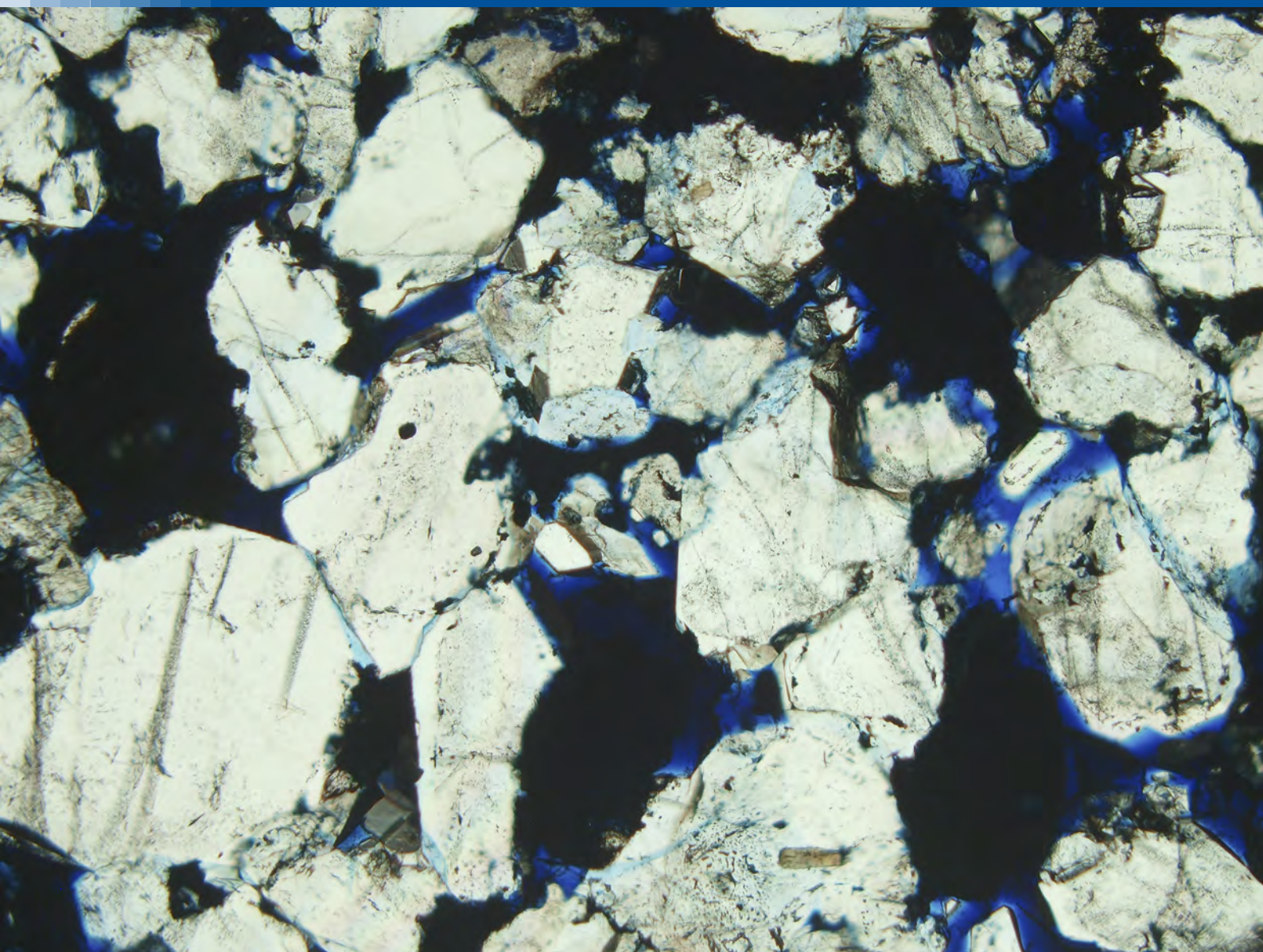
The Research Council of Norway

Midterm evaluation of research centres for petroleum activities

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



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Preface

This evaluation report presents the midterm evaluation of the two centres for petroleum research, in PETROSENTER. The centres were established in 2013 as a result of the Government's white paper Meld. St. 28 (2010–2011) «An industry for the future – Norway's petroleum activities». The white paper Meld. St. 7 (2011–2012) «The High North» is a key document for one of the centres.

The centres are co-funded by the host institution, research partners, user partners and the Research Council of Norway. The user partners are expected to actively participate in the governance, financing and research activities at the centres, and must conduct significant innovation activities of their own as well as be able to take advantage of the research results when developing their activities.

The centres have been established for a maximum period of eight years: an initial five year period with the possibility of a three-year extension. The evaluation will form the basis for a decision about whether to continue the individual centre for the remainder of the overall eight-year term, or to wind it up after five years. The evaluation will also give advice to the centres on aspects of their activity that should be improved.

The members of the evaluation panel were:

- Alison McKay, University of Leeds, UK
- Fridtjof Riis, Norwegian Petroleum Directorate, NO
- Craig Smalley, Imperial College, UK
- Angus Best, National Oceanography Centre, UK
- Ingela Dahllöf, Göteborgs Universitet, SE

The Research Council of Norway wants to express a great appreciation to the international evaluators. Particular thanks go to Alison McKay for her professional leadership of the panel and the process of writing the report. The evaluation team has accomplished to communicate well with the centres. The team has produced a report which will be of great value both for the further activities of the centres and for the Research Council in the administration of this and similar schemes.

Fridtjof Fossum Unander
Executive director

Siri Helle Friedemann
Director

Contents

1 Overall report

1.1 Introduction

The Research Centres for Petroleum project (PETROSENTER) was initiated in 2013, and has a project portfolio of two centres. The research centres are time-limited, and are characterised by broad objectives, a long-term perspective and a targeted focus in order solve identified challenges for exploitation of the Norwegian petroleum resources.

The Centres were established for a maximum period of eight years: an initial five year period with the possibility of a three-year extension. The midterm evaluation will form the basis for a decision by the Research Council of Norway (RCN) whether to continue each individual centre for the remainder of the overall eight-year term, or to wind it up after five years. The evaluation will also give advice to the centres on aspects of their activity that should be improved.

1.2 Evaluation procedure

The Centres were evaluated by a team of five experts. Four were experts with the competence to evaluate the Centres from a scientific point of view. A further “generalist” had experience from similar programs for university-industry research collaboration on an international level. The generalist led aspects of the evaluation related to the management, organisation and funding of the Centre, and also its interactions with user partners, in terms of mutual mobility of researchers, transfer of results and stimulation of innovations.

