Public

End report for ACTOM, Act on Offshore Monitoring

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1. Identification of the project and report

Project title	ACTOM, Act on Offshore Monitoring
Project ID	299661
Coordinator	University of Bergen
Project website	https://actom.w.uib.no
Reporting period	September 2019-February 2023.

Participants

Organisation	Main contact(s) + E-mail	Role in the project
University of Bergen	Guttorm Alendal <Guttorm.alendal@uib.no>	Coordinator, WP5 lead
	Sigrid Eskeland Schütz <Sigrid.Schytz@uib.no>	WP1 and WP3 lead (shared)
	Dorothy Jane Dankel <Dorothy.Dankel@uib.no>	WP3 lead
	Anna Oleynik <Anna.Oleynik@uib.no>	Research, development in WP2
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OCTIO Environment	Martha Lien <martha.lien@octio.com>	Partner contact
	Bjarte Fagerås <bjarte.fageraas@octio.com>	Advise from industry perspective
PML	Jeremy Blackford <JCB@pml.ac.uk>	WP2 lead, UK national contact, research

	Marius Dewar <made@pml.ac.uk>	Research, development in WP2
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	Stefan Carpentier <stefan.carpentier@tno.nl>	Research and implementation in all WPs
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BEG	Katherine Romanak <katherine.romanak@beg.utexas.edu>	Partner contact, research

2. Executive summary

The ACTOM project has been executed by a highly cross-disciplinary group of scientists from Europe and the USA. The core of the project has been to develop a Decision Support Tool for offshore monitoring and environmental impact assessments for offshore geological CO_2 storage sites. To assure that the toolbox adequately addresses the right societal issues and research questions, the ACTOM project included a substantial work package on societal embedding of the CO_2 storage techniques developed.

The ACTOM Decision Support Tool (DST) is a fully autonomous code base that works on Linux, MS, and Mac platforms. It requires site specific data, in a documented format and a small number of user criteria (thresholds, leak rates). From that it will calculate in a matter of minutes optimal monitoring strategies and indicative impact fields. The DST can be run independently, although with no liability accepted. Potential users are encouraged to contact one of the project partners to discuss use.

The DST is documented at designated web page (link) and, among others, this page contains:

- a summary overview of the DST, https://youtu.be/bA4FGIbydmA
- a detailed description of the DST methodology https://youtu.be/bRGFBD2AySY
- a video demonstrating our case studies for three sites in the Gulf of Mexico and in the North Sea https://youtu.be/Tiv2Hn30kcw
- instructions to access and download the DST: https://github.com/ACTOMtoolbox
- Contacts enabling stakeholders to discuss applications with the project partners.

We estimate that in bringing the disparate compute codes together, developing fast emulators for scenarios and automating the DST outputs we have achieved a 3+ point Technology Readiness Level increase from TRL 3/4 to TRL 7.

Role and contributions of each project partner

All partners have been very active in the project and contributed with their diverse expertise. As a rule, all partners took part in the biweekly meetings.

University of Bergen had the overall coordination responsibility of the project and had shared WP lead on WPs 1,3 and 5. Sigrid Eskeland Schütz, from the Faculty of Law, had the responsibility of coordinating the review of the regulatory framework and took part in the RRI activities in WP3. Dorothy J. Dankel, from the Department of Biological Sciences, coordinated the RRI activities in WP3. At the Department of Mathematics Guttorm Alendal, Anna Oleynik, and others, took part in the development of the toolbox in WP2 and performing the site studies in WP4. Parisa Torabi, hired in the in-kind PhD position, will continue her PhD studies beyond the project period utilizing the toolbox and assure publication of results.

NORCE led WP4, shared lead on WP1, and contributed within all WPs. Sarah Gasda led WP4, the site studies, and contributed also with her general knowledge and network within CCUS. Abdirahman Omar co-led WP1 and was responsible for the technological overview done there. He contributed with the Cseep method for the toolbox in WP2. Late in the project period, Gisle Andersen with colleagues, performed the Norwegian survey within WP3.

OCTIO was active in the biweekly meetings and Bjarte Fagerås contributed with his experience in offshore monitoring and industrial offshore projects.

