The Research Council of Norway

Basic and long-term research within Engineering Science in Norway

Bibliometric analysis

Evaluation
Division for Science

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NIFU

Nordic Institute for Studies in
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Evaluation of Engineering Science – Publication and Citation Analysis

National Indicators and International Comparisons

Institutional Analyses

Dag W. Aksnes

March 2015

Preface

This report presents a bibliometric analysis of research in engineering science and is a background report of the evaluation of the discipline. The report is written on the commission of the Research Council of Norway by Research Professor Dag W. Aksnes (project leader) at the Nordic Institute for Studies in Innovation, Research and Education (NIFU).

Oslo, 03.03.15

Sveinung Skule	Susanne L. Sundnes
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Contents

Summary

There has been a strong growth in the publication output within Engineering science the recent years. During the period covered by the evaluation (2009-2013), the number of journal articles has increase by 49 %, which is significantly higher than the Norwegian total, all fields (26 %).

In a global context, Norway is a very small country science-wise. In Engineering science, the Norwegian publication output amounts to 0.56 % of the world production of scientific publications in 2013. In comparison, Norway has an overall publication share of 0.62 % (national total, all fields).

In terms of citation rate, Norway ranks as number 11 among 20 countries analysed, with a citation index of 117 (2009-2012). This means that the publications are cited 17 % above the world average, but the performance of Norwegian Engineering science is somewhat below that of the leading countries. However, there are large differences between the various Engineering subfields. The publications in some of the fields (Construction & building technology and Petroleum engineering) are particularly highly cited.

There is extensive international research collaboration. In Engineering science, 56 % of the journal articles had co-authors from other countries in 2013. In other words, more than one out of two publications was internationally co-authored. This is slightly below the national average (60 %). The USA is the most important collaboration partner, and 10 % of the Norwegian articles within Engineering science also had co-authors from this nation.

The Norwegian University of Science and Technology is by far the largest contributor to Norwegian Engineering science, followed by the University of Oslo, the SINTEF foundation and the University of Agder. Together the four institutions account for more than half of the national publication output in the field. The industry accounts for 9 % of the Norwegian scientific journal production in Engineering science.

The report also presents analyses of individual departments and research groups. We find large differences in terms of performance on the bibliometric indicators.

1 Introduction

This report presents the results of a bibliometric study of the institutions included in the evaluation of engineering science in Norway. Both the institution/department level and the research group level are analysed. In addition the report contains a macro analysis of Norwegian engineering research in an international comparison.

Publication and citation data have increasingly been applied as performance indicators in the context of science policy and research evaluation. The basis for the use of bibliometric indicators is that new knowledge – the principal objective of basic and applied research – is disseminated to the research community through publications. Publications can thereby be used as indirect measures of knowledge production. Data on how much the publications have been referred to or cited in the subsequent scientific literature can in turn be regarded as an indirect measure of the scientific impact of the research.

The report is structured as follows: The first chapter presents the data and the methodology applied in the study. The second chapter gives an overview of Norwegian engineering research in an international context. Next follows separate chapters on each of the departments and institutes included in the evaluation. A final appendix chapter provides a general introduction to bibliometric indicators, particularly focusing on analyses based on Thomson Reuters data.

2 Data and methods

2.1 Data sources

The study is based on two main data sources. One source is Thomson Reuters (formerly known as Institute for Scientific Information (ISI)), the producer of the most important database for bibliometric purposes. Another is the publically accessible database CRIStin, which is a joint system for registration of scientific publications applied by Norwegian higher education institutions and research institutes.

2.2 Included departments and researchers

The analysis covers research units within the following institutions, departments and institutes:

Universities and university colleges:

Gjøvik University College

- Faculty of Technology, Economy and Management

Norwegian University of Life Sciences

- Department of Mathematical Sciences and Technology

Norwegian University of Science and Technology (NTNU)

- Department of Engineering Design and Materials
- Department of Civil and Transport Engineering
- Department of Electric Power Engineering
- Department of Energy and Process Engineering
- Department of Hydraulic and Environmental Engineering
- Department of Marine Technology
- Department of Material Science and Engineering
- Department of Petroleum Technology and Applied Geophysics
- Department of Product Design
- Department of Production and Quality Engineering
- Department of Structural Engineering

Telemark University College

- Faculty of Technology

University of Agder

- Department of Engineering Sciences

University of Bergen

- Department of Physics and Technology

University of Stavanger

- Department of Mechanical and Structural Engineering and Materials Science
- Department of Petroleum Engineering

University of Tromsø

- The Department of Engineering and Safety

Østfold University College

- Faculty of Engineering

Research institutes (institute sector):

- Institute for Energy Technology (IFE)
- IRIS Energy
- MARINTEK
- Norwegian Geotechnical Institute (NGI)
- SINTEF Building and Infrastructure
- SINTEF Energy Research
- SINTEF Fisheries and Aquaculture
- SINTEF Materials and Chemistry

The general chapter on Norwegian engineering science (Chapter 3) is, however, not limited to these units. Here, all Norwegian publishing in journals within engineering science is included.

The analysis of the departments and institutes (Chapter 4) is limited to the personnel selected for the evaluation. In other words, we do not present analyses of the total publication output of the departments. Only people listed by the units in their self-assessments have been included in the analysis (i.e. researchers submitting CVs). We have assumed that the relevant or core personnel at the units have been listed and that the approach would give an adequate picture of the research output of the selected research groups. Even though the list of personnel may not be complete for all units, junior personnel will often co-author with senior/tenured staff at the departments. Therefore, research papers of missing junior staff may appear on the publication lists anyway.

2.3 Methods

The analysis covers the five-year period 2009-2013. The general chapter on Norwegian engineering science (Chapter 3), also includes some publication indicators for the entire 2004-2013 period. From the Research Council of Norway we obtained information on the institutions, departments and persons encompassed by the evaluation, including the distribution of personnel on research groups. The analysis of the departments and research groups is based on the following two basic criteria:

- Only publications where the department/institute is listed as an author address are included in the analysis (i.e. publications that have contributed to publication points for the department/institute).
- Only publications by people listed by the units in their self-assessments have been included in the analysis (i.e. researchers submitting CVs).

Both criteria have to be met. This means that the analysis will not include publications published by a person before he/she became affiliated with their present place of employment. There is a delay from the research is carried out to the appearance of the publication. For the newly appointed personnel this means that none or very few of their publications will be included. The basic justification underlying this methodology is that the evaluation has its focus on the institution and research group level, and is not an evaluation of individual persons. In addition, the evaluation does not encompass personnel not working at the units anymore. Therefore, it is important to emphasise that the publication output of a department or group sometimes may be substantially higher than what is reflected in our figures.

In a similar way, publications of listed part-time personnel such as Adjunct Professors (Professor IIs) are only included when the part time affiliated departments have been listed as (one of the) author addresses. This means that usually only part of their research output is included.

We have used the lists of institutions and persons as a basis for publication searches. The analyses in Chapter 4 are primarily based on the publications registered in the publically accessible databases CRIStin, and not on the publication lists compiled for the evaluation. CRIStin is a registration system for scientific publications employed by Norwegian universities and other higher education institutions, as well as units in the institute sector. The CRIStin publication data (scientific publications) are summarised in the Norwegian DBH database and are used for the calculation of the performance based budgeting of Norwegian higher education institutions. Publication data for the higher education institutions are available in CRIStin for the entire period analysed (2009-13), while data for units in the institute sector are available for the 2011 to 2013 period only. Here, we for 2009 and 2010 have used data from NIFUs Key figure database, also including data on scientific publications (Nøkkeltalldatabasen).

We have only included contributions published in publication channels qualifying as scientific in the performance based budgeting system. The following publication types are qualified: full-papers (regular articles, proceedings articles) and review articles published in journals or books (i.e. not short contributions like letters, editorials, corrections, book-reviews, meeting abstracts, etc.) and books/monographs.

A database which NIFU has purchased from Thomson Reuters is applied in the study. This is the *National Citation Report* (NCR) for Norway, containing bibliographic information for all Norwegian articles (articles with at least one Norwegian author address). Data for each paper include all author names, all addresses, article title, journal title, document type (article, review, editorial, etc.), field category, year by year and total citation counts and expected citation rates (based on the journal title, publication year and document type). The 2013 edition of NCR, with data covering 1981-2013 was used. The NCR database is a subset of the more well-known database *Web of Science*, based on the three citation indexes: Science Citation Expanded; Social Sciences Citation Index; and Arts & Humanities Citation Index. However, the NCR does not include two additional citation indexes of *Web of Science*: The Conference Proceedings Citation Index, and The Book citation index.

The calculation of citation indicators has been based on aggregated bibliometric statistics at country and field/subfield level, which NIFU purchased from CWTS at Leiden University, the Netherlands. These data were applied for the purpose of creating reference standards (see below) and for the general analyses in Chapter 3.

The individual researcher represents the basic unit in the study, and the data were subsequently aggregated to the level of departments/units. We have used the group/section structure described in the factual information reports the departments have submitted to the Research Council of Norway. Here the departments have listed the persons who are included in the evaluation and their group/section affiliations. In other words, we have applied a personnel based definition where a department or group is delimited according to the scientific staff included in the evaluation. It should be noted that some of the "groups" represent more informal structures whereas other "groups" correspond to formal subdivisions within the departments. As described above, we have included all publications of the individuals examined, but not work carried out before they became affiliated at the respective departments.

Some publications were multiple reported. The reason is that when a publication is written by several authors it will appear on the publication lists of all the authors, and will accordingly occur more than one time. In order to handle this problem we removed all the multiple reported items in the analysis of departments and groups, i.e. only unique publications were left.

2.3.1 Publication output

Scientific productivity can in principle be measured relatively easy by the quantification of published material. In practice it is more difficult, since a number of issues have to be faced. In particular the choice and weighting of publication types and the attribution of author credit are important questions to consider. Many publications are multi-authored, and are the results of collaborative efforts involving more than one researcher or institution. There are different principles and counting methods that are being applied in bibliometric studies. The most common is "whole" counting, i.e. with no fractional attribution of credit (everyone gets full credit). A second alternative is "adjusted counting" where the credit is divided equally between all the authors (Seglen, 2001). For example, if an article has five authors and two of them represent the department being analysed, the department is credited 2/5 article (0.4). One can argue that these counting methods are complementary: The whole or integer count gives the number of papers in which the unit "participated". A fractional count gives the number of papers "creditable" to the unit, assuming that all authors made equal contributions to a co-authored paper, and that all contributions add up to one (Moed, 2005). As described above, in this study, possible double occurrences of articles have been excluded within each unit. This means that papers co-authored by several researchers belonging to the same department or group are counted only once. We have used the "whole" counting method.

We have not calculated productivity indicators, i.e. number of publications per researcher. This is due to the fact that we have not available systematic data on the length of each person's affiliations with their present place of employment. As the newly appointed personnel will have none or very few of their publications included, it would be unfair to include them in a productivity analysis. Nevertheless, the ratio between the number of persons included and the number of publications at least give a rough indication of the productivity level, i.e. a high scientific publication productivity or a low.

2.3.2 Citation indicators

Only publications published in journals indexed in the Thomson Reuters database NCR are included in the analysis. The engineering field is moderately well covered in this database. This is due to the particular publication pattern of engineering research where proceedings papers play an important role, a significant part of this output will not be covered by the database.

The individual articles and their citation counts represent the basis for the citation indicators. In the citation indicators we have used accumulated citation counts and calculated an overall (total) indicator for the whole period. This means that for the articles published in 2009, citations are counted over a 5-year period, while for the articles published in 2011, citations are counted over a 3-year period (or more precisely a 2-3 year period: the year of publication, 2012 and 2013). Citations the publications have received in 2014 are not included in the citation counts. The citation counts used in the study are calculated by CWTS using a particular algorithm, and the citation counts may differ from the one found in the *Web of*

Science database. Articles from 2013 are not included in the citation analysis as these have not been available in the literature for a sufficiently long time to be cited. To a certain extent this also holds for the 2012 articles. We have, however, included these articles, but it is 'expected' that these articles are uncited or very poorly cited.

The problem of crediting citation counts to multi-authored publications is identical to the one arising in respect to publication counts. In this study the research groups and departments have received full credit of the citations – even when for example only one of several authors represents the respective research groups or department. This is also the most common principle applied in international bibliometric analyses. There are however arguments for both methods. A researcher will for example consider a publication as "his/her own" even when it has many authors. In respect to measuring contribution, on the other hand, (and not participation) it may be more reasonable to fractionalise the citations, particularly when dealing with publications with a very large number of authors.

The average citation rate varies a lot between the different scientific disciplines. As a response, various reference standards and normalisation procedures have been developed. The most common is the average citation rates of the journal or field in which the particular papers have been published. An indicator based on the journal as a reference standard is the Relative citation index – journal (also called the Relative Citation Rate). Here the citation count of each paper is matched to the mean citation rate per publication of the particular journals (Schubert & Braun, 1986). This means that the journals are considered as the fundamental unit of assessment. If two papers published in the same journal receive a different number of citations, it is assumed that this reflects differences in their inherent impact (Schubert & Braun, 1993). Below the indicators are further described.

<u>Relative citation index – journal</u>

For the Relative citation index – journal we used the mean citation rate of the department's journal package, calculated as the average citation rate of the journals in which the group/department has published, taken into account both the type of paper and year of publication (using the citation window from year of publication through 2013). For example, for a review article published in a particular journal in 2010 we identified the average citation rates (2010–2013) to all the review articles published by this journal in 2010. For each department we calculated the mean citation rate of its journal package, with the weights being determined by the number of papers published in each journal/year. The indicator was subsequently calculated as the ratio between the average citation rate of the department's articles and the average citation rate of its journal package. For example, an index value of 110 would mean that the department's articles are cited 10 % more frequently than "expected" for articles published in the particular journal package.

Relative citation index – field

A similar method of calculation was adopted for the Relative citation index – field (also termed the Relative Subfield Citedness (cf. Vinkler, 1986, 1997)). Here, as a reference value we used the mean citation rate of the subfields in which the department has published. This reference value was calculated using the bibliometric data from the NSI-database. Using this database it is possible to construct a rather fine-tuned set of subfield citation indicators. The departments are usually active in more than one subfield (i.e. the journals they publish in are assigned to different subfields). For each department we therefore calculated weighted averages with the weights being determined by the total number of papers published in each subfield/year. In Thomson Reuter's classification system some journals are assigned to more than one subfield. In order to handle this problem we used the average citation rates of the respective subfields as basis for the calculations for the multiple assigned journals. The indicator was subsequently calculated as the ratio between the average citation rate of the department's articles and the average subfield citation rate. In this way, the indicator shows whether the department's articles are cited below or above the world average of the subfield(s) in which the department is active.

Example

The following example can illustrate the principle for calculating relative citation indexes: A scientist has published a regular journal article in *Energy & Fuels* in 2010. This article has been cited 12 times. The articles published in *Energy & Fuels* were in contrast cited 9.9 times on average this year. The Relative citation index – journal is: (12/9.9)*100 = 121. The world-average citation rate for the subfield which this journal is assigned to is 8.8 for articles published this year. In other words, the article obtains a higher score compared to the field average. The Relative citation index – field is: (12/8.8)*100 = 136. The example is based on a single publication. The principle is, however, identical when considering several publications. In these cases, the average of all publications included is used as indicator.

It is important to notice the differences between the field and journal adjusted relative citation index. A department may have a publication profile where the majority of the articles are published in journals being poorly cited within their fields (i.e. have low impact factors). This implies that the department obtains a much higher score on the journal adjusted index than the field adjusted index. The most adequate measure of the research performance is often considered to be the indicator in which citedness is compared to field average. This citation index is sometimes considered as a bibliometric "crown indicator" (van Raan, 2000). In the interpretation of the results this indicator should accordingly be given the most weight.

The following guide can be used when interpreting the *Relative citation index – field*:

Citation index: > 150: Very high citation level.

Citation index: 120-150: High citation level, significant above the world average.

Citation index: 80-120: Average citation level. On a level with the international average of the field (= 100).

Citation index: 50-80: Low citation level.

Citation index: < 50: Very low citation level.

It should be emphasised that the indicators cannot replace an assessment carried out by peers. In the cases where a research group or department is poorly cited, one has to consider the possibility that the citation indicators in this case do not give a representative picture of the research performance. Moreover, the unit may have good and weak years. In engineering science the citation rates are generally low compared to for example biomedicine. This weakens the validity of citations rates as performance measure in engineering science. Citations have highest validity in respect to high index values. But similar precautions should be taken also here. For example, in some cases one highly cited researcher or one highly cited publication may strongly improve the citation record of a group or even a department. We have only calculated citation indexes for the research groups that have published at least 10 papers during the time period analysed.

As described in Chapter 5, citations mainly reflect intra-scientific use. In a field like engineering science with strong technological and applied aspects it is important to be aware of this limitation. Practical applications and use of research results will not necessarily be reflected through citation counts. Moreover, as described above, the engineering field is only moderately well covered by the database applied for constructing citation indicators, and the indicators are based on a limited part of the research output (although the most important). During the work with the report, it has become apparent that several departments/groups only have a small proportion of their journal publications indexed in the database. This is important to consider when interpreting the results, and one should be careful with putting too much emphasis on the citation indicators.

Other databases exist which cover the engineering field better. These databases are however not as well adapted for bibliometric-analyses as the NCR-database, and has not been available to us. Moreover, citations counts can be retried from Google Scholar which has a much broader coverage of the research literature. Accordingly, the citation counts would have been much higher if this database had been used. Unfortunately, the data quality is not very good, and it is difficult to distinguish between researchers sharing the same name. Therefore, this database has not been applied in the report.

2.2.3 Journal profiles

We also calculated the journal profile of the departments. As basis for one of the analyses we used the so called "impact factor" of the journals. The journal impact factor is probably the most widely used and well-known bibliometric product. It was originally introduced by Eugene Garfield as a measure of the frequency with which the average article in a journal has been cited. In turn, the impact factor is often considered as an indicator of the significance and prestige of a journal.

The Journal profile of the departments was calculated by dividing the average citation rate of the journals in which the department’s articles were published by the average citation rates of the subfields covered by these journals. Thus, if this indicator exceeds 100 one can conclude that the department publishes in journals with a relatively high impact.

3 Norwegian engineering science in an international context

This chapter presents various bibliometric indicators on the performance of Norwegian research within engineering science. The chapter is based on *all* publications within the field *Engineering science*, not only the articles published by the persons encompassed by the evaluation.[1] Moreover, as described in the Method section, only articles published in *journals* are included in the analysis in this chapter. The analysis is mainly based on *Web of Science* data (cf. Method section), where Engineering science is a separate category and where there also are categories for particular subfields within Engineering science. In the analysis we have both analysed Engineering science as a collective discipline and subfields. In the database, Engineering science is defined slightly more broadly than in the evaluation, and encompasses a few additional research fields not covered by the evaluation. When analysing subfields we have accordingly omitted some subfields of less relevance for this particular evaluation.

3.1 Scientific publishing

The Norwegian University of Science and Technology is the major contributor and accounts for almost one third (32%) of the Norwegian scientific journal publishing within Engineering Science. This can be seen from Table 3.1, where the article production during the two-year period 2012–13 has been distributed according to institutions/sectors. The basis for this analysis is the information available in the address field of the articles. While the University of Oslo by far is the largest university in Norway, this does not hold for Engineering science. Here, this university ranks as the second largest institution in terms of publication output (9 % of the national total). The University of Agder ranks as the third largest university with a proportion of 6 %, followed by the University of Bergen (5 %). In the Institute sector (private and public research institutes), institutes within the SINTEF-foundation are the largest single contributor with 6 % of the national total. It should be noted that the incidence of journal publishing in this sector is generally lower than for the universities due to the particular research profile of these units (e.g. contract research published as reports). The industry accounts for 9 % of the Norwegian scientific journal production in Engineering science. Similar to the Institute sector, only a very limited part of the research carried out by the industry is generally published. This is due to the commercial interests related to the research results, which means that the results often cannot be published/made public.

[1] Therefore, the figures do not correspond with the one presented in Chapter 4. In this chapter, all publications in journals classified within Engineering science have been included. In the next chapter, only publications by persons encompassed by the evaluation are included, but publications published in journals outside the Engineering science field are also counted.

Table 3.1 The Norwegian profile of scientific publishing in Engineering science. Proportion of the article production 2012-2013 by institutions*/sectors.

	Number of articles	Proportion
Norwegian University of Science and Technology	890	32 %
University of Oslo	254	9 %
University of Agder	158	6 %
University of Bergen	139	5 %
University of Stavanger	102	4 %
Norwegian University of Life Sciences	57	2 %
Vestfold University College	40	1 %
Higher education sector - other units	210	7 %
SINTEF Foundation**	172	6 %
SINTEF Energy Research	95	3 %
Institute for Energy Technology	43	2 %
Institute sector other units	325	12 %
Industry	261	9 %
Other units	74	3 %

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Only institutions/institutes with more than 40 publications within the Engineering sciences category during the time period are shown separately in the table.

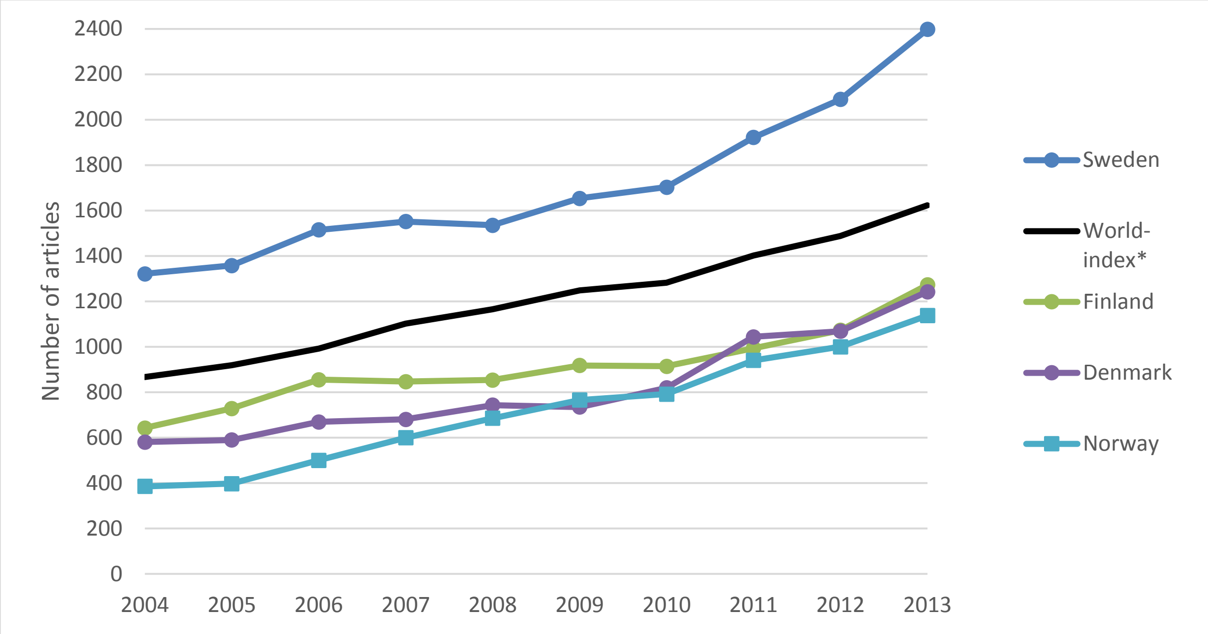
**) The SINTEF foundation consists of the following institutes: SINTEF Building and Infrastructure, SINTEF ICT, SINTEF Materials and Chemistry, SINTEF Technology and Society

In Figure 3.1 we have shown the development in the annual production of articles in Engineering science for Norway and three other Nordic countries for the period 2004–2013. Among these countries, Norway is the smallest nation in terms of publication output with approximately 1100 articles in 2013. Sweden is the largest country and has more than twice as many articles as Norway (2400 articles).

As described in Chapter 2 many publications are multi-authored, and are the results of collaborative efforts involving researchers from more than one country. In the figure we have used the “whole” counting method, i.e. a country is credited an article if it has at least one author address from the respective country.

The article production of all countries has increased significantly during the period. This probably reflects increasing resources for engineering research but also the fact that the publication database in terms of coverage has increased during the period. We have included a line for the world total for Engineering science in the figure, and the world production has increased by 87 % during the 10-year period. The corresponding figure for Sweden is 81 %, for Finland 98 %, for Denmark 114%, and for Norway 195 %. Thus, Norway has a much stronger relative growth than the other countries, but still ranks as the smallest nation in terms of research output.

Figure 3.1 Scientific publishing in Engineering science 2004-2013 in four Nordic countries. Number of articles.