Each site visit followed the same procedure. A two-hour morning session mainly addressed research at the Centre. This was followed by a 45 minute meeting with PhD students and post-docs. After lunch, there was a 45 minute tour and demonstration of facilities followed by a two-hour discussion on management and organisation of the Centre. The reports of the evaluation teams are based on these interviews as well as on the extensive written reports and self-assessments supplied by the Centre beforehand. A first draft of the report was compiled within 24 hours of the site visit. The report was finalised by email between the members of the evaluation team.

We were impressed by the quality of the written material, including the annual reports, supplied by the Centres as well as by the well organised and informative site visits. We wish to thank the RCN staff for the efficient organisation of the evaluation scheme. Our particular thanks go to Siri Helle Friedemann, Ingrid Anne Munz and Martin Røsok who represented RCN at both evaluations and to Ingrid Anne for her efficient management of the arrangements and for being instrumental in creating the open and informative atmosphere prevailing at both meetings with the Centres.

In the opinion of the evaluators the evaluation did identify progress, strengths and improvement opportunities for the Centres. We felt that the evaluation process was well designed to enable us to provide feedback, advice and recommendations to both the individual Centres and to RCN.

The terms of reference for the evaluations are given in Appendix 1, and panel members are listed in Appendix 2.

1.3 Results

The evaluation team saw strong science and excellent industry-academia collaborations at both Centres that were delivering significant impact to the organisations involved and to wider society. Each Centre was delivering scientific contributions that were within the remit of the PETROSENTER program. The overall structure of the self-evaluation documents was excellent and supported the evaluation team in drawing comparisons between Centres. However, on some occasions, the relationship between Centre activities and reported outputs was unclear.

Each Centre publishes a professionally produced annual report each year that is suitable for a lay audience. In addition, both Centres have high quality web sites that are easy to find using search engines or from the host institutions' web sites.

Both Centres are well connected with relevant international research communities and one has a functioning International Scientific Advisory Board (ISAB). Both Centres demonstrated that they are disseminating results to their international academic communities through publications and other appropriate mechanisms. International mobility of academic staff into and from the Centres was good. RCN does not require Centres to have an International Scientific Advisory Board in place from the start of their eight year journey. In the case where no ISAB was in place, we observed a missed opportunity to increase international visibility and to feed in international scientific insight that could have helped the Centre in its development and assisted in building international scientific critical mass through collaborations.

Both Centres had effective Boards and strong support from their host institutions. In addition, both Centres had clear management structures that ensured the smooth operation of the Centres.

The evaluation team met an impressive spectrum of enthusiastic and capable PhD students, post-docs and early career academics who were most appreciative of the opportunities they gained from being members of their respective Centres. It was noticeable that the PhD student and post-doc scientific training and experience was outstanding in both cases. However, for their longer term career development, they would benefit from additional transferable skills training and further personal development (including training in leadership, project management, commercialisation and entrepreneurship); in this respect the programme lags current international trends.

The downturn in the oil industry since the Centres were established had impacted a number of partners but it was impressive that both Centres had strong engagement with their industrial partners. The needs of some partners had changed since the Centres were established which makes some research areas more important than initially anticipated.

Cash contributions from industry were as required by the PETROSENTER funding and enable Centres to conduct significant scientific research in their areas of interest.

1.4 Conclusions and recommendations

While there are areas for improvement, each Centre is delivering the strategic and thematic priorities of its respective call and the PETROSENTER programme as a whole. Specific recommendations for each Centre are provided at the end of Section 2 for ARCEx and Section 3 for NIORC. The following is a recommendation to RCN.

1. In report templates, ask the Centres to highlight publications with industrial and international co-authors and to categorise outputs to separate out journal papers, conference papers and other publications.

Southampton/Göteborg/ Leeds/Stavanger/London, 17 October 2017

Angus Best (sign.) Ingela Dahllöf (sign.) Alison McKay (sign.)

Fridtjof Riis (sign.) Craig Smalley (sign.)

2 Research Centre for Arctic Petroleum Exploration – ARCEx (228107)

2.1 Introduction

On September 21, 2017, the evaluation team met with the Director, project leaders, PhD students, post-docs, representatives of the host institution and representatives of the industrial and research partners of ARCEx. In the morning, the discussions centred on the research at the Centre and there was a meeting with students and post-docs. In the afternoon there were three research presentations demonstrating results, and discussions on the management and organisation of the Centre. This evaluation is based on these interviews and on the extensive written reports (including annual reports and self-assessments) supplied to us beforehand. We thank the whole ARCEx team for an extremely well-organised meeting as well as very open and informative discussions.

2.2 Research

The Centre is organised according to five work packages.

- WP1: Basin analysis
- WP2: Petroleum systems and play concepts
- WP3: Environmental risk management
- WP4: Technology for eco-safe exploration
- WP5: Education and outreach

The material provided to the review team would have been improved by the inclusion of more scientific detail. As a result, several comments given in this section are of a general nature. Objectives and milestones for achieving the objectives are not defined for any of the work packages. A range of good publications were listed by the project workers but it was not clear how they relate to the deliverables of each work package and how they inform subsequent planned work in each work package. In addition, it was not clear what contribution ARCEx-funded work has made to these publications. This should be made clearer in subsequent reports to RCN. The Centre explained that the current tasks were designed to fill gaps in previous work using new exploration data, though this is not clear from the written documentation.

The main deliverables to industry for WP1 is an improved understanding of the tectonic history, uplift and subsidence, pressure and temperature history, mainly in the parts of the southern Barents Sea that remain relatively unexplored. This type of research has been conducted in the Barents Sea for many years, partly as RCN funded projects. According to the leader of WP1, the ARCEx Centre has selected areas for further studies with the strategy to complement previous work, with the future aim to improve the understanding of the tectonic history of the whole Barents Sea region. The leader of WP1 also said that some progress has been made in understanding the time relationship between maximum burial and trap formation in the eastern part of the Norwegian sector of the Barents Sea, a factor which is important for petroleum exploration. Deep seismic data was acquired to increase the regional geological knowledge by the Centre in 2014, and have not yet been interpreted fully. A study of the Loppa High has been undertaken and results published incorporating mapping and modelling using standard methods.

WP2 focuses on petroleum systems and plays. This is the task most directly related to petroleum geology; it is heavily analogue based, using outcrops on Svalbard, Bear Island, the Norwegian mainland and Greenland. Sedimentation and fluid migration (water along faults) in deep marine rift basins has been investigated using North East Greenland as a case study. The East Greenland study area can be seen as an analogue to the petroleum provinces along the margins of the Bjørnøya and Harstad Basins. Several field campaigns and cruises have already been carried out. The studies of outcrops are logistically challenging, they are only accessible during a short field season and large areas have not been studied in detail. Such studies are essential for training of young researchers and Svalbard is an important reference area for Barents Sea geology. Focussing on outcrop studies is therefore a good approach for a Centre with broad experience in organising fieldwork in the Arctic. The reasoning behind the choice of analogues, and the degree of suitability of each analogue to various parts of the Barents Sea, was not explained to us. Overall objectives for this work package should be defined, and subsequent work plans should be directed toward achieving these objectives, with clear timelines, milestones and deliverables. This could then be used to inform the choice of relevant analogues and how data derived from them are applied in the Barents Sea. We recognise the fieldwork aspects in WP2 are an excellent training ground for early career researchers. The new activity starting up in source rocks and pore pressure are good lines to follow.

