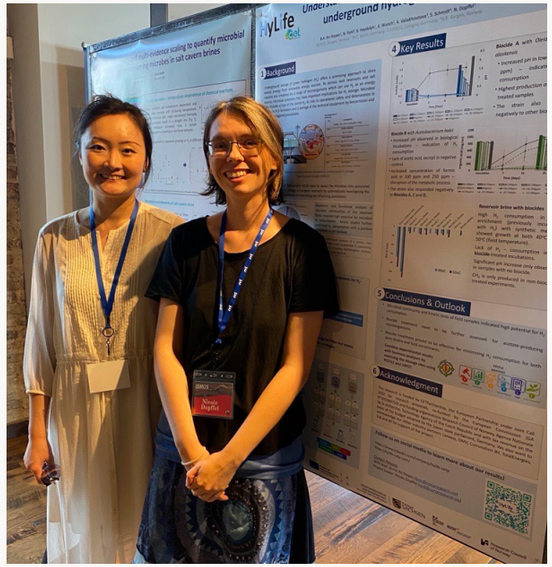
Cost	Amount
NORCE (Host Institution)	13 492
University of Bergen (Research Partner)	10 175
Industry Partners	525
International Academic Partners	277
Total	**24 469**

CSSR Funding*

Funding	Amount
The Research Council of Norway	12 565
NORCE (Host Institution)	1 698
University of Bergen (Research Partner)	4002
Industry Partners	6204
Total	**24 469**

* Figures in kNOK

Participants enjoying productive and inspiring exchanges at Vestland CCUS.



Members of the WP2 (Annie An Stepec, and Nicole Dopffel) attended the 10th ISMOS in Nashville, USA, where they presented some of the WP2 affiliated projects such as HyLife and MOCHYs (presented by the postdoc Verena Nikeleit).

Education and training

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 Schultzendorff	PhD	4/5	Reservoir simulation	9/2022 – 8/2026
Tongtong Yu	PhD	1	Reservoir physics experimental	1/2023 – 4/2026
Kirabo Erismas Mugwanya	PhD	1	Geosciences	4/2023 – 3/2026
Hasan Gürsel	PhD	1	Reservoir physics modelling	11/2023 – 10/2026
Catherine Padde Amusugut	PhD	1	Geosciences	7/2024 – 6/2027
Claudius Holeksa	PhD	1	Reservoir physics modelling	2/2025 – 1/2028
Melito Soares	PhD	2	Reservoir physics modelling	6/2025 – 5/2028
Trygve Tegnander	PhD	4/5	Reservoir simulation	8/2025 – 8/2029
Maksim Lysyy***	PhD	HyPe	Reservoir physics experimental	3/2020 – 6/2024
Eda Önal**	PhD	ExpReCCS	Reservoir simulation	9/2023 – 8/2026
Åsmund van Brussel Synnevåg**	PhD	MuPSI	Reservoir simulation	2/2025 – 1/2028
Frank Acosta**	PhD	Hydra	Reservoir physics experimental	4/2025 – 4/2029
Stefano Galati**	PhD	gigaCCS	Reservoir simulation	9/2025 – 8/2028
Antoine Lechevallier	Postdoc	4	Reservoir simulation	4/2024 – 3/2026
Verena Nikeleit**	Postdoc	MOCHyS	Microbiology	6/2024 – 5/2026

*Defended | **Associated PhD/PostDoc

Masters theses in 2025

Name	WP	Supervisor	Exam date	Title
Olivia Wood	1	Jakub Both, Enrico Facca	Jun/25	Advancing Optimal Transport Metrics for Data Comparisons
Sindri Snær Sigurðarson	3	Jakub Both, Rolf Lorentzen, Andreas Størksen Stordal	Jun/25	Multi-objective Wind Farm Layout Optimization with Multiple Turbine Types

PhDs


Mathias Methlie Nilsen


Raymond Mushabe


Peter von Schultzendorff


Tongtong Yu


Kirabo Erismas Mugwanya


Hasan Gürsel


Catherine Padde Amusugut


Claudius Holeksa


Melito Soares


Trygve Tegnander


Maksim Lysyy


Eda Önal


Åsmund van Brussel Synnevåg


Frank Acosta


Stefano Galati

Postdocs


Antoine Lechevallier


Verena Nikeleit

As of December 2025, the Centre funded 10 PhD candidates and one postdoctoral researcher. In addition, the associated projects ExpReCCS, HyPe, HyDRA, MuPSI, and gigaCCS supported five PhD candidates and one postdoctoral fellow (MOCHyS). During the year, three new Centre-funded PhD candidates began their projects, and one candidate completed and successfully defended his degree.