Plymouth Marine Laboratory (PML) led WP2 and coordinated the development and implementation of the toolbox. Jerry Blackford had the overall responsibility for the toolbox development and, due to his long record of accomplishment within CCUS, contributed within all activities in the project. Marius Dewar implemented many of the components in the toolbox and built the routines for information flow, including the output report. He also had a key role in performing the site studies in WP4. Darren Snee was our expert on the Docker technology and online hosting of the toolbox.

University of Dundee contributed with their expertise in regulations and law, Raphael Heffron was co-authoring the report that was the main deliverable from WP1. Due to a change of personnel, Sufyan El Droubi came into the project team at a late stage and did a study of the regulations in Brazil for the final webinar.

TNO, Stefan Carpentier contributed across all activities in the project, especially with technical expertise for the report in WP1, geological risk maps and discussions in WP2, and with the site studies in WP4.

LANL Rajesh Pawar contributed across all activities in the project, especially with his experience with subsurface modelling and he contributed with data for the Gulf of Mexico site study.

BEG Katherine Romanak, with er long record of accomplishment within CCUS research, contributed to all WPs in the project, especially in the RRI activities in WP3 and providing contacts to prepare for the Gulf of Mexico studies. Together with colleagues, she led the US survey in WP3.

3. Short description of activities and final results

Overall activities and results.

Much of the activities within the project has evolved around the ACTOM Decision Support Tool development. Supported by the regulatory and technological activities in WP1 and the societal aspect in WP3, the support tool was developed in WP2. In parallel, the site studies were prepared in WP4. Data sources identified and collected, and the site studies were performed and reported at the final webinar. The project has been reporting results at international conferences, included the last two GHGT conferences. In the aftermath of the project, we aim to present results at international conferences and have a couple of peer-reviewed manuscripts in the pipeline. A web page presenting the Decision Support Tool is online: https://www.pml.ac.uk/science/projects/ACTOM-Decision-Support-Tool. Here the DST is described, it links to the GitHub repositories for different operative systems and shows produced a video presenting the toolbox. The video can also be found on YouTube: https://www.youtube.com/watch?v=bA4FGIbydmA.

As reported in Annex 6, all partners used the allocated resources according to plans. UiB and TNO were the only partners that contributed with in kind funding. For UiB this is mostly the PhD position allocated from the Faculty of Mathematics and Natural Sciences. For TNO it was internal use of time. In addition, we were able to secure funding from the Academia Agreement between UiB and Equinor that funded much of the work done by Anna Oleynik. We refer to the more thorough reporting to our respective national funding agencies for more details on project financial reporting.

WP1 Baseline

In the first WP1 meeting in December 2019 we recognised the importance of shortlisting technology/tools, and selecting which international legal instruments, jurisdictions, regulations and associated national CCS-projects to be addressed in the project. The work was then followed up through monthly WP1 meetings throughout 2020. These meetings as well as subtask forces were open for all project members. This proved to be useful and the whole ACTOM contributed to the discussions and work that shaped up the results from this WP.

After producing the first preliminary results in medio 2020, both regarding technology and regulation, we reached out to ACTOM stakeholders, meaning storage operators and relevant administrative bodies in charge of assessing the impact assessment and the suggested CCS monitoring plan. We aimed for feedback in semi-structured dialogue meetings. These meetings were in addition to facilitating for co-production and sharing of knowledge, a part of the Responsible Research and Innovation (RRI)-approach in WP3. Two such dialogue meetings were conducted on Teams, with Norwegian stakeholders (in Norwegian, but some presentations in English from team members) and international stakeholders (in English), respectively. The meetings were built upon the same structure, with presentations from the team-members of the project and relevant preliminary results. Besides being open for more general input and viewpoints, some specific prepared issues/questions were presented for the participants and discussed during the meeting.

Among the questions identified by the team members as important to have feedback on and discuss, were: Are there examples on any minimum monitoring (technology) requirements prescribed by law? What is the aim of the regulation (including the link to the impact assessment and the outcome of it)? When it comes to the choice of the monitoring technology, does the administration have full discretion (non-prescriptive regulation)? Are there any unwritten minimum monitoring requirements to ensure that the project is being monitored "well enough" / "properly"? Are there unwritten maximum requirements based on a proportionality test? If yes; how can they be reflected in the online web-based tool for designing a monitoring program?   As a result, we had interesting perspectives form the stakeholders of “unwritten” knowledge as to the approach to and design of a CCS monitoring program and associated choice of monitoring technology.