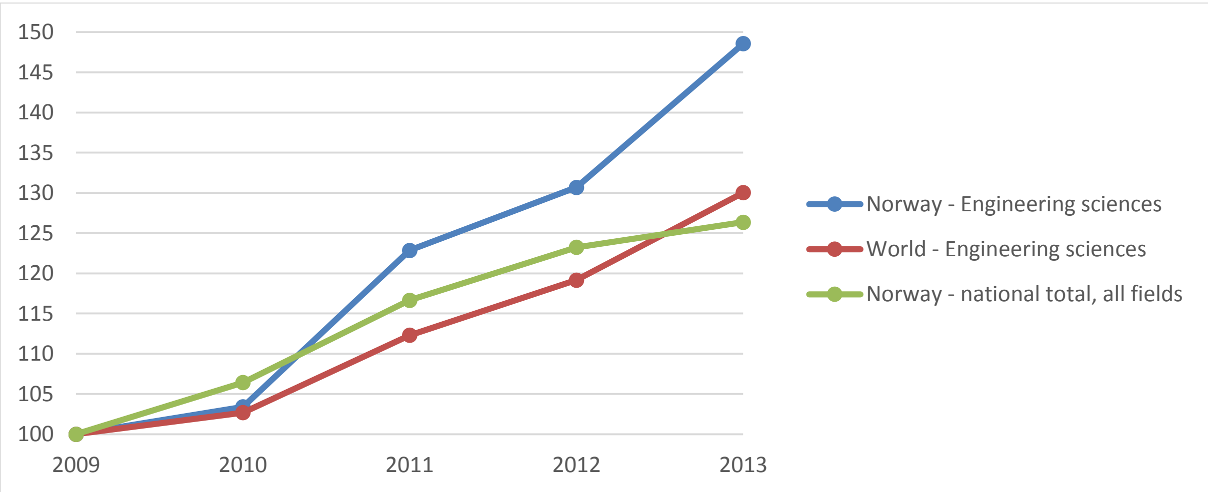


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

*) The "world index" is a reference line, calculated as the world production of articles in Engineering science divided by 100.

Figure 3.2 shows the relative growth for the period covered by the evaluation, 2009-13. During this period, the publication number of Norwegian Engineering science has increase by 49 %. This is higher than the world total in Engineering Science (30 %) and higher than the Norwegian total, all fields (26 %). In other words, Norwegian Engineering science stands out with a strong growth in the research volume reflected trough publications.

Figure 3.2 Scientific publishing in Engineering science and Norwegian total 2009-2013. Relative growth, 2009 =100.

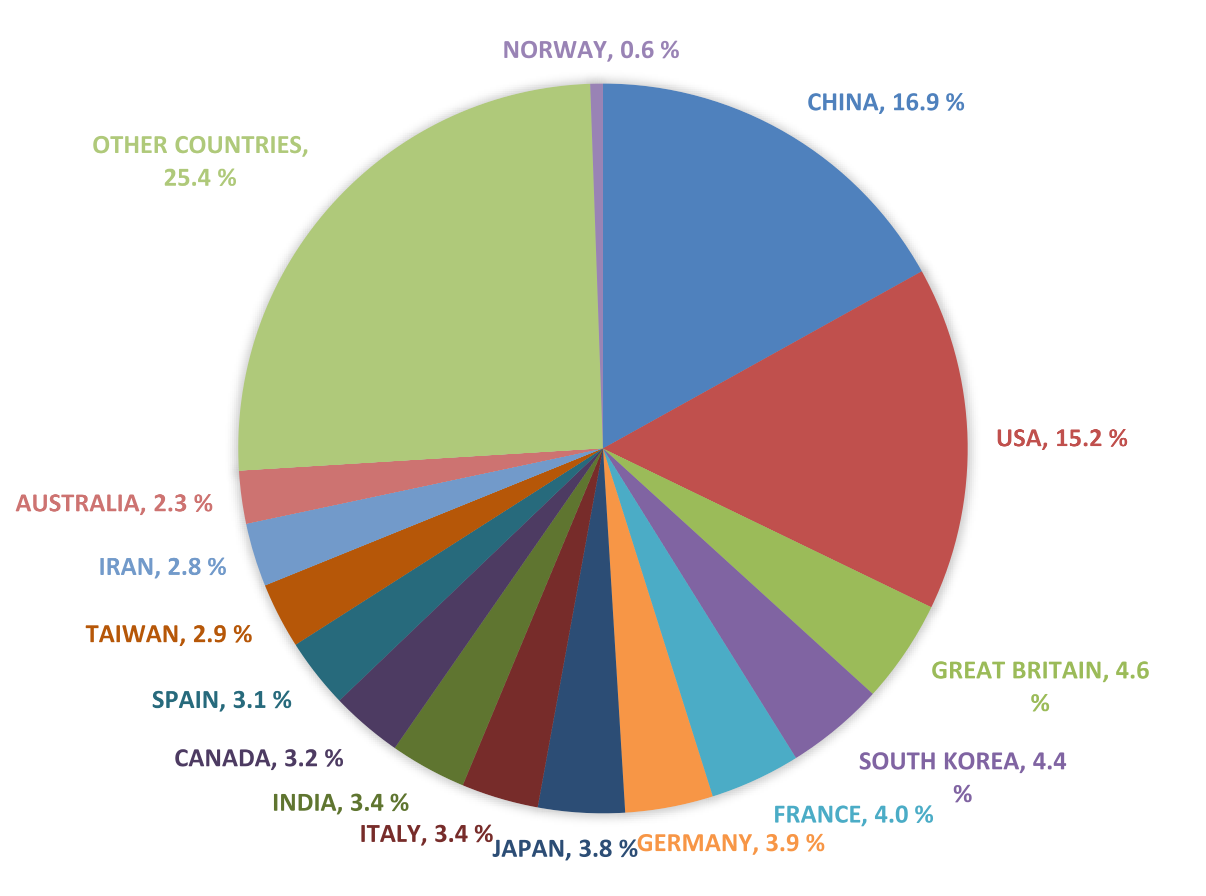


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

In a global context, Norway is a very small country science-wise. In Engineering science, the Norwegian publication output amounts to 0.56 % of the world production of scientific publications in 2013 (measured as the sum of all countries' publication output). In comparison, Norway has an overall publication share of 0.62 % (national total, all fields). This means that Norway contributes slightly less to the global scientific output in Engineering science than in other fields.

Figure 3.3 shows the contribution of individual countries to the global research output in Engineering science. China is the largest research nation with 16.9 % of the world production slightly above USA with 15.2 %

Figure 3.3 Scientific publishing in 2013 in selected countries, Proportion of world production in Engineering science.

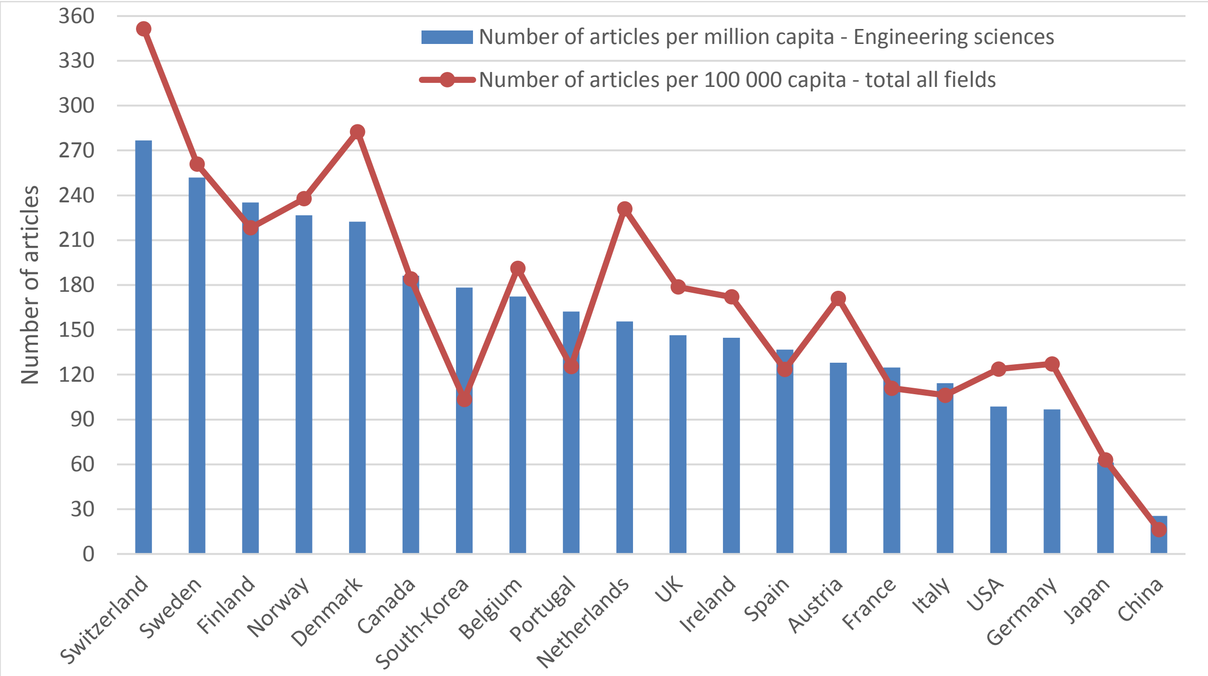


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

There are no international data available that makes it possible to compare the output in terms of publications to the input in terms of number of researchers. Instead, the publication output is usually compared with the size of the population of the different countries – although differences in population do not necessarily reflect differences in research efforts. Measured as number of articles per million capita, Norwegian scientists published almost 230 articles in Engineering science in 2013. In Figure 3.4 we have shown the corresponding publication output for a selection of other countries (blue bars). Here Norway ranks as number four, and has a larger relative publication output than the majority of other countries. Switzerland has the highest number with almost 280 articles, and Sweden ranks as number two with 250 articles per million capita.

In Figure 3.4 we have also shown the production (per 100,000 capita) for all disciplines (national totals) (red line). This can be used as an indication of whether Engineering science has a higher or lower relative position in the science system of the countries than the average. For example, for South-Korea, Engineering science clearly ranks above the national average, while the opposite is the case for Denmark.

Figure 3.4 Scientific publishing per capita in 2013 in selected countries, Engineering sciences and all disciplines.



Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

In order to provide further insight into the profile of Norwegian Engineering science we have analysed the distribution of the articles at subfield levels. This is based on the classification system of Thomson Reuters where the journals have been assigned to different categories according to their content (journal-based research field delineation). Some journals are assigned to more than one category (double counts). Although such a classification method is not particularly accurate, it nevertheless provides a basis for profiling and comparing the publication output of countries at subfield levels.

Category descriptions – Engineering Sciences

Acoustics: Covers journals on the study of the generation, control, transmission, reception, and effects of sounds. Relevant subjects include linear and nonlinear acoustics; atmospheric sound; underwater sound; the effects of mechanical vibrations; architectural acoustics; audio engineering; audiology; and ultrasound applications

Automation & Control Systems: Covers journals on the design and development of processes and systems that minimize the necessity of human intervention. Journals in this category cover control theory, control engineering, and laboratory and manufacturing automation.

Construction & Building Technology: Includes journals that provide information on the physical features and design of structures (e.g., buildings, dams, bridges, tunnels) and the materials used to construct them (concrete, cement, steel). Other topics covered in this category include heating and air conditioning, energy systems, and indoor air quality.

Energy & Fuels: Covers journals on the development, production, use, application, conversion, and management of nonrenewable (combustible) fuels (such as wood, coal, petroleum, and gas) and renewable energy sources (solar, wind, biomass, geothermal, hydroelectric). Note: Journals dealing with nuclear energy and nuclear technology do not appear in this category.

Engineering, Chemical: Covers journals that discuss the chemical conversion of raw materials into a variety of products. This category includes journals that deal with the design and operation of efficient and cost-effective plants and equipment for the production of the various end products.

Engineering, Civil: Includes journals on the planning, design, construction, and maintenance of fixed structures and ground facilities for industry, occupancy, transportation, use and control of water, and harbor facilities. Journals also may cover the sub-fields of structural engineering, geotechnics, earthquake engineering, ocean engineering, water journals and supply, marine engineering, transportation engineering, and municipal engineering.

Engineering, Electrical & Electronic: Covers journals that deal with the applications of electricity, generally those involving current flows through conductors, as in motors and generators. This category also includes journals that cover the conduction of electricity through gases or a vacuum as well as through semiconducting and superconducting materials. Other relevant topics in this category include image and signal processing, electromagnetics, electronic components and materials, microwave technology, and microelectronics.

Engineering, Environmental: Includes journals that discuss the effects of human beings on the environment and the development of controls to minimize environmental degradation. Relevant topics in this category include water and air pollution control, hazardous waste management, land reclamation, pollution prevention, bioremediation, incineration, management of sludge problems, landfill and waste repository design and construction, facility decommissioning, and environmental policy and compliance.

Engineering, Geological: Includes multidisciplinary journals that encompass the knowledge and experience drawn from both the geosciences and various engineering disciplines (primarily civil engineering). Journals in this category cover geotechnical engineering, geotechnics, geotechnology, soil dynamics, earthquake engineering, geotextiles and geomembranes, engineering geology, and rock mechanics.

Engineering, Industrial: Includes journals that focus on engineering systems that integrate people, materials, capital, and equipment to provide products and services. Relevant topics covered in the category include operations research, process engineering, productivity engineering, manufacturing, computer-integrated manufacturing (CIM), industrial economics, and design engineering.

Engineering, Marine: Includes journals that focus on the environmental and physical constraints an engineer must consider in the design, construction, navigation, and propulsion of ships and other sea vessels.

Category descriptions – Engineering Sciences

Engineering, Mechanical: Includes journals on the generation, transmission, and use of heat and mechanical power, as well as with the production and operation of tools, machinery, and their products. Topics in this category include heat transfer and thermodynamics, fatigue and fracture, wear, tribology, energy conversion, hydraulics, pneumatics, microelectronics, plasticity, strain analysis, and aerosol technology.

Engineering, Ocean: Includes journals concerned with the development of equipment and techniques that allow humans to operate successfully beneath and on the surface of the ocean in order to develop and utilize marine journals.

Engineering, Petroleum: Covers journals that report on a combination of engineering concepts, methods, and techniques on drilling and extracting hydrocarbons and other fluids from the earth (e.g., chemical flooding, thermal flooding, miscible displacement techniques, and horizontal drilling) and on the refining process. Relevant topics in this category include drilling engineering, production engineering, reservoir engineering, and formation evaluation, which infers reservoir properties through indirect measurements.

Instruments & Instrumentation: Includes journals on the application of instruments for observation, measurement, or control of physical and/or chemical systems. This category also includes materials on the development and manufacture of instruments

Mechanics: Includes journals that cover the study of the behavior of physical systems under the action of forces. Relevant topics in this category include fluid mechanics, solid mechanics, gas mechanics, mathematical modeling (chaos and fractals, finite element analysis), thermal engineering, fracture mechanics, heat and mass flow and transfer, phase equilibria studies, plasticity, adhesion, rheology, gravity effects, vibration effects, and wave motion analysis

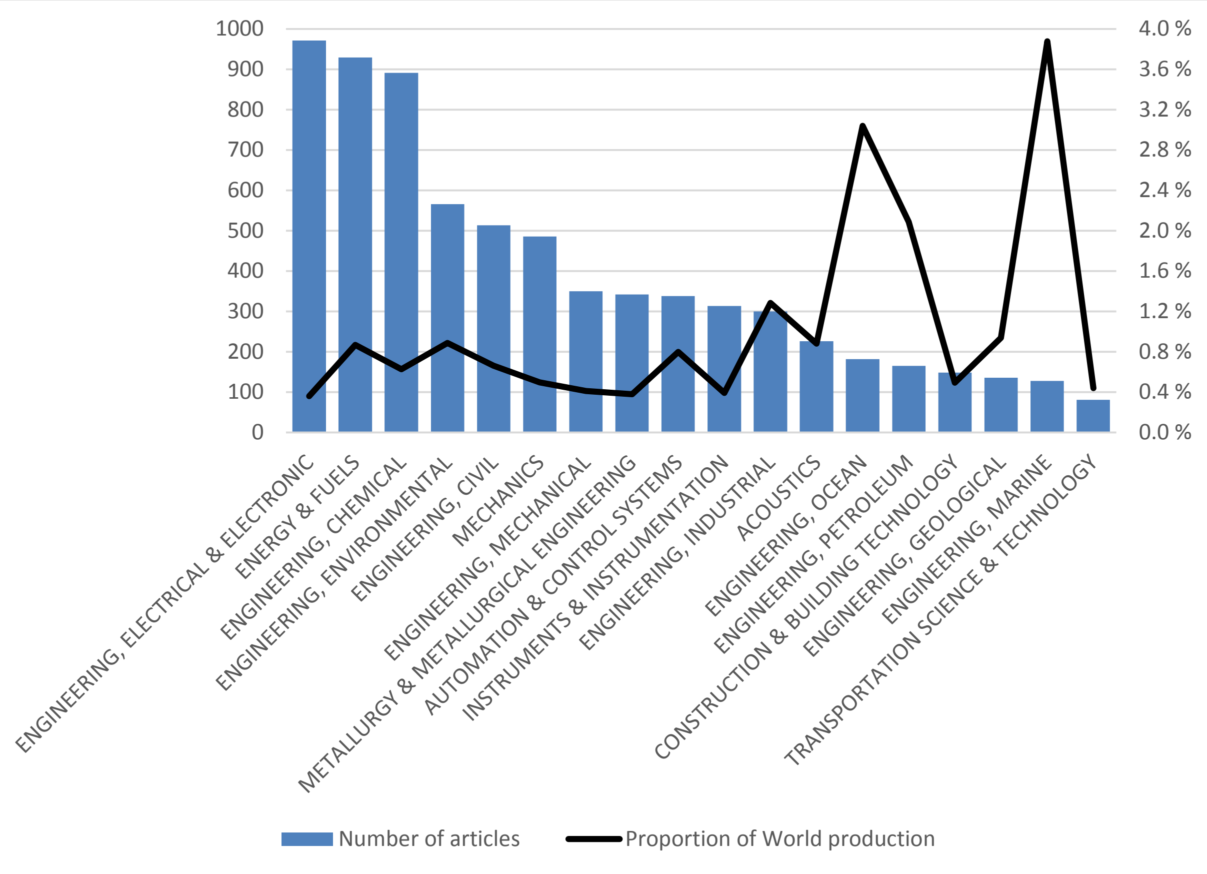
Metallurgy & Metallurgical Engineering: Includes journals that cover the numerous chemical and physical processes used to isolate a metallic element from its naturally occurring state, refine it, and convert it into a useful alloy or product. Topics in this category include corrosion prevention and control, hydrometallurgy, pyrometallurgy, electrometallurgy, phase equilibria, iron-making, steel-making, oxidation, plating and finishing, powder metallurgy, and welding.

Transportation Science & Technology: Covers journals on all aspects of the movement of goods and peoples as well as the design and maintenance of transportation systems. Topics covered in this category include logistics, vehicular design and technology, and transportation science and technology. Note: Journals that concentrate on transportation safety, policy, economics, and planning are not included in this category.

Figure 3.5 shows the distribution of articles for the 5-year period 2009–2013. We note that Electrical & electronic engineering is the largest category, and almost 1000 articles have been published within this field by Norwegian researchers during the period. Next follows Energy & fuels with 930 articles and Chemical engineering with approximately 900 articles.

The figure also shows the Norwegian share of the world production of articles (black line). As described above, the overall figure for Engineering science is 0.56 %. At subfield levels, this proportion varies significantly, from 0.36 % in Electrical & electronic engineering to 3.9 % in Marine engineering. The proportion is also very high in Ocean engineering and Petroleum engineering, 3.0 and 2.1 %, respectively.

Figure 3.5 Scientific publishing in Engineering subfields, Norway, total number of articles for the period 2009–2013 and proportion of the World production.

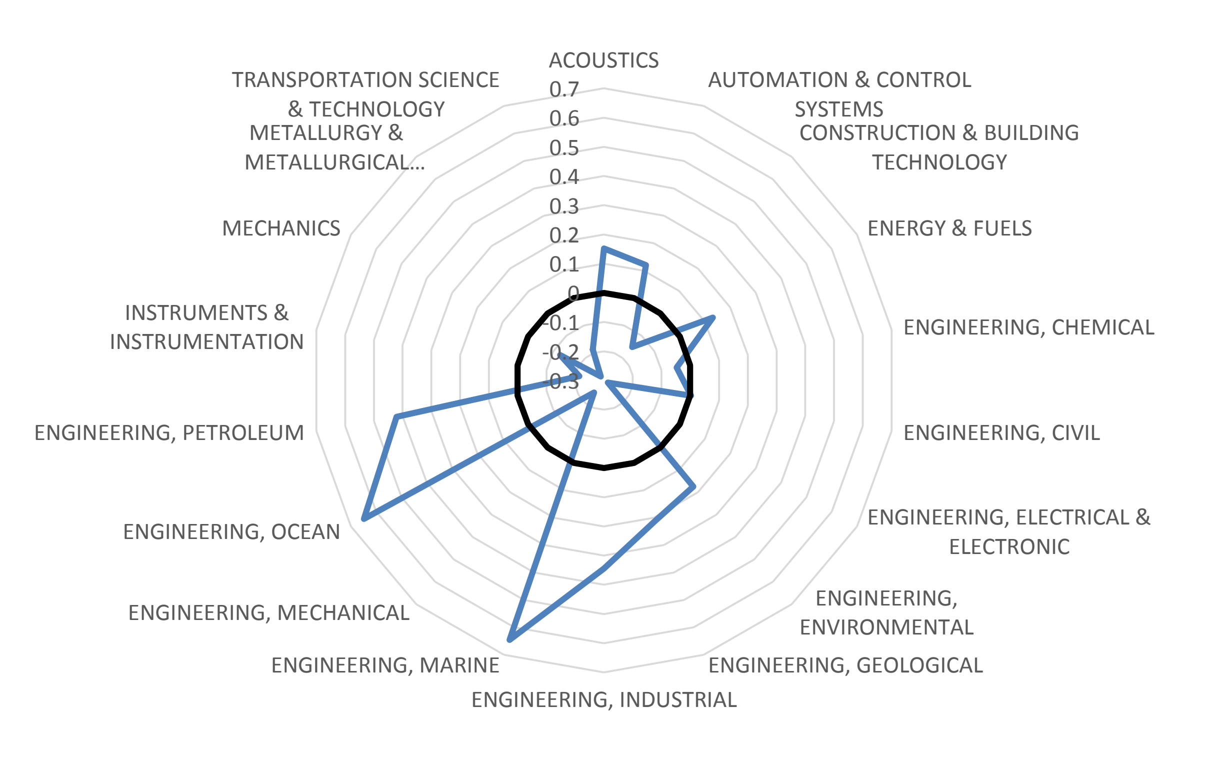


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

The particular distribution of articles by subfields can be considered as the specialisation profile of Norwegian Engineering science. In order to further assess its characteristics, we have compared the Norwegian profile with the global average distribution of articles. In figure 3.6 we have shown the so-called "relative specialization index", RSI.[2] As can be seen, Norway has a research profile deviating much from the average internationally (the black line in the figure). Noteworthy is a very strong specialisation in Marine engineering, Ocean engineering and Petroleum engineering (RSI = 0.65-0.42). We also find a positive specialisation towards Environmental engineering, Acoustics, Energy & fuels and Automation & Control systems (RSI = 0.18-0.12). On the other hand, Norway has little research output relatively speaking (a negative specialisation) within many fields, in particular Electrical & electronic engineering, Metallurgy and Metallurgical engineering and Mechanical engineering where the RSI is in the range -0.28-0.25.

[2] The relative specialization index (RSI) shows if a country has a higher or lower proportion of publications in a particular field compared to the average for all countries where RSI = 0. In other words it characterizes the internal balance between disciplines, but says nothing about production in absolute terms. If RSI> 0 indicates a relative positive specialization (in terms of scientific publications) in the field.

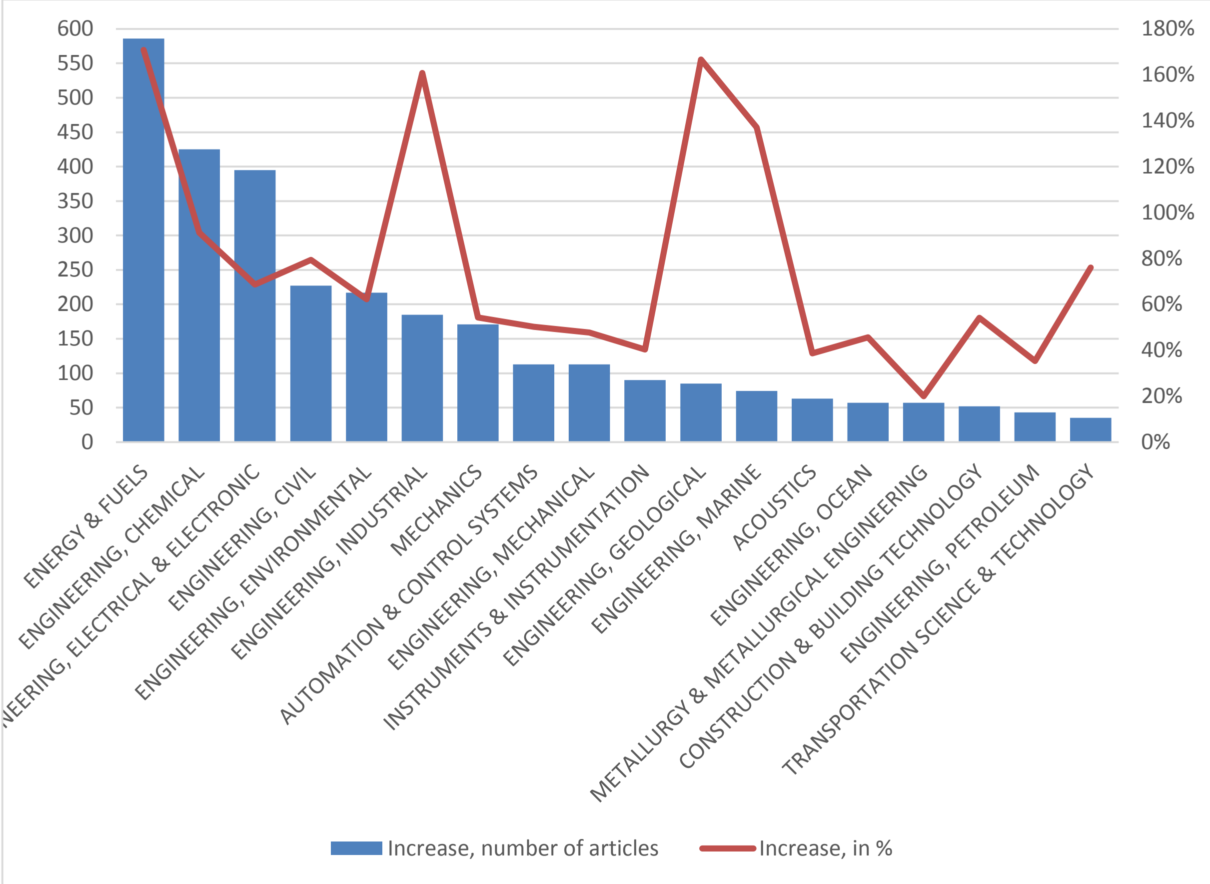
Figure 3.6 Relative specialisation index for Norway in Engineering sciences, 2009-2013.



Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

We have also analysed how the article volume per subfield has developed during the past 10 years. In the analysis, we have divided the period into two 5-year periods, 2004-2008 and 2009-2013. Figure 3.7 shows the increase in the article volume from the first to the second period, both in numbers and as relative increase. In absolute counts the increase is largest for the subfield Energy & fuels where the article volume has increased by almost 600 articles. There is also a significant increase for Chemical Engineering and Electrical & electronic engineering (approximately 400 articles). Measured in relative terms, Energy & fuels also shows the strongest increase (171 %) followed by Geological engineering (167 %) and Industrial engineering (161 %). Accordingly, the figures suggest that in particular the Norwegian research on energy and fuels has increased significantly during the period.

Figure 3.7 Scientific publishing in Engineering subfields, Norway. Increase in publications from 2004-2008 to 2009-2013. Numbers and relative increase in %.



Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

We have also identified the largest Norwegian contributors to the research output within the different engineering subfields. The results are shown in Table 3.2. We will not comment the figures for each subfield. We note that the Norwegian University of Science and Technology (NTNU) is the largest contributor in most, but not all of the fields. Among the exceptions, we find Petroleum engineering, where the industry sector accounts for the largest number of articles.

Table 3.2 The Norwegian profile of scientific publishing in Engineering science subfields. Number of articles and proportion of the article production 2012-2013 by institutions/institutes.*

Institution/Institute	No articles	Proportion*	Institution/Institute	No articles	Proportion*
ACOUSTICS			AUTOMATION & CONTROL SYSTEMS		
NTNU	50	31%	NTNU	59	32%
Hospitals	19	12%	UIA	33	18%
UIB	17	11%	Industry	19	10%
UIO	15	9%	UMB	15	8%
Industry	12	7%	NOFIMA	13	7%
CONSTRUCTION & BUILDING TECHNOL			HIT	12	6%
NTNU	46	51%	ENGINEERING, CIVIL		
SINTEF- foundation	25	28%	NTNU	124	41%
Industry	12	13%	UIO	44	14%
ENERGY & FUELS			Industry	29	10%
NTNU	228	35%	SINTEF- foundation	22	7%
Industry	70	11%	ENGINEERING, PETROLEUM		
SINTEF- foundation	56	9%	Industry	19	24%
ENERGISINT	50	8%	UIS	16	20%
UIO	40	6%	NTNU	15	19%
UIS	37	6%	IRIS	13	16%
UMB	26	4%	UIB	11	14%
UIB	25	4%	ENGINEERING, ELECTRICAL & ELECTRONIC		
IFE	21	3%	NTNU	163	28%
ENGINEERING, CHEMICAL			UIO	74	13%
NTNU	218	41%	Industry	49	8%
SINTEF- foundation	58	11%	UIA	43	7%
UIS	40	7%	UIB	37	6%
Industry	37	7%	ENERGISINT	26	4%
ENERGISINT	33	6%	SIMULA	25	4%
UIB	28	5%	SINTEF- foundation	22	4%
HIT	21	4%	HIVE	21	4%
UIO	20	4%	FFI	16	3%
TELTEK	17	3%	Hospitals	14	2%
ENGINEERING, ENVIRONMENTAL			UITO	12	2%
NTNU	100	28%	UNIK	12	2%
UIO	36	10%	INSTRUMENTS & INSTRUMENTATION		
NIVA	28	8%	UIO	35	17%
UMB	23	6%	UIB	33	16%
SINTEF- foundation	21	6%	NTNU	26	13%
NGI	19	5%	HIVE	17	8%
Industry	18	5%	NOFIMA	14	7%
NILU	11	3%	SINTEF- foundation	14	7%
			UMB	14	7%
			Industry	12	6%

Table 3.2 continued.

Institution/Institute	No articles	Proportion*	Institution/Institute	No articles	Proportion*
ENGINEERING, INDUSTRIAL			METALLURGY & METALLURGICAL ENGINE		
NTNU	47	32%	NTNU	112	54%
UIS	32	21%	SINTEF- foundation	61	29%
SINTEF- foundation	15	10%	IFE	17	8%
ENGINEERING, MARINE			ENGINEERING, OCEAN		
NTNU	45	64%	NTNU	64	52%
MECHANICS			Industry	13	10%
NTNU	139	48%	FFI	11	9%
SINTEF- foundation	27	9%	UIO	11	9%
Industry	23	8%	ENGINEERING, MECHANICAL		
UIO	19	7%	NTNU	110	52%
ENERGISINT	14	5%	Industry	27	13%
			UIO	12	6%

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Proportion of the Norwegian total production within the field. Only institutions/institutes with more than 10 articles within the categories during the time period are shown separately in the table.

Legends: ENERGISINT: SINTEF Energy research, FFI: The Norwegian Defence Research Establishment, HIT: Telemark University College, HIVE: Vestfold University College, IFE: Institute for Energy Technology, IRIS: International Research Institute of Stavanger, NGI: Norwegian Geotechnical Institute, NILU: Norwegian Institute for Air Research, NIVA: Norwegian Institute for Water Research, NOFIMA: The Norwegian Institute of Food, Fisheries and Aquaculture Research, NTNU: Norwegian University of Science and Technology, UiA: University of Agder, UiB: University of Bergen, UiO: University of Oslo, UiS: University of Stavanger, UITO: University of Tromsø, UMB: Norwegian University of Life Sciences, UNIK: University Graduate Centre.

The Norwegian contributions in the field of Engineering science are distributed on a large number of different journals (665 during the period 2009–2013). However, the frequency distribution is skewed, and a limited number of journals account for a substantial amount of the publication output. Table 3.3 gives the annual publication counts for the most frequently used journals in Engineering science and related fields for the period 2009–2013. The 52 most frequently used journals shown in the table account for almost 50 % of the Norwegian publication output in Engineering science.

On the top of the list we find journals from different subfields: *Energy and fuels* (128 articles), *International journal of hydrogen energy* (98 articles), *Reliability engineering & system safety* (88 articles), and *Safety science* (84 articles). The table also shows how the Norwegian contribution in the various journals has developed during the time period. From the list of journals one in addition gets an impression of the overall research profile of Norwegian research within Engineering science.

Table 3.3 The most frequently used journals for the period 2009–2013, number of publications* from Norway, Engineering sciences.

	2009	2010	2011	2012	2013	Total
ENERGY & FUELS	15	30	24	27	32	128
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY	16	18	16	35	13	98
RELIABILITY ENGINEERING & SYSTEM SAFETY	21	16	21	13	17	88
SAFETY SCIENCE	17	18	15	19	15	84
ENERGY POLICY	11	13	18	14	26	82
INTERNATIONAL JOURNAL OF GREENHOUSE GAS CONTROL	7	7	19	25	18	76
MATHEMATICAL PROBLEMS IN ENGINEERING		1	1	19	53	74
MODELING IDENTIFICATION AND CONTROL	15	10	9	11	14	59
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS ETC	5	12	18	9	15	59
ACCIDENT ANALYSIS AND PREVENTION	10	8	11	8	18	55
JOURNAL OF PETROLEUM SCIENCE AND ENGINEERING	12	11	10	9	12	54
IEEE TRANSACTIONS ON INFORMATION THEORY	11	9	10	14	8	52
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA	4	16	11	10	11	52
COLD REGIONS SCIENCE AND TECHNOLOGY	8	6	13	11	13	51
JOURNAL OF OFFSHORE MECHANICS AND ARCTIC ENGINEERING-TRANSACTIONS OF THE ASME	8	7	6	14	10	45
IEEE TRANS ULTRASONICS FERROELECTRICS FREQ CONTROL	12	5	7	11	7	42
PHYSICS OF FLUIDS	7	6	9	10	9	41
ULTRASOUND IN OBSTETRICS & GYNECOLOGY	8	6	11	8	8	41
JOURNAL OF HYDROLOGY	9	6	7	10	8	40
OCEAN ENGINEERING	5	6	10	8	11	40
MARINE STRUCTURES	7	5	9	7	8	36
CHEMOMETRICS AND INTELLIGENT LABORATORY SYSTEMS	8	2	4	12	8	34
IEEE TRANSACTIONS ON GEOSCIENCE & REMOTE SENSING	5	3	14	5	7	34
JOURNAL OF FLUID MECHANICS	6	11	5	8	4	34
SPE DRILLING & COMPLETION	6	3	7	6	11	33
APPLIED ENERGY	7		6	7	11	31
ENERGY AND BUILDINGS	3	5	10	5	8	31
JOURNAL OF INSTRUMENTATION	4	4	5	6	12	31
IEEE TRANSACTIONS ON POWER DELIVERY	7	6	3	6	7	29
IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	6	7	6	3	7	29
SPE JOURNAL	2	11	6	5	4	28
AUTOMATICA	8	1	5	3	10	27
ENERGY	1	4	5	5	12	27
IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	8	4	6	4	5	27
WIRELESS PERSONAL COMMUNICATIONS	4	6	13	1	2	26
JOURNAL OF MICROMECHANICS AND MICROENGINEERING	1	7	6	7	4	25
JOURNAL OF CHEMOMETRICS	6	10	4	3		23
RENEWABLE ENERGY	2	2	6	7	6	23
STOCHASTIC ENVIRONMENT RESEARCH & RISK ASSESSMENT	5	5	4	6	3	23
IEEE JOURNAL OF OCEANIC ENGINEERING	4	2	2	5	9	22
INTERNATIONAL JOURNAL OF MATERIAL FORMING	5	13	2		2	22
JOURNAL OF PROCESS CONTROL	5	2	3	7	5	22
BIORESOURCE TECHNOLOGY	3	2	5	6	5	21
BIOMASS & BIOENERGY		1	6	6	7	20
CEMENT AND CONCRETE RESEARCH	5	3	2	6	4	20
JOURNAL OF NATURAL GAS SCIENCE AND ENGINEERING		10	4	4	2	20
INTERNATIONAL JOURNAL OF IMPACT ENGINEERING	7	4	3	1	4	19
JOURNAL OF POWER SOURCES	3	4	4	2	6	19
SOLAR ENERGY MATERIALS AND SOLAR CELLS		3	5	9	2	19
COMPUTERS & OPERATIONS RESEARCH	3	4	3	3	5	18
IEEE TRANSACTIONS ON COMMUNICATIONS	5	2	3	5	3	18
IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	3	4	2	5	4	18
SPE RESERVOIR EVALUATION & ENGINEERING	6	6	1	3	2	18

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

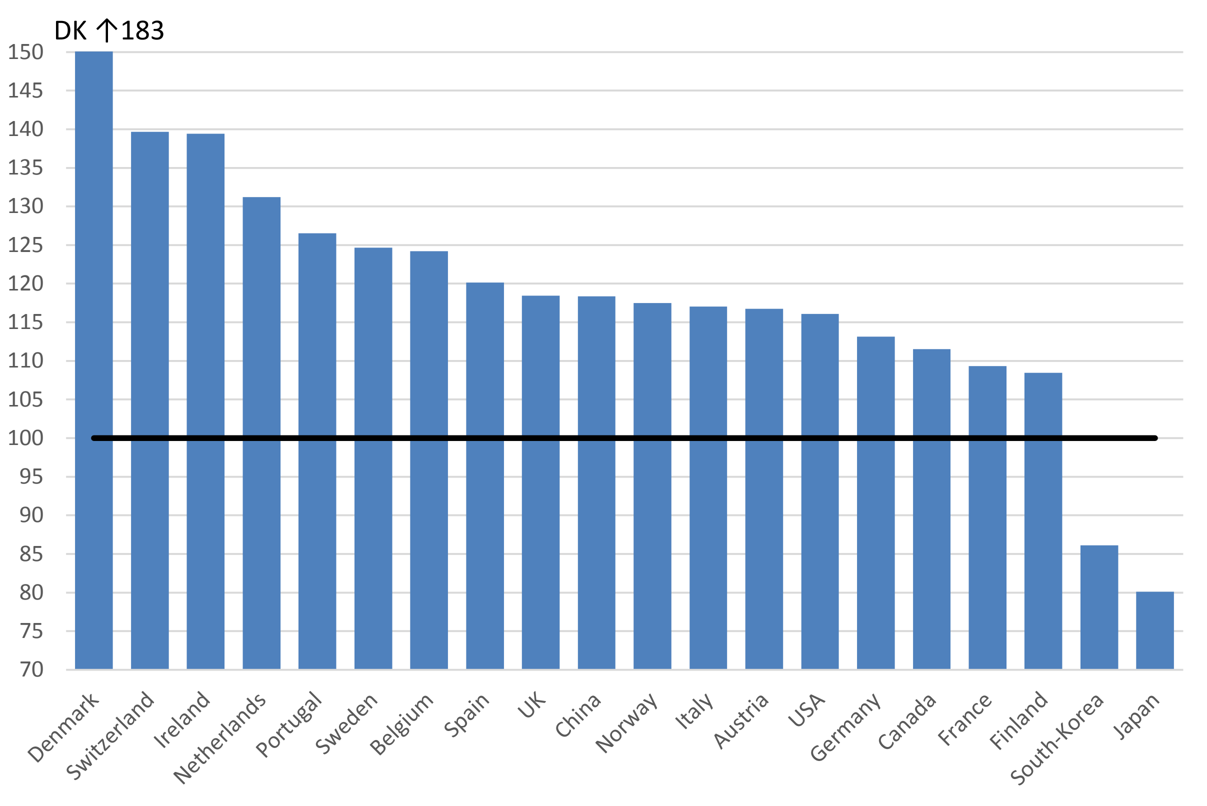
*) Includes the following publication types: articles, review papers, proceedings papers, and letters.

3.2 Citation indicators

The extent to which the articles have been referred to or cited in the subsequent scientific literature is often used as an indicator of scientific impact and international visibility. In absolute numbers the countries with the largest number of articles also receive the highest numbers of citations. It is however common to use a size-independent measure to assess whether a country's articles have been highly or poorly cited. One such indicator is the relative citation index showing whether a country's scientific publications have been cited above or below the world average (=100).

Figure 3.8 shows the relative citation index in Engineering science for a selection of countries, based on the citations to the publications from the four year period 2009–2012. The publications from Demark and Switzerland are most highly cited. Denmark has a citation index of 183, far above the world average. Norway ranks as number 11 among the 20 countries shown in this figure, with a citation index of 117. In other words, the performance of Norwegian Engineering science in terms of citations is somewhat below that of the leading countries. Still, the Norwegian citation index is clearly above world average, although this average does not constitute a very ambitious reference standard as it includes publications from countries with less developed science systems. The Norwegian index in Engineering science is also lower than the Norwegian total (all disciplines) for this period, which is approximately 130.

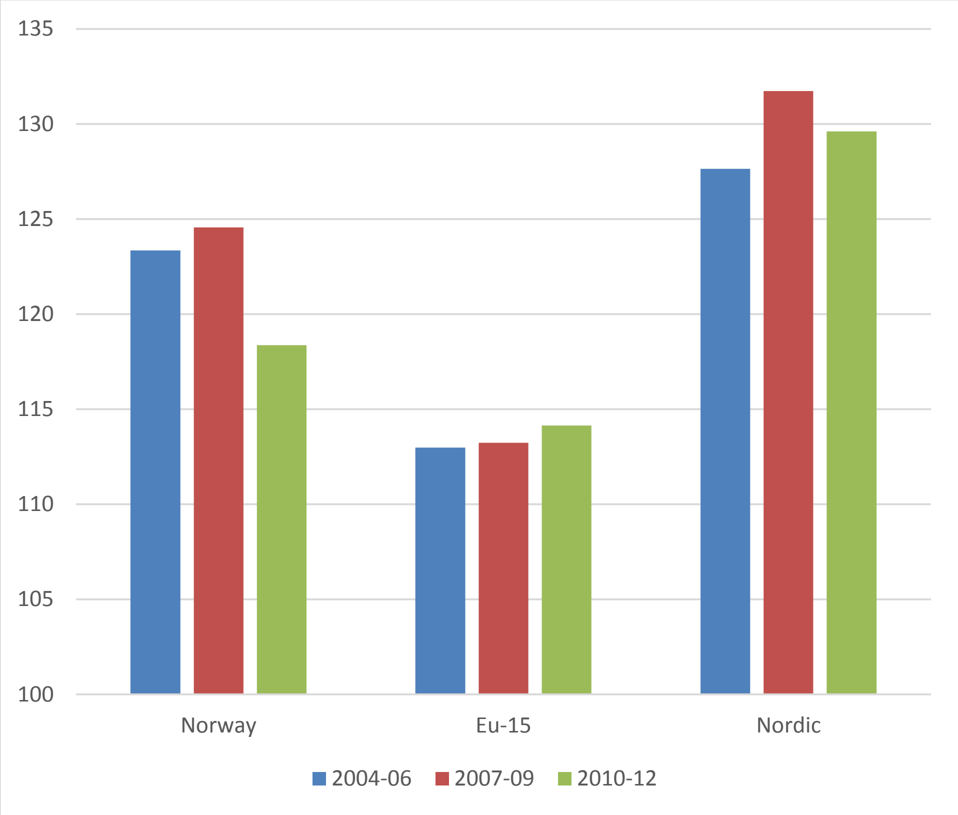
Figure 3.8 Relative citation index in Engineering sciences for selected countries (2009–2012).*



Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.
*) Based on the publications from the period 2009-2012 and accumulated citations to these publications through 2013. World-average = 100.

We have also analysed how the citation rate of the Norwegian publications within Engineering science has developed over the period 2004–2012. The results are shown in Figure 3.9 (based on three-year periods). Also the respective averages for the Nordic countries, the EU-15 have been included in this figure. As can be seen, there are some variations in the Norwegian citation index. In the first two periods, the citation index was somewhat higher than in the most recent period, although the decrease is not very strong (125 in 2007-09 and 117 in 2010-12). During all three periods, the Norwegian articles have been cited below the average for the Nordic countries but above the average for the EU-15 countries.

Figure 3.9 Relative citation index* in Engineering sciences for Norway compared with the average for the Nordic countries, the EU-15 countries for the period 2004–2012, 3-years averages.



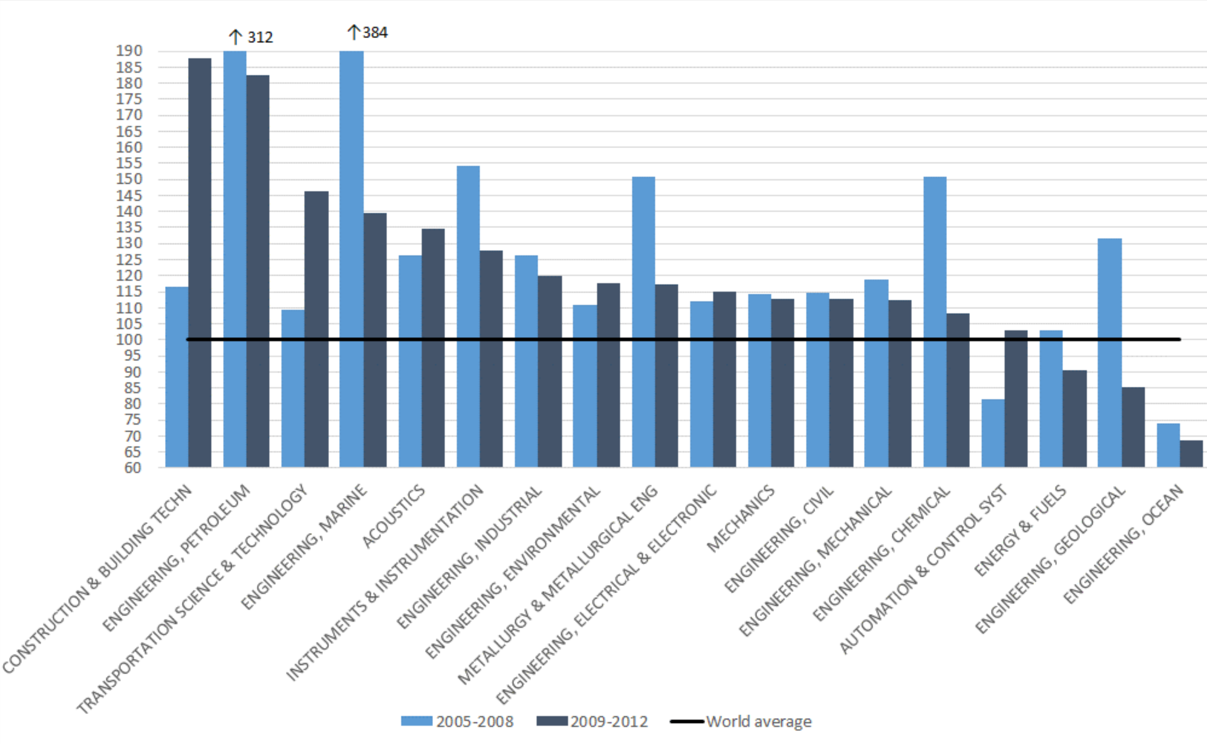
Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

*) Based on annual publication windows and accumulated citations to these publications.

The overall citation index for Engineering science does, however, disguise important differences at subfield levels. This can be seen in figure 3.10 where a citation index has been calculated for each of the subfields within Engineering science for two periods: 2005–08 and 2009-12. In the most recent period, the Norwegian publications in two subfields are particularly highly cited: Construction & building technology and Petroleum engineering, with citation indexes of 188 and 183, respectively. Norway also performs very well in Transportation science & technology and Marine engineering (citation indexes above 135). Lowest citation rate is found for Ocean engineering (69), Geological engineering (85) and Energy & fuels (91). Thus, in these fields the citation indexes is far below the world-average.

For most of the fields, there are not large changes in the citation index over the periods. However, there are some exceptions. In Construction & building technology the citation index has increased from 116 to 188, and in Transportation science & technology from 109 to 146. The citation rate has dropped significantly in Petroleum engineering, Marine engineering, Metallurgy & metallurgical engineering, Chemical engineering and Geological engineering. In the first two fields, the citation index was extremely high in the period 2005-08 (over 300). However, these are rather small fields in terms of number of articles included, and the citation rate may be strongly influenced by the presence or absence of particularly highly cited papers. The data shows that the Norwegian citation index of the fields has been very high during the past 20 years.

