The Research Council of Norway

Basic and long-term research within Engineering Science in Norway

Report from the principal evaluation committee

Evaluation
Division for Science

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Statement from the Principal Committee

The members of the Principal Evaluation Committee for the Evaluation of basic and long term research within Engineering Science in Norway submit this report, based on the general conclusions and recommendations of the three evaluation panels: Panel 1: Energy and Process Technology, Panel 2: Products, Production, Project Management, Marine Systems and Renewable Energy, and Panel 3: Civil Engineering and Marine Structures.

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

Wolfgang Rauch (Chair)

Derek John Fray

Ralf Preu

Dr. Manfred Kleidorfer, University of Innsbruck, Austria, acted as scientific secretary of the principal committee.

1. Executive Summary

1.1. Introduction

This international evaluation assessed the quality and the relevance of engineering science in Norway in 64 research units from universities, university colleges and relevant research institutes. The evaluation is a follow-up of a previous evaluation ten years earlier.

According to the terms of reference the framework of the evaluation is the comparison of the performance against an international standard. The benchmark used in this evaluation is the performance that is to be expected from a university type research institution active in the specific field with about 40% of the staff resources devoted towards research.

Engineering research has been found to have a favourable situation with respect to funding and industry participation. On the other hand, there is a low level of patenting observed, and a modest level of business innovation between Norwegian engineering science and small and medium-sized enterprises, which limits opportunities.

1.2. General Performance

Overall, the research performed in the evaluated units gives a good impression. On a general basis engineering science in Norway is slightly above average for scientific quality and clearly above average with respect to impact and relevance of its research. This gives an indication of the more applied nature of the research conducted. On the other hand there is statistical evidence of a certain weakness in the area of fundamental research as there is a lack of groups conducting excellent research with little (current) practical use.

The performance of the whole sector is more homogenous than scattered. While this makes for rare instances of underperforming units, it also indicates that only few of the research groups are operating at a world leading position in their field. For both – excellent groups and underperforming ones – there is no obvious systematic reason for the performance, but the differences seems to be rather due to leadership, opportunity and boundary condition (in both ways).

At the higher level there are two fields (marine technology and climate / fossil fuel research) that clearly outperform. The excellence in these areas corresponds with key technologies in Norway, which indicates a good linkage between research and industry.

1.3. Specific Observations

With respect to the international cooperation, the situation in engineering sciences in Norway has room for improvement. The mobility of researchers is not sufficient at an international standard and this leads to a limited participation in EU projects. What is especially notable is the low participation in international academic services (e.g. editorial boards of top ranked journals in the field).

It is recognised that the engineering science field has made considerable efforts to increase its visibility and publication output over the last decade. However, Norwegian Engineering research is still not sufficiently visible in journals with high impact factors and this must be increased.

As an overall impression, the committee has found universities and university colleges had a relaxed attitude at the department level towards leadership and long-term planning. This leads to ambiguous structures and procedures with regard to the management of resources and the mode of collaboration with partners. Research is performed more on the basis of opportunities and personal expertise/interest rather than a convincing strategy. This leads to scattered and widespread research, in parts repetitive more than complementary which also questions whether the research efforts should be carried out equally at all levels, i.e. at all new universities and university colleges.

Research in the engineering field is of paramount importance for Norwegian industry and society. The national cooperation between research and (established) industry is excellent and supports the Norwegian commitment towards a technology driven society. On the other hand, there is little visible environment for technology innovation such as guided support for spin-off companies, clear rules regarding commercialisation of intellectual property, the rights for university staff and incentives for inventors and risk based financing.

Recruitment of academic staff has already previously been identified as one of the key bottlenecks in the advance of engineering sciences in Norway and the picture has not changed.

1.4. Summary

Overall, the sector performs at a quite good level in an international context, but could do even better given the advantageous conditions in terms of funding, resources and industrial interest.