The fellows contribute to research across production optimisation, reservoir physics, hydrogen storage, geosciences, and reservoir simulation. A monthly seminar series supports the development of scientific presentation skills, and fellows are encouraged to contribute to the Centre's Open Webinar series, which is open to a wider audience and aims to disseminate research progress broadly.

Publications

Journal publications

Dopffel, N.; Shaker Shiran, B.; Mayers, K.; **An-Stepec**, B.A.; Kedir, A.; **Heydolph, B.; Hajibeygi, H.; Djurhuus, K.** Pressure up to 60 bar has no major effect on the overall hydrogen consumption of the sulfate reducer Oleidesulfovibrio alaskensis. *Journal of Applied Microbiology*, **136**, lxaf077 (2025).

Landa-Marbán, D.; Sandve, T.H. pyopmspe11: A Python framework using OPM Flow for the SPE11 benchmark project. *Journal of Open Source Software,* **10**, 7357 (2025).

Liu, N.; Fernø, M.A. Calcite-functionalized microfluidic chip for pore scale investigation of biogeochemical interactions in porous media. *Lab on a Chip,* **25**, 2320–2324 (2025).

Liu, N.; Ostertag-Henning, C.; **Fernø, M.A.; Dopffel, N.** Growth on hydrogen by the sulfate-reducing Oleidesulfovibrio alaskensis induces biofilm dispersion and detachment–Implications for underground hydrogen storage *Environmental Science and Technology*, **59**, 7095–7105 (2025).

Mushabe, R.; Liu, N.; Dopffel, N.; Ersland, G.; Fernø, M.A. Experimental study of microbial hydrogen consumption rates by Oleidesulfovibrio alaskensis in porous media. *InterPore Journal,* **2,** (2025).

Mushabe, R.; Liu, N.; Dopffel, N.; Ersland, G.; Fernø, M.A. Impact of specific surface area on anaerobic microbial hydrogen consumption by a sulfate reducer: A sand pack study (https://doi.org/10.1016/j.ijhydene.2025.150861). *International Journal of Hydrogen Energy*, **166**, (2025)

Mykkeltvedt, T.S.; Sandve, T.H.; Gasda, S.E. New sub-grid model for convective mixing in field-scale CO_2 storage simulation. *Transport in Porous Media,* **152**, (2025).

Nilsen, M.M.; Lorentzen, R.J.; Leeuwenburgh, O.; Stordal, A.S.; Barros, E. Closed-loop workflow for short-term optimization of wind-powered reservoir management. *Cleaner Energy Systems,* **12**, 100213.(2025).

Nilsen, M.M.; Lorentzen, R.J.; Stordal, A.S.; Leeuwenburgh, O.; Barros, E. Wind-powered reservoir management with application to robust multi-objective optimization. *Computational Geosciences,* **29,** (2025).

Nordbotten, J.M.; Fernø, M.A.; Flemisch, B.; Kovscek, A.R.; Lie, K.-A.; **Both, J.W.**; Møyner, O.; **Sandve, T.H.**; Ahusborde, E.; Bauer, S.; Chen, Z.; Class, H.; Di, C.; Ding, D.; Element, D.; Flauraud, E.; Franc, J.; Gasanzade, F.; Ghomian, Y.; Giddins, M.A.; Green, C.; Fernandes, B.R.B.; Hadjisotiriou, G.; Hammond, G.; Huang, H.; Kachuma, D.; Kern, M.; Koch, T.; Krishnamurthy, P.; Lye, K.O.; **Landa-Marbán, D.**; Nole, M.; Orsini, P.; Ruby, N.; Salinas, P.; Sayyafzadeh, M.; Torben, J.; Turner, A.; **Voskov, D.V.**; Wendel, K.; Youssef, A.A. Benchmarking CO_2 storage simulations: Results from the 11th Society of Petroleum Engineers Comparative Solution Project. *International Journal of Greenhouse Gas Control*, **148**, 104519 (2025).