After revising the report and refining the results, the WP 1 team, in close collaboration with WP 3, held an international presentation of the WP 1 findings on 13 October 2020, 14.00–15.30 CET in a hybrid seminar in Bergen/on Zoom (Link). In the invitation online we asked; “*What tools for marine monitoring can be used today? What are the capabilities of these tools? What does national and international law require of marine monitoring?*” It was made as an invitation to an open webinar.

Dorothy Dankel (WP3 leader), Abdirahman Omar and Sigrid Schütz met in a studio in Bergen, in line with the local COVID-restrictions. The key report findings were presented. Then, in line with the RRI-approach in the project, we facilitated a discussion with the WP 1 team in a panel, where Katherine Romanak and Raphael Heffron attended online and presented respectively on international perspectives and international legal perspectives. The panel opened for questions from the participants, writing in the chat. We had some interesting feedback, and some reassurance where no "protests" were raised.

The report was then finalized, and published online in 2021: Schütz, Omar & Carpentier, (2021), *Report on regulations and technological capabilities for monitoring CO_2 storage sites* (link). During the final weeks of the project the regulations in Mexico and Brazil were addressed and presented at the final webinar. We are in the process of updating the report with this added information, we aim to author a peer review publication based on the report.

WP2 Digital

The aim of the decision support toolbox is to provide a coherent, inter-active set of tools, specifications and processes that will enable multiple stakeholder communities to understand, agree and subsequently implement environmental monitoring for offshore carbon storage projects.

The ability to assess monitoring strategies and environmental impact potential rests upon the ability to simulate a comprehensive range of release scenarios such that the monitoring target or impact area can be fully characterized. That ability initially resides in high resolution, coupled, hydrodynamic-biogeochemical models which provide meter-scale resolution of dispersive plumes whilst retaining multi-scalar forcing factors such as tidal, geostrophic and wind driven mixing. Given that such models are computationally demanding, limiting multiple scenario iteration, ACTOM has developed a fast simulator based on one-off site-specific hydrodynamic simulations. The subsurface geophysical/geological input is now characterised as surface maps that contain per coordinate probabilities of a CO_2 leakage/seepage and its magnitude. These probabilities are derived from 3D seismic subsurface models and simulated reservoir models containing structural elements like faults, stratigraphic traps, spill points etc. The biogeochemical baseline has been defined and examples for test cases provided by site specific observations and model simulations.

Within the toolbox, the approaches to defining anomaly criteria have been optimised including 1) identifying small chemical changes that occur at unusually rapid rates or 2) departures from stoichiometric ratios seen in natural systems. The deployment strategies to be considered in the next phase include those based on 1) "Greedy Set" algorithms and 2) neural nets and inverse ensemble methods.

The initiative to develop decision support tool was presented at GHGT-15 in *A Toolbox to Assist in Designing Marine Monitoring Programs for Offshore Storage Sites* by Blackford et al., combining and streamlining previous and novel computational approaches to aid appropriate, rigorous, and cost-effective monitoring of offshore carbon storage, thereby developing easily accessible software for designing optimal monitoring strategies for offshore storage. This development would align industrial, societal, and regulative expectations with technological capabilities and limitations enabling the optimisation of marine monitoring strategies including:

- Enabling operators to properly plan, cost and adapt monitoring strategies to site-specific circumstances, hence accelerate the planning phase and implementation.

- Enabling regulators to reliably, independently quantifiably assess that a proposed monitoring strategy delivers an acceptable standard of assurance from license applicants.
- Enabling regulators and operators to communicate to the effectiveness of proposed monitoring strategies to enable informed societal consensus in view of Marine Spatial Planning (MSP) and Responsible Research and Innovation (RRI).

The toolbox was developed in an environment which utilises Docker and associated container technologies. Docker containers wrap up software and dependencies into a standardized unit for software development that includes everything needed to run, including the code, light operating system, tools, and libraries. This guarantees that your application will always run the same on any system and makes collaboration as simple as sharing a container image. A simple Graphical User Interface (GUI) allows the user to specify locations of data and user specified settings, with optional default values and built-in test data sets. Inter-container communications and external inputs are facilitated through framework mandated services and datatypes. Docker containers running the various processes are mandated by the framework, this covers requirements, behaviour, libraries, inputs, and products. Mandating file types such as NetCDF and remote data sources allows the system to benefit from existing technologies and data sources. The toolbox is publicly available on GitHub: https://github.com/ACTOMtoolbox under a MIT license.