2. Research areas – major general findings

2.1. Introduction and framework of assessment

The Ministry of Education and Research of Norway has assigned the task of performing subject-specific evaluations to the Research Council of Norway (RCN). The Division of Science decided to evaluate basic research within engineering science in universities, university colleges and relevant research institutes during 2014. This is to follow a previous evaluation in engineering science that was carried out in 2004. The general objective of this evaluation is to review the overall state of basic and long term research in engineering science in Norway, in order to set future priorities, including funding priorities, within and between individual fields of research.

Since the evaluation comprises a number of institutions that are quite different in setup, scope and organisation, the panel had to define a standard for evaluation. According to the terms of reference the framework of the evaluation is the comparison of the performance against an international standard. The benchmark used in this evaluation is defined as a university type research institution with about 40% of the staff resources devoted towards research. The ranking 3 for scientific quality and productivity and C for relevance and impact defines the performance that is to be expected from a university institution active in this specific field, in an international comparison.

Taking the grades 3 and C as a benchmark for performance makes clear that such ranking is by no means negative, but instead the international standard. Only few institutions are able to outperform this standard on all levels and the top level ranking 5 and A is indicating a world leading position. The comparison of this assessment e.g. with earlier evaluations must take into account this framework.

It is also clear, that research institutions that are devoting less staff resources to publication of results like e.g. SINTEF and MARINTEK will not fare equal in such framework as a university institute. It must be expected that the scientific productivity is less, but quite often the relevance and impact might compensate for that. Likewise university colleges that put emphasis on teaching instead of research will hardly be able to have a scientific output as compared to the benchmark. Again this is not an indication of inferiority but reflects the overall strategy of the institution.

Defining one benchmark, common for all evaluated institutions was a deliberate decision to allow for comparison. To make compensations for the different types of institutions would have opened up for ambiguity in the evaluation results.

Another aspect that has to be mentioned as terms of reference is that the evaluation was based on the documented performance within a given period. Visible improvements (or also shortcomings) that are clearly taking effect within the years to come are not taken into account in the ranking but are indicated either in the text or in the recommendations.

2.2. Research groups

Figure 1 gives a general overview on the affiliation of the 64 research groups covered in this evaluation. It is quite obvious that NTNU is dominant with respect to groups participating – in total 30 (47%). The equivalent in terms of research institutions is SINTEF (including MARINTEK) where 15 research groups have been assessed (23%). Together NTNU and SINTEF make for more than 2/3rd of the field of engineering science (based on the count of research groups). Since both institutions are predominately located in Trondheim the importance of that location for Norwegian engineering research is obvious.