Shaker Shiran, B.; Aarra, M.; **An-Stepec, B.A.; Heydolph, B.; Carlsen, D.L.; Djurhuus, K.; Dopffel, N.** Effects of microbial activities on hydrogen storage efficiency in porous media. *International Journal of Hydrogen Energy*, **154**, (2025).

Viveros Acosta, F.E.; Liu, N.; Fernø, M.A. Biogeochemical interactions and their role in European underground hydrogen storage. *Minerals,* **15,** 929 (2025).

Xu, J.; **Liu, N.** Editorial for the Special Issue of Minerals: "Mineral Dissolution and Precipitation in Geologic Porous Media. *Minerals,* **16**, 36 (2025).

Conference Proceedings

Folkvord, O.; Both, J.; Eikehaug, K.; Nordbotten, J.M.; Fernø, M.A. Laboratory evaluation of physical variability of multiphase flow during CO_2 sequestration. In: World CCUS Conference 2025, September 2025 (2025)

Lechevallier, A.; Sandve, T.H.; Landa-Marbán, D.; Kane, B.; Gasda, S.E. Incremental machine learning for near-well prediction: A non-linear preconditioning approach to faster history matching. In: SPE Reservoir Simulation Conference, Galveston, Texas, USA, March 2025. (2025)

Lechevallier, A.; Sandve, T.H.; Landa-Marbán, D.; Kane, B.; Gasda, S.E. Random features learning in incremental machine learning: Fast non-linear preconditioning for history matching. In: 86th EAGE Annual Conference & Exhibition, June 2025 (2025)

Mykkeltvedt, T.S.; Khrulenko, A.; Gasda, S.E. The role of petroleum fields in advancing CCS on the Norwegian continental shelf. In: World CCUS Conference 2025 (2025)

Mushabe, R.; Minougou, J.D.; Landa-Marbán, D.; Kane, B.; Sandve, T.H. Predicting ultimate hydrogen production and residual volume during cyclic underground hydrogen storage in porous media using machine learning. In: ESAIM: Proceedings and Surveys (2025)

Nilsen, M.M.; Lorentzen, R.J.; Leeuwenburgh, O.; Stordal, A.S.; Barros, E. Closed-loop workflow for short-term optimization of wind-powered reservoir management. In: 86th EAGE Annual Conference & Exhibition, June 2025 (2025)

Highlighted conference contributions

Flemisch, B.; Nordbotten, J.M.; Fernø, M.; Kovscek**, A.;** Lie, K.-A.; **Both, J.W.; Møyner, O.; Sandve, T.H.** The 11th Society of Petroleum Engineers Comparative Solution Project: Summary Report. SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS25) (2025).

Helland, J.O.; Jettestuen, E.; Aursjø, O. Pore-scale level-set simulation of drainage-imbibition cycles of trapped gas during decline and incline of reservoir pressure. InterPore 2025, Albuquerque, New Mexico, USA (2025).

Kane, B.; Sandve, T.H.; Landa-Marbán, D. Machine learning for solver acceleration in the context of reservoir simulation. ENUMATH 2025, Heidelberg, Germany (2025).

Landa-Marbán, D.; Sandve, T.H.; Gasda, S.E. A coarsening approach to the Troll Aquifer model.TCCS-13, Trondheim (2025).

Landa-Marbán, D.; Tveit, S.; Gasda, S.E. Impact of hydrodynamics on microbial transport and growth in porous-reservoir hydrogen storage. InterPore 2025, Albuquerque, New Mexico, USA (2025

Lechevallier, A.; Sandve, T.H.; Landa-Marbán, D.; Kane, B.; Gasda, S.E. Incremental machine learning for near-well prediction: A non-linear preconditioning approach to faster history matching. SPE Reservoir Simulation Conference, Galveston, USA (2025).

Lechevallier, A.; Sandve, T.H.; Landa-Marbán, D.; Kane, B.; Gasda, S.E. Random features learning in incremental machine learning: Fast non-linear preconditioning for history matching. EAGE, Toulouse, France (2025).

