

Basic and long-term research within Engineering Science in Norway

Report from Panel 1: Energy and Process Technology

Evaluation
Division for Science



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Coverdesign: Design et cetera AS
Photos: Shutterstock/Colourbox

Oslo, April 2015

ISBN 978-82-12-03413-6 (pdf)

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Statement from the Panel

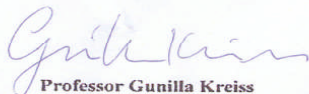
The Evaluation Panel no. 1 for the Evaluation of the basic and long term research within Engineering Science in Norway – Energy and Process Technology – hereby submit the following report.

The views presented in this report are the consensus among the members of the Evaluation Panel. The report represents an agreed account of the assessments and recommendations.

The Panel evaluated the following Organisations and Departments: Norwegian University of Science and Technology, Faculty of Engineering Science and Technology, Department of Energy and Process Engineering: Thermal Energy, Industrial Process Technology, Fluids Engineering, Energy and Indoor Environment; Department of Petroleum Technology and Applied Geophysics: Petroleum Technology and Applied Geophysics; Norwegian University of Science and Technology, Faculty of Information Technology, Mathematics and Electrical Engineering, Department of Electric Power Engineering: Electric Energy Conversion, Electric Power Technology, Electric Power Systems; Norwegian University of Science and Technology, Faculty of Natural Sciences and Technology, Department of Materials Science and Engineering: Physical Metallurgy, Process Metallurgy; Telemark University College, Faculty of Technology: Process-, Energy- and Automation Engineering; University of Bergen, Department of Physics and Technology: Petroleum and Process Technology; University of Stavanger, Department of Petroleum Engineering: Petroleum Engineering; IRIS, IRIS Energy: Drilling and Well Modelling, Enhanced Oil Recovery, Reservoir; SINTEF Energy Research: Bioenergy, Combustion, Flow Phenomena, Power Conversion and Transmission.



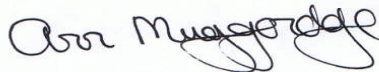
Professor Derek John Fray FRS (Chair)



Professor Gunilla Kreiss



Professor Sten Bay Jørgensen



Professor Ann Muggeridge



Professor Wolfgang Gawlik

Professor Carsten Schwandt, University of Nizwa in Oman, acted as the Scientific Secretary of the Evaluation Panel

1. Executive Summary

Overall, out of the 20 research groups that were evaluated, the scores went from fair to very good for Scientific Quality and Productivity (SQP), and from low to very high for Societal and Industrial Relevance and Impact (SIRI). 30% of the departments fell into the top right quartile of the evaluation criteria plot with 40% on the borderline and 30% falling below either/or the good line for SQP and SIRI. It should be noted that there were no truly outstanding departments by international standards and reasons for this were relatively high teaching loads, some difficulties with recruitment and lack of resources for performing basic research or research not linked to solving present day industrial problems. However, overall, all the departments performed research that was very useful to Norwegian industry and society and some departments performed internationally rated research. Generally, the amount of basic research performed was below that of most leading scientific nations. The gender balance had improved since the last evaluation but still had some way to go to reach parity.

2. Overall description and conclusions

2.1. Engineering science

Engineering science is called ‘the sciences of the artificial’ by Herbert Simon (*The Sciences of the Artificial*, The MIT Press, Cambridge, MA, 1981). Simon states that “the central task of natural science is to show that complexity, correctly viewed, is only a mask for simplicity, to find patterns hidden in apparent chaos”. The world we live in today is increasingly a man-made or artificial (synthesised) world. This world of artifact, design and operation is the result of engineering science. Engineering science aims to develop and apply scientifically-based methods to develop and operate objects, machines and processes as well as produce their materials for the benefit of mankind. It is noteworthy that this may also require inputs from social sciences and psychology to ensure that these materials, objects, machines and processes are useful, safe and accessible to everyone.

2.2. General description of the evaluated research fields

The diagram, shown in Figure 1, visualises the spread of Scientific Quality and Productivity (SQP) of the research groups assessed versus the spread of Societal and Industrial Relevance and Impact (SIRI) of the groups. The plot is derived from the individual figures in Section 4, and it illustrates that the SQP of the research groups ranges from fair to very good (with good meaning that a group performs to the international standard normally to be expected from a research group in its field), and that the SIRI varies more from low to very high (with good again meaning that a group performs to the international standard normally to be expected). The plot furthermore shows that 30% of the groups fall totally into the upper right hand quartile of the SIRI versus SQU plot, 40% are on the borderline, and 30% fall below the good lines for either SQP or SIRI. No groups were rated excellent for SQP and only one was rated as very high under SIRI. It can also be seen that there is a minor trend for higher SQP for university research groups, while there is on average a higher SIRI for the institutes’ research groups. It should be noted that none of the institute research groups falls into the bottom left corner. The detailed assessment criteria can be found in Chapter 5.2.

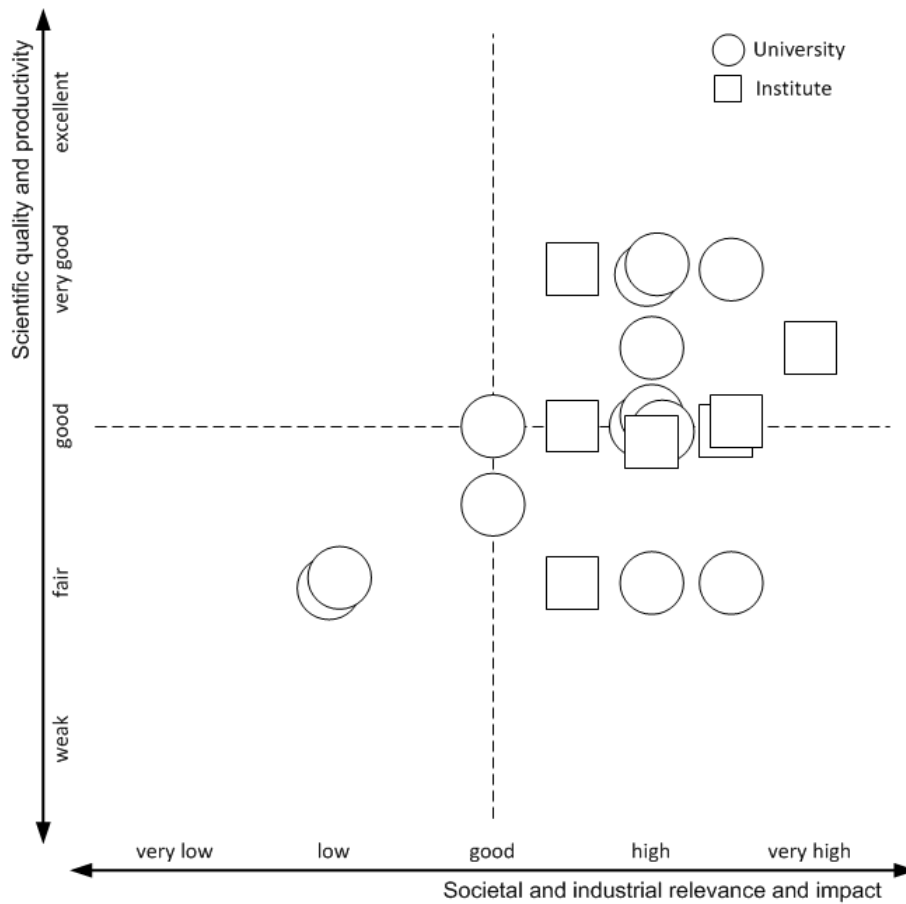


Figure 1: Plot of Scientific Quality and Productivity (SQP) versus Societal and Industrial Relevance and Impact (SIRI).

2.3. Impact of national excellence centres

Norway has established a number of well-funded research institutes and centres of excellence. The Panel has noted that some of these organisations have had a significant positive effect upon many of the university groups evaluated, both in terms of research capacity and research infrastructure. These organisations include the Centres of Excellence and Centres for Research-based Innovation and Centres for Environmentally Friendly Energy Research. Since the Panel only has encountered a subset of the Engineering Science groups, the most visible specific centres are mentioned in the individual group evaluations. The Panel does note that the ability to plan and undertake joint research efforts is strongly correlated to having a joint research strategy for both the university and institute research groups.

The traditional location for fundamental research into engineering science is in university departments. In addition Norway has a long tradition for institute-based research. These institutes develop solutions for industry most often in close collaboration with a university. The Panel has found that these institutes provide an effective way to translate university findings into practical solutions and then deliver those solutions to the companies where they

will be used. In turn, they stimulate further research in the universities to tackle industrial challenges for which the universities might otherwise not have the relevant knowledge or experience. This model of universities linked to research institutes has had a significant influence on Norwegian industry and society.

2.4. Research co-operation nationally and internationally

The research institutes have, to some extent, successfully engaged in European research projects. However, the university departments and groups have done this to a much lesser extent. This is unfortunate for the further globalisation of Norwegian engineering science, as participation in EU projects encourages researchers to build networks with leading scientists and engineers and their research groups across Europe. Having established these networks through EU projects, it is then easier to apply for further such projects.

Many research staff in universities and institutes have international contacts but staff do not get involved in international committees, e.g. in organising international conferences, as much as is seen in other countries. Such international committee work is important in creating new international contacts and building relationships with those contacts. It is also a way of increasing international visibility.

Therefore the Panel recommends that further incentives be established to encourage both universities and institutes to participate in European research projects and to encourage research staff to become involved in international committees.

2.5. Funding and infrastructure

Most departments were reasonably well funded and the infrastructure well maintained although the Panel did not actually see the facilities. Very few departments raised these issues as being of concern.

2.6. Training, recruitment, gender balance and mobility

There is a general consensus among the reviewed institutions that the salaries for all academic levels, starting at PhD student level up to full professorship, are not competitive compared to equivalent positions in industry. Several institutions commented that it was particularly difficult to recruit and retain staff with industry-related expertise because of the salary disparity between industry and universities. This is a worldwide challenge in engineering science, although it should be noted that there are other advantages to working in academic institutions that many academic staff feel compensate for the lower salary. This salary disparity also results in difficulties in recruiting PhD students as most MSc students tend to leave universities after graduating. Thus, PhD positions are often filled with international candidates. On one hand, this is an opportunity for departments to increase international visibility and mobility that many departments actively take advantage of and, moreover, many

of the international PhD students stay with local industry and institutions after graduating. On the other hand, sometimes issues arise in departments that teach courses in Norwegian as this is obviously difficult for non-Norwegian-speaking PhD students. Nonetheless there is still a lack of qualified PhD students and academic staff in some areas, meaning that there is understaffing and consequent overload of the existing academic staff with teaching and administrative duties. This in turn reduces the group's scientific output in terms of publications and limits their ability to propose and then undertake research projects.

In common with most engineering science internationally, there is a significant gender imbalance in all groups and departments assessed by the Panel. The percentage of females goes down from MSc to PhD students to permanent staff. However, the Panel notes that the research institutes have a higher proportion of female scientists, and in many groups a very good one indeed by international standards, as compared with the academic institutions. Continued efforts are needed to recruit more women, and the Panel suggests seeking a better understanding of why some groups are more successful than others at attracting and retaining women.

2.7. Research council policy

Many of the groups mentioned that some of the Research Council grants and contracts required industrial support. Generally, industry works on a relatively short time span and is, usually, disinterested in long-term blue-sky research. Citations in fundamental science are generally much higher than in engineering, so if the goal is to raise the profile of Norwegian science and engineering, it may be prudent to give more grants and contracts that do not also require industrial support.

2.8. Intellectual property

Many institutions are active in creating intellectual property, patents, spin-outs and licensing their technology. However, it seems that several of them obtain negligible financial benefit from this arrangement. The universities in other countries are able to receive royalties from their arrangements with industries. As an example, a company that takes a licence pays a royalty to the university which is split equally three ways between the university, the department in which the invention was created, and the inventors. This applies also to research supported by the company except, if the company is determined to own all of the IP, it pays a substantially higher overhead rate on the contract.

These arrangements, if introduced in all institutions creating such IP, may go some way to meeting the complaint that university salaries are too low in comparison with industry.

2.9. The importance of peer reviewed publications

The publication rate of groups has increased over the assessment period but it could be increased further particularly in peer reviewed scientific journals. The majority of the groups and individuals assessed in this review are concentrating on disseminating their research via specialist conferences and conference proceedings. There is little focus on publication in peer reviewed scientific journals. Presentations at specialist conferences are essential for rapid dissemination of ideas, networking and increasing exposure to industry, but publication in peer reviewed journals is equally important as it provides a free evaluation of an individual's scientific ideas, methods and results, gives them an international academic audience for their work and provides an objective evaluation of its importance via citation indices. This, in turn, leads to a higher international profile and further opportunities for international collaboration with overseas universities and potentially encourages higher quality applications for academic positions that are advertised.

New technologies result from scientists and engineers devising new methods and processes. It is important that these methods and processes are documented so that other scientists and engineers can build on these techniques. It is also important that they are reviewed by these scientists and engineers to ensure that these techniques really are new and fit for purpose. This is best achieved by writing papers for peer reviewed archival journals at level 2. The Panel strongly recommends that the Norwegian Government's initiative for universities and institutes to publish in peer reviewed level 2 journals be pursued. If journals do not yet exist where the specific type of knowledge can be published, then efforts should be undertaken to establish new journals in an internationally coordinated effort.