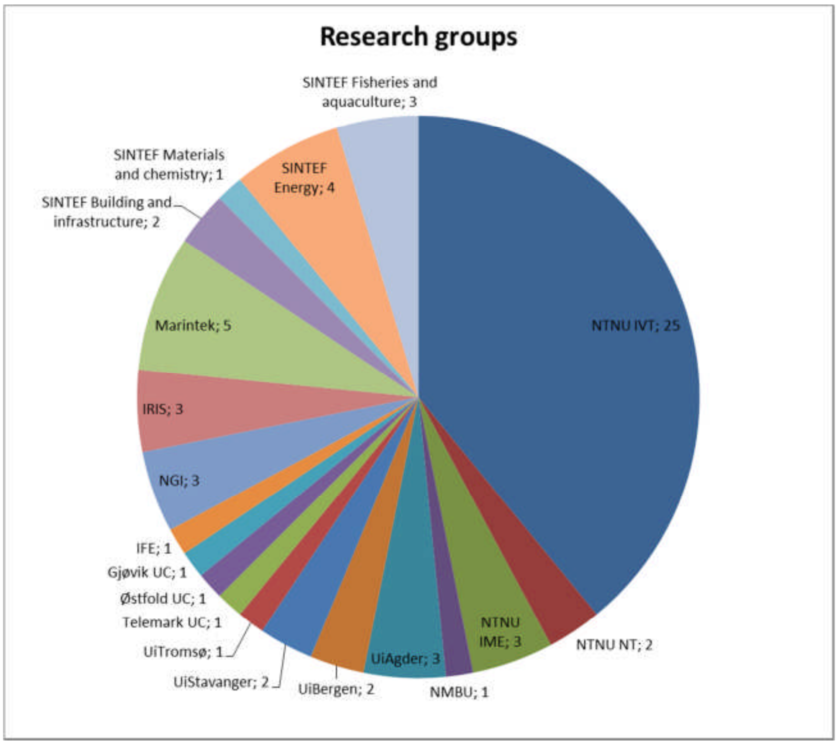

Figure 1: Number of research groups involved in the evaluation and their affiliation to institutions - in total 64 groups.

2.3. Quality and relevance of research conducted at unit level

Figure 2 summarizes the findings from the 3 panels in terms of quantified performance from each of the research groups assessed. On a general basis engineering science in Norway is slightly above average for scientific quality and clearly above average with respect to impact and relevance of its research. This gives an indication of the more applied nature of the research conducted. This impression gets reinforced when crosschecking for “blue sky” and high risk research: A group conducting excellent research without any (current) practical use would be located at the top left part of the diagram (ranked E and 5). The complete lack of research groups with such performance indicates a certain weakness in the area of fundamental research.