Parts of the tasks in WP3 involve improving models for risk assessment and management by (1) adding new data to the SYMBIOSIS ecosystem model and (2) expanding the theoretical backbone for the risk assessment model used by industry to encompass Arctic conditions. Both activities are of high value for ensuring sustainable oil exploration in the Arctic. The upgrade of benthic-pelagic coupling processes due to climate change is one part of this work, but it is unclear what has been done on the benthic ecosystem and how that fits into the ecosystem model or risk assessment. There is also a need to plan more clearly the incorporation of the new data into the ecosystem model, and to identify what other data would be beneficial further to reduce uncertainties. Doing this should inform the Centre on future tasks, aims and objectives. The theoretical backbone of the risk assessment model is finished and has been shared with industry; it is suggested that the actual use of it is documented to provide concrete evidence of its validity to end-users. Likewise, improvement of the ecosystem model should be described and documented in at least one peer-reviewed article.

Another part of WP3 is focussed on ecosystem impact: using laboratory experiments to determine sensitivity of key species to oil related contamination, and field studies to improve understanding of effects on mammals from seismic data acquisition practices (in collaboration with WP4). There seems to be increasing focus on effects of noise on mammals from the oil industry, and the Centre should explore whether suggestions for “best practices” could be developed from the research performed, perhaps in the coming years as a joint WP3 and 4 activity. More emphasis is needed on key species in the ecosystem model other than Arctic cod, such as the part of the food web consisting of its prey (and the prey’s prey). We understand the financial constraints and encourage the Centre to seek external funding and collaboration with Russian scientists on ecotoxicology. It would be beneficial also to the research and management community if the standardised protocols for toxicity testing on arctic species were published in open literature.

In WP4, progress has been made on assessing and reducing the effect of air gun noise on marine mammals, and seismic acquisition methods over ice. Establishment of the geophysical laboratory at Svea is an important achievement for ARCEx and its collaborators, and we expect much good work to come out of this in the remainder of the funding period. It will be valuable to see the integrated geophysical and geological results from onshore, through nearshore to offshore in ice-covered areas. There are possible links to the work at CAGE (the host university’s Centre for Arctic Gas Hydrate,

Environment and Climate) on interpretation of seismic data in sediments affected by hydrate and permafrost in the transition zone from land to sea, although no indication of active or potential synergies with CAGE were indicated by ARCEx.

2.3 Relevance and utility for users

There is an increasing number of peer reviewed publications, 23 in 2016, and 16 so far in 2017. ARCEx researchers reported that they are on target to exceed the planned 160 papers in the lifetime of the Centre. However, it is not clear whether some of these papers are partly or completely funded by previous projects or written by authors not part of the Centre.

The Centre's knowledge dissemination activities include an annual workshop for consortium members, other task-based workshops and annual half day visits to each partner company. These are highly valued by all but one of the participating companies who gave high scores to the usefulness of the knowledge deriving from the Centre, and to the quality of communication with the Centre. In the interview session, the industry representatives present spoke enthusiastically about the results of the project being important to their future exploration activities. This is very positive.

The Centre has important impact for the local community, creating value by training highly skilled people, many of whom may remain in the area and work in high-technology industries. The Centre also supports local research centres such as AKVAPLAN NIVA and NORUT. The Centre provides a national focus for Arctic exploration issues, and its reputation is growing internationally with their presence in publications and at international conferences. The Centre also has a modest number of contributions in the media and popular science press.

2.4 Internationalisation

The Centre brings together internationally recognised research leaders from six Norwegian universities and four research institutes. The number of publications in international conferences and journals has increased after a slow start and the majority (82%) are co-authored with international researchers. The agreement on the international boundary between Norway and Russia in the East Barents Sea has created new opportunities for data sharing, particularly with researchers in Russia. Although there are clear opportunities to share knowledge of this region, there are currently no Russian collaborators in the Centre. The international profile of the Centre could be promoted further by an ARCEx focussed international meeting where leading researchers in relevant fields can present their work and be exposed to ARCEx results. RCN does not require Centres to have an International Scientific Advisory Board in place but the formation of such a group would create new opportunities to increase the international visibility of the Centre and the number and depth of international collaborations.

2.5 Researcher training and recruitment

The panel met a group of nine post-docs and PhD students, including two using video conferencing, who highlighted many strengths of the Centre. A key strength was the diverse educational backgrounds of the Centre's researchers, and the opportunities this provides to learn about other research areas and how their academic knowledge can be used in practice. The students appreciated the adminstrative support they received from the Centre's administrative coordinator and the enthusiasm of the Centre's director who supports researchers by engaging with industry partners and facilitating collaborations with relevant people in partner organisations. They have access to funding for travel and are given opportunities to develop leadership and management skills, for example, by taking responsibility for their projects and organising events such as cruises. When asked how they thought the Centre could be improved, they expressed a wish for more involvement from industry. In addition, clearer descriptions and planning of interrelationships between work packages, tasks and activities would help individual researchers to engage with the wider Centre and strengthen their own activities. An example given by the students where cross work package benefits have already occurred was environmental research from WP3, which strengthened an application from WP4 to conduct research using seismic methods in an immature area of the Arctic.

There is a specific work package, WP5, dedicated to education and outreach with identified leaders although it has no documented breakdown of tasks, milestones or a plan of action. However, the Centre has been very successful in attracting and recruiting a diverse range of students and has contributed to new MSc specialisations in petroleum geoscience and ecotoxicology at the host institution. The Centre encourages industry co-supervisors for ARCEx PhD students and has affiliated PhDs from the host research partners. At the interview, the panel learnt that the Centre is starting to work on industrial secondments and internships (for early career researchers and masters students) which is to be encouraged. In addition, researcher posts attract large numbers of applicants (typically 50-99 per post) and several have been awarded to women. However, not all offers of research positions were accepted. For example, two PhD positions were recently offered to female scientists who turned down the offers that were made.