2.10. Strategy process

A weakness mentioned in many SWOT analyses from the academic groups, and also seen by the Panel, is the lack of collaboration within groups and the lack of joint research both within and outside the groups. Combining expertise and research networks within research groups would yield many synergies that could potentially improve the research outputs of all within the group. The Panel also notes that processes for developing a joint strategy in academic environments are in general lacking or very weak. There is a strong connection between having a joint strategy and being able to undertake joint research efforts.

The institutes tend to have a policy of regularly creating, reviewing and refreshing a research strategy in discussion with all employees in the institutes. As a result they have, in general, very well formulated strategies and are host to many big interdisciplinary projects and centres. The universities also need to create their own research strategies to provide a focus and direction for their research and to enable them to plan how to resource that research through the generation of research proposals, the creation of laboratories, the hiring of staff with relevant expertise, etc. These strategies should have a long-term focus of at least 5 years and be reviewed and updated regularly.

Another important aspect of the strategy process is to clarify the different roles of academic institutions and research institutes. In many cases there are very close collaborations between academic groups and corresponding groups at the research institutes. This has mainly positive effects, but the academic research in such collaborations seems to be influenced towards the applied research of the institutes. The Panel believes that the academic researchers should focus more strongly on basic research aspects and that this is possible to do whilst maintaining strong connections to applications.

Overall, the Panel strongly recommends that all university groups and departments focus on developing well thought out strategies that engage all staff within the group. These strategies should be reviewed and refreshed at regular intervals, as is done in the research institutes. The Panel has seen that having such a strategy has enabled the institutes to take leading roles in formulating research proposals and then obtaining funding for these proposals.

3. Overall recommendations

For the Research Council:

- Strengthen fundamental research in engineering science to enable scientifically-based development towards innovative solutions. This could be achieved by funding more proposals that do not need industrial involvement

For universities:

- Those universities, which do not have a strategic planning procedure, are advised to implement a sliding planning procedure where the longer term, say 5-year, strategy is updated regularly while the next year's effort is detailed in a separate implementation plan. This sliding procedure should involve the whole university community.
- Aim to publish more in peer reviewed high-impact journals (those that publish papers that are recognised internationally in terms of originality, significance and rigour).
- Clarify the role of university and institute research groups and the relationship between them.
- Encourage staff to participate in international committees.
- Establish incentives for university groups to encourage further participation in European research projects.

For research institutes:

- Further pursue the Norwegian Government's initiative to publish engineering science research in peer reviewed peer reviewed high-impact journals.
- Clarify the role of university and institute research groups and the relationship between them.
- Encourage staff to participate in international committees.
- Encourage greater participation in EU research programmes.

4. Description and evaluation of the Institutions and Research Units

4.1. Norwegian University of Science and Technology – Faculty of Engineering Science and Technology

4.1.1. Department of Energy and Process Engineering

Evaluation Units:

Thermal Energy
Industrial Process Technology
Fluids Engineering
Energy and Indoor Environment

General comments on the department level:

The department is managed by a Management Group which meets monthly led by the Head of Department. In addition, there is another group that takes the initiatives for new areas of research. The department also works closely with SINTEF Energy Research in some areas. The department and SINTEF are sharing office location and the use and maintenance of laboratory facilities to about 50%.

The funding of the department is 45-50% from the State and the remainder comes from the RCN, the European Union and industry. The general budget responsibility and resource allocation is at the departmental level and not in the research groups. Any changes in the laboratory infrastructure is led by a laboratory manager in close cooperation with the Head of Department, whereas the development of research strategies is initiated at group level and coordinated at departmental level. However, the research groups seem to have weak processes in developing strategy, even though the new research strategy of the Faculty of Engineering Science, developed in 2012, would be a very good starting point for formulating local strategies.

A major part of the work of the Thermal Energy Group is concerned with carbon capture, and it is worthwhile noting that Professor Olav Bolland contributed to the reports of the Intergovernmental Panel on Climate Change, which was awarded the 2007 Nobel Peace Prize. Professor Bolland was a lead author for the IPCC Special report on Carbon Dioxide Capture and Storage. The Thermal Energy Group has been very successful in attracting EU support (350 million NOK from the EU FP7 Programme). The Faculty of Engineering Science and Technology created a Science Plan in 2012 which contained 7 activities associated with the department: CO₂ capture; natural gas, oil and bioenergy; offshore wind energy; developing sustainable societies; sustainable and innovative energy in Norway; hydropower; and energy and efficient buildings. These activities were chosen because there was very active research ongoing in these areas in the Faculty and they were in line with national priorities.

The department has good facilities that are presently being upgraded, together with good administrative support. The department encourages journal publications and the publication figures are distributed to all academic staff. As well as publications, the department encourages patent applications and the creation of start-up companies.

On the teaching front, there is a large variation in the teaching loads between professors but the average is below that for the rest of the university. This demonstrates the importance of not having too high a teaching load if a high international profile is required.

Out of the 32 professors and associate professors, only 3 are female. The department is following NTNU's policy on finding female candidates to fill positions but it still has some way to go. There are difficulties, in some areas, to find Norwegian tenured employees due to the high wage level in Norwegian industries.

The department is very successfully collaborating in a large number of national and international programmes as well as with industry.

Overall this is a very successful department.

Follow up from previous evaluations:

Since 2004, the number of articles in conference proceedings increased by 60% whilst those in peer reviewed journals increased by 900%, demonstrating that the department is performing much better and is raising its and the university's international profile. It was noted that the department should try to move away from too much applied research to more fundamental research. This has not happened as it is difficult to achieve this change without more unfettered government funding. The close connections with SINTEF, where research is more applied, may also be an influencing factor.

Recommendations to the department/institution:

- Continue to address the gender balance.
- Consider ways of undertaking and publishing more fundamental research.
- Encourage the weaker groups to improve.
- Initiate process for developing research strategies in the groups and in the department, aiming at involving all researchers.
- Clarify the difference in roles between academic researchers and research scientists at SINTEF.

4.1.1.1. Thermal Energy

Description of the research unit:

The Thermal Energy Group investigates combustion from engines, catalytic combustors, pyrolysis of biomass, bioenergy, thermal turbo machinery and power cycles, carbon capture

and sequestration. The main research area is carbon capture and sequestration (CCS). The group has political influence in this area and has obtained financial support from the RCN. There is also a strong presence at conferences and in the literature, providing visibility and maintaining optimism despite a reticent attitude in Europe.

The staff consists of 5 professors of which 1 is female, 2 associate professors and 2 adjunct professors.

Strategy, organization and research cooperation:

The strategy plan consists of 4 areas that are in line with national strategies. The group is well organised, has well-resourced laboratories and has many international collaborations. There is a good balance between experimental and computer modelling work. There is a difficulty in recruiting well-qualified Norwegian PhD students due to the attraction of Norwegian industries where there is a distinct career path. However, there is no problem in hiring non-Norwegian PhD students as, fortunately, most stay in the country and join Norwegian industries after completion of their PhDs.

Overall, the group can be regarded as being very strong. In the past 4 years the group's research income has averaged about 3 million euros per year in research funding. There is also cooperation on CCS with two universities in China.

Scientific quality and productivity:

Grade: 4

The group publishes actively and has produced nearly 200 papers in the past 4 years which is satisfactory. The papers are generally well cited.

Societal and industrial relevance and impact:

Grade: A-B

The group has considerable influence in addressing the needs of industry for technologies in the 21st century and is also involved in the National Norwegian Petroleum Technology Strategy. Carbon dioxide capture technology is also very important.

Recommendations to the research unit:

- Generate more international publications and try to increase the publication rate of less productive staff.
- Enhance basic research.
- Address the problem of the lack of Norwegian research students.

4.1.1.2. Industrial Process Technology

Description of the research unit:

The group has 10 professors of which 3 are adjunct. However, 4 of the 7 full professors will retire within the next decade. Gender balance is not achieved since there are no female professors.

The Industrial Process Technology Group has a broad area of research including gas processing and multiphase transport, gas liquefaction, process integration and pinch analysis, heating and refrigeration, and food engineering. In all fields the research is closely related to industrial applications. The group has contacts with national institutions and a very good international network, but there is little cooperation between academics in the group.

The research is carried out in cooperation with industry in mutually beneficial ways.

Strategy, organization and research cooperation:

The main strategy is to strengthen theoretical analysis with experimental laboratory tests, but the group has not developed a common research strategy document. Consequently, the group has potentially the problem of not being seen as one group, which may have a negative impact on recruitment.

The connection with national industry and the collaboration with SINTEF are both very good.

The group has substantial external research funding but mostly for short and medium timescales. The funding from strategic research funds is good. The support from industry is very good. The funding from the RCN and NTNU is also very good. However more long-term support is desirable. The group finds it difficult to work in fundamental research areas that are not supported by industry.

The group has an established track record in multidisciplinary research. This is evident from the number of awards to the group both nationally and internationally.

The group graduates almost 1 PhD per faculty member per year. It has had a tradition for publishing at conferences but this has slowly started to shift towards publication in peer-reviewed journals.

The group has an established collaboration with Shanghai Jiatong University in China. The collaboration includes an exchange programme for MSc and PhD students.

The publication frequency is 2 to 3 journal papers per professor per year. The impact in terms of citations is average for the field, however the individual h indices are rather low, which indicates that the academic research impact is rather low. This may be improved in the future due to the relatively recent effort to increase the number of journal publications. The collaboration with Jiatong University is expected to impact positively on the publication output through joint papers.

Unfortunately the group is fragmented across various buildings, with some PhD students located far away from their supervisors.

Scientific quality and productivity:

Grade: 2

This group has an international reputation in carbon dioxide heat pumps, liquid natural gas transport, tunnel dryers for fish, and process exergy analysis, but the scientific quality suffers

from both the fragmented impression of the group and the low number of peer reviewed journal publications.

Societal and industrial relevance and impact:

Grade: B

The industrial impact within most research areas is clearly important, especially for Norwegian industry. The societal impact on the car industry is very good as is the impact on food industry. While the impact on industry is impressive, there is a much lower impact on public debates and policy matters.

Recommendations to the research unit:

- A research strategy should be developed for and by the group.
- A balanced recruitment plan is required for young and middle-aged professors to replace professors who are close to retirement in the selected focus areas. This should also aim at improving the gender balance in the group.
- The group should continue to improve its publication output in peer reviewed international journals.
- The group should be co-located with its PhD students, if feasible.
- The group members need to cooperate better to obtain larger projects.

4.1.1.3. Fluids Engineering

Description of the research unit:

The group consists of 7 professors, 1 adjunct professor, 4 associate professors, and 2 emeritus professors. Very recently a new group leader was appointed. Research activities of the group are generally divided into two main areas, classical fluid mechanics and hydropower machines, each housed in separate buildings. Eleven of the academics fall under classical fluid mechanics and have a strong tradition of fundamental scientific research particularly in theory, experiments and computations of turbulent flows. The group has particular expertise in both experiments and numerical simulation of turbulence, the development of better turbulence models and advanced experimental methods for basic turbulence research, and is very well published. It is currently expanding its activities into applied research such as wind turbines in line with NTNU's research strategy. Three academics are based in the Water Power Laboratory and primarily conduct industrially-based research related to hydropower.

Strategy, organization and research cooperation:

The material submitted to the Panel had been written by the previous group leader and did not describe a research strategy for the group. From reading this document and from the discussions with group representatives, it seemed that there is little collaboration within the group, but members of the group collaborate extensively with other parts of NTNU as well as with industrial partners and SINTEF, through various centres including NOWITECH (offshore wind), CEDREN (hydropower), and NORCOVE. The group is less active in

collaborative international research projects. The majority of the group's research funding comes via SINTEF and, possibly as a result, they have less focus on establishing their own, independent strategy and sources of research funding.

Scientific quality and productivity:

Grade: 3

The group has a reasonable publication rate in good journals and recognises the need to further increase their rate of publication. The scientific impact of the whole group is however rather uneven, with some individuals with much higher than average scientific impact and an international reputation for their research in the field of turbulent flows, and others with much lower than average impact.

Societal and industrial relevance and impact:

Grade: C

The group has played an important role in the development of hydropower machinery. Their industrial and societal impact will increase further through their participation in the Centres for Environmentally Friendly Energy Research.

Recommendations to the research unit:

- Develop a research strategy for the group, which also takes the Science Plan of the department into consideration. It is important to engage the whole group in the development of this strategy.
- Make careful choices of research areas, based on this strategy, when recruiting to replace retiring group members. Again try to focus on improving the gender balance in the group.
- There should be more emphasis placed on fundamental research.
- Aim to relocate the group into one corridor or area. This will tend to improve collaboration between members of the group.

4.1.1.4. Energy and Indoor Environment

Description of the research unit:

The group size is small, consisting of 3 professors, all male, 1 female associate professor and 3 adjunct associate professors, all male. The group concentrates on energy supply of buildings and heating, ventilation and air conditioning for good and healthy indoor environment.