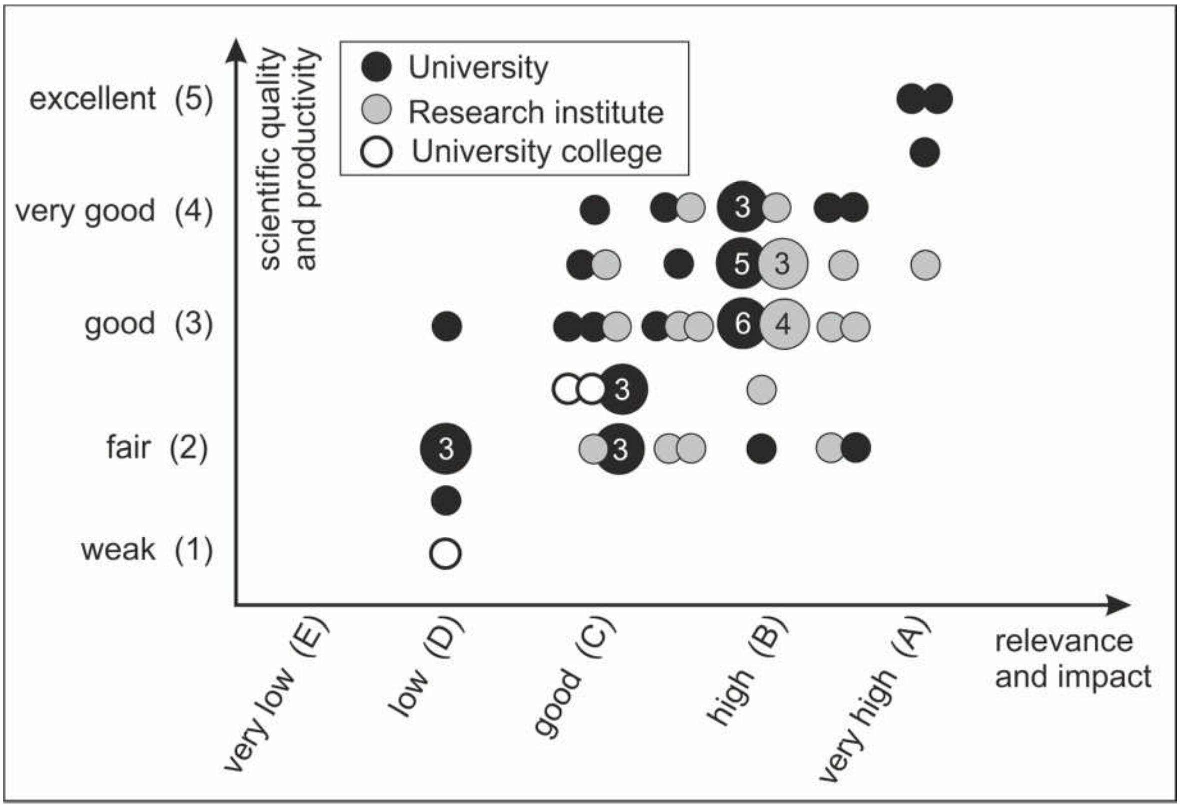

Figure 2: Quantification of the quality of the research (ordinate, y-axis) versus their relevance and impact (abscissa, x-axis) for all 64 research groups assessed. The markers indicate the type of the research groups ranked into university, research institute and university college. When there are 3 or more groups preforming equal (i.e. they are located at exactly the same point in the diagram) this is indicated by numbers in the dots.

The overall impression of Norwegian research in the engineering field is favourable. The performance of the whole sector is more homogenous than scattered. While this makes for rare instances of underperforming units, it also indicates that only two of the research groups got top rating (5 and A) indicating a world leading position in their field. These are SIMlab (Department of Structural Engineering at NTNU) and Marine Structures (Department of Marine Technology at NTNU). To be mentioned at nearly the same high level (4.5 and A) is the group for Industrial Ecology (Department of Energy and Process Engineering at NTNU).

The units Thermal Energy (Department of Energy and Process Engineering at NTNU), RAMS (Department of Production and Quality Engineering at NTNU) and Drilling and Well Modelling (IRIS Energy at the International Research Institute of Stavanger) also perform at a very high level.

The following five groups have been assessed at clearly below average: Civil Engineering and Offshore Construction (Department of Engineering Science at University of Agder), Engineering (Østfold University College), Water and Environmental Technology (Department of Mathematical Sciences and Technology at NMBU), Industrial Process

Technology (Department of Energy and Process Engineering at NTNU) and Energy and Indoor Environment (Department of Energy and Process Engineering at NTNU).

When analysing these underperforming groups it becomes clear that there is no systematic reason involved but more a lack of leadership and/or an unfavourable atmosphere to conduct research at international level. To conclude it has not been found that a whole research field is performing below average but only single groups.

2.4. Analysis with respect to research fields

Taking the results of the detailed evaluation to the next level, it is possible to identify the research fields where Norwegian engineering science is clearly outperforming. This is, on the one hand, marine technology and, on the other hand, climate and fossil fuel research (i.e. industrial ecology, thermal energy, energy utilization). The excellence in these areas corresponds with the key technologies in Norway, which indicates the good linkage between research and industry.

When considering the whole field (not certain units) the petroleum field gives a more scattered impression, performing good but, at the same time, not considered excellent. Given the relevance of the field to the Norwegian society this result is surprising.

Materials Science is found in different scientific disciplines. The research field within engineering science has not made a strong impression as although carrying out worthwhile research applied to existing industries, it has not embraced the latest developments at the forefront of materials science. If restructure of departments is considered, this could enhance materials science within engineering.

Some areas are not covered at all, e.g. cutting edge process technology like laser processing and 3D-microprinting. Norway may be missing out by not exploring these and other exciting areas.

Lastly, the field road & transport engineering is underperforming. This is mentioned as the research unit at NTNU is quite small but seems to be the only Norwegian research expertise in this area. As this is an essential infrastructure for Norway, the level of competence should be lifted to not become vulnerable in a traditional but important engineering field.

3. General findings from the panel reports

3.1. Statistical background information

The total R&D intensity (specified as research and development expenditures in percentage of the gross domestic product) in Norway was 1.65% in 2012 as compared to the average of 2.07% in the European Union[1]. But since Norway has the second highest gross domestic product (GDP) per capita in Europe, the actual amount of funding is one of highest per capita in Europe. The political commitment is to reach a 3% expenditure rate by 2030.