The toolbox simulates the footprint from a gas seep through the seafloor, building statistics of the resulting excess CO_2 concentration. Based on this, locations with the highest probabilities of detect such a seep can be identified, with subsequent design of cost-efficient monitoring programs. The technical description of the toolbox was presented at GHGT16 in *Demonstration of a Semi-Automated Decision Support Toolbox to Aid Operators in the Design of Efficient Environmental Offshore Monitoring Programs for CO_2 Storage Sites* by Dewar et al.

The toolbox requires multiple sources of site-specific data, these include 1) subsurface geophysical/geological data, where will the CO_2 most likely reach the seafloor, 2) hydrodynamic data, how will the CO_2 be transported and diluted within the water column and 3) marine biogeochemical data, to what extent will the signal be hidden within natural variability. In many cases, pre-existing data are available, although sparse, for other areas they are missing. Since the quality of the results from the toolbox is highly correlated with the quality of the data used as input, an important pre-process activity will be to assess the quality of the different data sets that are available for a site and identify the need for gathering additional data. During the site studies we have seen that biochemical time series from the seafloor could a necessity. See the section on WP4 Impact, for demonstrations of the decision toolbox on three different sites.

We have secured two speaking slots at the upcoming IEAGHG-Risk network meeting in June (28/29th) at Heriot Watt, Edinburgh. Here we will present the background understanding, the DST and offer demonstrations, in the context of well leakage https://ieaghg.org/conferences/2-uncategorised/1070-ieaghg-risk-management-network-meeting-2023.

There are currently at least two papers in the drafting stages, with potential for more. One will focus on the geophysical side but show how this contributes to the overall DST. Following on from this, a paper is being drafted on the case studies, showing how the DST can be selective on tools and outcomes dependent on the input data. For example, where leakage rates are too low to be detected against thresholds as was shown in some of the case studies, the DST can detect this early in the process and alternative paths may be suggested. This can include the use of varied input data to provide best coverage and sensor locations even with lower leakage rates, or to link to tools still in development beyond this project such as machine learning techniques for semi-automated detection with moving sensors such as AUV's. There are also further discussions on a magazine type piece for something like The Conversation, but this is still at initial stages.

The DST system is archived on GitHub and will remain available into the future. We do not envisage significant work to maintain existing capability, anything necessary, such as web updates will be addressed, as necessary. Adding new features will be contingent on obtaining further funding.

WP3 Responsibility

WP 3 facilitated RRI throughout the different work-packages, and RRI-sessions/workshops was held at each annual ACTOM meeting. The concept of "RRI-In-reach" was deployed, in that social aspects of CCUS technologies and marine monitoring are discussed in ACTOM *during* the development of the marine monitoring toolbox. This assures that feedback from stakeholders, and from other work packages in ACTOM, can guide the development of the WP2 toolbox.

After the introduction of corona restrictions, facilitating RRI had to been done online, like in the stakeholder dialogue meeting and open webinar held to disseminate results and get feedback from a wider community in WP 1. To reach out to a wider stakeholder group to understand their perceptions of CCS technology, we initiated and performed surveys on public perceptions on CCS-monitoring in Norway and the US.

In the US, we wanted to get a better understanding of how citizens in Texas, Louisiana and Florida react to different environmental monitoring schemes. We found that a simple, intuitive approach to CO_2 monitoring was preferred for both citizens we classified as having a "high science orientation" and those with a "low science orientation." Further, social norms matter: citizens we classify as having a "high science orientation" express trust in academic and industry expert support of a monitoring scheme while those we classify as "low science orientation" express trust based on community member support.

Our results support the use of simple images and figures to garner public understanding and support among citizens, simple image in our choice experiment was preferred. Our result also confirms insights from research on cultural cognition in that the source of the support of monitoring schemes, either from experts or from community leaders, affected the levels of trust of the CO_2 monitoring technologies. Further, our results underscore that communication of CO_2 storage monitoring schemes could highly benefit from an underlying social understanding of citizen values and social norms in Texas, Louisiana, and Florida. These results were presented at GHGT16 in *The effect of monitoring complexity on stakeholder acceptance of CO_2 geological storage projects*, by Atkinson et al.