Strategy, organization and research cooperation:

The main strategy is to work towards energy efficient buildings with integrated solutions for optimal use of heating, ventilation and air conditioning for the benefit of humans combined with a lower carbon footprint. It is endeavoured that each professor should supervise 2 to 4 PhD students, which is higher than at present. The group would also like to increase the number of staff. The group cooperates with SINTEF and several other Norwegian organisations. In all these cooperations most of the ideas come from the research group. There does not appear to be any international collaboration, except for visiting students.

Scientific quality and productivity:**Grade: 2**

At present the publication rate is low and it is intended to increase it to 2 papers per person and year. This current productivity is lower than might be expected.

Societal and industrial relevance and impact:**Grade: D**

The work of this group is very important but it does not seem to attract much financial support and, therefore, its impact is relatively low.

Recommendations to the research unit:

- Continue to pursue the group's goal of becoming an international leader in zero-emission buildings.
- Focus on a better publication strategy.
- Further increase cooperation with other parties, especially internationally.

4.1.2. Department of Petroleum Technology and Applied Geophysics

This department consists of only 1 research group and thus only submitted one part of the self-assessment.

Evaluation Units:

Petroleum Technology and Applied Geophysics

General comments on the department level:

The department has an unusual academic structure in that it combines both Petroleum Engineering and Applied Geophysics into one organisation. This partially reflects typical team structures in oil companies which are formed of geophysicists, geologists and petroleum engineers. It helps to strengthen its research and education, although maybe including the Applied Earth Sciences Group, which is currently in another department, would further strengthen the department.

The department has only had a full time Head of Department since 2013. This is surprising given the number of staff in this area and the number of students taught. The Head is supported by an administrative, technical and management team, and there is an informal research structure beneath the Head that reflects the current research projects being undertaken within the department. The self-evaluation comments on the uneven teaching load and it is clear that research output of staff is also uneven. This is possibly a consequence of the rather informal management structures that have been in place.

Follow up from previous evaluations:

The previous evaluation also commented on the lack of integration with the Geological Sciences and this has not been addressed. No comment was made about laboratory space this time, so presumably this is no longer a concern, perhaps because the research staff has access to facilities in other organisations with which they are collaborating. The previous evaluation commented on the applied nature of the department's research and lack of peer reviewed

journal papers. There is clearly an upward trend but this still needs to be improved (see further discussion at group level below). The department has won significant research grants from the RCN, so has worked towards improving its relationship with the Norwegian government as recommended in the previous report.

Recommendations to the department/institution:

- Provide a more formal management structure to ensure more equality in research and teaching workload between staff.
- Increase incentives to publish in peer reviewed journals.
- Develop a more detailed departmental strategy in consultation with staff and have a formal procedure for reviewing and refreshing the strategy at appropriate intervals.
- Consider integrating the department with a group working on petroleum geology.

4.1.2.1. *Petroleum Technology and Applied Geophysics*

Description of the research unit:

The Petroleum Technology and Applied Geophysics Group is focused on applied research related to the exploration and production of oil and gas. This is an important area for Norway given its large oil and gas reserves. At the end of 2013 the group had 20 full time academic staff with expertise in drilling, production, reservoir engineering and applied geophysics research. There were no female professors in the group. The group received more than 170 million NOK in research grants over the assessment period and had around 50 PhD students in total.

Strategy, organization and research cooperation:

A general high-level strategy is in place with an overarching research objective to help to maximise oil and gas recovery in the Norwegian Shelf. No detailed plan was provided that described the specific research priorities within the group to enable this to be achieved, although it is understood that such a plan has been developed but is only available in Norwegian and was therefore not submitted. There did not appear to be a formal process for reviewing and refreshing these priorities. Research is organised into ad hoc multidisciplinary project groups related to the major ongoing research groups and there is a good infrastructure in terms of laboratories and computing facilities to support these groups. Succession planning is a priority as the majority of staff are approaching retirement in the next 10 to 15 years. This should enable the group and department to recruit some women and thus improve the gender ratio, however they may need to take advice from other groups with more female staff to maximise this opportunity. Professors have informal contacts with other researchers in more than 20 countries and formal agreements and/or projects with 11 overseas organisations as well as other departments at NTNU, although cooperation with the Petroleum Group at SINTEF could still be improved.

Scientific quality and productivity:**Grade: 3**

The quality and number of publications from professors is very variable. While the total volume of research output is increasing, some individuals cite non-peer reviewed conference papers amongst their 3 most important publications, presumably because they do not have suitable peer reviewed journal papers. Others are publishing in the top journals in their field such as Geophysics. Overall there are however few papers in high-impact scientific journals and this should be improved in the future in order to increase the international visibility of the group. The citation indices of staff range from good to weak. The overall rating is therefore an average of these varying outputs.

Societal and industrial relevance and impact:**Grade: B**

The group has 13 major research projects funded by a mixture of different oil companies and the RCN. These cover the areas of both petroleum technology and geophysics. The department is host to a national research centre for research-based innovation (SFI) Integrated Operations. The group is also an active participant in the Centre for Environmentally Friendly Energy (FME) BIGCCS, the SFI DrillWell, and recently also in the new national Arctic Research Centre. This research into carbon capture and storage, drilling and seismic surveying in the Arctic and improved oil recovery has high societal relevance. Research support by more than 30 different companies shows that the research is also industrially important.

Recommendations to the research unit:

- Focus on recruiting new, younger staff with both petroleum/geophysics and non-petroleum backgrounds before older staff retire.
- Recruitment of more female staff requires more women to apply in the first place. Discuss with other departments/groups with more female staff to learn how they have achieved this.
- Improve publishing strategy, target more scientific, high-impact journals as well as the standard SPE journals and conference presentations. This will improve scientific relevance and impact.

4.2. Norwegian University of Science and Technology – Faculty of Information Technology, Mathematics and Electrical Engineering

4.2.1. Department of Electric Power Engineering

Evaluation Units:

Electric Energy Conversion
Electric Power Technology
Electric Power Systems

General comments on the department level:

The department has a wide range of expertise and activity in electric power engineering. It has a stable research income coming from a balanced mix of short-term applied and long-term basic research with involvement of industry and external research partners, amongst them SINTEF Energy Research. While there is a longstanding and successful cooperation with SINTEF, there appear to be some issues which should be resolved, including low visibility of the department and joint supervision of PhD students. The department should strengthen the internal cooperation between the research groups in order to build up and operate the new Smart Grid Laboratory (supported by a National Infrastructure grant). This would also increase research focus on key competence areas and selected common strategic goals for the department, for which the department is internationally recognised, i.e. converters, hydropower systems and markets, high voltage insulator systems, modelling and voltage transients.

Follow up from previous evaluations:

Publication rates, especially in peer reviewed journals, have increased since the last evaluation, but they are still below average for the field. It appears that journal publication is restricted, to some extent, by the IP terms in various research projects funded by industry.

Recommendations to the department/institution:

- Improve integration of the individual groups and establish the terms of cooperation with SINTEF.
- Improve IP handling strategies to enable more publications in journals.
- Put in place measures to increase publication rate, especially in peer reviewed journals.

4.2.1.1. *Electric Energy Conversion*

Description of the research unit:

The group includes 3 professors and 11 additional staff, covering research competences in power electronics, electrical machines, and digital control of electrical energy converters.

Basic research activities focus on power electronics circuit topology and modelling, electric machine design, and electric energy conversion modelling and control.

Strategy, organization and research cooperation:

The group's strategy to work on both basic and applied research is successful insofar as there is significant industry funding for the research. New ideas and further development could be enhanced by improving cooperation with the other research groups in the department and ensuring that staff is located in the same corridor or area. While aspiring to be involved in Horizon 2020, the group has not participated in such international research yet because it is already heavily occupied with other projects. The research cooperation with SINTEF could be improved. The age profile of academic staff and the current gender imbalance need to be addressed.

Scientific quality and productivity:

Grade: 3

The research group has a publication strategy based on a combination of conference papers and refereed journals. While all scientific results tend to be published, the group in general has a low publication output. However, those articles published have a rather high citation index in the field. The number of PhD students is falling because of a lack of supervisors due to changes in personnel.

Societal and industrial relevance and impact:

Grade: B

The mission of the group is to serve the Norwegian and international industries. This mission is being achieved as relevant industry has been attracted to the location of the university and the research group. Cooperation with international industry, the main ones being Siemens and Rolls Royce, has been established and maintained. 6 patents have resulted from this cooperation and have been licensed to the industrial partner. This uses a new system in which the university owns the rights and takes care of licensing.

Recommendations to the research unit:

- The cooperation with SINTEF should be reviewed and improved.
- The group should be co-located and be incorporated into a bigger group. This new group should cooperate to develop a suitable research strategy.
- Publication rates and the number of publications in peer reviewed journals should be improved.

4.2.1.2. *Electric Power Technology*

Description of the research unit:

The group includes 3 professors, 2 associate professors and 14 additional staff, covering research and education in the fields of insulation technology, cable technology, power supply to offshore and subsea installations, calculation of current and transient voltages, maintenance and condition monitoring of components, electrical installations in buildings, electromagnetic compatibility, and lighting technology.

Strategy, organization and research cooperation:

There is a strategy document in place and it is regularly revised, endeavouring to look 5 years ahead. Relevant topics for the future, including offshore and subsea grids, have been identified and are to be investigated further, as the competence in the group is high for these topics. There seems to be a lack of common strategy with SINTEF and a difficult cooperation in general, partly because of a competition for funding rather than making joint applications. Teaching and administrative tasks are a constant drain on the resources. There is a strong gender imbalance in the staff, which the group intends to tackle initially at MSc student level.

Scientific quality and productivity:

Grade: 2

The publication rate among the group is rather heterogeneous. While some members of the group have followed the suggestion, from the previous assessment, to move from conference papers to refereed journal papers, others still have a strong preference for conference papers. In total, the group has had a relatively low output of scientific papers in the last years, with citations of these papers significantly below average in the field. Nonetheless it should be noted that software for calculating and analysing fast transients developed in the research group has been widely used worldwide in industry.

Societal and industrial relevance and impact:

Grade: D

The group is active in international committees such as CIGRE and IEEE. There is at present no involvement in European projects as staff does not have the time to contribute. This is due to existing commitments to other projects and a general understaffing of the group. Industrial outlets exist through ABB, Nexans and other relevant industries. The future research impact is likely to increase, with the new Smart Grid Laboratory being installed, work on new materials being underway for mechanical circuit breakers and dynamic rating of power products, and the main investments having been taken in the high-current laboratory and also in laboratories for heating, lighting, installation. However, at present, the overall impact is low.

Recommendations to the research unit:

- The benefits of cooperating with SINTEF should be reviewed and strategies for improving this cooperation should be established.
- Publication rate in peer reviewed journals and overall research output should be improved.

4.2.1.3. *Electric Power Systems*

Description of the research unit:

As of the end of 2013, the research group included 4 professors and 7 part-time/associate professors and 25 additional staff, with core expertise in electric power system engineering, economics and markets. Research activities cover Smart Grids, offshore grids, and hydropower and markets.

Strategy, organization and research cooperation:

The strategy for basic and pre-competitive research seems to be adequate, as well as the overall process for developing research strategies based on the group's expertise and experience. However, implementation of this strategy is inhibited by institutional structures. There has been a decline in funding from the RCN although the research fits in well with national strategies. The fragmentation of the group due its members being located in different areas is proving to inhibit communication and hence cooperation. Efforts to acquire funds within the Nordic area and EU projects would increase international visibility.

Scientific quality and productivity:

Grade: 4

The group is among the world leaders in its field of activity, although the scientific community in this area is quite small. All results are publishable, with the group having the highest output of research papers among the groups in the department. While the publication rate in general could be improved, the average citation index in the field is high.

Societal and industrial relevance and impact:

Grade: B

The major impact on the scientific community is the development of methodologies and procedures for the utilisation planning and operation of hydropower plants and transmission systems. Most of the PhD students graduating in the group work in these fields. The biggest contribution to society is a method developed for the distribution of hydropower, which is now fully commercialised via a SINTEF spin-out. These methods are used by operators in all Nordic countries. Research results are also used in teaching at advanced level.

Recommendations to the research unit:

- Staff should increase their work on external committees, e.g. professional organisations and conference organisation, to help increase national and international visibility and impact.
- The group should be co-located to facilitate communication.
- More attention should be given to acquiring EU projects.
- The publication strategy should be improved in terms of overall publication rate and publication in peer reviewed journals.

4.3. Norwegian University of Science and Technology – Faculty of Natural Sciences and Technology

4.3.1. Department of Materials Science and Engineering

Evaluation Units:

Physical Metallurgy

Process Metallurgy

General comments on the department level:

The Department of Materials Science and Engineering is in the Faculty of Natural Sciences and Technology. The Faculty conducts research and education within natural sciences, environmental sciences, biotechnology, chemistry, physics, materials and chemical engineering. The Department consists of 4 groups, Physical Metallurgy, Process Metallurgy, Inorganic Chemistry, and Electrochemistry. The latter two groups do not form part of this evaluation. The Head of Department is a member of the Faculty Management Group and reports to the Dean. The department has a Board of Directors which includes representatives from industry. The department is well served by committees and has set up a well-organised number of support officers.

The research budget of the department comes 13% from industry, 70% from RCN, of which the majority is through collaborative projects (competence and innovation projects) with industry and other research partners, 2% from EU grants, and 13% from NTNU. The support from the EU is increasing. It is intended to have a better distribution of the load between teaching and research.