While the public spending for R&D was found to be similar to the EU average (0.79% vs. 0.74%) it is noticeable that R&D intensity from the private sector was significantly lower (0.87% vs. 1.31%). In general, Norwegian science performs well above European average as e.g. expressed by the indicator "excellence in Science & Technology" which is 67.6 as compared to the average value of 47.8 in the EU[1] ("excellence in Science & Technology" is a composite indicator which includes ERC grants, top universities and research institutes, etc.).

On the other hand, a relative weakness is seen in the low levels of patenting, and the modest level of business innovation among small and medium-sized enterprises. This is attributed to the fact that traditional industry activities are related to the extraction and processing of natural resources.

In recent years, R&D policy and strategy have focussed on the sectors oil and gas, energy, climate change, biotechnology, nanotechnology and the maritime sector.

3.2. Funding of research

For the engineering sector, the panels have found a rather good funding situation, which is partly in contradiction to the statistical data[1]. The reason is that the actual amount of funding per capita is one of the highest in Europa (due to the high GDP in Norway). From a general point of view, funding is not seen as key bottleneck to engineering research. Especially with regard to applied research there seems to be ample opportunities to have on-going research financed. What has been identified as weakness though, is the lack of funding for fundamental research in engineering sciences. This leads to a shortcoming of "blue skies research" (research without clear goal), which again is detrimental to innovation.

Likewise the state and the financing of research facilities in Norway has been found as satisfactory. Of course there are problems on a local basis and financing of national research

[1] Research and Innovation performance in the EU, Innovation Union progress at country level 2014, European Commission, http://ec.europa.eu/research/innovation-union/pdf/state-of-the-union/2014/iuc_progress_report_2014.pdf

infrastructure requires special effort (as e.g. the Ocean Space Centre) but the overall situation is good.

3.3. International cooperation

With respect to the international cooperation the situation in engineering sciences in Norway has room for improvement. While there are contacts and collaborations on a personal basis, there is a lack of structured and organised cooperation. The mobility of the researchers is not sufficient at an international standard, which again leads to a limited participation in EU projects.

What is especially notable is the low number of participation in external academic activities. Only a few Norwegian scientists are found as (key) members of international panels, among conference organisers and – even more importantly – on the editorial boards of top ranked journals. This might be a result of lack of recognition of academic services in the personal evaluation of scientists but is detrimental for internationalisation.

What is positive is the high number of international PhD students entering the system, which eventually will work against the trend.

3.4. Publications and visibility of Norwegian research

It is recognised that the engineering science field has made considerable effort to increase its visibility and publication outreach over the last decade. However, there is an abundance of publications in conference proceedings, book chapters and low impact journals. It is recognised that the key audience of engineering science is reading exactly those publication outlets but international science evaluations are requiring publications in top ranked and peer reviewed journals. Norwegian Engineering research is currently not sufficiently visible in journals with high impact factors and should make efforts to increase its publication rate there.

3.5. Strategic planning and leadership

Strategic planning and leadership is generally required on all levels, from national strategies to department planning. As an overall impression, the committee has found for universities and university colleges there was a predominately relaxed attitude at the department level towards leadership and long-term planning. This leads to ambiguous structures and procedures towards the management of resources and the mode of collaboration with external partners. As an example, the committee could not extract a commonly defined and clear relationship between SINTEF and NTNU, but, unfortunately, diverging modes of cooperation.

Following the same line of argument, long term strategic planning has been found missing in many instances at universities and university colleges, which leads to suboptimal recruitment of staff. That is, recruitment has been frequently found to be not strategic (based on research fields and innovation) but rather a replacement or following teaching needs.

As a national strategy new universities and university colleges are urged to conduct research. The evaluation has identified a quite variable quality of research at these institutes but, in general, the standard is well below the average international level. This is due to a lack of a conducive research environments and the relative high teaching load that leaves little room for top class research. As an alternative – at least for university colleges – these institutions could focus on applied research and technology innovation. This would be more in line with their aspirations.