During the final months of the project, we performed a survey in Norway. The questionnaire was designed to assess people's opinions on CO_2 storage, with special emphasis on their perceptions on safety and monitoring. As earlier surveys also indicate, there is little knowledge about CCS in the Norwegian population, three quarters of the respondents have no or little previous knowledge of CCS. Half of the respondents are positive to the technology, but a large share of them (about one fifth) do not have an opinion. Most people find it particularly important that monitoring ensures that leaks are quickly detected and stopped. The least important factor is that "ordinary people understand how the monitoring works", although 35% of the respondents do find this very important. The results also indicate that it is unlikely that the public have opinions on different monitoring options. Finally, mentioning leakage or monitoring in the way we did in this survey, does not influence opinions or risk perceptions among the respondents. We are still analysing these data and will later publish the results in a suitable channel, in combination with other relevant surveys.

WP 4 Impact

The activities in WP4 centred around demonstration of the ACTOM toolbox for three site studies of planned first-mover projects in Norway and the Netherlands and anticipated storage deployment in Texas waters of the Gulf of Mexico (GoM), USA. The intention was not to replicate or influence monitoring strategies for these sites, but to demonstrate the toolbox in a real-world setting and promote the added value of toolbox functionality with regards to optimized strategies that account for geologic risk, cost-benefit, and maximum effect.

The site-specific data needed, i.e., 1) subsurface geophysical/geological data, 2) hydrodynamic data, and 3) marine biogeochemical data, can often be collected from pre-existing data. Since the quality of the results from the toolbox is highly correlated with the quality of the data used as input, an important pre-process activity will be to assess the quality of the different data sets that are available for a site and identify the need for gathering additional data. During the site studies we have seen that biochemical time series from the seafloor represent the biggest challenge to collect.

We have demonstrated the use of different data sources and use of additional modelling, especially to simulate CO_2 migration through the overburden for a site in the Gulf of Mexico and two sites in the North Sea, one in the Norwegian sector and a southern site in Dutch waters. The study was presented at GHGT16: *The Impact of Pre-Project Data Quality and Quantity on Developing Environmental Monitoring Strategies for Offshore Carbon Storage: Case Studies from the Gulf of Mexico and the North Sea*, by Alendal et al.

4. Project impact

The broad international project group has addressed the priority research directions, identified in the *Mission Innovation*[1] report, bridging storage (i.e., monitoring) and crosscutting (i.e., social aspects in decision making) themes. The project has made significant advances in aligning marine monitoring efforts with legislation, and vice versa, providing a blueprint to assure that legislation does not postpone, or undermine, offshore storage projects by being unnecessarily stringent or ineffectual.

A rigorous cost-benefit assessment of monitoring strategy will allow for informed communication between operators, regulators, and the public. The ACTOM decision support tool delivers the ability to design a site-specific marine monitoring program. The tool kit is:

- adaptable to any offshore region targeted for storage.
- capable of evolving as algorithms and new methodologies are developed.
- updatable with underpinning data as this comes on stream.
- allow operators to demonstrate conformity to regulations and expectations.
- a tool alluding to multi-site cooperation on monitoring.

Viewing CCUS and offshore storage in the framework of the Sustainable Development Goals, will ease communicating the benefits of the technology while addressing the uncertainties and risks in a coherent way. Overall, we believe that we have contributed with research that support communication and public acceptance of CO_2 storage in geological formation beneath the seafloor.

The ACTOM toolbox is at a stage that will make it useful for operators and governments as it is. The ACTOM team is ready to assist in performing site specific studies, including the need to gather additional data to increase the quality of the toolbox predictions. We also see several new algorithms that could be implemented in the toolbox to further increase the applicability of the toolbox, especially in post processing of results.

5. Implementation

The broad international project group has addressed the priority research directions, identified in the Mission Innovation1 report, bridging storage (i.e., monitoring) and crosscutting (i.e., social aspects in decision making) themes. The project has made significant advances in aligning marine monitoring efforts with legislation, and vice versa, providing a blueprint to assure that legislation does not postpone, or undermine, offshore storage projects by being unnecessarily stringent or ineffectual.