The department has the highest profile in materials in Norway and is expanding its remit from conventional metals to functional materials, nanotechnology and electrochemical energy storage. Although this is small at the present time, the ambition is to attract EU money in this area as well as other areas in the department. The department has very strong contacts with industry over a number of years although the steel industry is easier to deal with than the aluminium industry where access to confidential information is more restricted. With company grants the department would prefer freedom to publish whilst SINTEF looks after the more confidential aspects of the contracts. With regard to publications, journals are preferred as it gives access to a wider audience.

The department is well aware of the importance of innovation and one of its key objectives is to expand this area.

Regarding the number of staff, this is satisfactory under normal circumstances, but sabbaticals and illness can increase the load on staff. There is considerable help for new staff so that they quickly settle into the department and become productive. There is also career planning for the most promising postdoctoral research workers. There are career-planning meetings with all academics that take place once a year.

Recruitment is based on research ability, but the demand arises from teaching needs and, since the appointment of new staff, the age distribution is very much better than at the time of the previous evaluation. Furthermore, some of the professors will retire over the next 10 years and this will allow the department to recruit younger staff who could work in the expanding area of functional materials.

The department uses some sophisticated equipment in order to characterise the materials it researches, and it is important that funds are found to keep this equipment up to date so that the department can remain competitive.

Follow up from previous evaluations:

Since the last evaluation, 3 new professors have been hired and another position is vacant and this will be filled shortly. The number of female professors has increased considerably. Since 2004, light metals research has continued and more research on production of solar cell materials is now undertaken. In order to reflect this change, the name of the Department was changed to Materials Science and Engineering and the name of the Extractive Metallurgy Group to Process Metallurgy Group. There is now a more effective leadership in place and a much better organisational structure.

Recommendations to the department/institution:

- Increase the funding from EU.
- Continue to move into the research of functional materials as this is a more highly cited area than research on conventional materials.

4.3.1.1. *Physical Metallurgy*

Description of the research unit:

The group consists of 7 full professors, all male, 1 female associate professor and 6 adjunct professors for teaching and co-supervision of students. The activities are related to casting and solidification, alloy development, phase transformations, mechanical testing, metallography, advanced characterisation by SEM/TEM, forming, welding/joining, and numerical modelling and simulations, mainly related to aluminium and silicon solar cell materials. There are also some activities on steels and other metals.

Strategy, organization and research cooperation:

The strategy is to maintain a high international standard in light metal processing and alloy development to support Norwegian industry. It is the intention of the group, together with other university departments and SINTEF, to become the leading European academic group for light metal casting as well as crystal plasticity, forming and formability, modelling and simulation of microstructures and properties, nano-structuring and ultra-fine grained materials, joining of similar and dissimilar materials. It is also planned to re-new and further develop the experimental facilities, including the SEM laboratory.

The academic staff collaborates internationally, mainly in the form of joint publications, although there are formal agreements between NTNU with Shanghai Jiatong University and Chongqing University. There is industrial collaboration in light metals technology in the form of a number of competence and innovation projects co-funded by industry and the RCN with Hydro, Alcoa and Sapa and in solar cell technology with Elkem, REC, Norsun and the Quartz Corporation, as well as with Statoil. Much of the research is interdisciplinary. However, at the present time, there is no strategy plan.

Scientific quality and productivity:

Grade: 3

The scientific quality is good rather than outstanding with relatively few citations but this is a restricted field. There is no evidence of blue-sky research, or any new ideas, perhaps due to a lack of funding.

Societal and industrial relevance and impact:

Grade: B

The department has filed 2 patents concerned with metal joining and a company, Hybond A/S, has been established with Statoil Technology Invest being the major shareholder, with the goal of moving from the prototype stage to commercialisation. Much of the department's research is related to solving industrial problems.

Recommendations to the research unit:

- Should formally create a research strategy, including as one objective to increase the number of papers in high-impact journals.
- Should define recruitment strategy to replace those staff that will retire in the foreseeable future.

4.3.1.2. Process Metallurgy

Description of the research unit:

The research group consists of 3 professors and 1 associate professor of which 3 are female and 2 adjunct professors who are both male. The group has a national responsibility to maintain a high international standard concerning ferroalloy production, silicon production, aluminium refining and recycling, as well as TiO₂ pigment production, refining and recycling. In general the research group focus on thermodynamics, heterogeneous kinetics and transport phenomena in relation to extraction, refining and recycling of metals and alloys.

Strategy, organization and research cooperation:

The strategy is to expand research into the development of resource-efficient and environmentally-benign processes in the fields of ferroalloy, silicon and light metals production, refining and recycling, mainly together with industry, other university departments and SINTEF. This strategy is demonstrated by a joint SFI initiative, which will serve as a basis for research activities in the EU in the areas of process technology, waste, recycling and raw materials. Already, in the department, there is support from the EU on the recovery of rare earth elements from waste. In the immediate past the group has been active in

programmes such as Thermotech, Carbomat, Biocarbon, Fume, Score, Roma, Rira and Gasferrosil, requiring close collaboration with other Norwegian groups. There are also examples of collaboration with groups from around the world. There is a close cooperation with the Physical Metallurgy Group and overlap in projects and group meetings but the overriding desire is to stay a separate group.

Scientific quality and productivity:

Grade: 3-4

The group publication level is increasing in terms of journal publications although journals in process metallurgy generally have low impact factors. The group's plan to increase research in new areas including recycling and biomaterials should raise their profile considerably. Many interesting projects were described in their self-assessment and the personnel showed great enthusiasm for their work and the future opportunities in mixing technologies for greater effect. The progress of the group is however hampered by the low number of research students.

Societal and industrial relevance and impact:

Grade: B

All the projects have considerable industrial relevance in both Norway and the EU. The group works closely with SINTEF and Norwegian companies, and this collaboration has led to the Norwegian metal producing industries being the cleanest and most energy efficient in the world.

Recommendations to the research unit:

- Should formally define a stronger research strategy, including long-term research objectives.
- Should encourage the formation of an official forum for their main conference (INFACON) in order to have registered publications, and should try harder to identify and publish in suitable peer reviewed journals.
- Devise a way of attracting more research students.

4.4. Telemark University College

4.4.1. Faculty of Technology

Evaluation Units:

Process-, Energy- and Automation Engineering

General comments on the department level:

The Technical Faculty of Telemark University College (TUC) has developed a research strategy with 2 focus areas: sustainable energy, including biogas, hydrogen, hydroelectric power, CO₂ capture and alternative fuels, as well as oil and gas.

The strategy is focusing upon the desires of the local industry which traditionally was process industry but has shifted towards offshore and renewable energy. Industrial relevance and interactions with industry is ensured through a local advisory board with representatives from local industry.

TUC has a recruiting policy where both the teaching competence and the research expertise are considered. The teaching area is decided together with local industry to ensure that their educational needs are satisfied. Recruitment is often planned through developing individuals from MSc to PhD etc., and this may also be used to ensure succession planning, considering the present relatively high proportion of professors in the faculty who are in their 50s and 60s.

To strengthen further development of engineering science, TUC has instigated an incentive system to reward authors of publications in peer reviewed journals in order to shift from conference papers to more peer reviewed journal publications approved by the Norwegian Association of Higher Educations Institutions.

TUC has established an IP policy in an effort to protect the interests of the College and the employees. Because of limited commercialisation by TUC, the patent rights to industry have been sold with, for example, a clause on renegotiation of an additional fee after a period of 5 years to ensure a fair reward depending on the actual use of the patent. Presently TUC has a strategy on patents combined with an open access policy.

Gender balance is an issue which the faculty is attempting to address.

The Faculty of Technology has a yearly budget of 75 million NOK (2013) of which 13% stems from grants. The funding for the Process, Energy and Automation Engineering Group is not detailed.

Being a university college, the staff on average has a very high teaching load and the time allocated for research is very limited. To pursue the strategy for increasing research efforts, it is necessary to engage additional staff. However, TUC also recruits personnel who are intended to have a nearly full teaching load in an attempt to be able to reduce the teaching load for productive researchers. TUC also actively supports writing of grant applications.

TUC Faculty of Technology has educated PhDs together with NTNU for over 20 years. TUC has recently developed 3 PhD programmes of which 1 is for the Faculty of Technology.

The Faculty of Technology has an active policy to achieve gender balance. Presently there are 37% females on the institutional staff. In addition the Faculty has a senior policy which provides 8 sabbatical days per year for staff aged more than 60 years. However there is no policy in place to ensure succession of older highly-qualified staff members with younger individuals over time, but succession planning is a central topic in the selection of every new employee.

The Faculty considers that recruitment is difficult due to a combination of the salary gap between public and industrial jobs and the fact that many university researchers are employed for a long time in temporary positions before finally obtaining a permanent post. The Faculty also plans to attract more staff in order to increase its own resources and to develop more industrial support.

The Faculty has a sabbatical arrangement to enable researchers to spend time abroad, however relatively few staff members use this possibility.

Follow up from previous evaluations:

Telemark University College was not part of the evaluation carried out by the Research Council in 2004.

Recommendations to the department/institution:

- The number of staff needs to be increased.
- The gender balance needs improving.

4.4.1.1. *Process-, Energy- and Automation Engineering*

Description of the research unit:

The group performs research within process, sustainable energy and automation engineering.

Strategy, organization and research cooperation:

The research group intends to pursue sustainable energy and oil and gas as their future high-priority areas, which fits well with the research group's main competence areas of chemical and bio engineering and modelling and control. In this selection the group follows an application-oriented national strategy, which enables it to team up with the local industrial expertise that often has a global perspective. However there are several groups in other institutions already active in oil and gas in Norway. The research group could benefit from working in close proximity with these.

The group has 30 professors of whom about half submitted their CVs to the Panel. Many staff members have part-time employment at other organisations, e.g. Tel-Tek.

Scientific quality and productivity:

Grade: 2-3

The group's self-evaluation stated that their strategy is defined by their PhD programme.

The research group has nationally and also internationally fairly strong research positions within process safety, sustainable energy and process modelling, simulation and control. The group has established a state-of-the-art research infrastructure in collaboration with local industry and Tel-Tek. Much research is also supported through collaborative projects with research infrastructure located at collaboration partners both nationally and internationally. During the past 3 years the group has educated 14 PhDs of which 6 were supervised jointly with NTNU. Presently the group has 19 PhD students enrolled, of which 14 are funded by TUC and 5 are supported externally. The research activities would benefit from the PhD students and postdocs being located more closely to their professors.

The publication rate in peer reviewed international journals is about 1 journal paper per professor per year, which is reasonable considering the presently limited available time for research. However, the impact in terms of citations, of 70%, is relatively low for the field. The individual h indices are consequently also modest, with few exceptions.

The group has demonstrated engineering science research relevant to support local industry and has maintained these contacts over a long period. The group is also able to publish their results in international peer reviewed journals. However additional research published in conference papers should likewise be published in international peer reviewed journals.

Societal and industrial relevance and impact:

Grade: C

The group has good collaboration with local industry with many joint projects of small and medium size. Nearly all of the ongoing projects are co-financed via RCN grants and industry. The group also collaborates with other departments including the local ICT department.

The group does work on multifaceted problems.

Several patentable innovations have been generated by TUC staff, however the patents have been issued by industry.

Recommendations to the research unit:

- Group needs to continue to integrate existing interests with those of the community.
- Develop a strategy document and move towards offshore and renewable energies industries.
- Increase the number of papers in peer reviewed journals.
- Time and administrative help is needed to produce successful EU proposals.
- TUC should consider filing their own patents.

- The group could benefit from being located more closely together, also with the PhD students and postdocs.

4.5. University of Bergen

There is no engineering faculty or department at the University of Bergen, instead Engineering is an integrated part of the activities at several of the departments.

4.5.1. Department of Physics and Technology

Evaluation Units:

Petroleum and Process Technology

General comments on the department level:

The department has 35 members of faculty of which 4 are female. The Faculty of Mathematics and Science did, in 2000, form an interdisciplinary programme within engineering called 'Process Technology', and subsequently the present department name was adopted. The strategy since has been to maintain a fifty-fifty balance between basic and applied physics/technology research in terms of faculty members.

The Head of Department changed recently and the new Head will initiate the development of a new departmental strategy. The intention is to build upon the present strong research groups and concentrate on these to avoid subcritical groups mentioned in the SWOT analysis. The new strategy will be based upon the present 2011-2015 strategy plan, which already has improved the publication score, strengthened the extramural funding to the same level as the university funding, and aimed at increasing strategic collaboration with other institutes such as Bergen University College to stimulate innovation. Presently the department does not have an external advisory board to provide guidance.

The department has 6 research groups. The group leaders are elected from among the group faculty. The department has organised the research into a matrix organisation which enables effective usage of fundamental competences within widely different application areas, thereby better supporting interdisciplinary research.

The department has invested in in-house experimental facilities which mainly have been funded by external grants. In addition the research groups have access to advanced instrumentation belonging to their collaborators such as Statoil (MRI) and Haukeland University Hospital (PET/CT).

Follow up from previous evaluations:

Presently the department is working on proposing 3 new MSc degree programmes in engineering: 'subsea development', 'medical technology' and 'renewable energy', thereby attempting to distribute the students more evenly between the research areas. This is done as a result of the 2010 evaluation of physics research and as part of the development strategy. As recommended in 2010, the laboratories are being updated.