Figure 3.10 Relative citation index in Engineering science subfields, 2005-2008 and 2009–2012.*

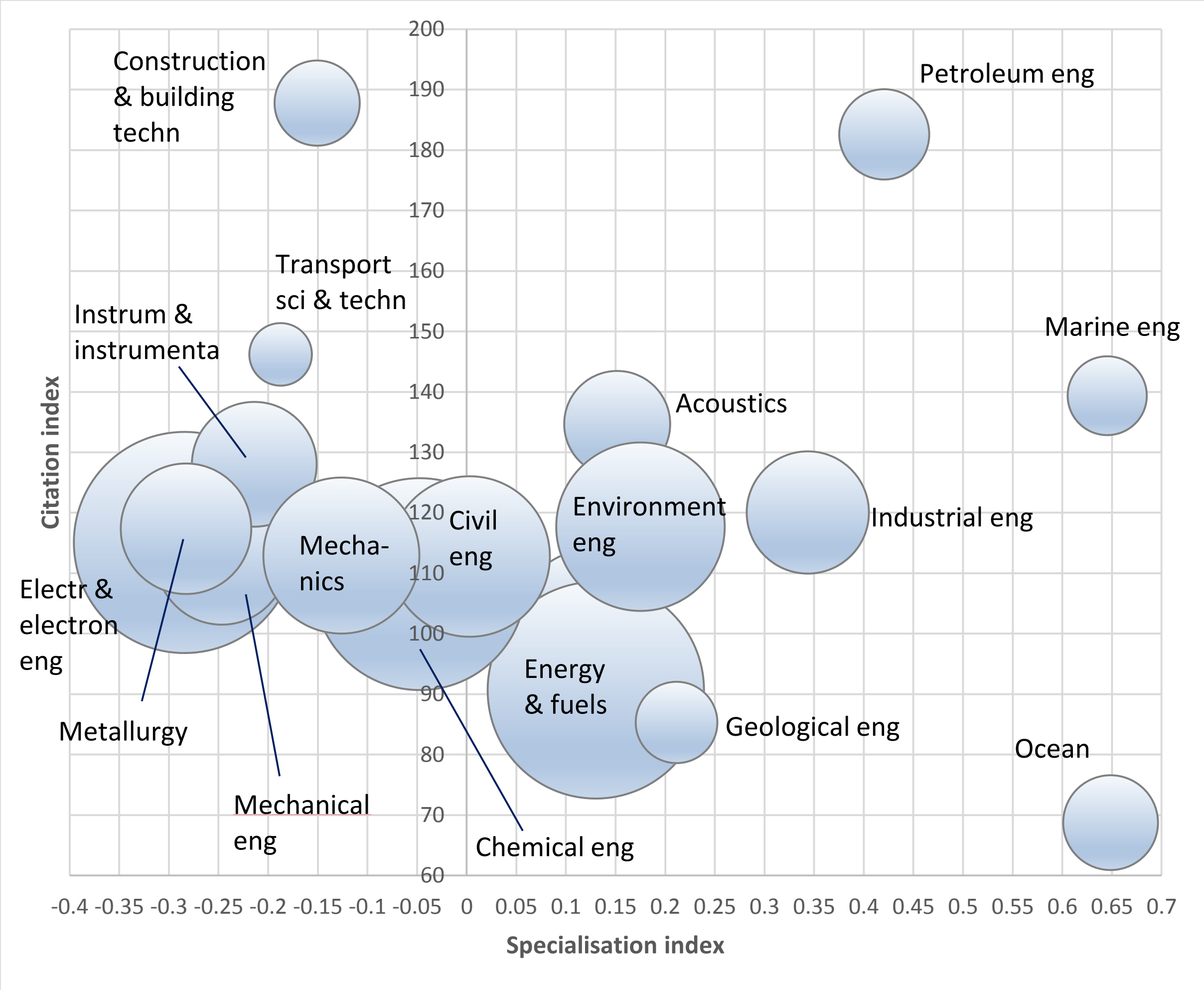


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

*) Based on the publications from the period and accumulated citations to these publications through 2013.

In Figure 3.11 various indicators for Norwegian Engineering science subfields have been put together in one figure. Here, the size of the bubbles is proportional to the number of articles of the respective subfields.

Figure 3.11 Bibliometric indicators for Norwegian Engineering science subfields. Relative citation index (2009-2012), Relative specialisation index (2009-13), and publication volume (number of articles 2009-13).



Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

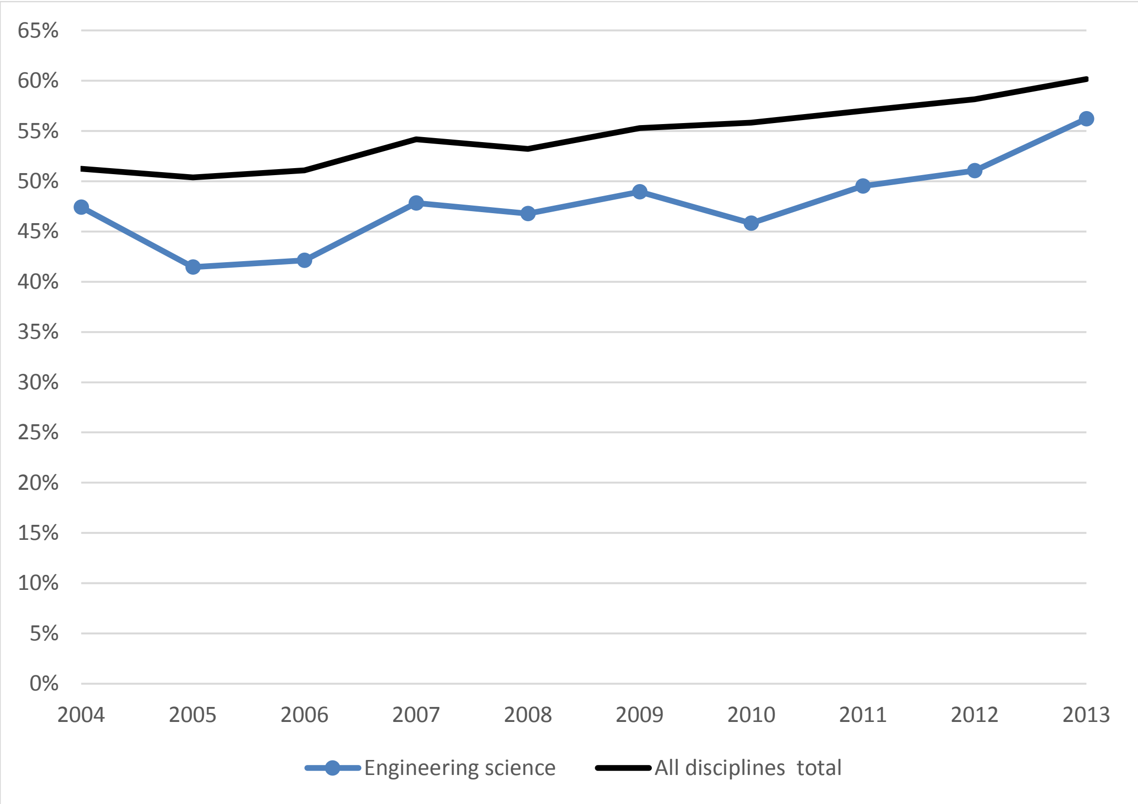
3.3 Collaboration indicators

This chapter explores the Norwegian publications involving international collaboration (publications having both Norwegian and foreign author addresses) and national collaboration (publications having author addresses from different Norwegian institutions). Increasing collaboration in publications is an international phenomenon and is one of the most important changes in publication behaviour among scientists during the last decades.

In Figure 3.12 we have shown the development in the extent of international co-authorship for Norway in Engineering science and for all disciplines (national total). In Engineering science, 56 % of the articles had co-authors from other countries in 2013. In other words, more than one out of two publications was internationally co-authored. This is slightly below the national average (60 %).

The proportion of international collaboration in Engineering science has increased from 47 % (41 % in 2005) to 56 % during the 10 year period. The national total has increased during the period from 51 % in 2004 to 60 % in 2013. Thus, Engineering science follows the national trend with increasing role of international collaboration.

Figure 3.12 The proportion of international co-authorship, 2004–2013, Norway.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

Which countries are the most important collaboration partners for Norway in Engineering science? In order to answer this question we analysed the distribution of co-authorship. Table 3.4 shows the frequencies of co-authorship for the countries that comprise Norway's main collaboration partners in the period 2009-2013.

The USA is the most important collaboration partner, and 10 % of the Norwegian articles within Engineering science also had co-authors from this nation. Then follows China with 7 % of the Norwegian articles co-authored with Chinese scientists. Next on the list are the UK, France, Sweden and Germany.

Table 3.4 Collaboration by country* 2009–2013. Number and proportion of the Norwegian article production in Engineering sciences with co-authors from the respective countries.

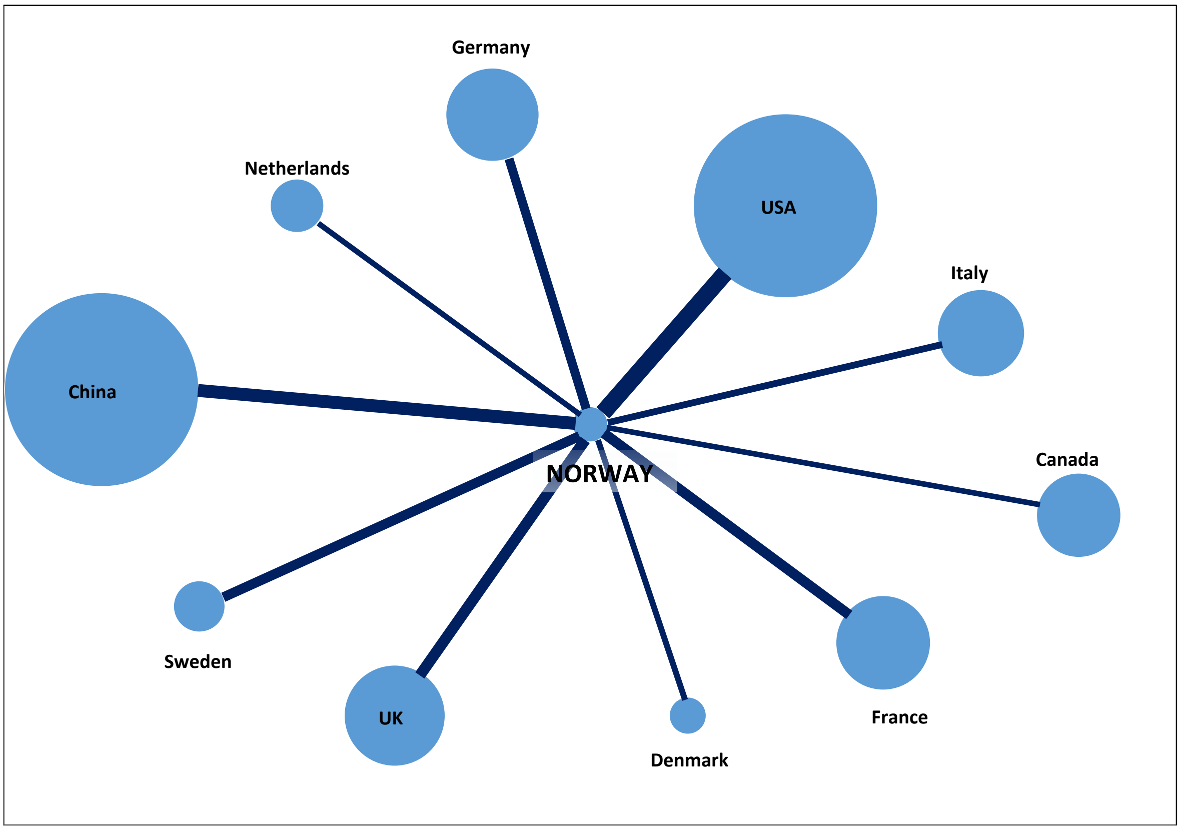
Country	No. articles	Proportion	Country	No. articles	Proportion
USA	450	9.7 %	Finland	96	2.1 %
China	344	7.4 %	Australia	82	1.8 %
UK	296	6.4 %	Russia	81	1.7 %
France	269	5.8 %	India	76	1.6 %
Sweden	263	5.7 %	Belgium	71	1.5 %
Germany	232	5.0 %	Japan	66	1.4 %
Italy	181	3.9 %	Poland	59	1.3 %
Denmark	160	3.5 %	Greece	53	1.1 %
Canada	148	3.2 %	Czech Rep	50	1.1 %
Netherlands	146	3.2 %	South Korea	50	1.1 %
Spain	143	3.1 %	Austria	48	1.0 %
Switzerland	108	2.3 %	Iran	42	0.9 %

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Only countries with more than 40 collaborative articles are shown in the table.

In Figure 3.12 we have illustrated the international collaboration profile of Norwegian Engineering science graphically for the 10 most important collaborative partners.

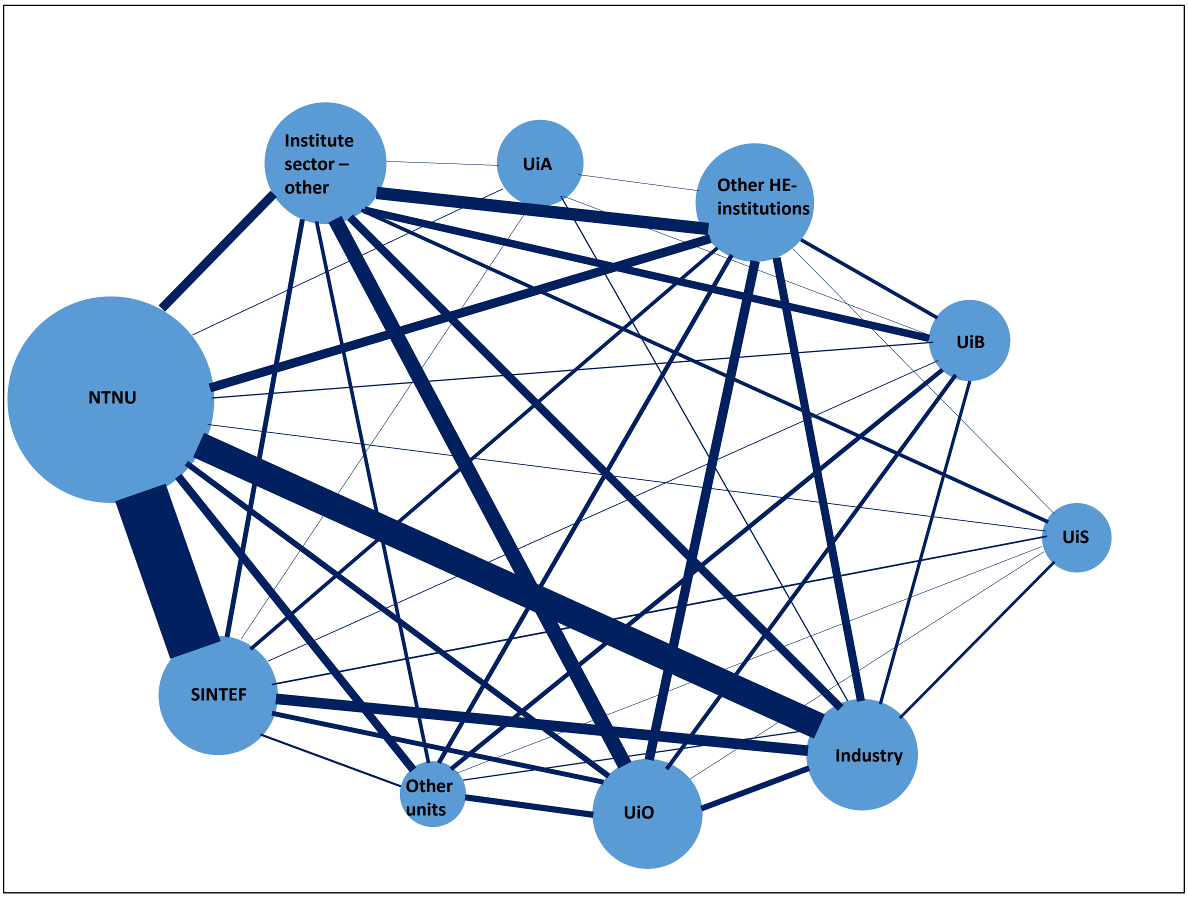
Figure 3.12 Graphical illustration of the international collaboration profile* of Norwegian Engineering science (2009-2013).



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.
*) Only the 10 most important collaborative countries are shown in the figure. The surface area of the circles is proportional to the total publication output in Engineering sciences of the countries, while the breadth of the lines is proportional to the number of collaborative articles with Norway.

In similar way, we have analysed the national collaboration based on co-authorship, and the results are illustrated in Figure 3.13 (based on the 2012-13 publications, only the largest institutions/institutes are included). In the figure, the surface area of the circles is proportional to the total publication output in Engineering science, while the breadth of the lines is proportional to the number of collaborative articles. Not surprisingly, there are very strong collaborative links between the Norwegian University of Science and Technology (NTNU) and SINTEF. There are also strong links between NTNU and the industry. Of the universities, UiO has significantly more external national collaboration in relative terms than the universities in Agder, and Stavanger. The research profile of the units in the institute sector, is characterised by extensive external national collaboration.

Figure 3.13 Graphical illustration of the national collaboration profile* of Norwegian Engineering sciences (2012-2013).



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.
*) Only the largest institutions/institutes in terms of publication output are shown in the figure. The surface area of the circles is proportional to the total publication output in Engineering sciences, while the breadth of the lines is proportional to the number of collaborative articles.

The data underlying Figure 3.13 are given in Table 3.5. For example, we note that 57 % of the total number of publications from SINTEF also had co-authors from NTNU, while the corresponding figure for NTNU was 19 %. Moreover, almost one third of the publications from the industry were co-authored with researchers from NTNU, and conversely 9 % of NTNU's publications involved collaboration with the industry. The shares are lower for NTNU than the opposite because NTNU has the highest number of total publications (cf. N), while the number of collaborative publications the shares are calculated from, are identical. However, NTNU is not the university with the highest number of collaborative articles with the institute sector generally (excluding SINTEF). Here, the University of Oslo (UiO) ranks on the top with 15 %.

Table 3.5 National collaboration by sector/institution. Proportion of publications in Engineering science with collaboration (2012-13).

		Collaborating institution/sector										
		NTNU	UIO	UIA	UIB	UIS	HE	SINTEF	INST	INDU	OTHER	N*
Institution/sector	NTNU	-	2%	0%	0%	0%	3%	19%	3%	9%	3%	890
	UIO	7%	-	-	5%	0%	11%	6%	19%	7%	8%	254
	UIA	2%	-	-	1%	-	1%	1%	1%	3%	-	158
	UIB	3%	9%	1%	-	-	8%	2%	17%	7%	10%	139
	UIS	3%	1%	-	-	-	1%	6%	11%	9%	2%	102
	HE	10%	10%	0%	4%	0%	-	4%	14%	9%	5%	294
	SINTEF	57%	5%	0%	1%	2%	4%	-	5%	11%	2%	298
	INST	9%	15%	1%	8%	4%	13%	5%	-	8%	3%	311
	INDU	32%	7%	2%	4%	3%	10%	13%	10%	-	2%	261
	OTHER	28%	22%	0%	15%	2%	15%	8%	9%	4%	-	92

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Total number of publications (includes publications with and without national collaboration).

Legends: NTNU: Norwegian University of Science and Technology, UiA: University of Agder, UiB: University of Bergen, UiO: University of Oslo, UiS: University of Stavanger, HE: Other higher education institutions, INST: Institute sector (excluding SINTEF), INDU: Industry. SINTEF: The SINTEF group institutes.

4 Institutional analyses

This chapter presents bibliometric indicators for each of the departments and institutes included in the evaluation. Several tables and figures are presented for each department along with a few brief comments. Please note – and be warned – that some general points are mentioned again and again (in each chapter, as some readers will focus on one chapter, only) and that many formulations appear repeatedly.

4.1 Gjøvik University College

Figure 4.1.1 Most frequently appearing words in the included publication titles, 2009-2013.
Source: Data: CRIStin. Calculations: NIFU.

One research group from Gjøvik University College is included in the evaluation: The Sustainable Manufacturing group. Table 4.1.1 shows publication indicators for the research group for the period 2009-2013. There are 13 persons included (with submitted CVs). This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

In total, 35 articles have been published during the period. The research group is very young, and most of the publications that can be attributed the group are from 2011 and 2012.

Table 4.1.1 Number of publications, 2009–2013, Gjøvik University College, Faculty of Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
Sustainable Manufacturing	13	35	83%

Source: Data: CRIStin. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, 83 % of the articles have been published in journals/series. Table 4.1.2 gives the most frequently used journals – limited to series with at least three publications during the period 2009–2013.

Table 4.1.2 The most frequently used journals/series,* number of publications 2009–2013. Gjøvik University College, Faculty of Engineering.

Unit	Journal/series	No. of articles
Sust. Manufacturing	Procedia CIRP	6
	Permafrost and Periglacial Processes	3

Source: Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.1.3 contains citations indicators based on the journal articles index in the NCR-database and published in the period 2009–2012. It should be noted that the citation analysis is based on 12 articles only, which limits the reliability of the citation indicators. The field normalized citation rate is 164. In other words, the articles are cited 64 % above the world average. One article published in *Permafrost and Periglacial Processes* in 2010, where Gjøvik University College has one of several contributors, accounts for almost half of the citations.

Table 4.1.3 Citation indicators, 2009–2012 publications indexed in NCR.* Gjøvik University College, Faculty of Engineering.

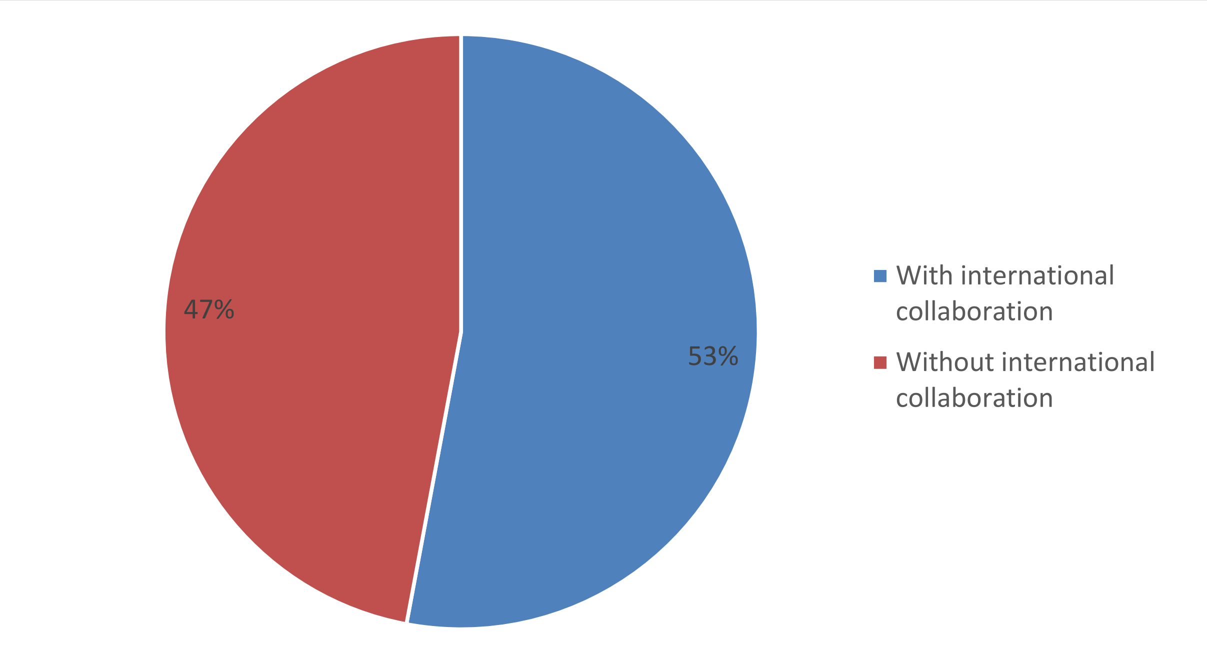
Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
Sust. Manufacturing	13	91	44	143	164	249

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.
1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

Of 17 articles indexed in NCR during the period 2009-13, approximately one half had co-authors from other countries (cf. Figure 4.1.2).

Figure 4.1.2. International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=17). Sust. Manufacturing.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.2 Norwegian University of Life Sciences

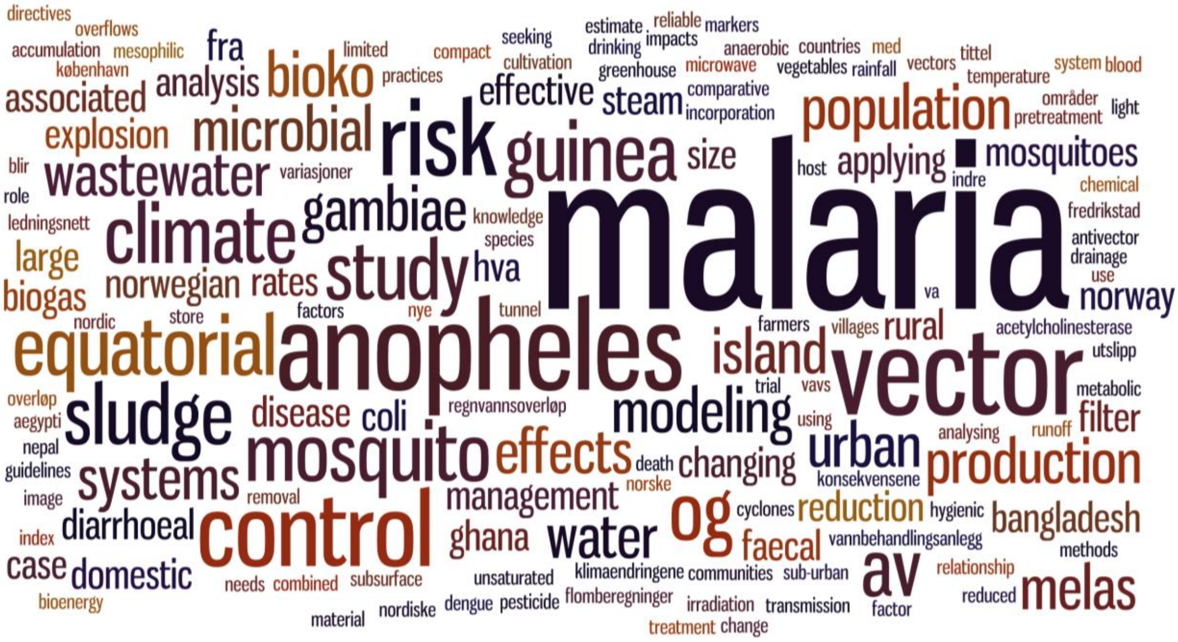


Figure 4.2.1 Most frequently appearing words in the included publication titles, 2009-2013.
Source: Data: CRIStin. Calculations: NIFU.