Mugwanya, K.; Eide, C.H.; Gawthorpe, R. Sedimentary signals of climate change: geological controls on the depositional architecture and heterogeneity of transgressed fluvial systems in the northern North Sea. 8th International Meeting of Sedimentology, International Association of Sedimentologists (IAS), Huelva, Spain (2025).

Mykkeltvedt, T.S.; Sandve, T.H.; Landa-Marbán, D.; Gasda, S.E. A sub-grid model for convective mixing applied to the 11th SPE Comparative Solution Project. SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS25), Baton Rouge, USA (2025).

Nordbotten, J.M. Two-point stress approximations for simulating mechanical response in porous media. InterPore 2025, Albuquerque, USA (2025).

Yu, T.; Liu, N.; Djurhuus, K. Pore-scale experimental study of particle dynamics and filter cake formation in porous media during produced water reinjection. Abu Dhabi International Petroleum Exhibition & Conference (ADIPEC), Abu Dhabi, United Arab Emirates (2025).

Zamani, N.; Gasda, S.E.; Landa-Marbán, D.; Sandve, T.H. Unraveling salt precipitation mechanisms: Insights into dominant driving forces. InterPore 2025, Albuquerque, USA (2025).

Selected academic lectures

Gasda, S.E. Simulating our way to CO_2 storage at climate-relevant scales. SIAM Conference on Mathematical & Computational Issues in the Geosciences (GS25), Baton Rouge, Louisiana, USA, October 2025. (2025)

Gasda, S.E. Modeling at multiple scales: how simulations help decision making for large-scale CO_2 storage. Bergen Conference on Modeling and Simulation of Coupled Subsurface, VISTA, Norway. (2025)

Gasda, S.E. 25 years of geological CO_2 storage modeling and simulation: learnings and way forward. Njord Seminar, UiO, Oslo. (2025)

Gasda, S.E. Competing for pressure space in multi-actor storage hubs. The Annual International Carbon Capture and Storage Conference, CCS 2025, Oslo, 3–4 December 2025. (2025)

Landa-Marbán, D. Pre- and post-processing tools for OPM: pycopm and plopm. OPM Summit, Bergen. (2025)

Lechevallier, A.; Sandve, T.H.; Landa-Marbán, D.; Kane, B.; Gasda, S.E. Efficient nonlinear preconditioning for reservoir simulation history matching using random features learning. CSSR Open Webinar Series.(2025)

Mushabe, R.; Liu, N.; Dopffel, N.; Ersland, G.; Fernø, M.A. Underground hydrogen storage in porous media: Microbial controls and multiphase flow. CSSR Open Webinar Series. (2025)

Mykkeltvedt, T.S.; Khrulenko, A. CO_2 storage potential on the Norwegian continental shelf. CSSR Open Webinar Series. (2025)

Mykkeltvedt, T.S.; Sandve, T.H.; Landa-Marbán, D.; Gasda, S.E. A sub-grid model for convective mixing applied to the 11th SPE CSP. TIME4CO_2 Kick-off and International Workshop on Image Analysis and Modelling of Laboratory Porous Media Flow, UiB, Tysnes.(2025)

Nilsen, M.M.; Lorentzen, R.J.; Leeuwenburgh, O.; Stordal, A.S.; Barros, E. Closed-loop workflow for short-term optimization of wind-powered reservoir management. CSSR Open Webinar Series.(2025)

Nordbotten, J.M. CO_2 storage: Experimental and computational validation. Baltic Carbon Forum 2025, Tallinn, Estonia. (2025)

Nordbotten, J.M. Reproducibility in reality and computation. Computational Sciences – Quo Vadis, Trondheim, Norway. (2025)

Nordbotten, J.M. Understanding data and simulations for flows in porous media. InterPore, CSSR Webinar (2025)

Nordbotten, J.M. Validering og verifisering av beregningsmodeller for kompleks fysikk. Hvordan forutsi og utvikle systemer i komplekse omgivelser? TVA/Tekna/AE, Norway. (2025)

Products

Jettestuen, E.; Aursjø, O.; Vinningland, J.L. – Lattice Boltzmann code extended for particle transport. A general-purpose lattice Boltzmann solver. **https://github.com/eje74/BADChIMP-cpp**. GitHub (2025).