Recommendations to the department/institution:

- Continue organisational efforts as delineated in the self-assessment.

4.5.1.1. *Petroleum and Process Technology*

Description of the research unit:

The group has 2 major research activities: Thermodynamic Modelling and Reservoir Physics. These research activities have joint efforts within CO₂ storage and hydrate-related research.

The group has 3 professors and 2 associate professors of which 1 is female. The group has presently 2 postdocs. Among the 16 PhD students 31% are female, and of the 21 MSc students in Physics 57% are female. Presently there are 11 externally funded PhD students. During the last 3 years 5 PhDs have graduated of which 1 is female. The interview revealed that the group has, almost uniquely, MSc students that are all Norwegian.

Strategy, organization and research cooperation:

The research group has numerous national and international research collaborations, both with academic and industrial partners. The group has developed a wide international network which also provides access to a broad range of experimental infrastructure which is necessary for the heavily experimental research. The development of the NorTex Petroleum Cluster is a most interesting initiative which aims at integrating relevant industries into different university research collaborations within petroleum education and research.

Both MSc and PhD students are exchanged with collaborating international departments to perform specific measurement series.

On the national level the research collaboration with the industry is very strong as indicated by the 8-year programme FME-SUCCESS on aquifer storage of CO₂. The research group has also taken the initiative to establish the Petroleum Research School of Norway wherein all 5 major research groups in Norway collaborate to provide more intensive courses for PhD students with research within petroleum.

Scientific quality and productivity:

Grade: 4

Within Reservoir Physics experimental and modelling studies are related to enhanced oil recovery, methane and CO₂ hydrate research, carbon capture utilisation and storage, imaging and special core analysis, covering investigations from the pore scale over core scale to block scale with model-based upscaling to field scale.

Within Thermodynamic Modelling the focus has been on ab-initio modelling of solid state matter, using density functional theory and phase field models to deal with interphase phenomena, thereby describing thermodynamics, interphase phenomena and transport processes from nano to micro scale as a basis for large scale model building.

Both of the above areas of research are at a leading international level.

The group has written many reports to industrial partners funding their research. The group also seems quite active in conference participation. The group has written 44 papers during the past 5 years of which 34 appeared as peer reviewed journal publications. The journals range from Petroleum Science and Engineering, Energy and Fuels, Energy Procedia, Physical Chemistry Chemical Physics to Mathematical Chemistry, which indicates the multidisciplinary approach of the group. The citation index for the field is only 64%, which is low considering the very extensive international collaboration network and the strength of the research. However, this may be connected to the fact that it is only recently that the focus has been shifted to publication in peer reviewed level 2 journals.

The group has an international co-authorship which is a little below the average for all units included in the publication analysis. This seems odd considering the active student exchange, which should be used to promote international cooperation resulting in peer reviewed journal publications.

Societal and industrial relevance and impact:

Grade: B

The research within the group is interdisciplinary. An example is the recent demonstration obtained by using MRI that sequestration of CO₂ in hydrate reservoirs spontaneously results in natural gas production, without heat injection and hydrate melting. This technology has been co-patented by UoB and ConocoPhillips and was successfully field-tested in 2012. Despite this its economic impact still remains to be ascertained.

The group has obtained 2 more patents in the relevant period and has also generated 7 additional ideas.

The group clearly has a significant contribution to society.

Recommendations to the research unit:

- Considering the high standard of the research it is essential to strengthen the academic impact of the effort, e.g. by focusing on continuing to increase publications of joint research results in peer reviewed journals. Such an undertaking will be expected to feedback into the group in terms of improved international contact and collaboration.
- Continue with the refurbishment of laboratories.

4.6. University of Stavanger

4.6.1. Department of Petroleum Engineering

Evaluation Units:

Petroleum Engineering

General comments on the department level:

The Department of Petroleum Engineering is formed of 2 study branches, Petroleum Geology and Petroleum Engineering. The latter is clearly an important area for Norway given its reliance on oil and gas production from the Norwegian Shelf. The Petroleum Engineering branch is further subdivided into 3 research groups, Drilling and Well Technology, Natural Gas Technology, and Reservoir Technology, but these were evaluated as 1 group for the purposes of this report. This combination of petroleum geology and petroleum engineering is a strength as it partially reflects the multidisciplinary nature of most oil industry study teams. It would be further improved if the department were also host to a research group in applied petroleum geophysics.

The role of the Head of Department is administrative and scientific leadership. There are informal group leaders. As a result there is no clear strategic focus and research direction for the department. This may also explain why both the written self-assessment and the group discussions were weak and did not represent the department's activities in the best light. This is disappointing as there is some excellent world leading research going on in some parts of the department.

Follow up from previous evaluations:

The previous evaluation also commented on the weak presentations from the department and recommended that the department should “develop common plans for further development of the department” and that this “strategy should emphasise why they are following certain lines of research”. This strategy is still not in place although it is clear that the department's research portfolio has developed to reflect the maturing nature of the Norwegian Shelf as suggested by the last Panel. It is not clear however whether this is a response to the previous evaluation or an adventitious reflection of the nature of funding obtained by the department. The number of PhD students within the department has increased, improving the depth of the research undertaken and the output of the department in terms of publications and qualified people who can continue petroleum-related research or work in the oil industry.

Recommendations to the department/institution:

- Appoint a head of department with responsibility for research and education who can establish a coherent strategy for the department in consultation with the research groups. They should also put in place a more formal organisation within the department, taking into account the strong and beneficial links with the sister research groups at IRIS.

- Consider establishing a research group in applied geophysics within the department or at least improving research collaboration with such a group.
- In the future the department should consider how to better express the societal impact of their research in language that can be understood by non-specialists and submit all the information requested for this Review in the format specified. The self-assessment material provided to the Panel was lacking in detail, giving the impression that the group did not feel this evaluation was important. This was disappointing as this was an opportunity for the department and the group to establish their research credentials in Norway, outside the rather narrow petroleum engineering field. This was compounded by the very detailed technical language used in meetings with the Panel.

4.6.1.1. *Petroleum Engineering*

Description of the research unit:

The Petroleum Engineering Group is formed of 3 sections, Drilling and Well Technology, Natural Gas Technology, and Reservoir Technology, which form the major part of the Department of Petroleum Engineering. The group employs 49 people, 26 are scientific staff and 16 are PhDs, postdocs and research assistants. It works closely with staff at IRIS and some staff are members of both organisations. The group has a number of laboratories and is involved in 3 research centres, Corec, DrillWell, and the National IOR Centre of Norway which it leads. It recruited 27 PhD students between 2009 and 2013, 26 of whom were international. Its research income exceeded 90 million NOK over the research period (not including the National IOR Centre which was only signed off in December 2013).

Strategy, organization and research cooperation:

The strategy for the group is very high level and insufficiently detailed. It is controlled by a board formed of 3 scientific employees, 1 administrative/technical employee, 1 external representative and 2 students. This board approves the department's strategy document and thus decides upon the priority research areas which correspond to the 3 different sections. The group publish their research results both through conferences, because of direct exposure to industry, and in journals, in order to achieve departmental targets for publication points. The group is involved in approximately 50 externally-funded research projects including participating in the COREC and Drill Well projects and leading the National IOR centre of Norway. 2 members of scientific staff are female. The group has staff with a range of ages. The group works closely with industry through the wide range of research projects they are involved with and also cooperates closely with colleagues in IRIS, but there is less clear cooperation between the different sections in the group.

Scientific quality and productivity:

Grade: 2

The scientific quality and productivity of the group in terms of peer reviewed journal papers is very variable. A few members have good productivity (level 3) and high impact in the field (level 4), but many of the CVs submitted for the evaluation did not provide values for citation

index or give the member of staff's best 3 publications for the evaluation period. Other CVs listed SPE conference papers which are not peer reviewed scientific publications. The average number of peer reviewed scientific publications in the assessment per member of staff was poor and this is reflected in the grading.

Societal and industrial relevance and impact:

Grade: A-B

The impact of improved oil recovery from the Norwegian Shelf on both the society and the oil industry is high. This group is involved in a wide range of projects addressing this, including leading the recently established and high-profile IOR centre (worth 50 million NOK from the RCN plus matching from industry over 5 years).

Recommendations to the research unit:

- The group should develop a more detailed scientific strategy specifying the particular scientific areas to be addressed and the time frame of perhaps 5 or 10 years. There should be a process for reviewing and refreshing this strategy over a specified time interval.
- Staff publication targets should be higher in terms of publication points with a focus on both high-impact peer reviewed scientific journals as well as petroleum conference presentations and SPE journal papers.

4.7. IRIS

The International Research Institute of Stavanger (IRIS), former Rogaland Research, is jointly owned by the University of Stavanger and the Rogaland Research. The Institute was formed in 2006. It is engaged in research and research-related activities in petroleum, new energy, marine environment, biotechnology, social science and business development.

4.7.1. IRIS Energy

Evaluation Units:

Drilling and Well Modelling
Enhanced Oil Recovery
Reservoir

General comments on the department level:

IRIS Energy's core activities are within the petroleum sector although they are also involved in research related to carbon capture and storage and renewable energy. It is led by the Senior Vice President, supported by a management team of 8 research directors. The department is formed of 7 research groups whose leaders report directly to the Vice President. There are regular meetings with IRIS management as well as annual meetings to discuss research strategy, informed by feedback from and discussion with the research groups. There is also an advisory board formed of research coordinators from oil companies and representatives from the University of Stavanger, the Norwegian Petroleum Directorate and Petoro. This board meets annually. There are further scientific advisory boards in automated drilling and improved oil recovery. IRIS Energy receives basic funding of between 7 and 8% of its total income, the remainder comes from industry.

The department is very well organised with appropriate structures in place to develop and refresh its research strategy with engagement from the research staff as well as suitable policies to manage and recruit staff. The proportion of female employees is higher than in universities engaged in similar research and the age profile of staff is a good mix of younger and more experienced staff. The organisation continues to focus on recruiting women. There is an impressive range of research laboratories. The department encourages its staff to publish, providing some time and budget to do so, within the constraints allowed by the IP commitments of its industry-funded research. There is a strong focus on SPE conferences and journals as these are attended and read by the potential clients of the researchers. Publication of some work is restricted by IP terms in the contracts with funding companies. It should be possible to enable more of such work to be published if suitable IP terms are negotiated with companies.

Follow up from previous evaluations:

IRIS was not part of the evaluation carried out by the Research Council in 2004.

Recommendations to the department/institution:

- Should negotiate harder for the right to publish when determining IP terms in industrial contracts.
- Further resources and incentives should be put in place to encourage staff to publish in peer reviewed, non-petroleum scientific journals as well as in the SPE journal.
- Continue to review, develop and refresh the research strategy.

4.7.1.1. *Drilling and Well Modelling*

Description of the research unit:

The Drilling and Well Modelling Group employed 18 scientific staff at the end of the assessment period, 5 of whom were female. The group has expertise in the mathematical modelling of drilling, the methodology of drilling wells, software engineering, control theory, machine control, validation and human factors design. It is internationally leading in this important field. It was involved in 10 major applied projects worth approximately 120 million NOK funded by different oil companies and/or the RCN. It was the leader of 7 of these projects.

Strategy, organization and research cooperation:

The group's current research is mainly focused on the goal of developing an automated drilling system with the intention of significantly reducing drilling costs and improving safety, especially when drilling wells in more complex and challenging environments. It is also engaged in a project improving oil recovery through drilling (DrillWell). This is an SFI led by IRIS. A third focus is to generate new concepts and solutions within the area of drilling wells and control systems. The group is led by a research director, who is responsible for personnel, finances and planning, and who is supported by 2 chief scientists, who focus on research direction. The chief scientists regularly participate in strategy discussions with the management of IRIS Energy and industry representatives. The group is divided into projects, the majority of which have a steering committee to monitor progress and research direction. The group works with other national organisations (SINTEF, UiS, NTNU) and oil companies (ConocoPhillips, Statoil, Wintershall, Total, Det Norske, Talisman) as well as with 19 overseas universities, including Texas A&M, University of Houston, MINES Paris Tech and Delft University of Technology. The group is growing and is continuing to recruit more personnel in order to be able to develop more research projects. It tends to recruit non-petroleum scientists and then train them in this discipline because trained petroleum and drilling engineers are in short supply as they can earn more in industry. The group allocates time and budget for paper preparation and revision but feels more time could be allocated to this task.

Scientific quality and productivity:

Grade: 3-4

A large proportion of the group's written output is confidential, driven by the IP obligations of their industry-funded projects. They produce a large number of conference papers as these

conferences are important venues for publicising the group's work to their industry clients and potential clients. Nonetheless many of these conference papers are subsequently accepted for publication in the peer reviewed journal SPE Drilling and Completion. The group have also published a few papers in more scientific journals on control theory, geothermal applications of their research and on cybernetics.

Societal and industrial relevance and impact:

Grade: A

Improved safety during drilling obviously has important positive benefits for the environment and oil rig workers, whilst reducing drilling costs is of major benefit to service companies and their oil company clients. The importance of the group's contribution in this area is demonstrated by the number of oil companies supporting their projects and the large sums invested by those companies in the group's research. The group has several patents that have so far led to 2 products being commercialised by a start-up company.