At the Norwegian University of Life Sciences there is one research group included in the evaluation: Water and Environmental Technology at the Department of Mathematical Sciences and Technology. The group consists of 9 people who have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

The researchers have published 42 publications during the period 2009-2013 that can be attributed Norwegian University of Life Sciences (cf. Table 4.2.1). The annual number of publications have been increasing during the period.

Table 4.2.1 Number of publications, 2009–2013, Department of Mathematical Sciences and Technology.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
Water & Env. Technology	9	42	100%

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).
Source: Data: CRIStin. Calculations: NIFU.

Table 4.2.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2009–2013. On the top of the list we find the Norwegian journal *Vann* with 12 articles.

Table 4.2.2 The most frequently used journals and number of publications 2009–2013.* Department of Mathematical Sciences and Technology.

Unit	Journal	No. of articles
Water & Env. Technology	Vann	12
	American Journal of Tropical Medicine and Hygiene	3

Source: Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.2.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. It should be noted that the citation analysis is based on 19 articles, only, and one article published in *Malaria Journal* in 2011 accounts for more than one third of the citations. The field normalized citation rate is 145. In other words, the articles are cited 45 % above the world average.

Table 4.2.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Mathematical Sciences and Technology.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
Water & Env. Technology	19	137	54	138	145	123

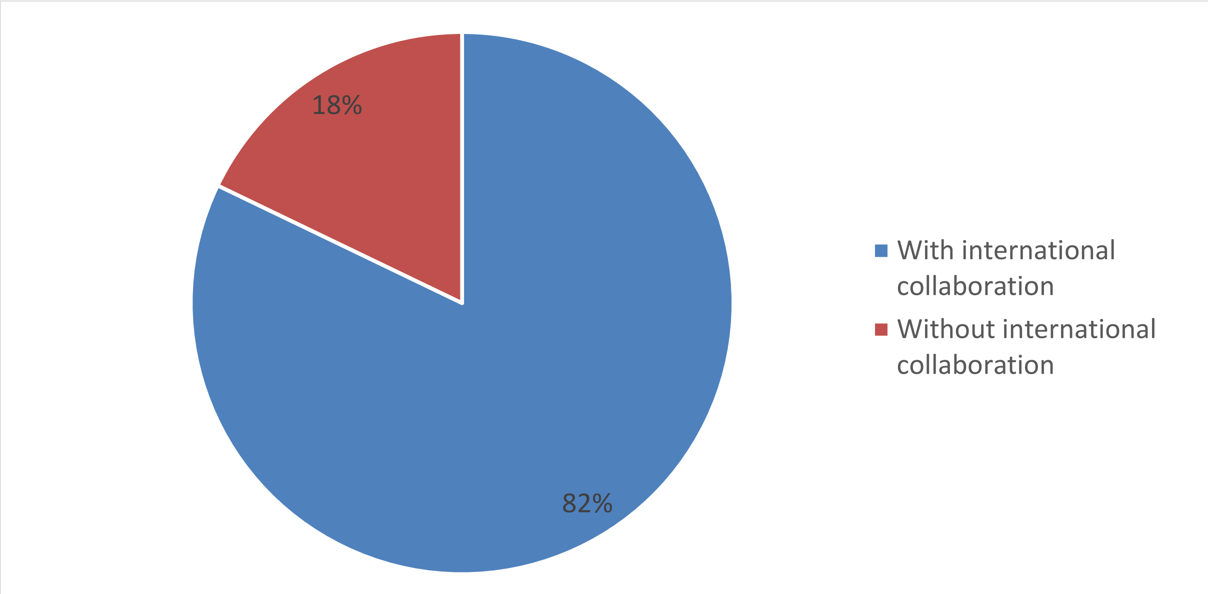
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

A large proportion of the group's publications have been co-authored in collaboration with scientists from other countries (82 %). This is shown in Figure 4.2.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=28), and gives an indication of the extent of international collaboration.

Figure 4.2.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 28). Water & Env. Technology.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3 Norwegian University of Science and Technology – Faculty of Engineering Science and Technology

There are research groups from 11 departments at the Norwegian University of Science and Technology (NTNU) included in the evaluation. Chapter 4.3 presents the results of the analysis of the nine departments at the Faculty of Engineering Science and Technology:

- Department of Civil and Transport Engineering
- Department of Energy and Process Engineering
- Department of Engineering Design and Materials
- Department of Hydraulic and Environmental Engineering
- Department of Marine Technology
- Department of Petroleum Technology and Applied Geophysics
- Department of Product Design
- Department of Production and Quality Engineering
- Department of Structural Engineering

4.3.1 Department of Civil and Transport Engineering

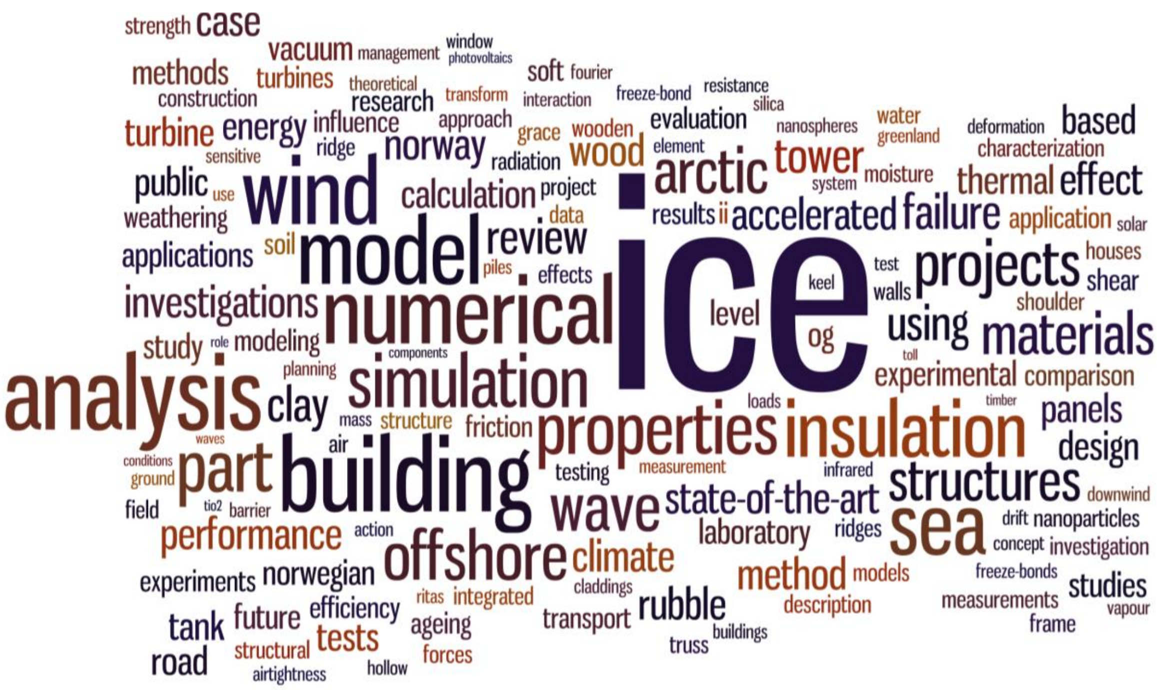


Figure 4.3.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Civil and Transport Engineering there are four research groups included in the evaluation: Building and Construction; Geotechnical Engineering; Marine Civil Engineering; and Road, Transport and Geomatics. In total 43 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 284 publications have been published during the period (cf. Table 4.3.1). This amounts to 5.3 % of the total publication output of the personnel included in the evaluation. The groups Building and Construction and Marine Civil Engineering are the largest in terms of publication volume, both with 108 articles.

Table 4.3.1 Number of publications, 2009–2013, Department of Civil and Transport Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	43	284	75%
Building and Construction	14	108	71%
Geotechnical Engineering	8	23	61%
Marine Civil Engineering	7	108	81%
Road, Transport and Geomatics	14	46	80%

Data: CRIStin. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Table 4.3.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.2 The most frequently used journals/series,* number of publications 2009–2013. Department of Civil and Transport Engineering.

Unit	Journal/series	No. of articles
Building and Construction	Energy and Buildings	11
	Journal of Building Physics	8
	Solar Energy Materials and Solar Cells	4
	Project Management Journal	4
	The Journal of Physical Chemistry C	3
	Tunnelling and Underground Space Technology	3
	Progress in organic coatings	3
	Advances in Materials Science and Engineering	3
	Wood Material Science & Engineering	3
Geotechnical Engineering	ISOPE - International Offshore and Polar Engineering Conference. Proceedings	4
	Geotechnique	3
Marine Civil Engineering	Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions	31
	ISOPE - International Offshore and Polar Engineering Conference. Proceedings	10
	Cold Regions Science and Technology	9
	Energy Procedia	8
	International Conference on Offshore Mechanics and Arctic Engineering	8
	Procedia Engineering	3
	Journal of Offshore Mechanics and Arctic Engineering-Transactions of The Asme	3
Road, Transport and Geomatics	Kart og Plan	3
	Journal of Geodetic Science	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the four groups together, the field normalized citation rate is 113. In other words, the articles are cited 13 % above the world average, but slightly below the national average for all groups included in the evaluation, which is 120. It should be noted, however, that only a minor fraction of the publications are indexed in NCR (78 articles, excluding 2013). The Building and Construction group performs very well in terms of citation rates with a field normalised citation index of 164. The citation indexes for the other groups are significantly lower, particularly for the Marine Civil Engineering, while the number of articles included from the Geotechnical Engineering is too low for calculating citation indexes.

Table 4.3.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Civil and Transport Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	78	303	31	119	113	98
Building and Construction	37	205	31	169	164	103
Geotechnical Engineering	2	6	3	-	-	-
Marine Civil Engineering	20	25	5	53	42	84
Road, Transport and Geomatics	19	67	16	92	87	103

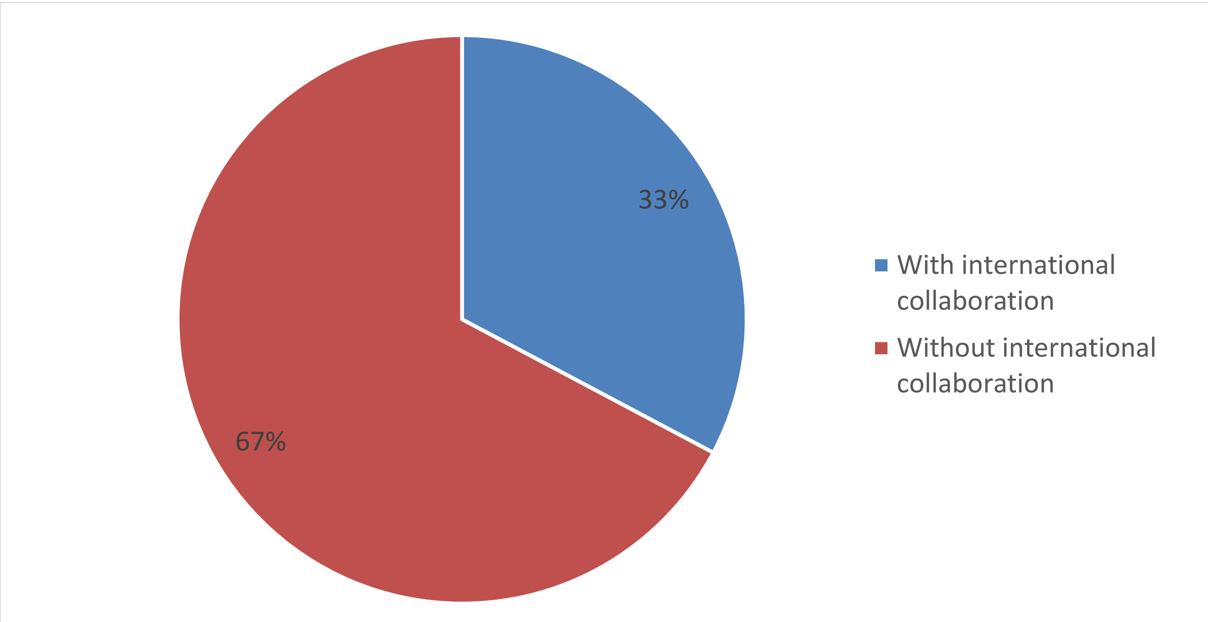
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 33 % of the four groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=119), and gives an indication of the extent of international collaboration.

Figure 4.3.2. International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=119). Department of Civil and Transport Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3.2 Department of Energy and Process Engineering

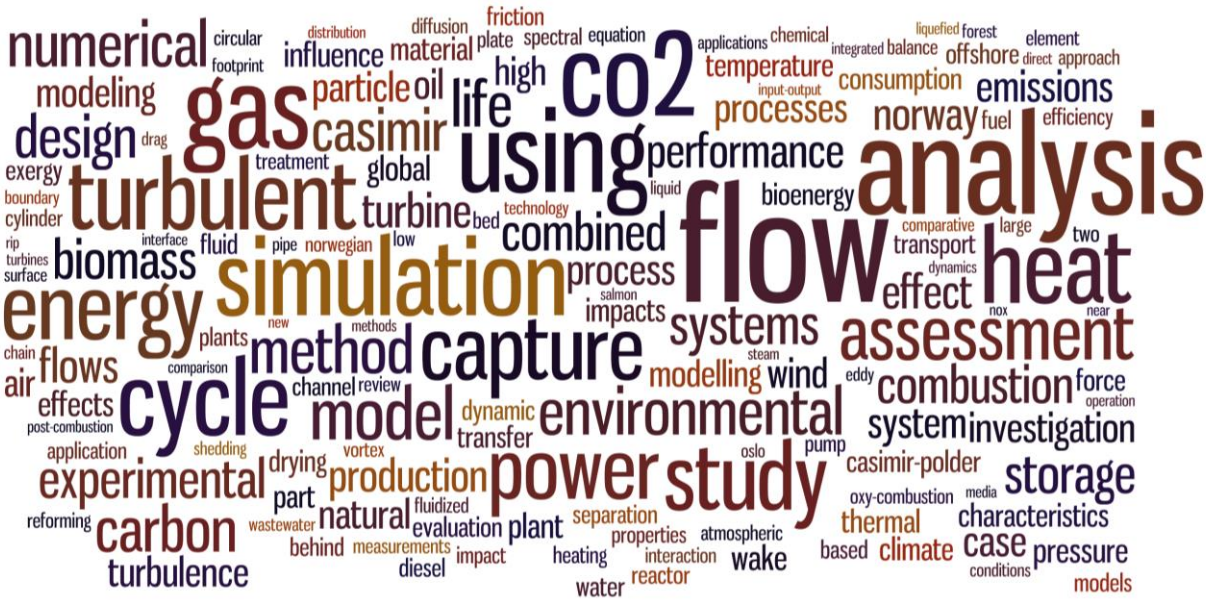


Figure 4.3.3 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Energy and Process Engineering there are five research groups included in the evaluation: Energy and Indoor Environment; Fluids Engineering; Industrial Ecology; Industrial Process Technology; and Thermal Energy. In total 56 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

The department is the largest of the units both in terms of number of researchers included and publication output. Altogether, 641 publications have been published during the period 2009-2013 (cf. Table 4.3.4). This amounts to 12.1 % of the total publication output of the entire personnel included in the evaluation. In contrast, the proportion of the included researchers is 9.0 %, which indicates that the productivity of the department is very high. The group Fluids Engineering is the largest with 244 articles.

Table 4.3.4 Number of publications, 2009–2013, Department of Energy and Process Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	56	641	90%
Energy and Indoor Environment	9	25	64%
Fluids Engineering	15	244	90%
Industrial Ecology	8	132	98%
Industrial Process Technology	11	143	89%
Thermal Energy	13	116	91%

Data: CRIStin. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

The large majority of the publications of the five groups have been published in journals and regular publishing series (90 %). Table 4.3.5 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.5 The most frequently used journals/series,* number of publications 2009–2013. Department of Energy and Process Engineering.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Energy & Indoor Env	Energy and Buildings	5	Indust-rial Ecology	Environmental Research Letters	4
Fluids Engi-neering	Physics of Fluids	23		Journal of Cleaner Production	4
	Physical Review A. Atomic, Molecular, and Optical Physics	18		Building Research & Information	4
	Journal of Fluid Mechanics	9		Urban Water Journal	3
	Journal of Physics, Conference Series	8		International Journal of Greenhouse Gas Control	3
	Computers & Fluids	6		Global Change Biology Bioenergy	3
	Energy Procedia	6	Indust-rial Process Tech-nology	Chemical Engineering Science	8
	International Journal for Numerical Methods in Fluids	6		Energy Procedia	6
	Physical Review E	5		Science et technique du froid	6
	Physical Review D. Particles and fields	5		International journal of refrigeration	6
	Journal of Fluids Engineering - Trancactions of The ASME	5		Applied Thermal Engineering	5
	Procedia Engineering	5		Journal of Natural Gas Science and Engineering	5
	Journal of Hydraulic Engineering	4		Computer - Aided Chemical Eng	5
	Acta Mechanica	4		Drying Technology	5
	Journal of Natural Gas Science and Engineering	4		Journal of Food Engineering	5
	International Journal of Heat and Fluid Flow	4		International Journal of Multiphase Flow	4
	Astrophysics and Space Science	4		Applied Energy	4
	IOP Conference Series: Earth and Environment	3		Energy Conversion and Management	4
	Wind Energy	3		Chemical Engineering Transact	4
	Chemical Engineering Science	3		Industrial & Engineering Chemistry Research	4
	Communications in Comput Phys	3		Energy & Fuels	3
	European Physical Journal D	3		Energy	3
	Physica Scripta	3		Applied Mathematical Modelling	3
	Intern Conference on Offshore Mechanics and Arctic Engineering	3	Thermal Energy	Energy & Fuels	22
	International Journal of Modern Physics A	3		Energy Procedia	14
Industrial Ecology	Environmental Science and Technology	23		International Journal of Greenhouse Gas Control	12
	Journal of Industrial Ecology	14		Applied Energy	4
	Economic Systems Research	8		Flow Turbulence and Combustion	4
	Energy Policy	7		Fuel processing technology	3
	The International Journal of Life Cycle Assessment	6		Energy	3
	Resources, Conservation and Recycling	5		Energy Conversion and Management	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.6 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the five groups together, the field normalized citation rate is 139. In other words, the articles are cited 39 % above the world average. This citation rate is also higher than the national average for all groups included in the evaluation, which is 120. The Industrial Ecology group performs very well in terms of citation rates with a field normalised citation index of 256, and one article particularly highly cited (Carbon Footprint of Nations: A Global, Trade-Linked Analysis. Published in *Environmental Science and Technology*, 2009). The citation indexes for the other groups are significantly lower, and close to the world average.

Table 4.3.6 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Energy and Process Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	349	2529	154	129	139	120
Energy and Indoor Environment	12	43	12	103	89	125
Fluids Engineering	138	613	36	105	102	114
Industrial Ecology	90	1311	154	208	256	136
Industrial Process Technology	58	272	24	91	88	108
Thermal Energy	61	330	48	109	108	118

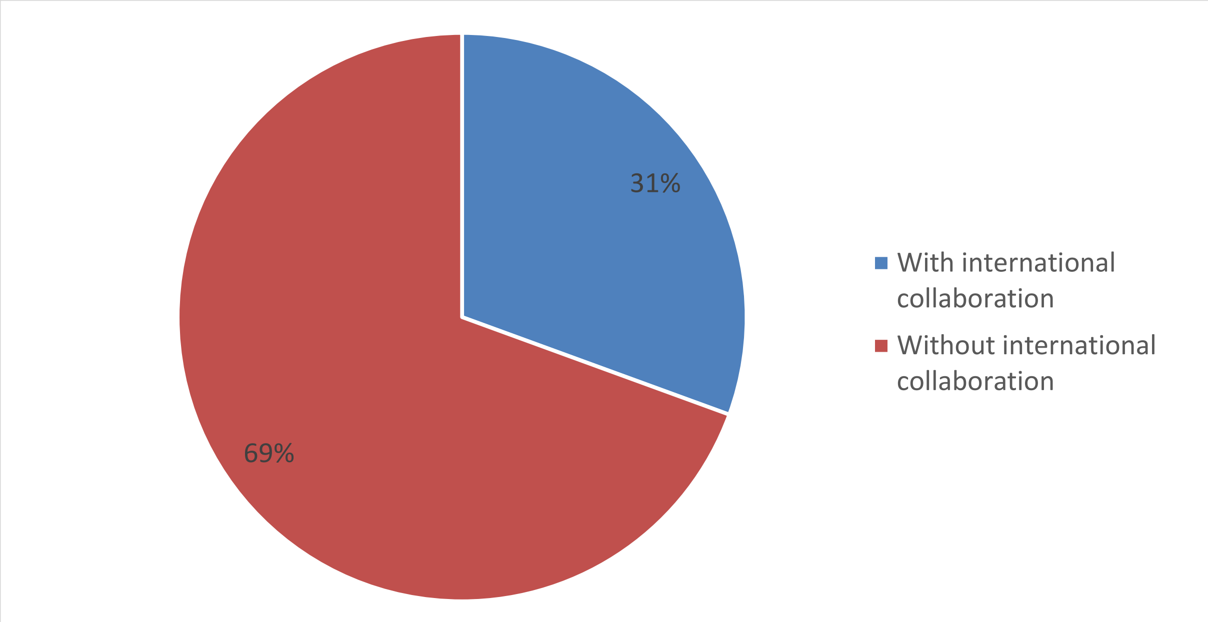
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 31 % of the five groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.4. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=471), and gives an indication of the extent of international collaboration.

Figure 4.3.4 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 471). Department of Energy and Process Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3.3 Department of Engineering Design and Materials

Figure 4.3.5 Most frequently appearing words in the included publication titles, 2009-2013.
Source: Data: CRIStin. Calculations: NIFU.

At the Department of Engineering Design and Materials there are two research groups included in the evaluation: Design, Analysis and Manufacturing and Materials. In total 17 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 144 publications have been published during the period (cf. Table 4.3.7). This amounts to 2.7 % of the total publication output of the personnel included in the evaluation. The two groups are almost equal in terms of publication volume, both with approximately 70 publications.

Table 4.3.7 Number of publications, 2009–2013, Department of Engineering Design and Materials.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	17	144	90%
Design, Analysis and Manufacturing	10	71	85%
Materials	7	77	95%

Source: Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

The large majority of the publications have been published in journals and regular publishing series (90 %). Table 4.3.8 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.8 The most frequently used journals/series,* number of publications 2009–2013. Department of Engineering Design and Materials.

Unit	Journal/series	No. of articles
Design, Analysis and Manufacturing	Key Engineering Materials	11
	International Journal of Material Forming	8
	NTNU Engineering Series	8
	AIP Conference Proceedings	6
	Proceedings of the International Conference on Engineering Design	5
	Lecture Notes in Production Engineering	3
Materials	ISOPE - International Offshore and Polar Engineering Conference. Proceedings	10
	Wear	7
	International Journal of Fatigue	5
	Materials Science & Engineering: A	4
	Modelling and Simulation in Materials Science and Engineering	3
	Procedia Engineering	3
	Engineering Fracture Mechanics	3
	Journal of thermal spray technology (Print)	3

Source: Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.9 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the two groups together, the field normalized citation rate is 82. In other words, the articles are cited almost 20 % below the world average. It should be noted, however, that only a minor fraction of the publications are indexed in NCR (42 articles, excluding 2013). The research group Materials performs better than the Design, Analysis and Manufacturing group in terms of citation rates, and the latter group has very few articles in NCR-indexed journals. The field normalised citation index for the Materials group is 101, which is identical to the world average but below the national average for all groups (120).

Table 4.3.9 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Engineering Design and Materials.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	42	137	17	109	82	80
Design, Analysis and Manufacturing	10	9	5	63	19	39
Materials	32	128	17	123	101	92

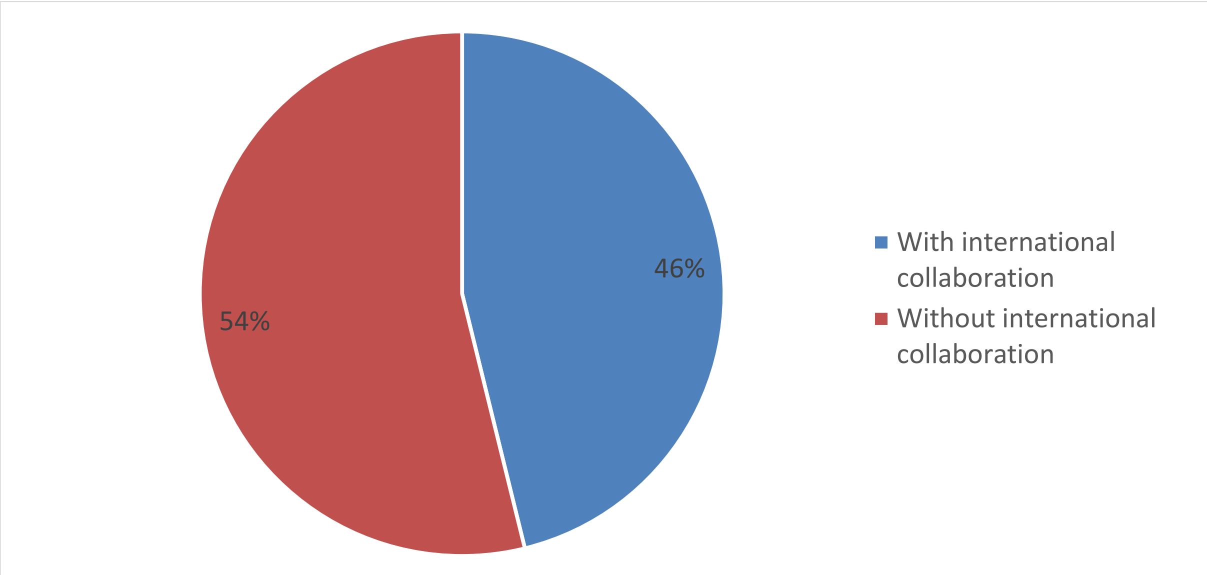
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total 46 % of the two groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.6. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=65), and gives an indication of the extent of international collaboration.