A rigorous cost-benefit assessment of monitoring strategy will allow for informed communication between operators, regulators, and the public. The pre-operational tool kit delivering the ability to design a site-specific marine monitoring program. The tool kit is:

- adaptable to any offshore region targeted for storage
- capable of evolving as algorithms and new methodologies are developed
- updatable with underpinning data as this comes on stream.
- allow operators to demonstrate conformity to regulations and expectations
- a tool alluding to multi-site cooperation on monitoring.

The project has contributed to the Mission Innovation Priority Research Directions, within of CO_2 storage and crosscutting themes, by studying the poorly understood link between regulations and risk-based marine monitoring demands. The project has directly addressed all research directions listed in Mission Innovation1 PRD S-5 and PRD S-4, even though the focus in the latter is on geophysical monitoring. The RRI approach will be used as a tool for social aspects in decision making, Mission Innovation1 PRD CC3.

6. Collaboration and coordination within the Consortium

The project started at the onset of the pandemic, the first lock downs in Europe and USA took place a few months after our kick-off meeting. This forced us to meet online, and we implemented a routine of meeting every two weeks for updates and general discussions. Due to the interest in the project from all partners, this turned out to a good replacement of less frequent physical meetings. We never met as a project group after the kick-off meeting, still the project obtained effective communication within the group.

The ACT collaboration made it possible for us to perform this cross-disciplinary project from national fundings, that would been impossible. Especially, a project that involved researchers from Europe and the USA assured that our work became relevant on both sides of the Atlantic.

Transnational value: Marine systems overlying offshore storage sites are highly heterogeneous such that any seep event would be unique to a given location and time of year. Further the “baseline” from which a seep must be distinguished are similarly heterogeneous. Consequently, we cannot define a generic set of rules for by which to deploy sensors for monitoring or to use as criteria by which to characterize an anomaly that would apply globally, or regionally or even consistently at one site across all seasons. However, the learning and the methodology by which detection criteria and monitoring strategies can be determined are eminently transferrable, depending on a robust characterization of local hydrodynamics and geochemistry. The ACTOM toolbox therefore enables transnational sharing of such methodologies, inter-comparison of similar methodologies facilitating further development and optimization and enable rapid transfer of knowledge to regions where little or no monitoring characterization has yet been considered.

7. Dissemination activities (including list of publications)

Our list of dissemination activities shows that we have been active in presenting results at various events and conferences. We are working on several manuscripts, aiming for publication in high impact peer-reviewed journals, reporting our results.

List of publications and dissemination activities

Type of publication: SPa = Peer reviewed Paper, PPa = Popular science presentation, Pat= Patent application, Po = Poster, OPa = Oral presentation and paper, PoPa = Poster and Paper, O = Oral Presentation, Web = Webinar, WS = WorkShop, V = Video, A = Abstract, B = Blog, I = Interview, PR = Press Release, Oth = Other, please specify.

	Date	Title	Presenter/ Authors	Reference/journal/event	Partners involved	Others involved	
O	05/11/ 2019	ACTOM; Act on offshore monitoring	Guttorm Alendal	Annual ACT meeting.	BEG;LANL;NORCE; OCTIO;PML;TNO;UiB ;UDundee;		
Po	05/11/ 2019	ACTOM; Act on offshore monitoring	Guttorm Alendal	Annual ACT meeting.	BEG;LANL;NORCE; OCTIO;PML;TNO;UiB ;UDundee;		
I	11/01/ 2020	CO2-lagring under havbotnen krev effektiv miljøovervaking	Guttorm Alendal	forskning.no	UiB;	Øystein Rygg Haanæs	In Norwegian
O	04/12/ 2019	CCS, legal constraints, and opportunities - Legal frameworks offshore	Sigrid Eskeland Schütz	Bergen CCUS Seminar 2019	NORCE ;UiB;		