3.6. Role of research for Norwegian Industry and Society

Research in the engineering field is of paramount importance for Norwegian industry and society. In spite of such a general goal, the committee identified a twofold picture: The national cooperation between research and (established) industry is excellent and supports the Norwegian drive towards a technology driven society. Such collaboration is well established and must be further promoted by all means. On the other hand, there is little visible environment for technology innovation such as guided support for spin-off companies, clear rules towards commercialisation of intellectual property rights for university staff and incentives for inventors and risk based financing. This impression is in line with the abovementioned lack of funding for blue-sky research, which is the usual starting point for technology innovation.

3.7. Recruitment of academic staff

Recruitment of academic staff has already previously been identified as one of the key bottlenecks in the advance of engineering sciences in Norway and the picture has not changed. There is a clear lack of Norwegian PhD students in the field, which is mainly due to the non-competitive salaries paid in universities as compared to industry. This shortcoming is currently counteracted by hiring foreign academics.

Likewise there is a difficult situation to recruit international staff at the level of Professorship in Norwegian Academia. Key obstacles are first, the salaries are on a par with international levels but not competitive to Norwegian industry and second, the remote location of Norwegian Engineering Universities (i.e. the provincial character of the surroundings).

Lastly, Norwegian engineering research has a pronounced problem with gender balance – especially with regard to the top positions. This is not specific to the Norwegian situation (in fact the conditions are favourable as compared to many other places) but is usually found in engineering science.

4. Follow-up of former evaluation

Norwegian Engineering science has been evaluated at a general basis in 2004. The referring report initiated a number of measures in the field that have been implemented in the years to follow. The current evaluation of 2014 did not assess the measures taken but rather reflect on the impact, i.e. if significant changes are seen in the data or mentioned in the interviews.

However, two points are to be taken into account when reflecting upon the follow-up from the last evaluation: First, the evaluation from 2004 comprised only 4 universities while the current one encompasses most of the higher education institutions for engineering as well as the dominant research institutions SINTEF, MARINTEK, NGI, IRIS and IFE. The larger number of assessed institutions must give a wider but also different picture. Second, when pointing to possible improvements towards quality and relevance of Norwegian engineering research it must be clear that this is a “moving target”. That is, recommendations from evaluations as such can only be seen as pointers on a trajectory but not as a clearly defined goal to be reached.

A number of issues have already been outlined in detail in Chapter 3 and will be only mentioned herein. In brief the committee has found the following:

- Gender balance in the field has improved but is still far from desired.
- Publication count is better but still should improve further – especially with respect to top quality publications.
- Recruitment of academic staff is still a bottleneck.
- In some of the important research fields mentioned in last evaluation report, i.e. energy systems, oil and gas technology, product engineering and materials science, neither outstanding results are seen nor obvious improvements in many of those. It is concluded that those fields do need further support.
- Following the recommendations from 2004, the fields mechatronics, microsystems and nanotechnology have been established but are still not very visible in the research groups covered in this evaluation. The establishment of favorable research conditions is important for those fields and should be followed up.
- The lack in fundamental research in engineering science has remained and there is still need to improve the situation with respect to incentives and funding.
- Entrepreneurship needs further encouragement.
- Despite the efforts to establish research at university colleges and new universities their role in relation to research is still unclear.

5. Recommendations

In this evaluation, the examining panels found that the overall performance of the assessed research groups is better than the international average standard. However, the panels have also identified several points in which different measures could improve Norwegian engineering science and its international visibility. Further, it is important to note, that engineering science is continuously evolving on an international level and thus continuous improvements are needed to remain competitive. This requires strategic thinking and planning on the national and on the institutional level. The panel suggests that the following points are taken into consideration.