Recommendations to the research unit:

- Increase research on human factors design, bringing in more theory from IT areas to add to the existing cooperation with CMR (human machine interface) and IFE (industry psychologists, test facility).
- Increase output of peer reviewed journal papers.
- Develop a longer-term focused research strategy and put in place processes to review and refresh that strategy.

4.7.1.2. *Enhanced Oil Recovery*

Description of the research unit:

The Enhanced Oil Recovery Group employed 16 scientific staff at the end of the assessment period, 4 of whom were female, as well as 1 postdoctoral fellow and 1 PhD student. 2 of the 3 chief scientists work part-time as members of the Faculty in the University of Stavanger. The group members have a good range of scientific backgrounds including physics, mathematics and chemistry as well as petroleum engineering. This provides important diversity in scientific thinking that helps to further improve the group's very good track record in EOR research. The group was involved in 10 major applied projects worth approximately 126 million NOK, funded by different oil companies and/or the RCN, and was part of the newly established National IOR Centre.

Strategy, organization and research cooperation:

The group aims "to contribute in understanding the fundamental mechanisms for releasing hydrocarbons from the reservoir" whilst contributing to "society's goal to produce energy in a safe, profitable and environmentally friendly way". These aims are clearly important as oil fields in the Norwegian Shelf approach maturity and production from conventional water or gas flooding begins to decline. The strategy explains how the group intends to achieve these aims through collaboration nationally, internationally and with the industry and through

recruiting appropriately trained staff. The group also aims to disseminate its findings through journal publications and conference presentations. The strategy does explain the broad scientific disciplines that will be investigated by the group but does not provide more detail on the priorities within those disciplines or quantifiable targets for publications and conference presentations. The organisation within the group and in particular the career path and development are clearly defined. It is evident that the collaboration described in the group strategy is achieved at the desired national (e.g. UiS, Institute for Energy Technology, University of Oslo, University of Bergen), international (e.g. Catholic Pacific University, Brazil, Cornell University, USA, Lawrence Berkley Lab., USA, UT Austin, USA) and industrial (e.g. BP, ConocoPhillips, Statoil, Wintershall) levels. PhD students are recruited from all over the world, usually to work on RCN projects. Most staff in the group engage in both experimental and modelling research.

Scientific quality and productivity:

Grade: 3

The group writes a mixture of scientific peer reviewed papers and conference papers and is not usually restricted by confidentiality clauses in its industrial research projects. The output of scientific peer reviewed papers is less than 1 per researcher per year and the citation indices associated with the researchers range from good to weak.

Societal and industrial relevance and impact:

Grade: A-B

The group has a large number of high-value research projects funded by the RCN and oil companies (including BP, Statoil, ConocoPhillips, GDF Suez, Dong, RWE-DEA) over and above involvement in National IOR Centre. It is tackling similar societally and industrially important issues to those being addressed by the UiS group, and in partnership with that group, and therefore both groups were awarded the same grade.

Recommendations to the research unit:

- Continue to increase focus on publication in peer reviewed journals, with the aim that each group member should be publishing more than 1 peer reviewed paper per year. The group should ensure that suitable time is made available to researchers to enable them to achieve this goal.
- There should be procedures to review and refresh the research strategy, in particular the group should be forming a strategy in the next 2 years to determine their research direction(s) once the National IOR Centre funding winds down.
- The cooperation with UiS is very good and beneficial scientifically for both groups, and this should continue to be strengthened.
- The group should consider applying for funding from the EU, perhaps in the area of CCS where the group has relevant skills.

4.7.1.3. *Reservoir*

Description of the research unit:

The Reservoir Group is focused on the scientific challenges of reservoir characterisation through history matching and simulation as well as the optimisation of oil recovery. It is internationally leading in the application of Ensemble Kalman Filter (EnKF) methods to oil reservoir history matching. It was formed of 9 people at the end of the assessment period, 3 of whom were women. The group had received more than 60 million NOK in research funding over the assessment period from the RCN and oil/energy companies including Total, Statoil, ConocoPhillips, Eni, Petrobras and Gaz de France. The group is located in Bergen.

Strategy, organization and research cooperation:

The group aims to produce top quality research in the field of improved reservoir management by the application and development of EnKF methods to reservoir history matching and through the development of Open Source reservoir simulation tools. The current strategy is to continue to focus on these existing areas of research. There is no long-term strategy although the group's expertise could be applied to uncertainty and optimisation problems in other fields including weather forecasting. The group has a policy of encouraging publications in peer reviewed scientific journals, in petroleum industry conferences and in more mathematically and computationally orientated conferences. The group is led by a research director advised by a chief scientist. Project leaders are allocated to the various research projects underway at any given time. The group has had two PhD students employed at IRIS and in addition the chief scientist has supervised two PhD students at UoB. Increasing the number of PhD students might help the group to improve its publication rate of peer reviewed scientific papers. There is extensive cooperation with both national universities (UiB, NTNU) and international universities (including MINES ParisTech, TU Delft, University of Tulsa, University of Oklahoma, University of Heidelberg and University of Stuttgart) through IRIS projects and joint publications. Moreover the chief scientist has a part-time position at the University of Bergen. The group collaborates with the Drilling Group through the DrillWell SFI Centre and the EOR group through the National IOR Centre of Norway but has not yet become engaged with experimentalists, which is essential if they wish to validate their simulation tools. The group validate their full field simulation tools on real field cases with data provided by the oil companies.

Scientific quality and productivity:

Grade: 4

The group are internationally recognised for their expertise in the application and development of EnKF methods to reservoir history matching but their scientific output is mixed. Some individuals have published a lot of papers with reasonable numbers of citations, but other group members have a less strong publication record. In addition the group have focused their dissemination efforts on lower impact SPE conference papers, as these help to market their work to industry sponsors. The grade awarded is an average based on the range of productivity and citations achieved by different members of the group. The group's expertise could be applied to uncertainty and optimisation problems in other fields including

weather forecasting, and it would therefore be highly desirable to spread results to a wider scientific community.

Societal and industrial relevance and impact:

Grade: B-C

The Open Porous Media software is societally beneficial as it can be used by academics nationally and internationally enabling them to develop this code for their own applications. It is anticipated that this code will have educational benefits for students. The EnKF technology that was first developed by this group has now been taken up by an independent company. Although the technology has not been adopted by oil companies, it nonetheless has the potential to benefit both society and companies by helping to improve decision-making during oilfield development.

Recommendations to the research unit:

- The group has a very narrow focus on developing EnKF for oil field history matching applications. They should broaden their vision to include research into optimisation as well as to collaborate with other groups to get experimental validation of codes. This should be captured in a longer-term strategic plan together with a procedure for regularly reviewing and refreshing this strategy.
- The group should continue to increase focus on publication in peer reviewed journals, with the aim that each group member should be publishing more than 1 peer reviewed paper per year. The group should ensure that suitable time is made available to researchers to enable them to achieve this goal.

4.8. SINTEF Energy Research

4.8.1. SINTEF Energy Research

Evaluation Units:

Bioenergy
Combustion
Flow Phenomena
Power Conversion and Transmission

General comments on the department level:

The organisation has recently successfully carried through a strategic process involving all the different levels. This is reflected in clear strategies at departmental and group levels. The organisation is good at making use of its combined competence, within the groups and across group boundaries, enabling interdisciplinary research. This is reflected in the fact that SINTEF Energy leads 4, out of 8, Centres for Environmentally Friendly Energy Research. There is a common policy for how new employees are mentored, and a clear career path within the organisation. The area is male dominated, but the number of female researchers at SINTEF Energy is higher than in the corresponding academic environments. According to the leadership only 25% of research is confidential and the remaining 75% could be published in scientific journals. However, the publication rate is much lower.

Follow up from previous evaluations:

SINTEF Energy Research was not part of the evaluation carried out by the Research Council in 2004.

Recommendations to the department/institution:

- To increase scientific impact by publication in scientific journals needs to be emphasised and prioritised.

4.8.1.1. *Bioenergy*

Description of the research unit:

The group has 10 research scientists of whom 8 have a PhD degree. The group has an even age distribution with 3 female employees.

The group has a number of main research areas, including biomass feedstock characterisation for efficient and environmentally friendly production of energy and of higher-value products such as biofuels. Aviation biofuel constitutes an important part of the biofuels project, aiming at biomass conversion through thermal pre-treatment methods for improving the fuel quality of biomass. The group is also concerned with systems analysis, i.e. detailed techno-economic analyses including process design and optimisation of district heating, and combined heat and power and biofuel production systems, through a multidisciplinary collaboration with industry and other research institutes. A further subject is the downscaling and improving of wood and

pellet stoves for domestic heating by lowering emissions, increasing efficiency and user friendliness.

Strategy, organization and research cooperation:

The research strategy is in tune with the overall SINTEF mission where bioenergy is one of 11 strategic priority areas. Bioenergy has a project portfolio where 35% is industry projects, 38% is knowledge-building projects, while 19% is long-term excellence projects, and the remainder is from other sources. The group has a well-equipped bioenergy laboratory with fundamental research-oriented rigs as well as pilot and small-scale rigs to gather insight into overall processes. The group has several successful international research collaborations both inside Europe and beyond. Collaboration with SINTEF Materials and Chemistry and SINTEF Fisheries and Aquaculture has led the production of biofuels and biochemicals from seaweed.

Scientific quality and productivity:

Grade: 3

The group has plenty of ambition and energy. It clearly has a large potential to improve its scientific output over the coming years. The group has already had an impact on technology development but limited research output thus far. The publication activity of the group is well above average. This indicates a rather strong publication performance for this applied research oriented group. However the *h* indices of the group members are still low, probably due to the only recent effort into increasing focus on peer reviewed publications.

Societal and industrial relevance and impact:

Grade: A-B

The group is contributing significantly to recent industrial developments towards meeting the national goal of doubling the bioenergy production by 2020. These contributions stem from mainly small-scale heating appliances for space heating, i.e. woodstoves and fireplaces, including the first very clean Norwegian pellet stove, and from strengthening the role of Waste-to-Energy (WtE) in the Norwegian renewable energy future. One of the WtE companies (Energos) has been directly formed from research at SINTEF. The group also has developed an “internal dryer” for complete and efficient combustion of wet waste on ships, which now has been patented and commercialised by an industrial partner for both ship and land applications. The dryer doubled the incineration capacity while ensuring effective combustion. The development of bio-jetfuels constitutes a future growth area for the Norwegian forestry sector.

Recommendations to the research unit:

- The focus on increasing publication in peer reviewed journals should be maintained. It can well be increased with the benefit of an increased focus on the core of engineering science aspects.

4.8.1.2. *Combustion*

Description of the research unit:

In 2013 the group was composed of 10 researchers, 9 male and 1 female, with considerable experience. Most of the researchers have a background in combustion science and are both experimentally and numerically oriented.

Strategy, organization and research cooperation:

The group's expertise and activities match well with several strategic areas at department level (carbon capture and sequestration (CCS), bioenergy, and to some extent energy efficiency, gas technology, and offshore wind power). However, over recent years, 75% of research activities relate to CCS technologies. The recent decline in CCS interest from authorities in Norway and Europe calls for a new strategy. The group sees many opportunities to use its expertise in other areas, but no strategic decision to make a choice has been taken. Shifting from large-scale combustion to car-engine combustion, including emission control and analysis of pollutants from new types of fuels, would be a strategic decision, as both areas cannot be covered simultaneously by a small group and there is also massive international competition in car-engine combustion research.

The group collaborates closely and extensively with NTNU. For a long time there has been cooperation with SANDIA National Laboratories. Research projects also include other SINTEF groups and international universities as well as industrial partners.

Scientific quality and productivity:

Grade: 2

At present the publication rate is rather low. The group works in an important area and has considerable experience and knowledge of how to include chemistry in direct numerical simulations of turbulence. The Panel believes the potential for considerable scientific impact is high.

Societal and industrial relevance and impact:

Grade: B-C

The group works in an important area, and makes important contributions through the many large projects funded by RCN, Gassnova, EU, and the regular industry projects.

Members of the group have been and are active in the redaction of strategic documents on national and international level.

Recommendations to the research unit:

- Management needs to initiate a strategic process to identify new research opportunities and prioritise accordingly.
- Increase motivation to publish.

4.8.1.3. *Flow Phenomena*

Description of the research unit:

The group consists of 11 researchers, 9 male and 2 female, with expertise in applied physics, process engineering, and numerical mathematics. The group is young and there is a strong interest in fundamental research related to modelling for fluid and thermodynamics phenomena using numerical and experimental techniques. The group's ambition is to follow new developments in these fields and to apply them to industry-relevant problems. The chief researcher plays a very important role in the group.

Strategy, organization and research cooperation:

The group has a clear organisation with a strong identity and a clear strategy in line with the overall SINTEF Energy strategy. It performs fundamental and application-oriented research related to CO₂, CCS and, more recently, subsea processes, as well as continuing to monitor and engage in new areas that match the group's competence. They maintain a dialogue with both the end-users of their research and the funding bodies. The group collaborates closely with NTNU, by co-supervision of PhD students, competence exchange, sharing of laboratories, research infrastructure and networks, as well as with other SINTEF groups and industry. The group has much international collaboration, including EU funding.