Figure 4.3.6 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 65). Department of Engineering Design and Materials.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3.4 Department of Hydraulic and Environmental Engineering

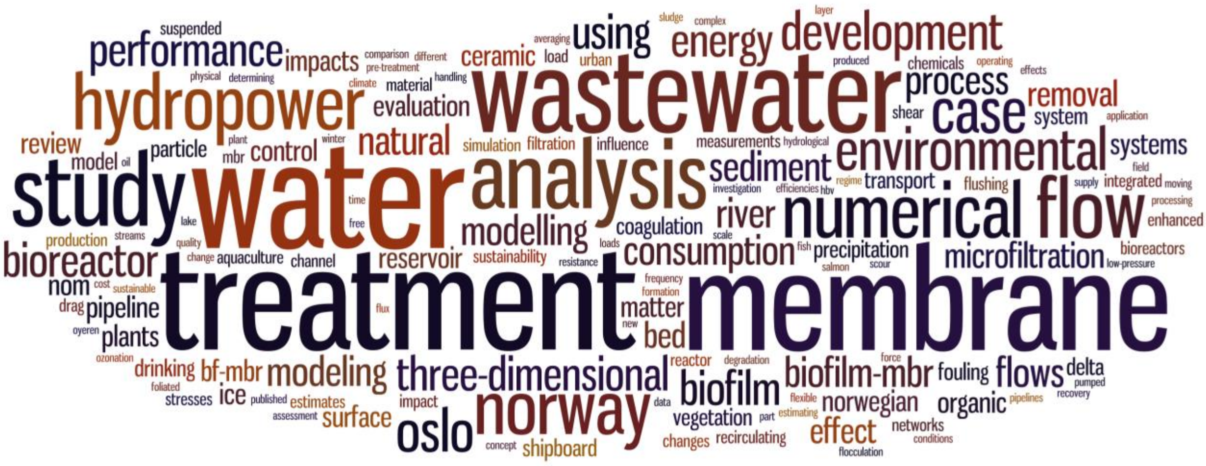


Figure 4.3.7 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Hydraulic and Environmental Engineering there are two research groups included in the evaluation: Hydraulic Engineering and Water & Wastewater Engineering. In total 19 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 130 publications have been published during the period 2009-2013 (cf. Table 4.3.10). This amounts to 2.4 % of the total publication output of the entire personnel included in the evaluation. In contrast, the proportion of the included researchers is 3.1 %. The two groups are of equal size both in terms of researchers included and publication volume.

Table 4.3.10 Number of publications, 2009–2013, Department of Hydraulic and Environmental Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	19	130	86%
Hydraulic Engineering	9	67	79%
Water & Wastew. Eng.	10	64	94%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

The large majority of the publications of the two groups have been published in journals and regular publishing series (86 %). Table 4.3.11 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.11 The most frequently used journals/series,* number of publications 2009–2013. Department of Hydraulic and Environmental Engineering.

Unit	Journal/series	No. of articles
Hydraulic Engineering	Journal of Hydraulic Engineering	4
	Rivers Research and Applications	4
	Engineering Applications of Computational Fluid Mechanics	3
	Hydro Nepal: Journal of Water, Energy and Environment	3
	Hydrology Research	3
	Journal of Hydraulic Research	3
	Journal of Hydrology	3
Water & Wastew. Eng.	Desalination and Water Treatment	7
	Separation science and technology (Print)	5
	Desalination	5
	Problemy Ekorozwoju	4
	Urban Water Journal	4
	Water Science and Technology	4
	Journal of Industrial Ecology	3
	Separation and Purification Technology	3
	Journal - American Water Works Association	3
	Journal of Industrial Ecology	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.12 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the two groups together, the field normalized citation rate is 95. In other words, the articles are cited almost on par with the world average, but below the national average for all groups included in the evaluation, which is 120. The two groups have almost equal field normalised citation indexes (92-97). The journals used for publications have somewhat lower impact factors than average, therefore the groups perform better using a journal normalised citation index (cf Method section).

Table 4.3.12 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Hydraulic and Environmental Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	69	331	26	133	95	93
Hydraulic Engineering	25	100	16	119	92	90
Water & Wastew. Eng.	44	231	26	141	97	95

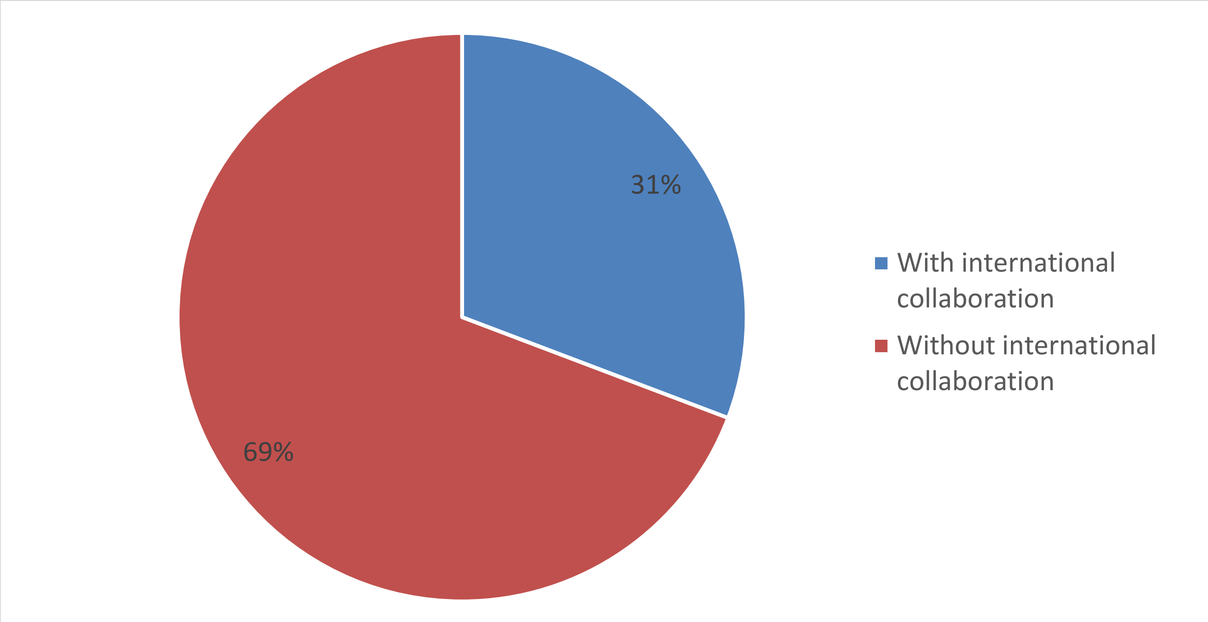
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 31 % of the two groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.8. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=91), and gives an indication of the extent of international collaboration.

Figure 4.3.8 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 91). Department of Hydraulic and Environmental Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3.5 Department of Marine Technology

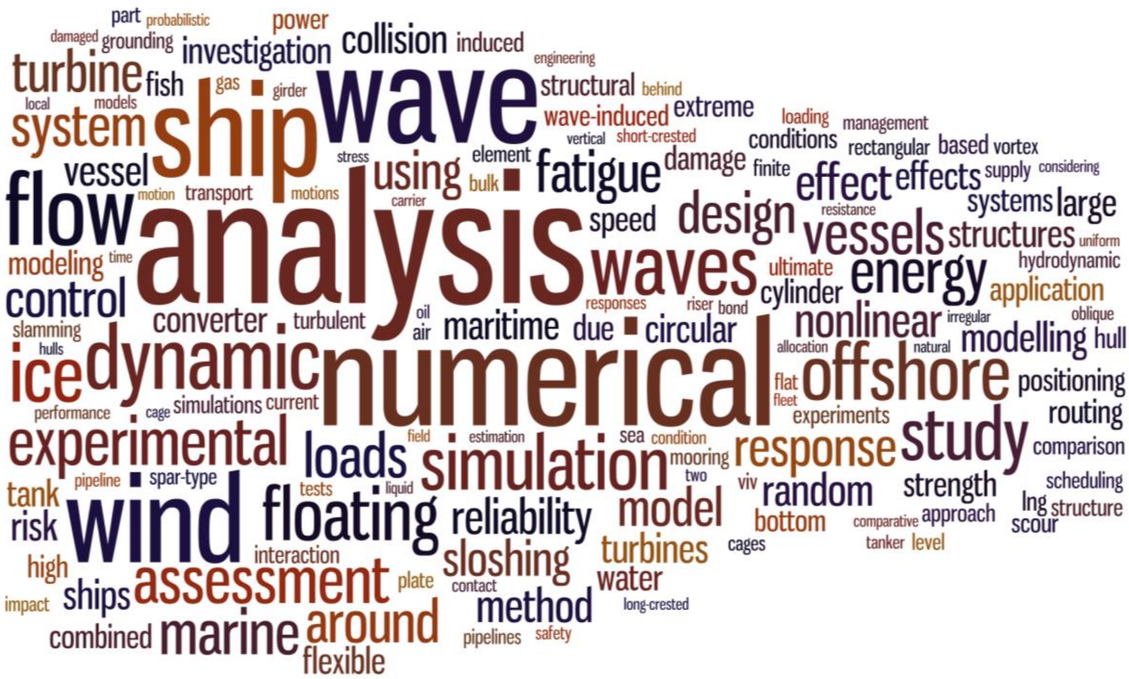


Figure 4.3.9 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Marine Technology there are two research groups included in the evaluation: Marine Structures and Marine Systems. In total 23 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 635 publications have been published during the period 2009-2013 (cf. Table 4.3.13). This amounts to 11.9 % of the total publication output of the entire personnel included in the evaluation. In contrast, the proportion of the included researchers is 3.7 %. In other words, the productivity of the groups is extremely high, particularly due to the publication output of the Marine Structures group (14 scientists have published 511 articles during the 5-year period).

Table 4.3.13 Number of publications, 2009–2013, Department of Marine Technology.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	23	635	72%
Marine Structures	14	511	70%
Marine Systems	9	135	79%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately three quarters of the publications of the two groups have been published in journals and regular publishing series. Table 4.3.14 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.14 The most frequently used journals,* number of publications 2009–2013. Department of Marine Technology.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Marine Structures	International Conference on Offshore Mechanics and Arctic Engineering	58	Marine Structures	Journal of Physics, Conference Series	4
	Journal of Offshore Mechanics and Arctic Engineering-Transactions of The Asme	30		Journal of Ship Research	3
	Elsevier IFAC Publications / IFAC Proceedings series	22		International Journal of Offshore and Polar Engineering	3
	Ocean Engineering	19		International Conference on Ship Manoeuvring in Shallow and Confined Water	3
	Marine Structures	17		Renewable energy	3
	Physics of Fluids	12		Aquacultural Engineering	3
	ISOPE - International Offshore and Polar Engineering Conference. Proce	12		Control Engineering Practice	3
	Journal of Marine Science and Technology	11		Wit Transactions on Ecology and The Environment	3
	Journal of Fluids and Structures	11	Marine Systems	International Conference on Offshore Mechanics and Arctic Engineering	8
	Coastal Engineering	11		Safety Science	7
	Applied Ocean Research	9		Springer Series in Reliability Engineering	6
	Cold Regions Science and Technology	9		Reliability Engineering & System Safety	6
	Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions	7		European Journal of Operational Research	5
	Ships and Offshore Structures	7		Computers & Operations Research	5
	Journal of Engineering for the Maritime Environment (Part M)	6		Marine Structures	4
	Journal of Fluid Mechanics	6		Maritime Policy & Management	4
	Energy Procedia	6		Computers & industrial engineering	3
	International Journal for Numerical Methods in Fluids	6		Journal of Cleaner Production	3
	American Control Conference	5		Ship Technology Research	3
	Structural Safety	5		Transportation Research Part C: Emerging Technologies	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.15 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the two groups together, the field normalized citation rate is 112. In other words, the articles are cited 12 % above the world average but slightly below the national average for all groups included in the evaluation, which is 120. The Marine Systems group performs better than the other group with a field normalised citation index of 142. Thus, despite a smaller volume in terms of number of publications, the publications are on average more cited.

Table 4.3.15 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Marine Technology.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	214	714	34	125	112	107
Marine Structures	171	496	23	120	102	104
Marine Systems	46	220	34	139	142	119

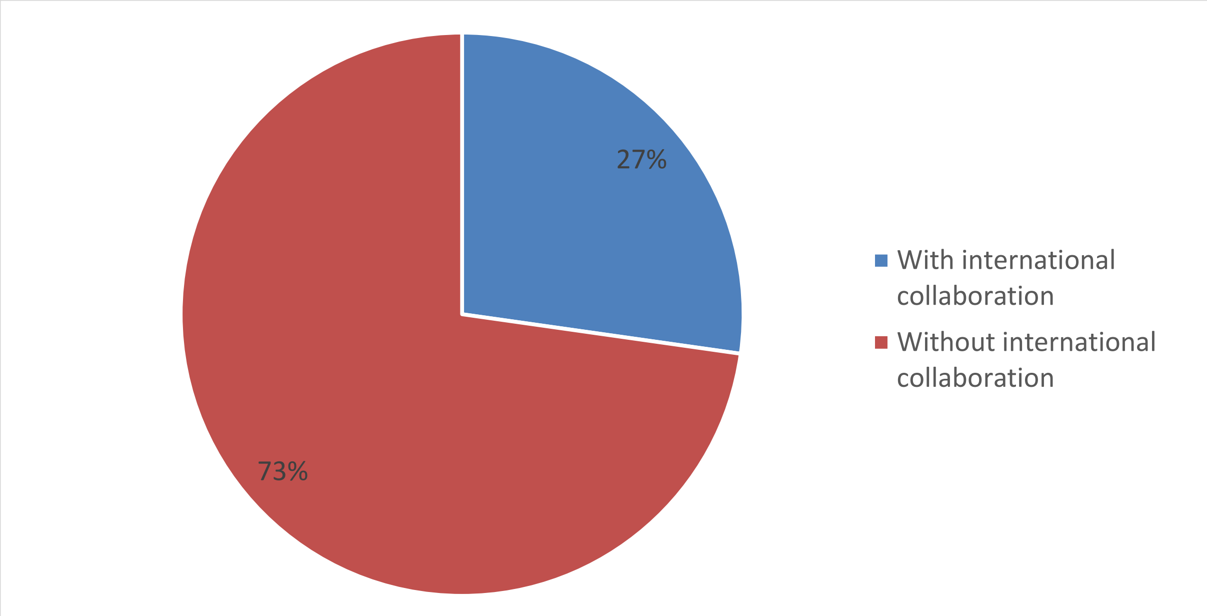
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 27 % of the two groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.10. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=290), and gives an indication of the extent of international collaboration.

Figure 4.3.10 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=290). Department of Marine Technology.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3.6 Department of Petroleum Technology and Applied Geophysics

Figure 4.3.11 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Petroleum Technology and Applied Geophysics there is one research groups included in the evaluation: Petroleum Technology and Applied Geophysics. In total 13 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 229 publications have been published during the period 2009-2013 (cf. Table 4.3.16). This amounts to 4.3 % of the total publication output of the entire personnel included in the evaluation. In contrast, the proportion of the included researchers is 2.1 %, which indicates that the productivity of the group is very high.

Table 4.3.16 Number of publications, 2009–2013, Department of Petroleum Technology and Applied Geophysics.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
Petroleum Technology and Applied Geophysics	13	229	66%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately two thirds of the publications of the group have been published in journals and regular publishing series. Table 4.3.17 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013. The journal most often used for publication is *Geophysics* with 42 articles.

Table 4.3.17 The most frequently used journals/series,* number of publications 2009–2013. Department of Petroleum Technology and Applied Geophysics.

Unit	Journal/series	No. of articles
Petroleum Technology and Applied Geophysics	Geophysics	42
	Geophysical Prospecting	18
	Society of Exploration Geophysicists. Expanded Abstracts with Biographies	15
	Journal of Geophysics and Engineering	14
	Journal of Petroleum Science and Engineering	7
	Transport in Porous Media	4
	First Break	4
	Geophysical Journal International	3
	European Association of Geoscientists and Engineers	3
	Energy and Environment Research	3
	International Journal of Greenhouse Gas Control	3
	SPE Reservoir Evaluation and Engineering	3
	International Journal of Petroleum Science and Technology	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.18 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. Despite a high productivity, the publications of the group are not very highly cited. The field normalized citation rate is 49. This means that the articles have been cited approximately half as frequently as the average article within the field. The group also tends to publish in journals with somewhat lower citation rates than average. However, it should be added that only a limited proportion of the publication output of the group is indexed in the NCR database.

Table 4.3.18 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Petroleum Technology and Applied Geophysics.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
Petroleum Technology and Applied Geophysics	80	208	18	85	49	72

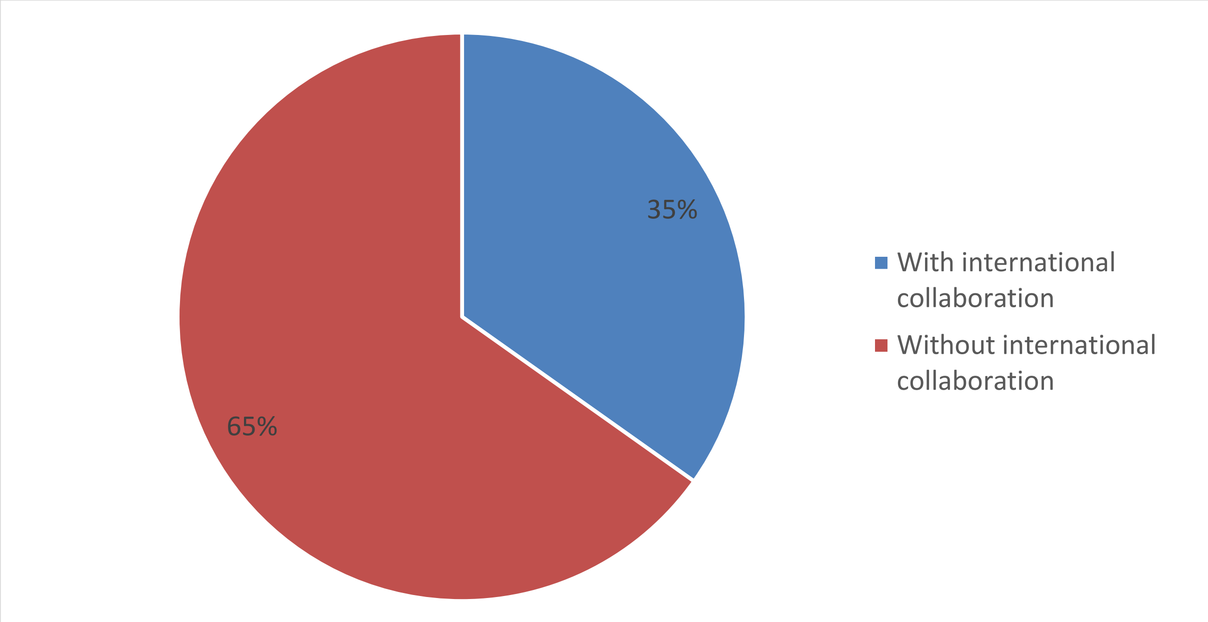
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 35 % of the group's publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.12. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=112), and gives an indication of the extent of international collaboration.

Figure 4.3.12. International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 112). Department of Petroleum Technology and Applied Geophysics.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3.7 Department of Product Design

Figure 4.3.13 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Product Design there is one research group included in the evaluation: Product Design. In total 9 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 92 publications have been published during the period 2009-2013 (cf. Table 4.3.19).

Table 4.3.19 Number of publications, 2009–2013, Department of Product Design.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
Product Design	9	92	42%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

The majority of the publications are not published in scientific journals or series. Table 4.3.20 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.20 The most frequently used journals/series,* number of publications 2009–2013. Department of Product Design.

Unit	Journal/series	No. of articles
Product Design	Proceedings of the International Conference on Engineering Design	7
	Sustainable Development	3
	Lecture Notes in Computer Science = Lecture notes in artificial intelligence	3
	International Journal of Product Development	3
	Journal of Design Research	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Only a few of the articles have been published in NCR-indexed journals (cf. Table 4.3.21), therefore citation indicators and indicators of international collaboration have not been calculated for this group.

Table 4.3.21 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Product Design.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal	Citation index – field	Journal profile
Product Design	9	13	5	-	-	-

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

4.3.8 Department of Production and Quality Engineering

Figure 4.3.14 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Production and Quality Engineering there are four research groups included in the evaluation: Production Management; Production Systems; Project and Quality Management; and RAMS (Reliability, Availability, Maintainability, Safety). In total 22 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 225 publications have been published during the period 2009-2013 (cf. Table 4.3.22).

Table 4.3.22 Number of publications, 2009–2013, Department of Production and Quality Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	22	225	69%
Production Management	6	45	91%
Production Systems	4	51	73%
Project and Quality Management	6	54	67%
RAMS	6	76	55%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately two thirds of the publications of the groups have been published in journals and regular publishing series. Table 4.3.23 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.23 The most frequently used journals/series,* number of publications 2009–2013. Department of Production and Quality Engineering.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Production Management	NTNU Engineering Series	15	Project and Quality	NTNU Engineering Series	5
	IFIP Advances in Information and Communication Technology	11		Project Management Journal	3
	IEEE International Conference on Industrial Engineering and Engineering Management	3		International Journal of Managing Projects in Business/Emerald	3
	Lean Management Journal	3	RAMS	Reliability Engineering & System Safety	14
Production Systems	NTNU Engineering Series	17		Journal of Risk and Reliability	5
	Expert systems with applications	4		Springer Series in Reliability Engineering	3
				Journal of Loss Prevention in the Process Industries	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.24 contains citation indicators of the department and its groups based on the journal articles (indexed in NCR) published in the period 2009–2012. It should be noted that only a small minority of the groups' publications have been published in NCR-indeed journals for which citation counts are available. It is therefore difficult to assess the performance of the groups using citation indicators. For most of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). Overall the publications are cited slightly below the field normalized world average (citation index 88) and significantly lower than the corresponding Norwegian average (index 120).

Table 4.3.24 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Production and Quality Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	36	128	11	97	88	103
Production Management	2	6	6	-	-	-
Production Systems	6	36	11	-	-	-
Project and Quality Management	9	16	9	-	-	-
RAMS	20	72	10	83	81	115

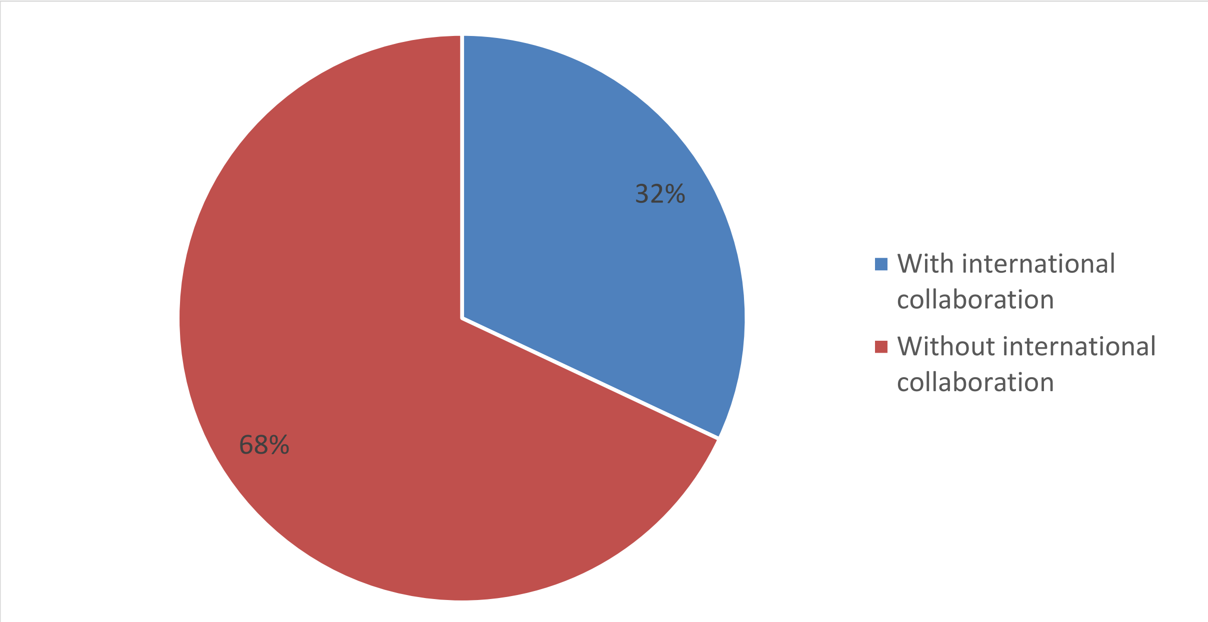
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 32 % of the four groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.15. In contrast, the average for all units included in the evaluation is 40 %. It should be noted again, that the analysis is based on the NCR-indexed publications (n=50), and only gives an indication of the extent of international collaboration.