Landa-Marbán, D. plopm: Simplified and flexible tool to visualize OPM Flow geological models **https://github.com/cssr-tools/plopm/releases/tag/v2025.10**. GitHub Pages (2025).

Landa-Marbán, D. *p*ycopm: An open-source coarsening framework for OPM Flow (2025). **https://github.com/cssr-tools/pycopm/releases/tag/v2025.04**. GitHub Pages (2025).

Lechevallier, A. Incremental Machine Learning for Near-Well Prediction: A Non-Linear Preconditioning Approach to Faster History Matching. **https://github.com/lechevaa/PET/tree/spersc25. https://github.com/lechevaa/opm-simulators/tree/spersc25.** GitHub Pages.(2025)

Popular science articles

Gasda, S.E. Carbon Storage: From Paradox to Possibility, TEDxØygarden. **https://youtu.be/aLX5rOxEHZ8?si=_So8-BiFTipCbcK7**

Reports and theses

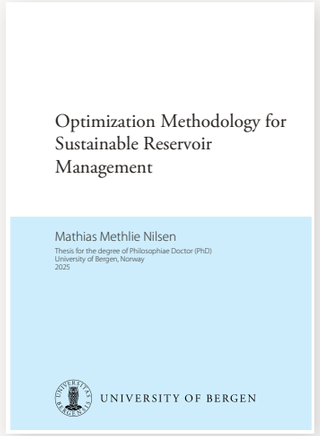
Masters theses

Wood, O. Advancing optimal transport metrics for data comparisons. **https://hdl.handle.net/11250/5336070**

Sigurðarson, S.S. Multi-objective wind farm layout optimization with multiple turbine types. **https://hdl.handle.net/11250/5339810**

PhD thesis

Nilsen, M.M. Optimization methodology for sustainable reservoir management, University of Bergen. **https://nva.sikt.no/registration/019b222991ba-4d559575-6361-42d4-b68a-c493b4806adf**



First PhD funded defense for CSSR:
Dr. Mathias Methlie Nilsen

TEDxØygarden 2025

At TEDxØygarden 2025, Sarah Gasda, the Centre Director, highlighted why underground CO_2 storage is one of the most promising climate solutions available today. Drawing on nearly 30 years of safe and proven storage, she explained how Europe's geology offers significant potential for reducing emissions and supporting a more sustainable energy future. Her talk emphasised that CO_2 storage is not about hiding a problem, but about enabling practical solutions that can help drive the green transition.

TEDx talk - Sarah Gasda - Link to YouTube

PHOTOS **MARKUS HOLE | PWC**

Outlook

CSSR enters 2026 with clear priorities and strong momentum. Four PhD candidates are scheduled to defend their theses, marking an important milestone in developing new expertise for the energy transition. The Centre will also host the 5th International Underground Hydrogen Summer School, providing an arena for knowledge exchange and interdisciplinary collaboration among students and experts.

Following the 2025 interim evaluation, CSSR will implement the recommendations aimed at maintaining the high-quality research we have come to expect from our world-class team. The coming year will be the bridge to the final period and the shift towards solidfying CSSR's legacy and maximising impact.

A key opportunity for international collaboration will come through the International Cluster of Excellence in Sustainable Subsurface Research (ICE-SSR). Supported by the INTPART programme, ICE-SSR will connect CSSR with leading global institutions to advance sustainable subsurface energy and carbon storage. The initiative will facilitate joint courses, workshops, and student exchanges, offering CSSR researchers and students access to a wider international network.

Together, these efforts will enhance scientific impact, strengthen innovation, and position CSSR as a leading contributor to sustainable subsurface solutions.

Follow our progress at cssr.no

Centre for Sustainable Subsurface Resources

CSSR
Centre for Sustainable
Subsurface Resources
cssr.no

HOST INSTITUTION

NORCE
Norwegian Research Centre AS

Postbox 22 Nygårdstangen
5838 Bergen
norceresearch.no

Centre for Sustainable Subsurface Resources

NORCE

UNIVERSITAS BERGENSIS

The Research Council of Norway