2.6 Partners and funding

The Centre originally had nine industrial partners and then unfortunately lost two due to companies withdrawing from the region. However, its ability to attract new partners has been demonstrated with a new partner being approved in recent weeks; at the interview, it was reported that two other companies have expressed an interested in joining. The process for attracting new partners has involved a systematic review of all the licences in the Barents Sea to identify potential target companies. Thereafter, key personnel in candidate companies have been contacted, resulting in the recruitment of a new partner in 2017 and with a view to expanding further the group of companies in 2018. However, it is recognised that the current industrial partners are reticent to share too much project information with potential new partners before they sign up. It is important that the Centre's research partners maintain efforts to stay close to the industry partners and to minimise the risk of further losses in the future.

The Centre has also gained additional funding from the local and regional development authorities which is commendable.

2.7 Organisation

The Centre has a well-designed and informative web site that is straight forward to access from the host's web site. There was strong evidence of commitment to the Centre from the host institution, research partners and leadership team. The Centre benefits from excellent administrative support which was acknowledged by the post-docs and PhDs.

The Centre has a relatively flat organisational structure. Initially there was one technical committee for each work package but, in order to support the dynamic nature of the research, this was replaced by a structure where the Technical Committees for WPs 1, 2 and 4 was substituted for one-to-one meetings. WP 3 continues with a separate technical committee. This structure was regarded as effective by all partners at the interview. Improved coordination between the work packages would be facilitated by a common technical committee or alternatively a scientific advisory group for the Centre as a whole, including all work packages.

Research strategy is discussed routinely by the ARCEx management team and any changes proposed to the Board for approval. However, the research strategy is not clearly articulated in a form that can be shared with people outside those involved in the discussions. This makes it difficult for early career researchers to see how their research fits with the Centre's strategy, as opposed to specific work packages, and for those outside the Centre to appreciate how individual research activities fit together within the Centre, and mesh with related funded programmes.

2.8 Relevance to the call and special stipulations

A clear strength of the Centre is its contribution to the overall objective in the call of "industry-oriented researcher training and long-term competence development … within topics that are crucial to the development of business and industry in Norway".

Most of the strategic priorities are addressed by the Centre, but more emphasis should be put on the strategic priorities of "local and regional value creation", "increased circum-polar collaboration" and "implementation of best practice and techniques". The panel believes that more has been done on these priorities than is recognised by the Centre, and that the suggested strategic plan and review of the organisation and management structure can help to identify and highlight work aimed at these priorities.

It is recognised that the special stipulations around organisational structure have been implemented but this structure may need to be reviewed following the establishment of a strategic plan.

2.9 Plans for the final three-year period

The Centre had a slow start but has accelerated its progress in the last two years and is now delivering its overall objectives although further clarification of scientific objectives is needed. A new industry partner has been approved by the Board and is in the process of joining the Centre. The plans proposed for the final three year period build on strengths of the Centre, but tend to focus on staff posts and lack detail on the sciencific work to be carried out, inter-dependencies, timelines, milestones and deliverables for the tasks.

2.10 Conclusion and recommendations to the Centre

This Centre is carrying out high-quality basic research to support future oil exploration and development that is relevant to the oil industry operating in the Barents Sea, and including the waters surrounding Svalbard, where consideration of petroleum exploration is still some way off. The Centre has strong commitment and support from the host university, as well as research and industry partners, and is building new knowledge that will be of long-term value to the industry. A range of activities are laying foundations for the creation of local and regional value. Research results are shared through peer reviewed publications and interactions with companies that range from one-to-one meetings through to an annual conference for members of the Centre. By including six Norwegian universities, four research institutes, and eight industry partners, the Centre provides an arena for connecting expertise across Norway, and is delivering increased cooperation between industry and research groups. The panel makes following recommendations.

1. The Centre defines a strategic plan for its research that highlights critical knowledge gaps being addressed, interdependencies between the Centre activities and related funded projects, and the overarching research goals and industry needs.
2. The Centre uses the strategic plan to inform the definition of a research plan to the end of the Centre funding period with explicit timelines for tasks, milestones and research outputs.
3. The WP leaders use the strategic plan to articulate how the research tasks relate to the Centre objectives, and to identify synergies and opportunities for future cross-disciplinary research.
4. The Centre investigates opportunities to generate eco-toxicological data for a more diverse range of species.
5. The Centre synthesises the research results to produce recommendations for industry best practice as a project deliverable: for example, a report on the assessment of environmental risk and the use of seismic methods aimed at industry practitioners and government policy makers.
6. The Centre implements a mechanism for capturing industrial and societal value and applications of research results. For example, this may involve a survey seeking to quantify stakeholder and end-user value.
7. The Centre places increased emphasis on the exchange of personnel between researchers and industry, capturing data on exchanges that take place and putting in place remedial actions to increase the number of exchanges if necessary.
8. The Centre puts in place mechanisms to encourage all early career researchers to gain some industrial experience.
9. The Centre liaises with the technology transfer and commercialisation departments of the host and research partners to identify and maximise impact opportunities.
10. The Centre further develops its collaborations with Russian scientists in the Barents Sea.
11. The Centre hosts an international meeting, or delivers a substantive thematic session at an established conference, before the end of the funding period to share research results from the Centre and to engage the wider research community.
12. The Centre investigates whether there are any systemic reasons why female applicants turn down offers of research positions and puts in place remedial actions if necessary.
13. The Centre reviews its organisational structures and processes to ensure that they are fit for purpose in delivering the strategic plan (see Recommendations 1-3).
14. The Centre updates the regional geological research catalogue with results of WP1 & 2 and produces a narrative around wider benefits of the Centre as part of the eight year deliverables (also, see Recommendation 1).
15. The Centre recasts its three year plan to reflect objective deliverables, work package tasks, and inter-dependent activities and timelines, rather than staff posts.

3 The National IOR Centre of Norway (230303)

3.1 Introduction

On September 19, 2017, the evaluation team met with the Director, project leaders, PhD students, post-docs, representatives of the host institution and representatives of the industrial and research partners of NIORC. In the morning the discussions centred on the research at the Centre and there was a meeting with the research students. In the afternoon there was a tour of the research laboratories and discussions on the management and organisation of the Centre. This evaluation is based on these interviews and on the extensive written reports (including annual reports and self-assessments) supplied to us beforehand. We thank the whole NIORC team for an extremely well organised meeting, and the open and informative discussions.

3.2 Research

The research profile of the Centre is based on the seven tasks and two themes defined at the beginning of the project and subsequently structured into a roadmap. This has helped to focus the work on the objectives of the Centre. Overall, the breadth and depth of activities combining laboratory rock sample and fluid chemistry studies, and computer model simulations, is impressive, using the latest analytical techniques, including X-ray and CT imaging, and digital rocks. These activities build on the core expertise and track record of the host and partner institutions, while entraining new expertise from international collaborators where required.