Figure 4.3.15 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=50). Department of Production and Quality Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.3.9 Department of Structural Engineering

Figure 4.3.16 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Structural Engineering there are four research groups included in the evaluation: Biomechanics, Concrete, SIMLab, and Structural Mechanics. In total 28 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 271 publications have been published during the period 2009-2013 (cf. Table 4.3.25). This amounts to 5.1 % of the total publication output of the entire personnel included in the evaluation.

Table 4.3.25 Number of publications, 2009–2013, Department of Structural Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	28	271	82%
Biomechanics	3	30	80%
Concrete	7	66	74%
SIMLab	9	97	87%
Structural Mechanics	9	86	83%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, 82 % of the publications of the groups have been published in journals and regular publishing series. Table 4.3.26 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.3.26 The most frequently used journals/series,* number of publications 2009–2013. Department of Structural Engineering.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Bio-mechanics	Biomechanics and Modeling in Mechanobiology	4	SIMLab	International Journal of Material Forming	4
Concrete	Nordic Concrete Research	21		Computational materials science	4
	Cement and Concrete Research	7		International Journal of Solids and Structures	3
	Materials and Structures	6	Structural Mechanics	Trita-MEK	4
	Corrosion Science	3		Wood Science and Technology	4
SIMLab	International Journal of Impact Engineering	14		Engineering Fracture Mechanics	3
	European Journal of Mechanics. A, Solids	7		Engineering structures	3
	Materials & design	6		International Journal of Solids and Structures	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.3.27 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the four groups together, the field normalized citation rate is 106. In other words, the articles are cited slightly above the world average but below the national average for all groups (120).

It should be noted, however, that only a limited part of the publications are indexed in NCR (127 articles, excluding 2013). The research group Concrete performs better than the other groups in terms of citation rates with a field normalised citation index of 149, but the calculation is based on a very small number of articles. Next follows the SIMLab group with a field normalised index of 119, on par with the national average.

Table 4.3.27 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Structural Engineering.

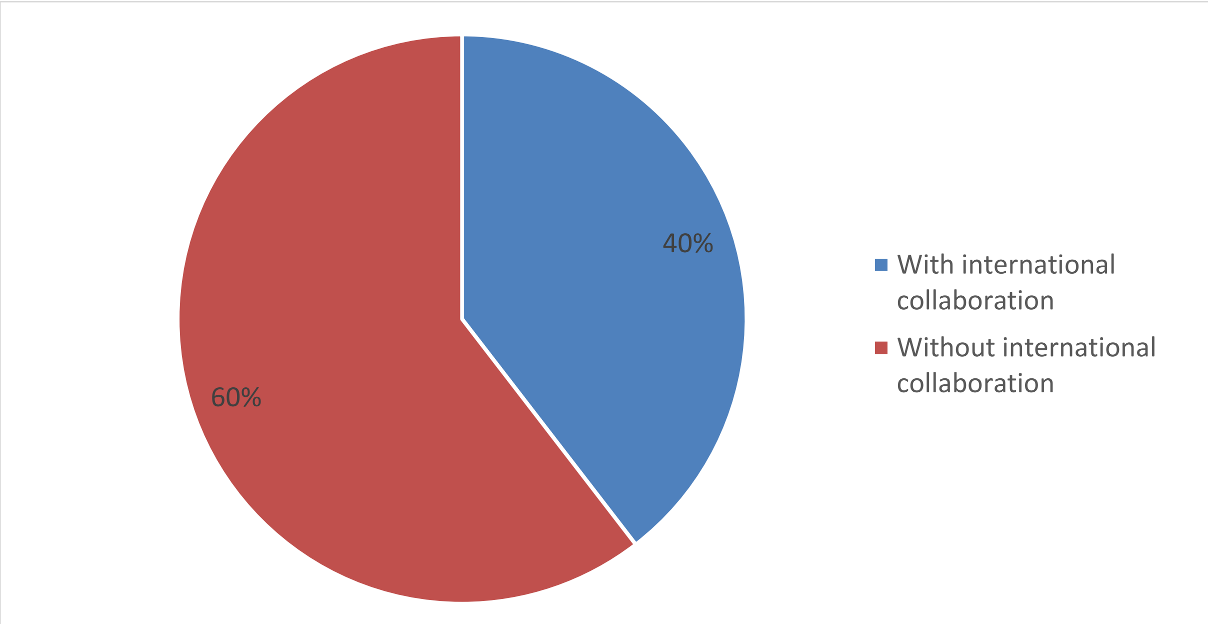
Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	127	662	36	105	106	110
Biomechanics	19	116	23	96	85	100
Concrete	10	58	18	147	149	118
SIMLab	62	360	36	115	119	109
Structural Mechanics	42	157	18	79	79	116

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.
1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 40 % of the four groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.3.17. The proportion is identical with the average for all units included in the evaluation. The analysis is based on the NCR-indexed publications only (n=177), and gives an indication of the extent of international collaboration.

Figure 4.3.17 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 177). Department of Structural Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

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

One department from the Faculty of Information Technology, Mathematics and Electrical Engineering (NTNU) is included in the evaluation: Department of Electric Power Engineering.

4.4.1 Department of Electric Power Engineering

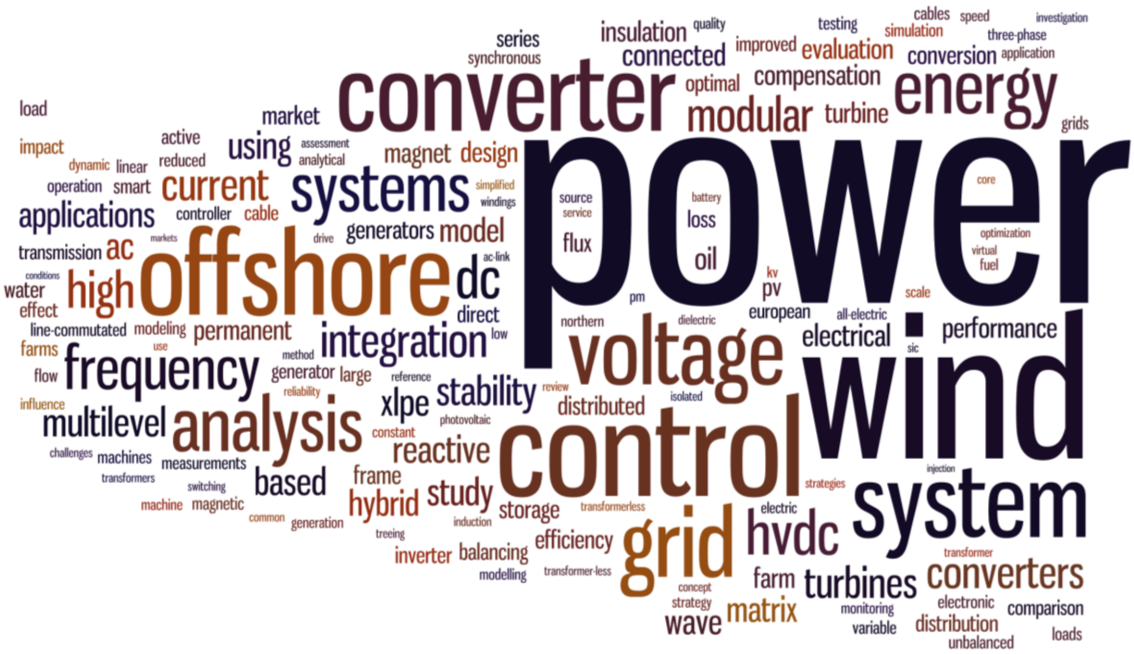


Figure 4.4.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Electric Power Engineering there are four research groups included in the evaluation: Electric Energy Conversion; Electric Power Systems; and Electric Power Technology. In total 21 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 346 publications have been published during the period (cf. Table 4.4.1). This amounts to 6.5 % of the total publication output of the personnel included in the evaluation. In contrast, the proportion of the included researchers is 3.4 %, which indicates that the productivity of the department is very high. The group Electric Power Systems is the largest in terms of publication volume with 185 articles.

Table 4.4.1 Number of publications, 2009–2013, Department of Electric Power Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	21	346	50%
Electric Energy Conversion	4	106	38%
Electric Power Systems	11	185	52%
Electric Power Technology	6	83	58%

Data: CRIStin. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Only 50 % of the publications appear in journals and regular series, with some variations across the groups. Table 4.4.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.4.2 The most frequently used journals/series,* number of publications 2009–2013. Department of Electric Power Engineering.

Unit	Journal/series	No. of articles
Electric Energy Conversion	Energy Procedia	5
	IEEE Industrial Electronics Society. Annual Conference. Proceedings	4
	Applied Mechanics and Materials	3
	IEEE transactions on power electronics	3
Electric Power Systems	Energy Procedia	10
	IEEE Power & Energy Society General Meeting	10
	Conference record of the Photovoltaic Specialists Conference	9
	IEEE transactions on industrial electronics	8
	IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies	7
	Electric power systems research	5
	IEEE Industrial Electronics Society. Annual Conference. Proceedings	5
	The Renewable Energies and Power Quality Journal	4
	Energies	3
	Annual Conference of the IEEE Industrial Electronics Society	3
	IEEE Transactions on Sustainable Energy	3
Electric Power Technology	IEEE Transactions on Power Delivery	8
	Conference on Electrical Insulation and Dielectric Phenomena. Annual Report	7
	IEEE transactions on dielectrics and electrical insulation	4
	Conference record of IEEE International Symposium on Electrical Insulation	3
	Energy Procedia	3

*) Limited to journals with at least three publications during the time period.

Table 4.4.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the three groups together, the field normalized citation rate is 145. In other words, the articles are cited 45 % above the world average. This citation rate is also higher than the national average for all groups included in the evaluation, which is 120. It should be noted, however, that only a very small fraction of the publications are indexed in NCR (49 articles, excluding 2013). The Electric Power Systems group performs very well in terms of citation rates with a field normalised citation index of 217, and one article particularly highly cited (Overview of Multi-MW Wind Turbines and Wind Parks. *Published in IEEE transactions on industrial electronics*, 2011). Also the Electric Energy Conversion groups obtains high citation indexes, while the indexes are rather low for the Electric Power Technology group.

Table 4.4.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Electric Power Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	49	203	56	98	145	136
Electric Energy Conversion	12	64	16	117	163	168
Electric Power Systems	22	128	56	101	217	183
Electric Power Technology	20	42	11	82	58	77

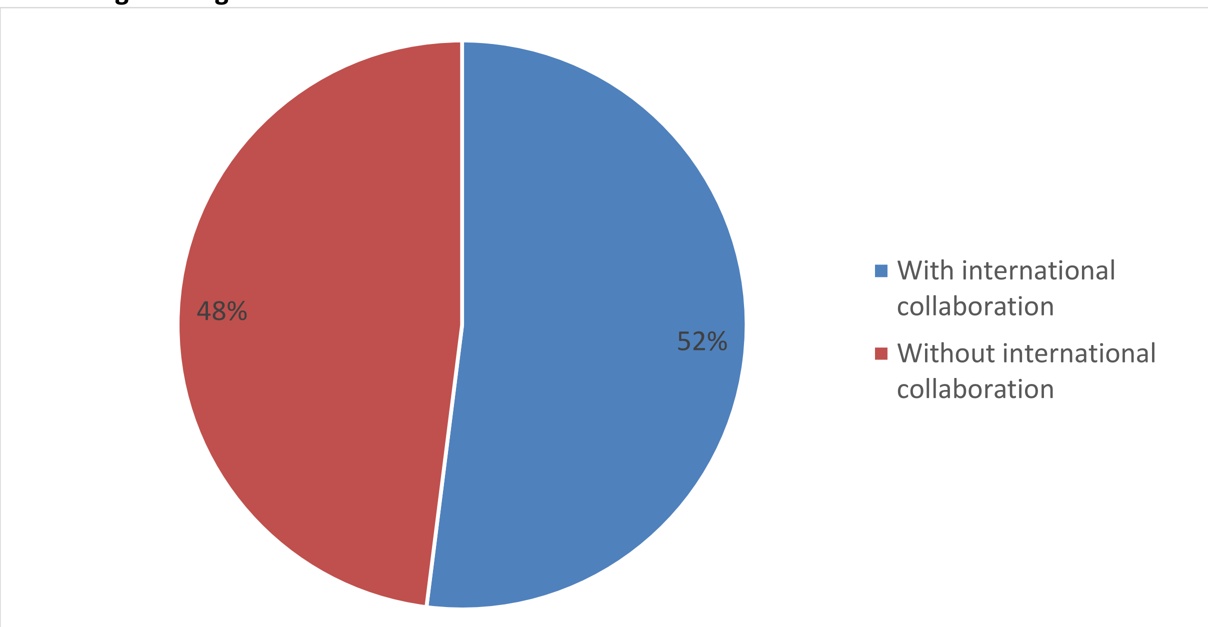
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 52 % of the three groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.4.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=75), and gives an indication of the extent of international collaboration.

Figure 4.4.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=75). Department of Electric Power Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.5 Norwegian University of Science and Technology – Faculty of Natural Sciences and Technology

One department from the Faculty of Natural Sciences and Technology (NTNU) is included in the evaluation: Department of Material Science and Engineering.

4.5.1 Department of Material Science and Engineering

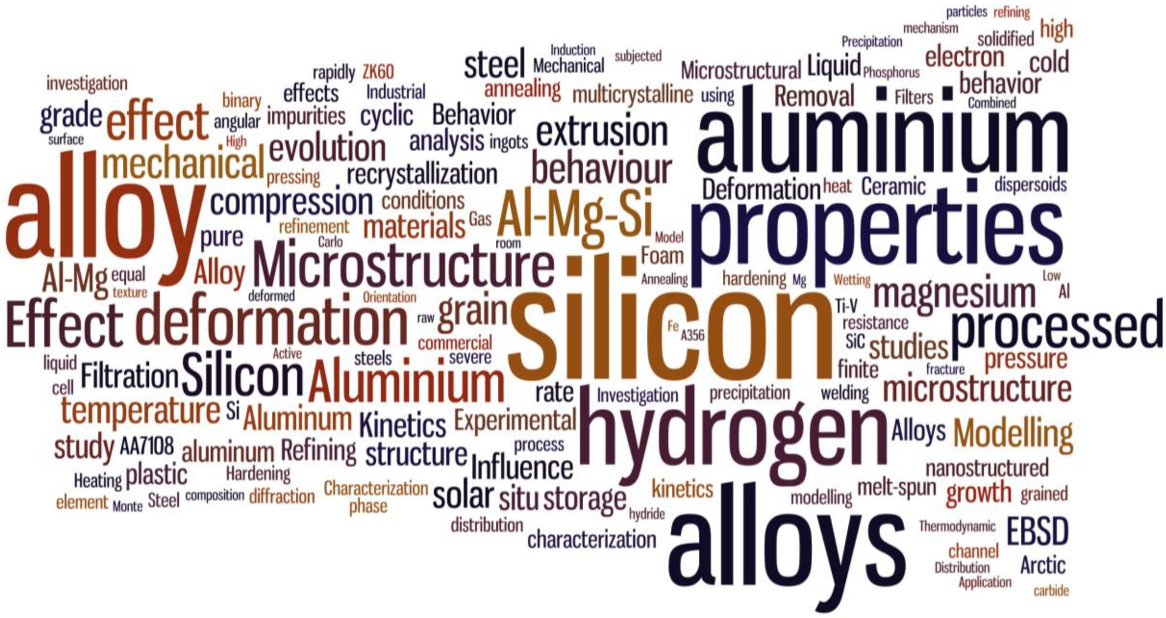


Figure 4.5.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Material Science and Engineering there are two research groups included in the evaluation: Physical Metallurgy and Process Metallurgy. In total 15 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 222 publications have been published during the period 2009-2013 (cf. Table 4.5.1). This amounts to 4.2 % of the total publication output of the entire personnel included in the evaluation. In contrast, the proportion of the included researchers is 2.4 %, which indicates that the productivity of the department is very high. The group Physical Metallurgy is the largest both in terms of personnel included and publication volume (162 articles).

Table 4.5.1 Number of publications, 2009–2013, Department of Material Science and Engineering

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	15	222	91%
Physical Metallurgy	11	162	94%
Process Metallurgy	4	62	85%

Data: CRIStin. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

The large majority of the publications of the two groups have been published in journals and regular publishing series (91 %). Table 4.5.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.5.2 The most frequently used journals/series,* number of publications 2009–2013. Department of Material Science and Engineering.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Physical Metallurgy	Materials Science Forum	16	Physical Metallurgy	Journal of Materials Processing Technology	3
	Materials Science & Engineering: A	14		ISIJ International	3
	Journal of Alloys and Compounds	13		International Journal of Materials Research - Zeitschrift für Metallkunde	3
	Transactions of Nonferrous Metals Society of China	11		Materials & design	3
	International journal of hydrogen energy	8	Process Metallurgy	Metallurgical and materials transactions. B, process metallurgy and materials processing science	13
	ISOPE - International Offshore and Polar Engineering Conference. Proceedings	6		JOM: The Member Journal of TMS	6
	Metallurgical and Materials Transactions. A	6		ISIJ International	4
	Acta Materialia	5		Light Metals	4
	Journal of Crystal Growth	4		Steel Research International	3
	Journal of Materials Science	4		Materials transactions	3
	Philosophical Magazine	3		Transactions of Nonferrous Metals Society of China	3
	Scripta Materialia	3			

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.5.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the two groups together, the field normalized citation rate is 84. This means that the articles have cited approximately 20 % below the world average and significantly below the national average for all groups included in the evaluation, which is 120. The Physical Metallurgy group performs slightly better than the Process Metallurgy group with a field normalised citation index of 91. The journals used for publications have somewhat lower impact factors than average, therefore the groups perform better using a journal normalised citation index (cf Method section), this particularly holds for the Process Metallurgy group.

Table 4.5.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Material Science and Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	124	566	29	123	84	89
Physical Metallurgy	89	469	29	120	91	96
Process Metallurgy	37	106	14	131	70	71

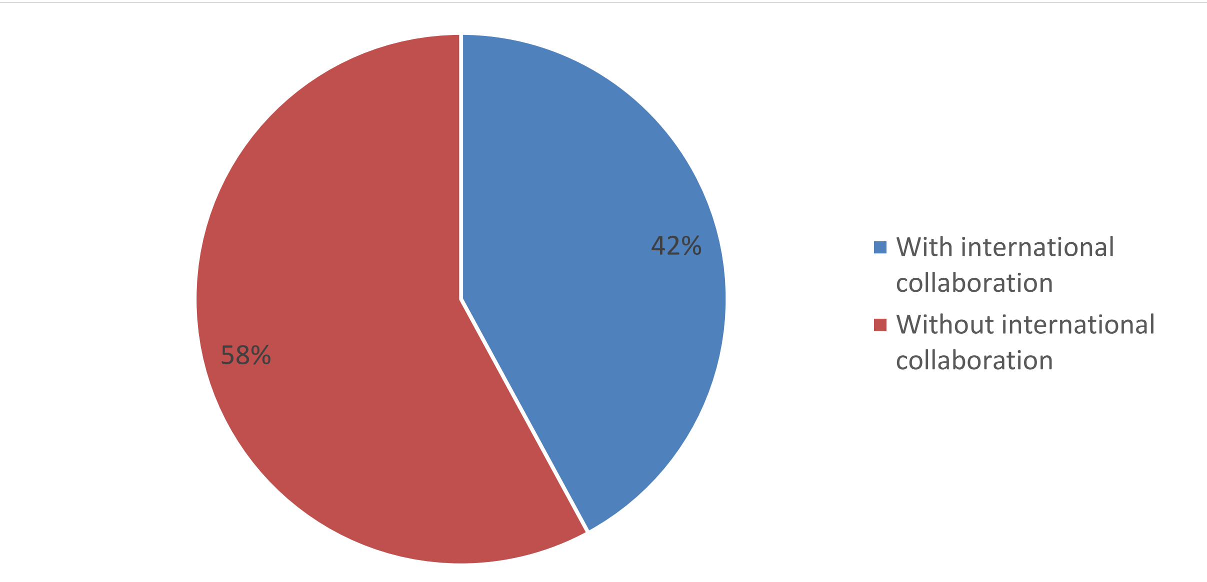
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 42 % of the two groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.5.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=162), and gives an indication of the extent of international collaboration.

Figure 4.5.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 162). Department of Material Science and Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.6 Telemark University College

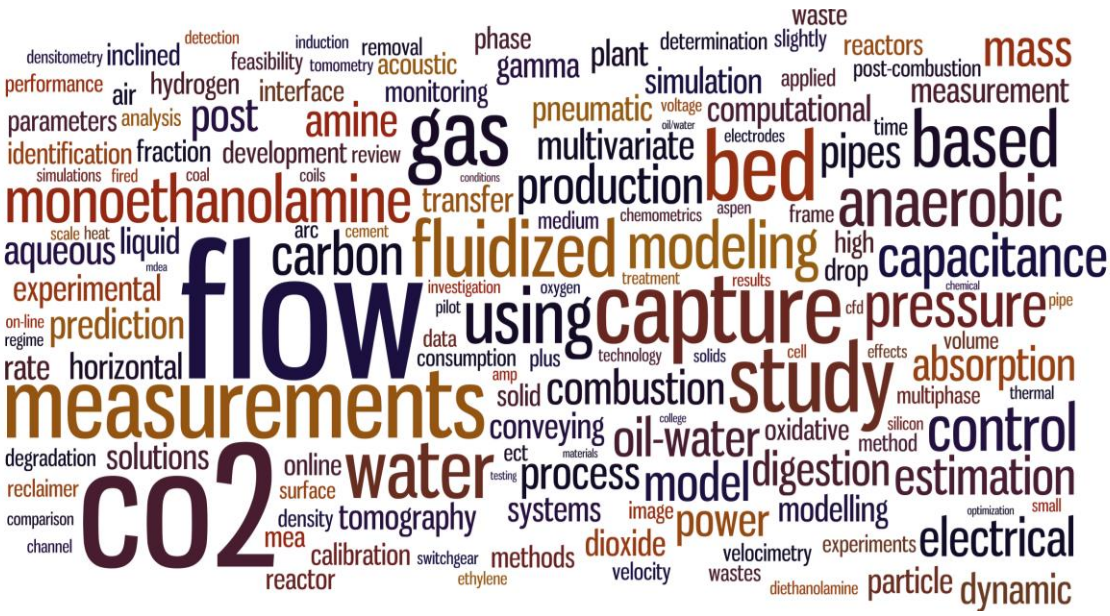


Figure 4.6.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Telemark University College there is one research group included in the evaluation: Process- Energy and Automation Engineering (PEAE). In total 15 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 165 publications have been published during the period 2009-2013 (cf. Table 4.6.1). This amounts to 3.1 % of the total publication output of the entire personnel included in the evaluation.

Table 4.6.1 Number of publications, 2009–2013, PEAE (Process- Energy and Automation Engineering).

Unit	Number of persons included	Total number of publications	Publications in journals/series*
PEAE (Process- Energy and Automation Engineering)	15	165	82%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, 82 % of the publications of the group have been published in journals and regular publishing series. Table 4.6.2 gives the most frequently used journals and series for the group – limited to journals with at least three publications during the period 2009-2013.

Table 4.6.2 The most frequently used journals/series,* number of publications 2009–2013, PEAE (Process- Energy and Automation Engineering).

Journal/series	No. of articles	Journal/series	No. of articles
Energy Procedia	23	Flow Measurement and Instrumentation	4
Modeling, Identification and Control	9	International Journal of Greenhouse Gas Control	3
WIT Transactions on Engineering Series	7	Measurement Science and Technology	3
The International Journal of Energy and Environment	6	Water Science and Technology	3
Powder Technology	6	Journal of Chemometrics	3
Journal of Chemical and Engineering Data	6	International Journal of Multiphase Flow	3
Industrial & Engineering Chemistry Research	6	Particulate Science and Technology	3
European Journal of Scientific Research	4		

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.6.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. The field normalized citation rate is 72. In other words, the articles are cited approximately 30 % below the world average. This citation rate is also significantly lower than the national average for all groups included in the evaluation, which is 120. It should be noted, however, that only a minor fraction of the publications are indexed in NCR (53 articles, excluding 2013).

Table 4.6.3 Citation indicators, 2009–2012 publications indexed in NCR.* PEAE (Process- Energy and Automation Engineering).