O	05/12/2019	ACTOM; Act on offshore monitoring	Guttorm Alendal	Bergen CCUS seminar, 2019.	BEG;LANL;NORCE;OCTIO;PML;TNO;UiB;UDundee;		
SPa	24/01/2020	Impact and detectability of hypothetical CCS offshore seep scenarios as an aid to storage assurance and risk assessment.	Blackford, Alendal, Avlesen, Brereton, Cazenave, Chen, Dewar, Jason, Phelps	International Journal of Greenhouse Gas Control, 95, 102949.	PML; NORCE; UiB	NOC, Heriot-Watt, UK	http://doi.org/10.1016/j.ijggc.2019.102949
SPa	09/02/2020	Optimal sensors placement for detecting CO2 discharges from unknown locations on the seafloor.	Oleynik, García-Ibáñez, Blaser, Omar, Alendal.	International Journal of Greenhouse Gas Control	NORCE; UiB		http://doi.org/10.1016/j.ijggc.2019.102951
WS	10/02/2020	ACTOM day	All ACTOM		All partners	SENSE, DIGIMON, int colleagues	
Oth	04/05/2020	Monitoring offshore CO2 storage projects, aligning capabilities with regulations and public expectations.	Alendal, all ACTOM	EGU general assembly 2020. Online, chat format, presentation of the project.	All partners.		https://egu2020.eu
SPa	19/06/2020	Binary Time Series Classification with Bayesian Convolutional Neural Networks	Gundersen, Alendal, Oleynik, Blaser	Algorithms	UiB		https://doi.org/10.3390/a13060145

		When Monitoring for Marine Gas Discharges					
Oth	19/07/2020	Semi Conditional Variational Auto-Encoder for Flow Reconstruction and Uncertainty Quantification from Limited Observations	Gundersen, Oleynik, Blaser, Alendal	Arxiv preprint	UiB		https://arxiv.org/abs/2007.09644
Web	13/10/2020	Report on potential conflicts in regulations and technological capabilities of monitoring Carbon Capture and Storage	Sigrid Eskeland Schütz, Abdirahman Omar, Dorothy Dankel, Raphael Heffron, Katherine Romanak.	ACTOM webinar	All		https://actom.w.uib.no/webinars/
Oth	23/09/2020	A Variational Auto-Encoder for Reservoir Monitoring	Kristian Gundersen, Seyyed A. Hosseini, Anna Oleynik, Guttorm Alendal	Arxiv preprint	BEG; UiB		https://arxiv.org/abs/2009.11693
SPa	23/01/2021	Towards improved monitoring of offshore carbon storage: A real-world field experiment detecting a controlled sub-seafloor CO2 release	Flohr A., Schaap A., ... Alendal G., ...Blackford J.,Oleynik A., et al.	International Journal of Greenhouse Gas Control,	PML; UiB	STEMM-CCS consortium	https://doi.org/10.1016/j.ijggc.2020.103237
SPa	28/01/2021	Semi-conditional variational auto-	Kristian Gunderse	Physics of Fluids	UiB		https://doi.org/10.1063/5.0025779

		encoder for flow reconstruction and uncertainty quantification from limited observations	n, Anna Oleynik, Nello Blaser, Guttorm Alendal				
	10/02/2021	ACTOM, act on offshore monitoring.	G Alendal	CLIMIT summit 2021	All		
	10/02/2021	Carbon Capture and Storage in 2021: What do we know and what do we not know?	D Dankel	Workshop during 2021 SDG conference in Bergen	All	REX-CO2	https://www.uib.no/en/sdgconference/133578/2021-sdg-conference-programme-sdgs-after-crisis
OPa	15/03/21	The stoichiometric Cseep method: A process-based technique to simultaneously detect CO2 seepage at the seafloor and quantify any extra carbon dissolved in the sampled seawater	A. Omar et al.	GHGT15	NORCE, UiB		https://ghgt.info/
OPa	15/03/21	The prediction of impact and anomaly criteria for leakage detection from offshore carbon storage sites through a comprehensive coupled network of hydrodynamic and	M. Dewar et al.	GHGT15	PML		https://ghgt.info/

		biogeochemical models					
OPa	15/03/21	A toolbox to assist in designing marine monitoring programs for offshore storage sites	J Blackford et al.	GHGT15	All;		http://dx.doi.org/10.2139/ssrn.3821572
PoPa	15/03/21	Practicing responsible innovation by engaging stakeholders with marine monitoring of storage sites	D Dankel et al.	GHGT15	All;		https://ghgt.info/
PoPa	15/03/21	Marine Monitoring of Storage Sites, Potential Conflicts in Regulations and Technological Capabilities.	S Schütz et al.	GHGT15	All;		https://ghgt.info/
PoPa	15/03/21	Application of Deep Learning for Characterization of CO2 Leakage Based on Above Zone Monitoring Interval (AZMI) Pressure Data	K Gundersen et al,	GHGT15	BEG; UiB		https://ghgt.info/
SPa	31/03/21	Detection and quantification of CO2 seepage in seawater using the stoichiometric Cseep method: Results from a	A. Omar et al.	International Journal of Greenhouse Gas Control,	NORCE; UiB		https://doi.org/10.1016/j.ijggc.2021.103310