The research covers mobilization of residual oil in pore space and improved sweep of mobile oil. Both sandstone and chalk reservoirs are addressed. The methods of smart water injection in chalk and polymer injection in sandstone have been selected as case studies. Today we see that these methods are consistent with a recent Norwegian Petroleum Directorate regional study[1] on increased recovery potential on the Norwegian Continental Shelf. For the future, it is important that the Centre continues to ensure an appropriate balance is maintained between studies on chalk and sandstones.

As the project has developed, the project has succeeded in creating contacts and collaborations with two service companies (Schlumberger and Halliburton) and several international and Norwegian universities and research institutions. As a result, the research covers a wider field than originally anticipated but it has kept the original focus. The use of international collaborations to add analytical capabilities not available within Norway is a commendable feature of the research: for example, having workers (some early career) with extended assignments working in Japan, China, the Netherlands and the USA.

The combination of work at different scales (nano, pore, core and field) is excellent. This means that, as well as defining the benefits of different EOR treatments empirically, the underlying mechanisms can be understood: so leading to a firm theoretical basis for subsequent modelling and optimization work.

The core-scale modelling and experimental work appears to be progressing according to plan and is of high quality. The focus on smart water, polymers and silicates is appropriate. However, it is

[1] "Positive prospects for producing more" Available from http://www.npd.no/en/Topics/Improved-Recovery/Temaartikler/Positive-prospects-for-producing-more/

important to distinguish here, and in all the activities, the difference between: (a) polymers used proactively in association with water injection (i.e., polymer flood, low salinity + polymer, surfactant flood + polymer) where the use of the polymer is designed into the flood to optimise sweep; and (b) polymers and silicates designed to be used reactively to remediate problems that arise with sweep, using treatments near the well (e.g., cross-linked polymer gels) or deeper into the reservoir (e.g., thermally activated polymers and silicates). Both these modes are important but (a) has much higher recovery impact on the Norwegian Continental Shelf. Operationally these are very different and the way in which they would be incorporated into reservoir optimization would need to be different. The adoption of studies into geo-mechanical influences of fluid flow is also encouraged to explore possible significant effects on reservoir integrity during saline or smart water injection.

While the results to date have focused on laboratory scale studies, the Centre has recognised the importance of upscaling experiments for model validation in their roadmap in the steps towards a full scale pilot study. Given the challenges of creating the controlled environment needed for porous media at decametre scale, the Centre is encouraged to consider possible solutions that are tractable within the available resources and timescale, as well as addressing activities that may require other sources of funding such as the RCN's Demo 2000 programme.

There has been, and will continue to be, more focus on large scale (decametres) testing than described in the original application, to bridge the gap between core scale testing and EOR pilots. This is good. The polymer yard test has been one of the outcomes that the users have appreciated the most. Planning for future large scale tests will be an important part of the work over the next three years. The users value the IORSim development which has the potential to bridge the gap between laboratory results and the full field potential. This will be a very valuable piece of software.

Plans for generic case studies demonstrating IOR methods using numerical software are sensible and a feasible way to compare the effectiveness of different techniques for a range of relevant field scenarios, guided by industry partner input. They may also be used to inform the design of future large scale test facilities on the pathway to full scale pilots. The Open Porous Media simulation model has a large interest internationally.

We acknowledge the adoption of 4D seismology statistical methods for improved reservoir history matching and predictions, a particularly important topic, and the introduction of a work programme on siliciclastic reservoirs. The implementation of Ensemble Kalman Filter techniques and early published results are particularly encouraging for this application, and the focus on this is welcomed. The real value of these approaches is to yield models with more accurate predictive capability for the purpose of aiding business decision-making. Therefore, it is important that the work on history matching and optimization is framed around how the models will be used by the end users to make decisions and add value.

There is a high level of results sharing among partners and internationally through conferences and workshops particularly aimed at industrial audiences. This is also reflected in the publication of results in peer reviewed journals, which has already reached a significant number (89). The open working environment and good results of the research has made it possible for the Centre to build up a wide network of collaborating institutions, and it could be said that the Centre is now a focal point for IOR internationally. This is very positive and beyond what could be expected at the start-up of the Centre.

The oil price fall in 2014 occurred after the Centre was established and created a new economic environment for petroleum related research. Nevertheless, the research prioritisation of the Centre is still pertinent for lower cost operations.

The Centre members strive to accomplish more sustainable products and techniques and are actively encouraged to consider environmental issues. This is commendable. Novel research on environmental effects of polymers and their degradation products needed for assessment of the environmental impact of polymer injection is being performed within the Centre, and there is also an awareness of potential environmental problems with new fluorescent compounds for tracers. Environmental risk identification, to identify present problems that need to be addressed, has also been done across projects. However, there is a need to deepen the understanding and practice of environmental impact and risk assessment, beyond risk identification, within the Centre. The members are fully aware that new products and techniques developed should decrease environmental impact but recognition of the need to assess the new products and techniques was somewhat lacking. For example, a new way to do smart water injection that reduces the amount of water used or a new tracer compound that requires smaller volumes does not necessarily lead to reduced environmental impact because the new techniques could have other drawbacks such as unwanted by-products or higher overall toxicity. Any new product or technique should therefore be systematically evaluated using an objective risk assessment methodology that both identifies and evaluates its own risks and allows for comparison with respect to environmental impact across a number of products and methods. Preferably a methodology that includes uncertainties will be applied to guide future efforts in product/process development and to identify information gaps that need to be closed. Such frameworks (and competence) are already available, at the University of Stavanger and the commercial partners, and should be implemented within the Centre, especially in projects that aim for future applications in an oilfield context.

We note that the proposed work on microbial EOR (Task 1.3) does not seem to have occurred. This may be justified based on the assessment of IOR potential (Task 7.4), but it would be good for the reasoning to be documented.

3.3 Relevance and utility for users

The partner companies have different backgrounds and objectives. Some of the partners plan or evaluate IOR projects in fields that they operate. Projects which are, or have been, considered by the companies include polymer, surfactants, smart water and CO_2. Other companies, which are not planning for IOR in the near future, will be interested in being updated on technologies and reservoir management in general. The partner companies cited various elements of the results that they were pleased with. These included the potential for faster workflows, improved core handling, 4D seismic workflows (several companies noted this), development of Open Porous Media and IOR simulation software, and large scale polymer degradation tests (several companies noted this).

Some companies reported that they had modified their work as a result of Centre activities. For example one company has adopted NIORC core flooding procedures and software, begun testing findings related to polymers and started to use the IORSim software. This impact is positive and demonstrates utility for some users. To increase the relevance of the history matching and optimization work, it is important to balance model development with work on how the models will be used by the partners to make business decisions. The service companies see the Centre as a valuable platform to interact with stakeholders, to understand the needs of oil companies and the capabilities of the University of Stavanger and the other research partners. They echo the desire of the oil companies to make progress towards larger scale tests and pilots. The companies expressed the need for earlier and closer involvement of the companies and the Technical Committee in the planning of such tests.