Scientific quality and productivity:

Grade: 3

The publication rate is reasonable but could be improved, even though the SINTEF target of 1 publication per scientist per year has been reached. It is noted that the group is still very young, and the publication rate can be expected to increase significantly as the members gain more experience.

The work on combining flow properties and thermodynamics, involving both laboratory experiments and modelling, can be expected to give significant scientific impact, through application of the techniques into different industrial settings.

Societal and industrial relevance and impact:

Grade: B-C

The group works in an important area and makes significant contributions, particularly through its projects in CO₂-transport (NORDICS, BIGCCS, and CO₂dynamics).

Recommendations to the research unit:

- Needs to continue to diversify engagement with different industrial partners.
- Need to share expertise within the group better to achieve further improved scientific output.
- Strive for higher publication rate than the SINTEF goal of 1 paper per year. Given the expertise within the group, a much higher scientific impact is within reach.
- The Panel appreciates the group's proactive search for future industrial challenges, which should be pursued further.

4.8.1.4. Power Conversion and Transmission

Description of the research unit:

The research group as of end of 2013 had 22 members. Its core competences and research activities are focused on power system dynamics, power electronics and control systems, with the main application areas being offshore wind, subsea power supply and integration of renewables into the power system.

Strategy, organization and research cooperation:

The group has a clear strategy focused on the strong competence in their research areas. The proactive approach in identifying new research fields and the general tendency to operate industry-oriented rather than industry-driven is highly appreciated by the Panel. The organisation of the group is sound. Various international collaborations established by the group prove that strategy and organisation allow for a competitive edge. There is a persisting gender imbalance due to the rather traditional development in the past, but now around 50% of the MSc students and an increasing number of applicants are female.

Scientific quality and productivity:

Grade: 3

There is a clear ambition to publish as much as possible, inhibited sometimes by restrictions in joint projects with industry, for cases where specific technological solutions have been developed, and the lack of funding set aside for preparing journal papers. Conference attendance and papers are mainly used for networking. The involvement of PhD students from NTNU is acknowledged to be important for both the group and the students.

Societal and industrial relevance and impact:

Grade: B

The main target of the group is to be able to respond to market requirements and to identify possible new customers. While this and the desire of industry for short-term solutions for existing problems inhibit long-term and basic research, the group shows a spirit of working towards long-term visions and the identification of aspects relevant in the future. PhD students are being closely monitored as they are potential future employees for the group and SINTEF.

Recommendations to the research unit:

- The unit should improve its publication output as the potential to do so is clearly visible.
- The group should maintain the approach of being industry-oriented rather than industry-driven.
- The group should maintain the proactive approach in the search of future research fields.

5. Mandate for the review

5.1. Terms of reference

Introduction

The Ministry of Education and Research has assigned the task of performing subject-specific evaluations to the Research Council of Norway (RCN). The Division of Science has decided to evaluate basic research within engineering science in universities, university colleges and relevant research institutes during 2014.

The previous evaluation of the research in engineering science was carried out in 2004.

The objective of the evaluation

The objective of this evaluation is to review the overall state of basic and long term research in engineering science in Norwegian universities, university colleges and relevant contract research institutes. The evaluation shall provide knowledge and recommendations for future development of basic research within engineering science in Norway, and lay the foundation for determining future priorities, including funding priorities, within and between individual fields of research.

For the institutions that are evaluated, the evaluation will provide knowledge, advice and recommendations that can be used to enhance their own research standards. For the RCN the evaluation will contribute to an improved knowledge base that is used when giving advice on research policies to the Norwegian Government.

Specifically, the evaluation is expected to:

- Provide a critical review of the strengths and weaknesses of basic and long term research in engineering science in Norway, both nationally as well as at the level of departments and individual research groups. The scientific quality shall be reviewed in an international context.
- Identify research groups that have achieved a high international level in their research or have potential to reach such a level.
- Identify areas of research that need to be strengthened in order to ensure that Norway in the future will have the necessary competence in areas of national importance.
- Discuss to what extent the research meets the demand of interdisciplinary research and future societal challenges.
- Assess the situation with regard to recruitment of PhD candidates in engineering science.
- Assess to what degree the previous evaluation have been used by the institutions in their strategic planning.

Organization and methods

The evaluation will be carried out by an international Evaluation Committee consisting of three sub-panels. Each panel will carry out the evaluation in their field of expertise.

- Energy and process technology
- Product, Production, Project management, Marine systems and Renewable energy
- Civil Engineering and Marine structures

The panels will base their evaluation on self-assessments provided by the departments/research groups, a bibliometric analysis provided by the Research Council, as well as on interviews and presentations given in meetings with the involved departments/research groups. The self-assessments from the institutions will include factual information about the organisation and resources, future plans, CVs, and publication lists of their scientific staff.

The panels are requested to present its findings in written reports. Preliminary reports will be sent to the departments/research groups included in the evaluation for a assessment of the factual information. The Committee's final reports will be submitted to the Board of the Division for Science for final approval.

The principal evaluation committee will consist of the leader and one member from each sub-panel.

Tasks of the evaluation sub-panels

The panels are requested to

- Evaluate research activities with respect to scientific quality, national and international collaboration. The evaluation shall focus on research that are/can be published in peer-reviewed publications and conferences. Contract research with restricted public access to the results is not included in this evaluation.
- Evaluate the relevance and impact of the evaluated research activities.
- Evaluate how the research is organized and managed.
- Submit a report with specific recommendations for the future development of research within engineering science, including means of improvement when required.

Aspects to be addressed in the sub-panel reports:

1. National aspects

- Strengths and weaknesses of Norwegian Engineering Science research in an international context
- Impact and relevance of the evaluated research with regard to the future needs of national and international business- and public sectors
- The impact of national excellence centers (SFF, SFI, FME, NCE, ...) on scientific quality and societal impact and relevance.

- Research cooperation nationally and internationally
- General resource situation regarding funding and infrastructure
- Training, recruitment, gender balance and mobility
- Any other important aspects for consideration

2. Institutions/departments

- Does the institution/department have an overall research strategy which feeds into the individual research group strategy?
- Is research leadership being exercised in an appropriate way?
- Is there sufficient collaboration between research groups within the institution/department?
- Are there satisfactory policies in place guiding the recruitment and handling of employees?
- Are the efforts to increase gender balance in scientific positions satisfactory?
- In which way have the previous evaluation (2004), national research policies and White Papers been used by the institution/department in its own strategic planning?

3. Research groups

Strategy, organization and research cooperation

- Has the research group developed a satisfactory strategy with plans for its research, and is it implemented?
- Is the size and organization of the research group reasonable?
- Is recruitment, including measures to address gender balance, handled satisfactory?
- Is there sufficient contact and co-operation with other research groups nationally, both within universities, university colleges and research institutes?
- Does the research group take active part in interdisciplinary/multidisciplinary research activities?
- Is the international network e. g. contact with leading international research groups, number of international guest researchers, and number of joint publications with international colleagues, satisfactory?
- Do they take active part in internationally funded projects, international professional committees, work on standardization and other professional activities?
- How is the long term viability of the staff and facilities evaluated in view of future plans and ideas, staff age, research profile, new impulses through recruitment of researchers?

Scientific quality and productivity: To be rated on a scale 1 - 5

- Do the research groups maintain a high scientific quality judged by the significance of contribution to their field, prominence of the leader and team members, scientific impact of their research?
- Is the productivity, e.g. number of scientific and professional publications and Ph. D. thesis awarded, reasonable in terms of the resources available?

- Do they show ability to work effectively with professionals from other disciplines, and to apply their knowledge to solve multifaceted problems?

Relevance and impact: To be rated on a scale A - E

- Do the research have a high relevance judged by impact on society, value added to professional practice, and recognition by industry and public sector?
- Does the research group have contracts and joint projects with business and public sector, are they awarded patents, or do they in other ways contribute to innovation?
- Does the research group contribute to the building of intellectual capital in industry and public sector?
- Do they play an active role in dissemination of their own research and new international developments in their field to industry and public sector?
- Do they play an active role in creating and establishing new industrial activity?

Tasks of the principal evaluation committee (Joint Committee)

The committee is requested to compile a summary report based on the assessments and recommendations from the three sub-panels. This report should offer an overall assessment of the state of the research involved. The report should also offer a set of overall recommendations concerning the future development of this research.

The committee is requested to:

- Summarize the overall scientific quality and relevance of the research within engineering science. Identify which research areas have a particularly strong scientific position in Norway, in a national and international context, and which are particularly weak?
- Summarize general assessments related to structural issues
- Summarize how the research institutions have followed up former evaluations
- Are there any other important aspects of research within engineering science that ought to be given special consideration on a national or international level?

The committee's conclusions should lead to a set of recommendations for the future development of research in engineering sciences in Norway.

Tentative outline of the joint report

- Executive summary
- Research areas – major general findings
 - Scientific quality
 - Impact and relevance
- Structural issues
- Follow up of former evaluations
- Other aspects of importance
- Recommendations

5.2. Assessment Criteria

Assessment of Research Groups

Three main areas of performance is highlighted for the research groups in the mandate for Evaluation of Engineering Science, and the mandate describes what is covered for each of these areas:

- **Scientific quality and productivity**
- **Relevance and impact**
- **Strategy, organization and research cooperation**

For two of these criteria an assessment should be made using a five point scale.

Scientific quality and productivity:

5 – excellent

4 - very good

3 – good

2 – fair

1 – weak

Relevance and impact:

A – very high relevance and impact

B – high relevance and impact

C– good relevance and impact

D – low relevance and impact

E – very low relevance and impact

Scientific quality and productivity

For “scientific quality and productivity” the following three points appear in the mandate:

- Do the research groups maintain a high scientific quality judged by the significance of contribution to their field, prominence of the leader and team members, scientific impact of their research?
- Is the productivity, e.g. number of scientific and professional publications and Ph. D. thesis awarded, reasonable in terms of the resources available?
- Do they show ability to work effectively with professionals from other disciplines, and to apply their knowledge to solve multifaceted problems?

For this item the following should be used as a basis for the rating. The rating **3 = good** means that the group performs to the standard normally to be expected from a research group in its field.

Excellent

International front position, undertaking original research and publishing in the best international journals and presenting research at recognised international conferences with peer review. High productivity. Very positive overall impression of the research group.

Very good

High degree of originality, a publication profile with a high degree of international publications in good journals and at recognised international conferences. High productivity and very relevant to the field internationally. Very positive overall impression of the research group.

Good

Contribute to international and national research with good quality research of relevance to international research development. Acceptable productivity. Positive overall impression of the research group. The group performs to the standard normally to be expected from a group in its field.

Fair

The quality of research is acceptable, but international profile is modest. Much routine work. Relevance and productivity of research is modest. No original contributions to the field of research. Overall impression is positive but with a distinct degree of scepticism from the evaluators.

Weak

Research quality is below good standards and the publication profile is meagre. Only occasional international publication or presentations. No original research and little relevance to problem solving. Not an overall positive impression by evaluators.

Relevance and impact

For “relevance and impact” the following five points appear in the mandate:

- Do the research have a high relevance judged by impact on society, value added to professional practice, and recognition by industry and public sector?
- Does the research group have contracts and joint projects with business and public sector, are they awarded patents, or do they in other ways contribute to innovation?
- Does the research group contribute to the building of intellectual capital in industry and public sector?
- Do they play an active role in dissemination of their own research and new international developments in their field to industry and public sector?
- Do they play an active role in creating and establishing new industrial activity?

The panel should give a rating of the research group based on how they evaluate the performance of the group related to these points. The rating **C = good relevance and impact** means that the group performs to the standard normally to be expected from a research group in its field.

A = very high and **B = high** means that the group is above standards and **D = low** and **E = very low** the group is below the standard to be expected for a group in its field.