		recent subsea CO2 release experiment in the North Sea					
O	08/04/21	What are the risks? How do we mitigate, monitor, and verify.	G Alendal	SPE virtual workshop: Offshore CCUS-the size of the price and the way forward.	All		https://www.spe.org/events/en/2021/workshop/21aho2/offshore-ccus-size-of-the-prize
Po	12/04/21	Assurance offshore monitoring, a cross-disciplinary approach	G Alendal	International Conference on Marine Data and Information Systems	All		https://imdis.seadatanet.org
Spa	29/04/21	Numerical modelling of CO2 migration in heterogeneous sediments and leakage scenario for STEMM-CCS field experiments	Saleem et al.	International Journal of Greenhouse Gas Control Volume 109, July 2021, 103339	PML; UiB		https://doi.org/10.1016/j.ijggc.2021.103339
Web		New methods for CO2-detection developed	A. Omar	Webpage Bjerknes Centre for Climate Research	NORCE; UiB; PML		https://bjerknes.uib.no/en/article/news/new-methods-co2-detection-developed
Spa	9/07/21	Efficient marine environmental characterisation to support monitoring of geological CO2 storage	J Blackford et al.	International Journal of Greenhouse Gas Control. Volume 109, July 2021, 103388	PML; BEG; UiB		https://doi.org/10.1016/j.ijggc.2021.103388
O	20/10/21	Prioritizing under contested public perceptions- how policy,	SE. Schütz	Beyond oil conference at Centre for Climate and Energy	UiB		

		regulation, technology and responsible research and innovation (RRI) frame public perception on climate technologies.		Transformation, UiB			
O	19/05/2022	ACTOM, Act on Offshore Monitoring.	G. Alendal et al.	5th International Workshop on Offshore Geologic CO2 Storage, New Orleans, May 19-20.	All		
O	10/6/2022	ACTOM, Act on Offshore Monitoring.	G. Alendal et al.	ACT knowledge sharing workshop, Rotterdam, June 2022.	All		
O	30/06/2022	ACTOM, Act on Offshore Monitoring.	G. Alendal et al.	US-Norway collaboration on CCS/CCUS, annual bilateral meeting 2022 in Bergen, Norway	All		
OPa	24/10/2022	The effect of monitoring complexity on stakeholder acceptance of CO2 geological storage projects	Romanak et al.	GHGT16	BEG,UiB		
PoPa	26/10/2022	THE IMPACT OF PRE-PROJECT DATA QUALITY AND QUANTITY ON DEVELOPING ENVIRONMENTAL MONITORING STRATEGIES FOR OFFSHORE CARBON STORAGE: CASE STUDIES FROM THE GULF OF MEXICO AND THE NORTH SEA.	Alendal et al.	GHGT16	All		

PoPa	26/10/2022	A SEMI-AUTOMATED TOOLBOX TO AID OPERATORS IN THE DESIGN OF EFFICIENT ENVIRONMENTAL OFFSHORE MONITORING PROGRAMS FOR CO2 STORAGE SITES	Dewar et al.	GHGT16	All		
PPa	27/10/2022	ACTOM: WEB basert verktøyskasse for sikker monitorering av CO2 under havbunnen	Oleynik et al.	Havlunsj i regi av GCE Ocean Technology	All		
O	08/02/2023	ACTOM	Alendal and all	CLIMIT summit	All		
Oth	28/02/2023	ACTOM DST webpage.	Blackford et al.		All		https://www.pml.ac.uk/science/projects/ACTOM-Decision-Support-Tool
V	28/02/2023	ACTOM video	Blackford et al.		All		https://www.youtube.com/watch?v=bA4FGIbydmA
Web	28/02/2023	ACTOM final webinar	ACTOM team	Our final webinar.	All		