Because the companies each have slightly (or in some case majorly) different objectives, it is important for the Centre to understand the needs of each individual company. While there is good mobility of staff between the academic partners, there is much less with the industry partners; this should be improved if possible, for example by encouraging companies to take MSc or PhD students as interns in areas related to their projects. A view expressed by one user was that the methods being researched may never be implemented because of their cost. It is thus important that cost reduction and operational challenges are included as an area of research. Cost should be one of the factors that is input to optimization exercises (i.e., as part of the objective function). Progress towards lowering costs could aid utility among the companies dramatically. Uncertainties should also be included (e.g. oil price) and new methods to improve recovery should be compared to other new and existing methods taking into account cost and ability to operationalise.

Dissemination of project results among the users, and externally, has been extensive. The annual conference is highly regarded, plus there are a range of other forms of output including the annual report, newsletters, and the website. At the time of the review there were 89 journal publications and over 200 conference papers, all of which help to transfer information to potential users, with more in the pipeline. As a result, the Centre is a highly visible focal point for IOR activities nationally and internationally.

3.4 Internationalisation

The Centre has an excellent international profile. Centre researchers participate actively in international conferences and policy-making organisations, and publish in international journals. Some publications are co-authored with international researchers. Researchers are also partners in EU funded projects and the Centre has hosted three international conferences on IOR. There are numerous examples of international researcher exchanges and PhD students were positive about the international experience they were able to gain from their membership of the Centre. The international Scientific Advisory Committee provides international perspectives on the Centre's activities and, based on their 2016 report, provides valuable independent scientific advice.

3.5 Researcher training and recruitment

The panel met an impressive group of students with diverse educational backgrounds from nine countries. They identified a wide range of benefits from membership of the Centre including access to researchers from different disciplines and levels of seniority, shared office space, their inclusion in Centre activities which occur at least monthly, funding for travel and opportunities for the development of wider skills. From the interviews, the panel felt that they would benefit from more opportunities to develop more awareness of industrial needs and drivers. In addition, while the students had numerous opportunities to develop research skills, including access to the recently established Norwegian Research School, decisions on whether or not to take these opportunities lay with individual researchers and their supervisors; a clearer expectation from the Centre's management team for all students to develop research skills outside their direct area of research could increase uptake of these opportunities. In response to questions on the environmental risk assessment of their projects, students noted that they report on this in their quarterly progress reports and were able to articulate potential environmental benefits of their research. However, there was no evidence of a systematic approach to the assessment of environmental risk that would,

for example, allow research outcomes to be compared with competing solutions in an objective manner.

It was excellent that the 26 PhD students and post-docs were able to explain how their projects fitted into the roadmap and contributed to the overall objectives. The dynamic and multi-disciplinary research environment at the Centre provides an excellent training ground for this cohort of PhD students and exposure to industry-facing problems and methods. Currently, the students' main access to the industrial partners is through discussions in seminars, workshops and other gatherings. For the future, the Centre is encouraged to arrange placements for students to industrial partners, for example, to carry out short term activities that will deliver value to the company and expose the students to the business environment.

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

3.6 Partners and funding

The Centre has a good cooperation with its industrial partners. Different partners have different fields of interests and some projects are conducted in cooperation with single partners while results are shared with the whole group. Given the global downturn in the price of oil, it is commendable that the Centre has maintained its strong set of project partners, with currently ten oil companies and two large service companies (Halliburton and Schlumberger). The membership has been reduced with DONG Energy leaving and BP and DNO (who were already partners) having merged to form Aker BP. This is partly offset by DEA joining as of next year.

Significant effort is being devoted to attracting new industry partners. For example, representatives of companies that are not members attend the annual conference, which is being used as an opportunity to solicit interest. The annual reports are widely circulated and designed to generate interest in the Centre's activities. In addition, the Centre has developed an ongoing "road trip" to visit potential partners and generate interest in the Centre. These measures are good and should be continued.

Six project proposals aligned with Centre activities have been funded by RCN and other funding bodies. This should also be continued to grow the funding base and increasingly become less dependent on PETROSENTER funding. From the interview, the Centre management team recognises the importance of maintaining the research beyond the eight year funding period. To this end, it is important that concrete plans are put in place to manage the end of PETROSENTER funding so that the valuable work of the Centre can continue. The plans should include building even closer relations with the current members such that funding from them can be maintained or augmented, continuing to build relations with potential new partners, and accessing research funding from EU programs, PETROMAKS or elsewhere. Care should be taken that such applications are coordinated to maintain the overall direction towards field tests that build on the Centre's research outputs and consolidate its legacy.

3.7 Organisation

The Centre has a clear identity that is evident from its well designed and accessible web site. The web site is straight forward to find from the host institution's web site. The management of the Centre is effective and efficient, with a clear management structure. The Centre director, theme and task leaders, and chairs of the Board and Technical Committee form a strong leadership team. The research roadmap is an effective way of managing the research projects and ensuring researchers can articulate how their research fits into the Centre's overall research strategy.

Overall, feedback from the industry partners was positive and raised no significant concerns. However, from the interview and the partner evaluations, the panel concluded that a number of partners have the view that it would be beneficial for the companies and Technical Committee to be much more involved in setting the direction of the research and the formulation of projects. This is especially important when preparing for large scale and field tests where knowledge and experience from the companies will be essential.

3.8 Relevance to the call and special stipulations

The Centre fulfills the original objectives in the call "to develop knowledge, expertise and technology relating to the development and operation of reservoirs on the Norwegian Shelf in order to achieve a higher recovery factor than under today's approved plans". The thematic areas are well chosen from the suggested priority areas in the call. It is at this stage difficult to assess the feasibility of knowledge to be carried through to implementation within the life-time of the Centre, but the projects all fit in to such a plan.

Some of the special stipulations have been addressed, such as a selection of field cases relevant to the Norwegian shelf, including focus on siliciclastic reservoirs, and strengthening the competence in geophysics. Evaluation of economic potential and the openness of research results and data sets need to be continuously addressed, to ensure progress and for potential prioritisation of projects. The special stipulation on environmental impact needs substantially more attention, as pointed out in the research section.

3.9 Plans for the final three-year period

The roadmap shows the plans throughout the project period and an overview of planned developments within each task is given in the self-evaluation document. However, despite the importance of environmental impact in the area, activities to support the use of a systematic approach to environmental risk assessment are not shown explicitly.

At the evaluation meeting, Task 7.1, the optimization of production, appeared to be based only on recovered volume. Subsequent discussions confirmed that all optimization projects optimize Net Present Value. Research results would be more directly applicable for industry if this was made clearer and optimisations also took account of environmental parameters.