6. Research groups included in the evaluation

Institution	Faculty/ Business area	Institute/ Department	Project group to be evaluated	Panel 1	Panel 2	Panel 3	
NTNU	Faculty of Engineering Science and Technology (IVT)	Energy and Process Engineering	Thermal Energy	x			
			Industrial Process Technology	x			
			Fluids Engineering	x			
			Energy and Indoor Environment	x			
			Industrial Ecology		x		
		Civil and Transport Engineering	Building and Construction				x
			Geotechnics				x
			Marine Civil Engineering				x
			Road, Transport and Geomatics				x
		Structural Engineering	Concrete				x
			SIMLab				x
			Structural Mechanics				x
			Biomechanics				x
		Marine Technology	Marine Technology				x
			Marine Systems		x		
		Engineering Design and Materials	Materials				x
			Design, Analysis and Manufacturing			x	
		Production and Quality Engineering	Production Systems			x	
			Production Management			x	
			Project and Quality Management			x	
			Reliability, Availability, Maintainability and Safety (RAMS)			x	
		Hydraulic and Environmental Engineering	Water and Wastewater Engineering				x
			Hydraulic Engineering				x

		Petroleum Engineering and Applied Geophysics	Petroleum Technology and Applied Geophysics	x			
		Product Design	Product Design		x		
	Faculty of Natural Sciences and Technology (NT)	Materials Science and Engineering	Physical Metallurgy	x			
			Process Metallurgy	x			
	Faculty of Information Technology, Mathematics and Electrical Engineering (IME)	Electric Power Engineering	Electric Energy Conversion	x			
			Electric Power Technology	x			
Electric Power Systems			x				
NMBU	Faculty of Environmental Sciences and Technology	Mathematical sciences and Technology	Water and Environmental Technology			x	
UiA	Faculty of Engineering and Science	Engineering Sciences	Mechatronics		x		
			Renewable Energy		x		
			Civil engineering and offshore Construction			x	
UiB	Faculty of Mathematics and Natural Sciences	Physics and Technology	Petroleum and Process Technology	x			
			Measurement Science and Instrumentation		x		
UiS	Faculty of Science and Technology	Department of Petroleum Engineering	Drilling and Well Technology	x			
			Natural Gas Technology				
			Reservoir Technology				
		Department of Mechanical and Structural Engineering and Materials Science	Mechanical Engineering and Materials Science				x
			Offshore-technology				
Civil Structural Engineering							
UiT	Faculty of Science and Technology	Engineering and Safety	Engineering and Safety		x		
Telemark University College	Faculty of Technology		Process, Energy and Automation Engineering	x			
Østfold University College	Faculty of Engineering		Engineering Sciences			x	

Gjøvik University College	Faculty of Technology, Economy and Management		Sustainable Manufacturing		x	
IFE		Energy and Environmental Technology	Solar energy		x	
NGI		Offshore energy	Computational Geomechanics			x
		Natural Hazards	Geosurveys			x
		Environmental Engineering	Water and Resources			x
IRIS		IRIS Energy	Drilling and Well modelling	x		
			Enhanced Oil Recovery	x		
			Reservoir	x		
MARINTEK		Offshore Hydrodynamics	Hydrodynamic Modelling			x
			Structural Engineering			x
		Ship Technology	Seakeeping and Control			x
		Maritime Transport Systems	Logistics and operations research		x	
		Energy systems and Technical Operation	Energy Systems		x	
SINTEF Building and infrastructure			Building physics Group			x
			Concrete Group			x
SINTEF Materials and Chemistry		Materials and Nanotechnology	Material- and Structural Mechanics			x
SINTEF Energy Research			Bioenergy	x		
			Combustion	x		
			Power conversion and transmission	x		
			Flow phenomena	x		
SINTEF Fisheries and Aquaculture			Fishing gear technology		x	
			Process Technology		x	
			Marine ICT		x	

7. Schedule for Panel meetings

PANEL 1						
Date	start time	end time	time	Activity	Group no	Location / group name
Sunday 9. nov						
Sunday	18:00	20:00	02:00	Introductory panel meeting		Trondheim, Rica Nidelven Hotel
Monday. 10 nov						
Monday	09:00	10:00	01:00	Preparatory panel meeting		Trondheim, Rica Nidelven Hotel
	10:00	10:15	00:15	Interview department	P1-3	NTNUNT Materials Science and Engineering
	10:15	10:45	00:30	Interview group	P1-3a	Physical Metallurgy
	10:45	11:00	00:15	Panel discussion		
	11:00	11:30	00:30	Interview group	P1-3b	Process Metallurgy
	11:30	11:45	00:15	Panel discussion		
	11:45	12:00	00:15	Break		
	12:00	12:15	00:15	Interview department	P1-2	NTNU IVT Petroleum Technology and Applied Geophysics
	12:15	12:45	00:30	Interview group	P1-2a	Petroleum Technology and Applied Geophysics
	12:45	13:00	00:15	Panel discussion		
	13:00	14:00	01:00	Lunch		
	14:00	14:15	00:15	Interview department	P1-1	NTNU IVT Energy and Process Engineering
	14:15	14:45	00:30	Interview group	P1-1a	Thermal Energy
	14:45	15:00	00:15	Panel discussion		
	15:00	15:30	00:30	Interview group	P1-1b	Industrial Process Technology
	15:30	15:45	00:15	Panel discussion		
	15:45	16:00	00:15	Break		
	16:00	16:30	00:30	Interview group	P1-1c	Fluids Engineering
	16:30	16:45	00:15	Panel discussion		
	16:45	17:15	00:30	Interview group	P1-1d	Energy and Indoor Environment
	17:15	18:15	01:00	Panel discussion - drafting of report		
Tuesday. 11 nov						
Tuesday	09:00	09:30	00:30	Preparatory panel meeting		Trondheim, Rica Nidelven Hotel
	09:30	09:45	00:15	Interview department	P1-9	SINTEF Energy
	09:45	10:15	00:30	Interview group	P1-9a	Bioenergy
	10:15	10:30	00:15	Panel discussion		
	10:30	11:00	00:30	Interview group	P1-9b	Combustion
	11:00	11:15	00:15	Panel discussion		
	11:15	11:30	00:15	Break		
	11:30	12:00	00:30	Interview group	P1-9c	Power conversion and transmission
	12:00	12:15	00:15	Panel discussion		
	12:15	12:45	00:30	Interview group	P1-9d	Flow phenomena
	12:45	13:00	00:15	Panel discussion		
	13:00	14:00	01:00	Lunch		
	14:00	14:15	00:15	Interview department	P1-4	NTNU IME Electric Power Engineering
	14:15	14:45	00:30	Interview group	P1-4a	Electric Energy Conversion
	14:45	15:00	00:15	Panel discussion		
	15:00	15:30	00:30	Interview group	P1-4b	Electric Power Technology
	15:30	15:45	00:15	Panel discussion		
	15:45	16:00	00:15	Break		
	16:00	16:30	00:30	Interview group	P1-4c	Electric Power Systems
	16:30	18:00	01:30	Panel discussion - drafting of report		

Wednesday 12 nov					
Wednesday	07:45			Departure from hotel	
	09:20	10:20	01:00	Travel to Oslo	Gardermoen, Radisson Blu Hotel
	11:30	12:00	00:30	Preparatory panel meeting	
	12:00	12:15	00:15	Interview department	P1-6 University of Stavanger
	12:15	12:45	00:30	Interview group	P1-6a UiS Petroleum Engineering
	12:45	13:00	00:15	Panel discussion	
	13:00	14:00	01:00	Lunch	
	14:00	14:15	00:15	Interview department	P1-8 IRIS
	14:15	14:45	00:30	Interview group	P1-8a Drilling and Well Modelling
	14:45	15:00	00:15	Panel discussion	
	15:00	15:30	00:30	Interview group	P1-8b Enhanced Oil Recovery
	15:30	15:45	00:15	Panel discussion	
	15:45	16:00	00:15	Break	
	16:00	16:30	00:30	Interview group	P1-8c Reservoir
	16:30	16:45	00:15	Panel discussion	
	16:45	17:00	00:15	Interview department	P1-5 UiB Physics and Technology
	17:00	17:30	00:30	Interview group	P1-5a Petroleum and Process Technology
	17:30	18:30	01:00	Panel discussion - drafting of report	
Thursday 13. nov					Gardermoen, Radisson Blu Hotel
Thursday	09:00	09:30	00:30	Preparatory panel meeting	
	09:30	09:45	00:15	Interview department	P1-7 Telemark UC
	09:45	10:15	00:30	Interview group	P1-7a Process, Energy and Automation Technology
	10:15	13:00	02:45	Panel discussion - drafting of report	
	13:00	14:00	01:00	Lunch	
	14:00	17:00	03:00	Panel discussion - drafting of report	
Friday 14.nov					Gardermoen, Radisson Blu Hotel
Friday	09:00	13:00	04:00	Panel discussion - drafting of report	
	13:00	14:00	01:00	Lunch	
	14:00	15:00	01:00	Panel discussion - drafting of report	
	15:00	16:00	01:00	Summary panel meeting	

8. Curriculum vitae for the Panel members

Professor Emeritus Derek Fray

Derek Fray is Director of Research and Emeritus Professor of Materials Chemistry at the Department of Materials Science and Metallurgy, University of Cambridge where he was Head of Department between 2000 and 2005. He obtained his degrees from Imperial College of Science and Technology, London and has worked as an Assistant Professor at M.I.T., Group Leader at Rio Tinto plc., and at the University of Leeds, where he was Professor and Head of Department of Mining and Mineral Engineering. He is a Fellow of the Royal Society, Royal Academy of Engineering, Royal Society of Chemistry and the Institute of Materials. He has published about 450 articles on materials processing and is cited as the inventor on over 300 patents of which 150 have been granted. He has been awarded many honours including Matthey Prize, AIME Extractive Metallurgy Technology Award, Sir George Beilby Medal, Kroll Medal, John Phillips Medal, Minerals, Metals & Materials Society's 2000 Extraction and Processing Distinguished Lecture Award, Billiton Medal, two Light Metals Reactive Metals Awards, the Institute of Materials Gold Medal and the Armourers and Brasiers' Award by the Royal Society, the first European Materials Societies FEMS Materials Innovation Prize and Medal and the Max Bredig Award by the US Electrochemical Society. He holds several honorary and visiting professorships. He is a founder director of Ion Science Ltd., Environmental Monitoring and Control Ltd., Metalysis Ltd., Camfridge Ltd., Inotec AMD Ltd., Chinuka Ltd., and La Serena Technologies Ltd.

Professor Gunilla Kreiss

Gunilla Kreiss obtained her Master of Science degree in Applied Mathematics from KTH in 1982 and her PhD in Numerical Analysis from the same institution in 1986. Gunilla stayed at KTH and became an Assistant Professor in 1987, an Associate Professor in 1993 and a Full Professor in 2003. Since 2006 she is a Professor of Numerical Analysis at the Division of Scientific Computing, Department of Information Technology, at Uppsala University. Since 1982 Gunilla has been teaching and developing different courses in numerical analysis, ranging from basic undergraduate to graduate level. She graduated 11 PhDs, is currently the main advisor to 4 PhD students, and supervised 3 postdocs. Gunilla was Head of the Numerical Analysis Group at KTH from 2004 to 2006, Member of a Faculty Appointment Committee at KTH from 2000 to 2006, and Chairman of the Faculty Promotion Committee at Uppsala University from 2008 to 2011, and she is Head of the Division of Scientific Computing at Uppsala University since 2012. Gunilla was a Member of more than 30 Grading Committees at thesis defences, an Opponent at 10 thesis defences in Sweden and Norway, a Scientific Reviewer for Faculty Appointment Committees at Swedish universities, the Organiser of the ENUMATH2009 conference in Uppsala in 2009, and she is a Member of the ENU-MATH Programme Committee since 2009.

Professor Emeritus Sten Bay Jørgensen

Sten Bay Jørgensen obtained his PhD in 1969 within Chemical Engineering from The Technical University of Denmark (DTU). His subsequent postdoctoral stay within Biomedical Engineering was at Columbia University until 1971 as Research Associate, whereupon he rejoined the faculty at the Department of Chemical Engineering at DTU. He was appointed full professor in 1986 within Chemical Engineering. During his tenure he has had many administrative positions including cofounder and center leader for Computer Aided Process and Product Engineering Center (CAPEC) 1997-2006. Since 2009 he is emeritus within the CPAPEC-PROCESS center at the Department of Chemical and Biochemical Engineering, DTU. He has been on several boards and committees, including member and chairman of a committee on energy efficiency in Industrial Processes and Products under the Danish Department of Energy 1986-1999. Presently he is an advisor and evaluator for a number of national research councils and for the EU; and he is a board member for companies. His main research interests have been within modelling for design of industrial processes and products and for investigating the dynamics and control of industrial and biomedical processes. More recently the interest has focused on functional modelling within Engineering Science for design and risk analysis. He has graduated 40 PhD students and supervised 12 postdoctoral candidates. He has published 14 book chapters and more than 125 papers in peer reviewed international journals.

Professor Ann Muggeridge

Ann Muggeridge holds the Total Chair in Reservoir Physics and EOR at Imperial College London. She has a BSc(Hons) in Physics from Imperial College and a DPhil in Atmospheric Physics from the University of Oxford. After completing her DPhil she worked at the BP Research Centre as a Research Reservoir Engineer for 5 years, followed by 4 years working a technical support engineer for oil reservoir simulation in SSI(UK) Ltd. She joined Imperial as a Governors' Lecturer in 1995 and has worked there since apart from a six month sabbatical at the Elf GRC in London and a 2 year sabbatical as a BP Technology Fellow from 2006-8. She has published more than 100 journal and conference papers in reservoir characterisation and modelling, upscaling, flow in porous media and enhanced oil recovery.

Univ.-Prof. Dr.-Ing. Wolfgang Gawlik

Wolfgang Gawlik graduated from Friedrich-Alexander-University (FAU) Erlangen-Nuremberg in Electrical Engineering, focus on Energy Technology. After finishing his studies, he worked as design engineer for turbo generators and as vice group leader novel construction at Siemens generator plant Erfurt for two years. From 1999 to 2004 he was research assistant at the chair of electrical energy supply of the FAU Erlangen-Nuremberg and finished his PhD in 2004. Until his appointment as University Professor for Energy Systems Technology at the Institute of Energy Systems and Electrical Drives at Vienna University of Technology in 2011 he was Senior Key Expert System Dynamics and Project Manager at Siemens Power Technologies International. His research interests are supergrids, smart grids /

microgrids and electromobility, universal grids and software for network analysis, planning and steady state and dynamic modelling.



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Cover design: Design et cetera AS
Cover photos: Shutterstock, Colourbox

Oslo, April 2015

ISBN 978-82-12-03413-6 (pdf)

This publication may be downloaded from
www.forskningsradet.no/publikasjoner