5.1. General recommendations to policy makers / RCN

- The role of the Research Council was found to be very helpful for research. The panel suggests that the RCN should continue its active support of Norwegian research and should in fact enhance its role to drive international excellence.
- The evaluation exhibited a lack of high-risk research, meaning the investigation of novel aspects at highest scientific level but without present practical use. Even if the sector is very applied by nature, opportunities and incentives for such high-risk and basic research should be established. The panels recommend strengthening fundamental research in engineering science to enable scientifically based innovation. This could be achieved by enhancing funding schemes that do not need industrial involvement.
- The national funding schemes are very successful. Two possible improvements are as follows: First, as instruments to promote top quality research, "centres of excellence" should be further enhanced. Second, a dedicated funding scheme for promotion of top-level publications could boost the scientific output. The latter would inherently increase the international standing of Norwegian engineering science.
- The current situation gives the impression that Norway distributes its research resources (both financial and human) evenly over the whole field. It must be questioned at a national level if that is the optimal approach. A viable alternative is the focus on strategic key aspects of national importance. Such strategic focus on certain research questions and fields could promote the scientific quality and output. Thereby a special focus should be given to topics which are relevant for the Norwegian society in a long-term perspective but which are not seen as outstanding in the moment (e.g., hydropower, energy efficiency, etc.). But likewise the continuous support of successful Norwegian research fields in key national technologies (e.g., petroleum industry, marine technology) is strongly recommended.
- As already stated in the earlier evaluation from 2004 the key bottleneck in the sector is the recruitment of academic staff. Measures must be taken on a national basis to work

against the common trend and promote engineering science in education. National and institutional PhD scholarship programs should be initiated for the promotion of excellent research and doctoral training in engineering science. Furthermore an intellectual property right strategy, holding patents and licensing thereof in combination with adequate rewards for the inventors as usual in many European countries would improve attractiveness of recruitment of high-level innovative researchers.

- Additionally, a further improvement of the gender balance is recommended. While quotas are not the only answer, achieving around 30% of female staff in research groups and departments is known to tip the balance and change the culture to subsequently attract more women.
- International visibility of Norwegian engineering science should be improved. Incentives for research groups should be established to encourage participation in European research projects and to encourage staff to participate in international committees, editorial boards, etc.
- On an international level, scientific success is more and more measured by evaluating characteristic numbers (e.g., h-index, number of citations, number of awards, etc.). In order to take a leading role in engineering science it is important to optimize these figures, which requires increased high class publications in ISI listed journals. It is recommended to establish incentives for such publications on a national level, for example by implementing dedicated funding schemes. The initiation of national and/or international awards in engineering science would additionally help to promote and reward excellence in research.

5.2. General recommendations to groups / institutions

- It has been noted already earlier that in general a strong focus should be put to publish more in ISI-listed journals and to seek a greater impact of publications. While this is recognized by most of the assessed groups already now as strategic goal, it requires planning research projects in a scientific way. Key is to identify research contributions upfront in projects so that such papers are actually produced and not lost in the course of the project.
- The research groups and departments should enhance international cooperation and awareness. Obvious strategies are first, to seek for more international funding (most obvious EU funding) and second, to encourage staff to participate in international committees and scientific services.
- The universities are encouraged to seek establishment of research chairs that will allow them to attract (for a specific period) established researchers from the international community. This could foster a change in the scientific research culture to move the research towards more internationally competitive levels.
- Several institutions show a lack in strategic long-term planning. The panels recommended for these institutions to implement a strategic planning procedure.

Stronger leadership installed at the department level can help to provide for clearer structures in the institutions and coordinated research strategies at a national level. Decisions for hiring new academic staff (especially on the professor level) should not be based on replacement of retiring persons or on teaching obligations but be a strategic decision for the re-alignment of the research direction. Teaching obligations can also be tackled by improving cooperation between institutions.

- Recruitment of academic staff has been mentioned as bottleneck by several institutions. The institutions/departments are encouraged to organize research education in a more structured way, e.g. by developing doctoral schools. Further an improvement of the gender balance is recommended.
- The role of SINTEF and its collaboration with NTNU is a result of the historical development. Time has come to investigate in clear and transparent structures and novel modes of operation.