Changes are planned based on input from industry and their needs and on important political and industry changes. In planning for the final three years, the roadmap should be reviewed to ensure that the research strategy reflects the current industry situation and provides for continuation of IOR activities beyond 2021. For example, CO_2 injection for EOR, which has a good record in onshore oil

production, was not regarded as attractive in 2013 due to lack of available CO_2. However, today, the oil price has levelled out while costs are generally reduced. If the planned full cycle Norwegian Carbon Capture & Storage pilot is successful, then CO_2 could be available from 2022. The Centre should monitor opportunities created by such changing circumstances when planning for the next three years and beyond.

3.10 Conclusion and recommendations to the Centre

This is a strong and highly performing Centre. In this first period the Centre has carried out high quality scientific research that has been externally recognised by international awards. The panel makes following recommendations.

1. The Centre adopts an objective approach to enable a systemic identification and assessment of environmental risks across all Centre projects including the application of research outcomes in the field.
2. The Centre develops a more detailed, concrete and coherent plan for the achievement of large scale tests including what is feasible to the end of eight years and beyond. These plans should include the purpose of the tests, key variables to consider, scales that are appropriate, and instrumentation that will be required.
3. The Centre continues to develop the case studies and use them more widely in the project, incorporating input from industry to make them representative of the real-world and relevant to the research.
4. The Centre (researchers and user partners) considers what implementation in the field would entail in terms of costs and operational challenges, and identify improvement opportunities to increase the likelihood of uptake, at least for the case studies.
5. The Centre improves its understanding of the needs of individual industry partners and establishes a strategy and plan for the exploitation of research results to inform the planning of Year 6-8 research including stage-gated research activities that focus on user needs, to build industry confidence and perception of value and so improve likelihood of acquiring the necessary data.
6. The Centre ensures students have equal opportunities for accessing budgets for travel and conferences.
7. The Centre provides students with more opportunities to build business skills, insights and awareness of industry needs and drivers.
8. The Centre prioritises plans for legacy funding in the final three years for continuity of activity after the end of PETROSENTER funding.
9. The Technical Committee participates proactively in the entire process for developing plans for field tests in dialogue with the Board.
10. The Centre articulates and documents the economic and technical reasoning behind the choice of IOR methods to focus on in the Centre's research projects.
11. The Centre accesses senior competence on environmental risk assessment (ERA) to support the establishment of an ERA that can be used on all Centre activities in planning and evaluation of results.
12. The Centre includes, in the production optimisation work planned for the final three years, technical, economic, operational and environmental parameters in optimisation objectives.

Appendix 1: Terms of Reference
Midterm Evaluation of PETROSENTER

Framework for the evaluation

Introduction
Two research centres were established in 2013 as a result of the Government's white paper Meld. St. 28 (2010–2011) «An industry for the future – Norway's petroleum activities». The white paper Meld. St. 7 (2011–2012) «The High North» is a key document for one of the centres.

The research centres are time-limited, and are characterized by broad objectives, a long-term perspective and a targeted focus in order solve identified challenges for exploitation of the Norwegian petroleum resources. It is also important that the centres stimulate researcher training in fields of importance to the user partners and encourage the transfer of research-based knowledge and technology.

It is required that the centres are co-funded by the host institution, research partners, user partners and the Research Council of Norway. The user partners are expected to actively participate in the governance, financing and research activities at the centres, and must conduct significant innovation activities of their own as well as be able to take advantage of the research results when developing their activities.

The centres have been established for a maximum period of eight years: an initial five year period with the possibility of a three-year extension.

Purpose of the evaluation
The evaluation will form the basis for a decision about whether to continue the individual centre for the remainder of the overall eight-year term, or to wind it up after five years. The evaluation will also give advice to the centres on aspects of their activity that should be improved. The evaluation will be carried out as a peer review.

Background for PETROSENTER
The PETROSENTER activity is funded by the Ministry of Petroleum and Energy (15 mill. kroner annually) and the Ministry of Foreign Affairs (5 mill. kroner annually). The centres were established through two different calls with dead-lines February 13, 2013 and May 29, 2013 respectively. A summary is given here, and the information to the applicants will be provided to the evaluation panel.

Research and knowledge centre for petroleum activities in the northern areas and the Arctic
Many of the undiscovered resources are expected to lie in the Norwegian Sea and Barents Sea. Exploration activity must be carried out as a part of a comprehensive marine management regime. Petroleum activities in the northern areas and the Arctic will be challenging and require new knowledge and technology.

The funding to the Research Council for this centre is provided by the Ministry of petroleum and energy and the Ministry of foreign affairs (equal shares). The objective is to develop a high-quality research and knowledge centre of relevance to the oil industry in the northern areas and the Arctic. Industry-oriented researcher training and long-term knowledge-building

are crucial. Research and knowledge-building activities should result in local and regional value creation and spin-off effects.

The application type Knowledge-building project for industry was used in the call. This application type requires collaboration with Norwegian industry, and the industrial partners must provide cash financing to cover a minimum of 20 per cent of the total project costs. In-kind contributions from the industrial partners cannot be included in the budgets. The call specified however that the applications should preferrably be planned with a larger budget framework than the minimum requirement to co-financing so that the Research Council's share of funding comprises about 50 per cent of the project costs. The application type has a standardized template for the project description and standardized evaluation criteria.

Research Centre for improved oil recovery on the Norwegian continental shelf
The current adopted plans provide an average expected recovery rate of 46 per cent for oil and 70 per cent for gas on the Norwegian Shelf (Meld. St. 28 (2010–2011)). The funding is provides by the Ministry of Petroleum and Energy. The objective is to develop knowledge, competence and technology for development and operation of reservoirs at the Norwegian continental shelf in order to achieve a higher recovery rate than the current plans.

The research and competence-building should take place in close collaboration with operators and stakeholders on the Norwegian continental shelf. New knowledge and technology from the centre should be applicable in the operator's implementation of new measures for improved volumetric sweep and new injection methods for recovery of immobile oil.

The application type Other support was used and amendments or additions to the general requirements were described in the call for proposals. Collaboration with the industry/user partners was required. The Research Council of Norway will fund a maximum of 50 per cent of the centre's annual budget. At least 50 per cent of the centre's annual budget must be funded by the centre's consortium comprised of the host institution, company partners and research partners. The company partners in the consortium shall contribute at least 25 per cent of the budget on their own.