5.3. General recommendations for future evaluations

- In general, it should be tried to include all research groups and institutions in future evaluations for getting comprehensive data and impressions. The non-participating groups should be encouraged, possibly required, to take part in the upcoming evaluations. Consider, whether a mandatory participation in such an evaluation for groups that receive substantial funding (e.g. above a certain amount of NOK) from the Norwegian Research Council is reasonable.
- A common way of judging publication/citation performance would be beneficial in the assessment and avoid ambiguity. It is suggested to either agree on one of the international standards (e.g. h-indexing), or to use the established Norwegian point system and explain it to the panelists.
- The extracted parameters of the publications in the self-assessments should use the same criteria as the bibliometric data/analysis and their definite use should be enforced.

6. Mandate for the review

6.1. 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 an 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 centres (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

- Does 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

6.2. 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:	**Relevance and impact:**
5 – excellent	**A – very high relevance and impact**
4 - very good	**B – high relevance and impact**
3 – good	**C– good relevance and impact**
2 – fair	**D – low relevance and impact**
1 – weak	**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 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:

- Does 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.

7. 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 Environ-mental 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	

8. Members of the principal evaluation committee

Professor Wolfgang Rauch (Panel 3)

Wolfgang Rauch studied Civil Engineering at the Technical University of Graz, Austria and at ETH, the Swiss Federal Institute of Technology, where he also graduated in 1985. In 1991 he achieved his PhD at the Institute of Environmental Engineering, University Innsbruck. Until 2002 he had positions at the University Innsbruck, the Technical University of Denmark and at EAWAG, Swiss Federal Institute for Environmental Science and Technology. In 1997 he obtained an advanced degree (Habilitation) in environmental engineering from the University Innsbruck. In 2002 he has been appointed full professor for sanitary engineering at the University Innsbruck. Since 2005 he is head of the Institute of Infrastructure Engineering.

Wolfgang Rauch has published app. 100 papers in peer-reviewed journals, among others in Science (345/6198). He holds an h-factor of 22 (SCI). He is well known in the international community due to his activity in international organisations. Among others he served as a member of the IWA task group on river water quality modelling and chaired the Joint Committee of IAHR and IWA on Urban Drainage in the period 2002 to 2005. Since 2013 he is the Chair of the IWA Program Committee. He serves as editor of one of the most important journals in the field that is *Water Research* and additionally as Editor in Chief for the journal *Water Science and Technology.*

Professor Derek Fray (Panel 1)

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.

Dr. Ralf Preu (Panel 2)

Ralf Preu is director of division “PV Production Technology and Quality Assurance“ at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, the largest European research institution in this field with more than 1200 employees. He obtained a diploma in physics in 1996 from the University of Freiburg, Germany. He also holds a degree in econophysics and a PhD in electric engineering from University of Hagen, Germany. His field of research includes innovative approaches and technologies for the fabrication of crystalline silicon solar cells. Dr. Preu joined Fraunhofer ISE in 1993 and has worked in various fields of photovoltaics, such as system monitoring, cell and module technology, characterization and simulation. In 2002, he became head of the group solar cell fabrication technology and since 2007 he is head of the division “PV Production Technology and Quality Assurance”. From 2004 to 2006, Dr. Preu was managing director of the Fraunhofer ISE Spin-Off company PSE mbH. He is author and co-author of more than 200 scientific publications, member of several scientific committees in his field and holds more than 15 patents. He and his team were repeatedly awarded internationally reknown prizes for his contributions to the PV community, including the Innovation Award Laser Technology 2014 for the successful industrial transfer of a laser based contacting process to increase the efficiency of solar cells. Since 2009 Dr. Preu holds lectures on Photovoltaic Technology at the University of Freiburg, with the Renewable Energy Management Master Program.

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