The centres to be evaluated are:

Project no	Project title	Host institution
228107	Research Centre for Arctic Petroleum Exploration	University of Tromsø
230303	National IOR Centre	University of Stavanger

Organisation of the evaluation

The evaluation panel

The centres will be evaluated by a panel of international experts. The panel will consist of five members with a generalist, who is experienced in research-based innovation, and four scientists with the following profile:

- Geology
- Reservoir technology
- Geophysics
- Environmental risks

The Research Council will aim at selecting scientific experts with broad experience. The same panel will be used for both centres. Each centre will be invited to suggest up to five suitable

scientific experts. The Research Council will decide whom to invite. One of the members of the panel will be appointed as the panel leader.

Methodology

The evaluations will be carried out on the basis of written background material and interview sessions during a site visit.

Background material for the evaluation

The following written material will form the background for the evaluation:

Report from Centres according to a standardized outline, from the individual centre featuring relevant information, including:

- A self-evaluation of the centre including sections on research accomplishments, important industrial or social results and potential for innovation, network, internationalisation, recruitment, financial aspects and organisation. The self-evaluation will also contain a research plan for the final three years.
- A fact sheet according to a template including CV for the management team, data for the staff working in the centre, list of publications, PhDs. candidates, financial data and selected indicators.
- A report and self-evaluation from the host institution
- A report and self-evaluation from each of the user partners
- A report and self-evaluation from each of the research partners
- Report from Scientific Advisory Board/Scientific Committee (for centres which have established this)
- Annual reports from the centres (2014, 2015, 2016)

From the Research Council

- INFORMATION FOR APPLICANTS Research and knowledge centre for petroleum activities in the northern areas and the Arctic
- INFORMATION FOR APPLICANTS Research Centre for improved oil recovery on the Norwegian continental shelf
- For each centre
    - Present contracts including project descriptions
    - Special stipulations in the Research Council decision in 2013
- A fact sheet on PETROSENTER scheme

Site visit

During the site visit the evaluation team should meet:
- The Centre Leader
- The Chair of the Centre Board
- Representatives from the industrial and/or public partners
- Representatives from collaborating research institutions
- Host institution staff incl. representatives from the top management
- Research leaders active within the Centre
- Doctoral students

The Research Council staff will be present at the site visits. The staff will act as administrators and should not take active part in the evaluation, but can add information during work sessions. The site visit will be carried out according to a standardized agenda.

Time frame

April 26, 2017: Decision of the evaluation mandate by Division board for Energy, Resources and Environment
September – November 2017: Site visits and reporting
December 13, 2017: Presentation of the evaluation report to the Division board for Energy, Resources and Environment

The background material will be distributed by The Research Council of Norway to all members of the evaluation team not later than one month prior to the site visits.

Mandate for the Evaluation Panel

The evaluation will review progress of scientific and industrial efforts, recognising it is early to expect conclusive results. The evaluators will form an opinion concerning the approach and measures taken so far by the individual centres to judge the potential for their long-term development towards a successful completion of the projects. Evaluators may offer suggestions for remedial action to enhance the prospects for centre success. The evaluation and suggestions for remedial actions must be within the framework of the calls and the contracts between the Research Council and the host institutions.

Success criteria

The evaluation team will make the evaluation in the context of the success criteria (Attachment).

Relevance to the call and special stipulations

In addition to the success criteria, the evaluation should also assess:

- to which extent the centre activities are fulfilling objectives in the calls (relevance).
- to which extent the centres have succeeded in fulfilling any special stipulations in the decision made by The Research Council's board committee.

Not to be included

To avoid giving a premature indication of The Research Council's decisions to prolong the individual centres, the evaluation panel shall not comment specifically on this issue.

The evaluation report

The evaluation report should be written in consensus by the evaluation team and sent to The Research Council of Norway, no later than six weeks after the site visits. The report must include individual reports for each centre. Before submission to the Research Council of Norway the centres shall be allowed to check draft reports for factual errors. The report should be written in English.

The report will be openly circulated to the centres, host institutions, relevant ministries and to any other agency or person who have expressed interest for this kind of information.

The report should include comments on the self-evaluation reports and the site visit.
Although the individual centres will be the main focus, the evaluators should also comment on the organisation of PETROSENTER scheme and the role of The Research Council of Norway.

Attachment: Success criteria[2]

The following criteria will likely be relevant in assessing the success of the centre throughout its period of operation:

Research

- The centre has a clearly-defined research profile, performs long-term, thematically relevant research of high international calibre within the area set out in the project description, and demonstrates this through the achieved doctoral degrees, scientific publications, presentations at respected international conferences and other forms of scientific recognition.
- The centre's activities are multidisciplinary, i.e. it links together various fields within science and technology subjects.
- Researchers from the host institution and the research partners actively participate in the centre's research activities.

Relevance and utility for users

- The centre is visible in national and international arenas where questions concerning petroleum activities and the recovery of petroleum resources are discussed.
- The centre has implemented measures to ensure that the expertise and results generated through research are effectively transferred and utilised by the user partners and, in general, works actively with the dissemination of research results to a broader range of user groups and the public at large.
- There is reciprocal mobility of personnel between the centre and centre partners.
- The centre's user partners have over time increased their research involvement as a result of their participation in the centre's activity.

Internationalisation

- The centre has distinguished itself internationally (e.g. the researchers have received awards or invitations to participate as keynote speakers at international conferences).
- The centre has achieved good standing in international research collaboration.
- The centre is involved in active, binding collaboration with international research groups and has contributed to the internationalisation of Norwegian research in other ways. The centre has at least one international partner of some renown.
- The centre attracts cutting-edge foreign researchers, both fellowship-holders and senior personnel, as guest researchers.

Researcher training and recruitment

- The centre promotes researcher training in an effective manner and helps to educate highly qualified personnel within its areas of focus.
- The centre has an educational programme, particularly at the master's and doctoral levels, and promotes recruitment in the centre's scientific areas, including increased recruitment of women researchers.

Partners and funding

- The centre has long-term funding from the host institution and its partners.
- The centre actively works to attract new partners.
- The centre has been successful in obtaining funding from other external sources.

[2] There are some differences between these success criteria and criteria in the calls. If the evaluation panel finds these differences significant, priority should be given to the calls.

Organisation

- The centre has achieved a highly visible profile, a distinct identity and a successful collaboration with its partners.
- The centre is organised in a manner that is closely aligned with the host institution's organisation.
- The centre has a board and management that ensure that the intentions and plans underlying the establishment of the centre are fulfilled.
- The centre has a unified management that has a strong degree of scientific and administrative independence.

Appendix 2: Evaluation panel members

Generalist (panel leader)
Prof. Alison McKay, University of Leeds

Geology
Dr. Fridtjof Riis, Norwegian Petroleum Directorate

Reservoir technology
Prof. Craig Smalley, Imperial College, London

Geophysics
Dr. Angus Best, Head of Marine Geoscience, National Oceanography Centre, Southampton

Environmental risks
Prof. Ingela Dahllöf, Göteborgs Universitet

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