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
PEAE (Process- Energy and Automation Engineering	53	169	33	101	72	88

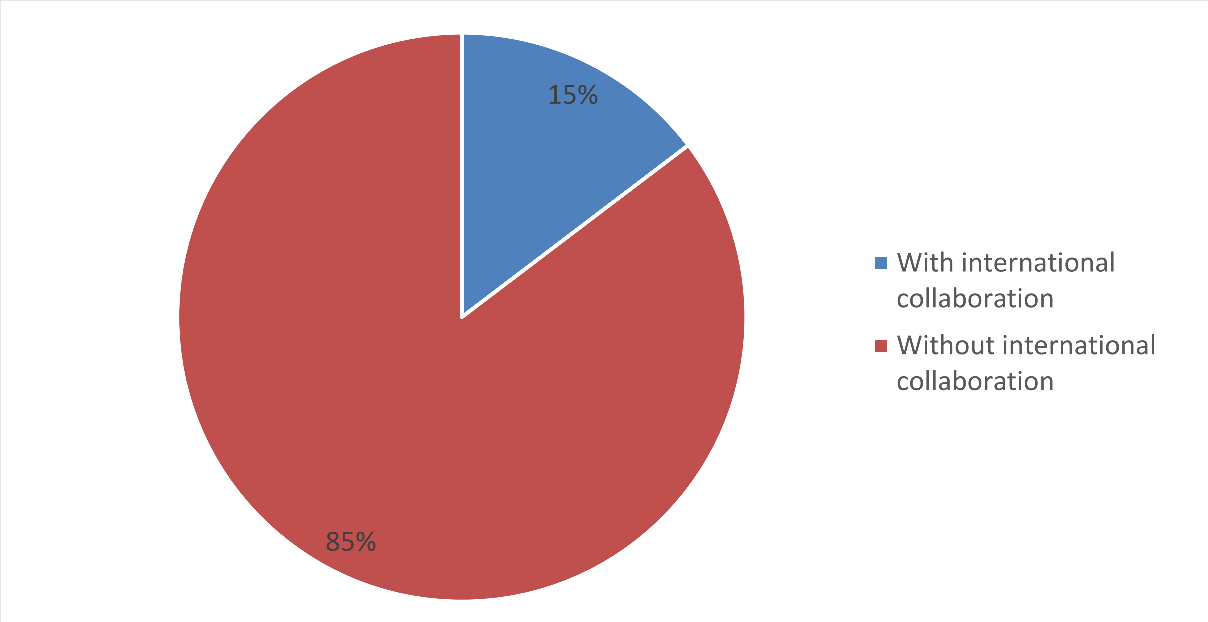
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 15 % of the group’s publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.6.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=75), and gives an indication of the extent of international collaboration.

Figure 4.6.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 75). PEAE (Process- Energy and Automation Engineering).



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.7 University of Agder

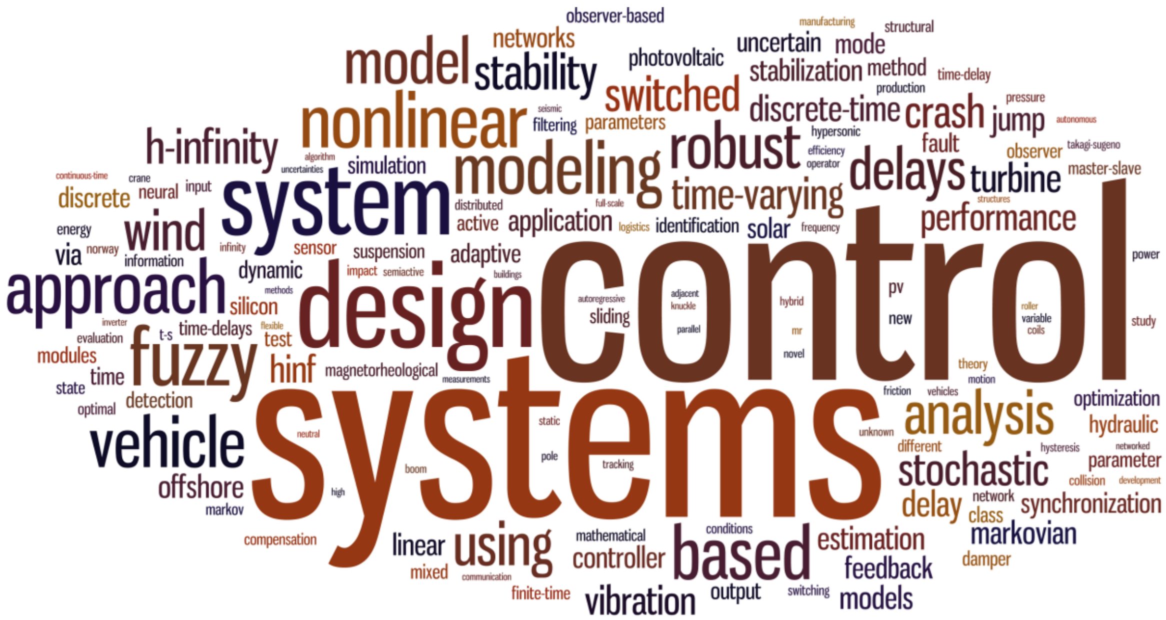


Figure 4.7.1 Most frequently appearing words in the included publication titles, 2011-2013.
Data: CRIStin. Calculations: NIFU.

There are three research groups at Department of Engineering Sciences Engineering at the University of Agder included in the evaluation: Civil Engineering and Offshore Construction; Mechatronics, and Renewable Energy. In total 32 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Table 4.7.1 shows publication indicators for the department and its research groups. In the period 2009-2013, more than 500 publications have been published by the personnel encompassed in the evaluation. This amounts to 9.6 % of the total publication output of the entire personnel included in the evaluation. In contrast, the proportion of the included researchers is 5.2 %, which indicates that the productivity is very high. There are, however, very large differences in the productivity across the research groups. While the personnel at the Mechatronics group are highly prolific, the Civil Engineering and Offshore Construction group only contributes with a few publications.

Table 4.7.1 Number of publications, 2009–2013, Department of Engineering Sciences.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	32	508	70%
Civil Engineering and Offshore Construction	7	12	50%
Mechatronics	10	417	72%
Renewable Energy	15	80	64%

Data: CRIStin. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, 70 % of the publications of the groups have been published in journals and regular publishing series. Table 4.7.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2009-2013. Therefore, for one of the groups there are no journals listed. As can be seen, The Mechatronics group has a very large number of publications in the journal *Mathematical problems in engineering* (71).

Table 4.7.2 The most frequently used journals/series,* number of publications 2009–2013. Department of Engineering Sciences.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Mecha-tronics	Mathematical problems in engineering (Print)	71	Mecha-tronics	IEEE conference proceedings	4
	Modeling, Identification and Control	19		International Journal of Wavelets, Multiresolution & Information Proce	4
	Abstract and Applied Analysis	16		WSEAS Transactions on Applied and Theoretical Mechanics	3
	International Journal of Control Theory and Applications (IJCTA)	12		Information Sciences	3
	Journal of the Franklin Institute	11		Mechatronics (Oxford)	3
	The International Journal of Advanced Manufacturing Technology	7		Annual Conference of the IEEE Industrial Electronics Society	3
	Journal of Applied Mathematics	6		Neurocomputing	3
	American Control Conference (ACC)	6		Proceedings of the institution of mechanical engineers: journal of systems and control engineering	3
	international journal of systems science	6		International Journal of Robust and Nonlinear Control	3
	Elsevier IFAC Publications / IFAC Proceedings series	6	Rene-wable Energy	Conference record of the Photovoltaic Specialists Conference	18
	IEEE Transactions on Magnetics	5		Journal of Electronic Materials	3
	ISOPE - International Offshore and Polar Engineering Conference. Proceedings	4		Renewable Energy	3
	IEEE transactions on industrial electronics	4		International Journal of Hydrogen Energy	3
	IEEE transactions on fuzzy systems	4			

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

We have also analysed the citation rate of the journal publications (indexed in NCR). The results are given in Table 4.7.3. The publications of the Mechatronics group are highly cited and the group obtains a field normalized citation index of 182, meaning that the articles are cited 82 % more than the corresponding world average. One article is particularly highly cited (New Delay-Dependent Exponential H-infinity Synchronization for Uncertain Neural Networks With Mixed Time Delays, *IEEE Transactions on Systems Man and Cybernetics Part B – Cybernetics,* 2010). Also the Renewable Energy group obtains a field normalised citation index clearly above the world average (131). It should be noted, however, that the calculations are based on a limited number of articles and one highly cited article accounts for a large proportion of the citations (Review of gas diffusion cathodes for alkaline fuel cells, *Journal of Power Sources*, 2009). For the Civil Engineering and Offshore Construction group we have not calculated relative citation indexes due to the small number of articles (cf. Method section).

Table 4.7.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Engineering Sciences.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	104	611	89	174	172	94
Civil Engineering and Offshore Construction	3	10	5	-	-	-
Mechatronics	84	398	89	186	182	89
Renewable Energy	18	203	81	125	131	114

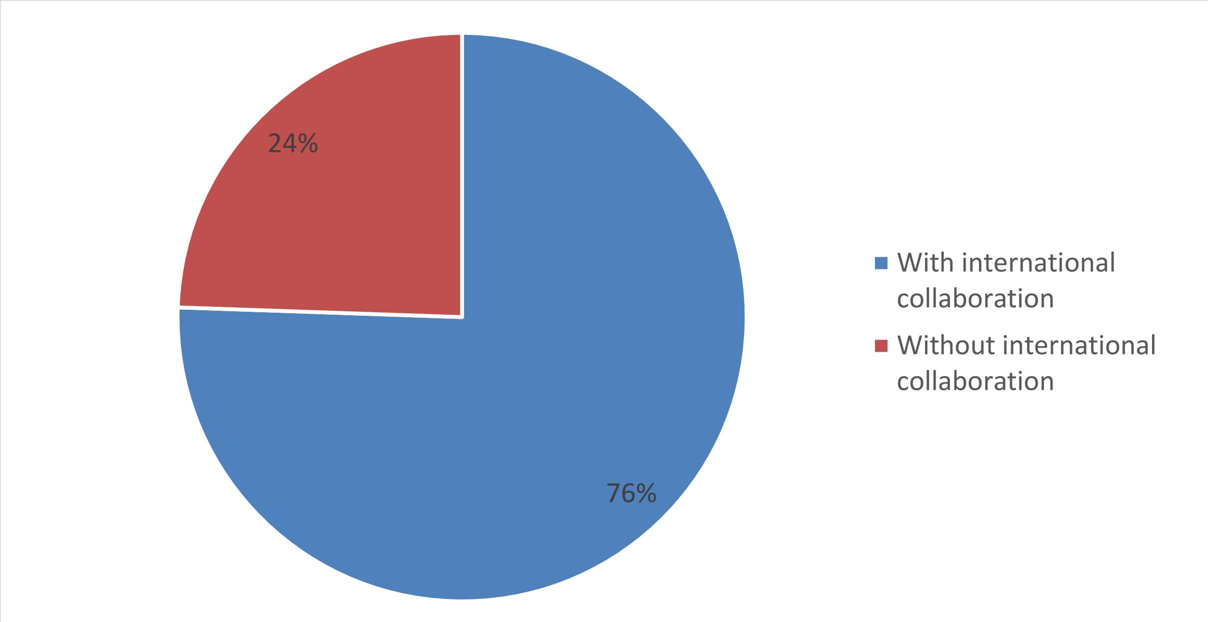
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

A large proportion of the groups' publications have been co-authored in collaboration with scientists from other countries (76%). This is shown in Figure 4.7.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=229), and gives an indication of the extent of international collaboration.

Figure 4.7.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 229). Department of Engineering Sciences.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.8 University of Bergen

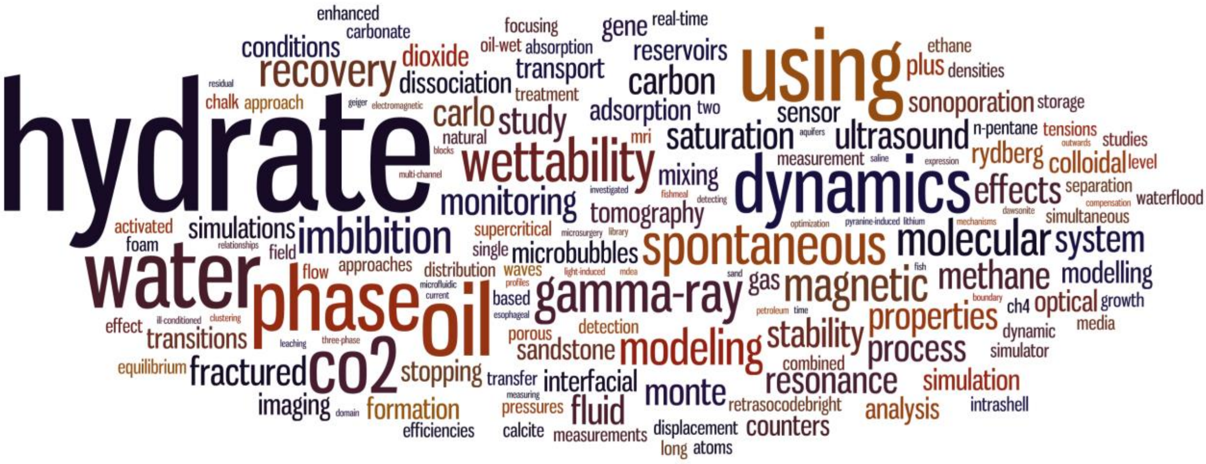


Figure 4.8.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the University of Bergen, the evaluation encompasses three research groups at the Department of Physics and Technology: Acoustics; Measurement science and instrumentation; and Petroleum- and process technology. In total 10 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 83 publications have been published during the period 2009-2013 (cf. Table 4.8.1). This amounts to 1.6 % of the total publication output of the entire personnel included in the evaluation.

Table 4.8.1 Number of publications, 2009–2013, Department of Physics and Technology.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	10	83	100%
Acoustics	2	11	100%
Measurement science and instrumentation	3	28	100%
Petroleum- and process technology	5	44	100%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

All the publications of the groups have been published in journals and regular publishing series. Table 4.8.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013. Therefore, for one of the groups there are none journals listed.

Table 4.8.2 The most frequently used journals/series,* number of publications 2009–2013. Department of Physics and Technology.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Measurement Science and instrumentation	Measurement science and technology	8	Petroleum- and process technology	Energy & Fuels	5
	Nuclear Instruments and Methods in Physics Research Section A	3		Physical Chemistry, Chemical Physics - PCCP	4
	Physical Review A. Atomic, Molecular, and Optical Physics	3		Energy Procedia	4
Petroleum- and process technology	Journal of Petroleum Science and Engineering	6		Journal of Mathematical Chemistry	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.8.3 contains some citation indicators for the research groups based on the journal articles (indexed in NCR) published in the period 2009–2012. However, for one of the groups (Aqoustics), we have not calculated relative citation indexes due to the small number of journal articles (cf. Method section). The two other groups have low scores in terms of citations. The Petroleum- and process technology group obtains a field normalised citation index of 64, while the corresponding figure for the Measurement science and instrumentation group is 38.

Table 4.8.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Physics and Technology.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	65	186	18	68	56	96
Acoustics	5	27	16	-	-	-
Measurement Science and instrumentation	26	35	4	54	38	97
Petroleum- and process technology	34	124	18	71	64	96

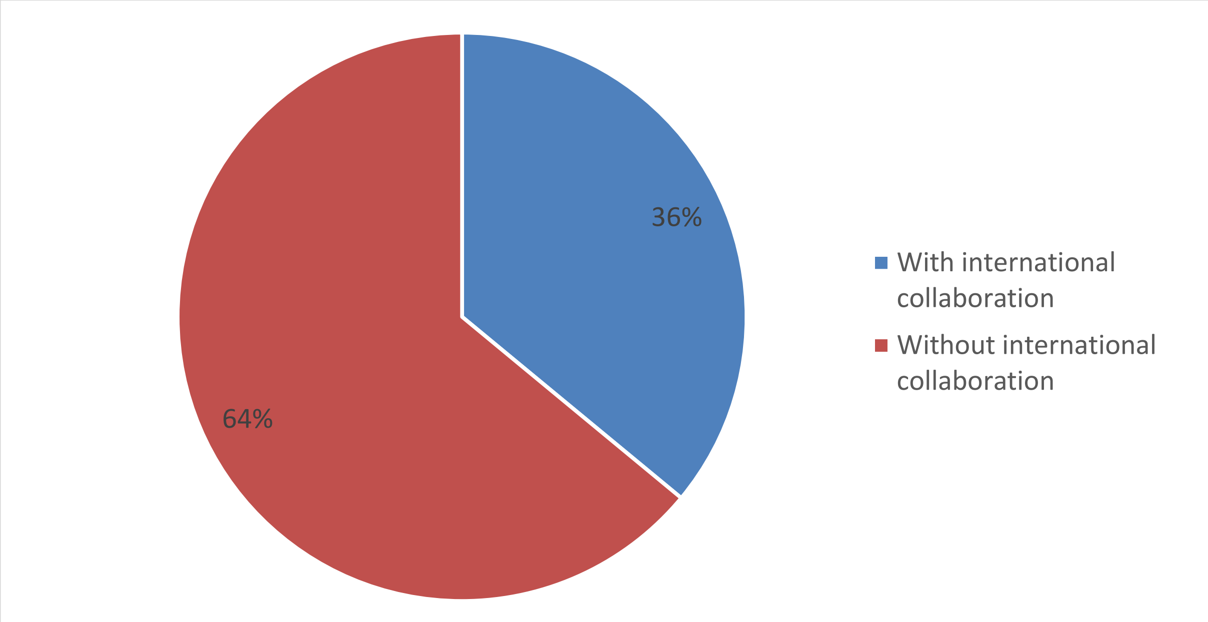
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 36 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.8.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=75), and gives an indication of the extent of international collaboration.

Figure 4.8.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 75). Department of Physics and Technology.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.9 University of Stavanger

There are research groups from two departments at the University of Stavanger included in the evaluation:

- Department of Mechanical and Structural Engineering and Materials Science
- Department of Petroleum Engineering

The two sections below contain the results of the analysis of these departments.

4.9.1 Department of Mechanical and Structural Engineering and Materials Science

Figure 4.9.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

There are three research groups at Department of Mechanical and Structural Engineering and Materials Science included in the evaluation: Civil Structural Engineering, Mechanical Engineering and Materials Science and Offshore Technology. In total 11 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Table 4.9.1 shows publication indicators for the research groups. In the period 2009-2013, more than 220 publications have been published. This amounts to 4.3 % of the total publication output of the entire personnel included in the evaluation. In contrast, the proportion of the included researchers is 1.8 %, which indicates that the productivity is very high. There are, however, very large differences in the productivity across the research groups and particularly the Offshore Technology group is highly prolific with almost 170 publications.

Table 4.9.1 Number of publications, 2009–2013, Department of Mechanical and Structural Engineering and Materials Science.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	11	229	68%
Civil Structural Engineering	3	21	67%
Mechanical Engineering and Materials Science	5	61	75%
Offshore Technology	3	169	64%

Data: CRIStin. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately two thirds of the publications of the groups have been published in journals and regular publishing series. Table 4.9.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.9.2 The most frequently used journals/series*, number of publications 2009–2013. Department of Mechanical and Structural Engineering and Materials Science.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Civil Structural Engineering	International Conference on Offshore Mechanics and Arctic Engineering	3	Offshore Technology	Journal of Quality in Maintenance Engineering	9
Mechanical Engineering and Materials Science	IEEE International Conference on Industrial Engineering and Engineering Management	11		International Journal of Systems Assurance Engineering and Management	9
	NTNU Engineering Series	4		ISOPE - International Offshore and Polar Engineering Conference. Proceedings	9
	IFIP Advances in Information and Communication Technology	3		Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions	3
	International Conference on Offshore Mechanics and Arctic Engineering	3		International Journal of Sustainable Strategic Management (IJSSM)	3
Offshore Technology	International Conference on Offshore Mechanics and Arctic Engineering	23		Reliability Engineering & System Safety	3
	IFIP Advances in Information and Communication Technology	10			

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.9.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. The field normalized citation rate is 74. In other words, the articles are cited approximately 30 % below the world average. This citation rate is also significantly lower than the national average for all groups included in the evaluation, which is 120. It should be noted however, that only a very small fraction of the publications are indexed in NCR (14 articles, excluding 2013) and for two of the groups, we have not calculated relative citation indexes due to the small number of journal articles (cf. Method section).

Table 4.9.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Mechanical and Structural Engineering and Materials Science.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	14	42	9	82	74	106
Civil Structural Engineering	4	11	7	-	-	-
Mechanical Engineering and Materials Science	2	10	9	-	-	-
Offshore Technology	10	29	7	70	70	110

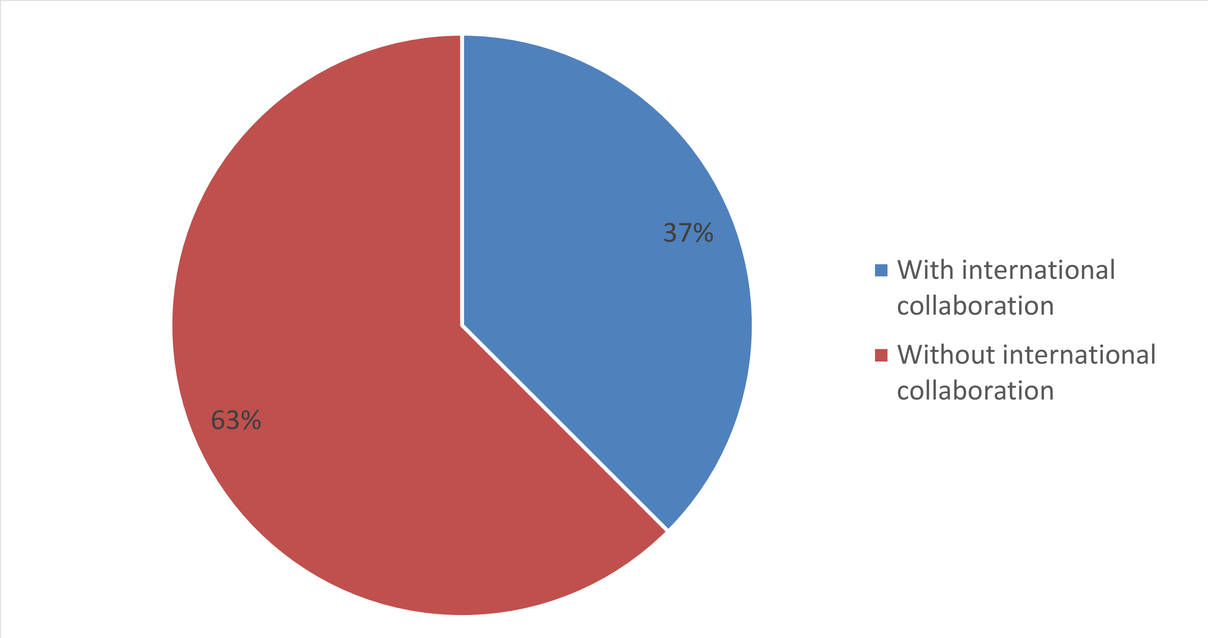
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 37 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.9.2. In contrast, the average for all units included in the evaluation is 40 %. It should be noted again, that the analysis is based on the NCR-indexed publications (n=24), and only gives an indication of the extent of international collaboration.

Figure 4.9.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=24). Department of Mechanical and Structural Engineering and Materials Science.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.9.2 Department of Petroleum Engineering

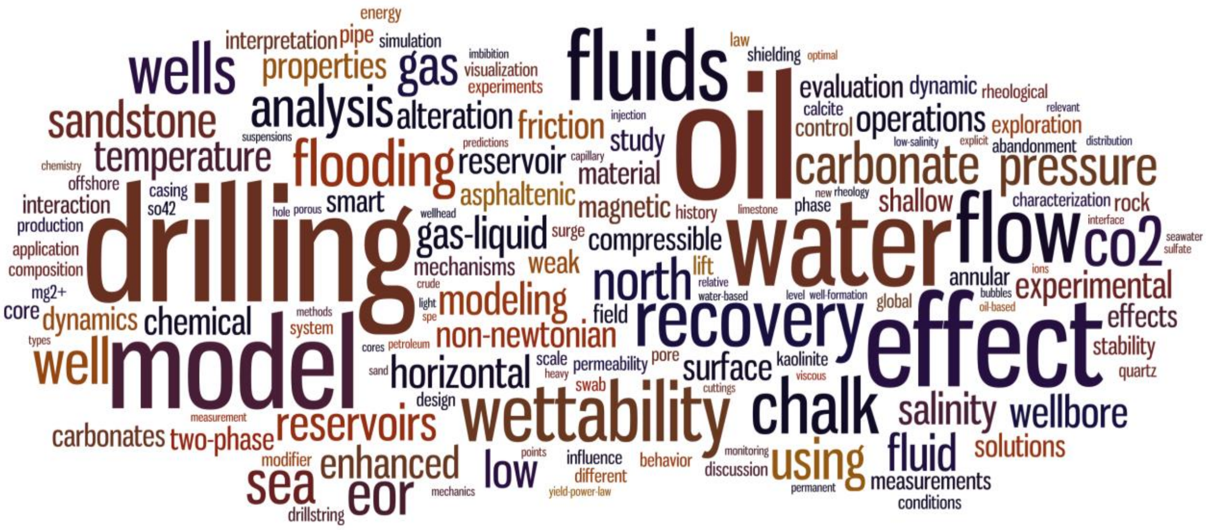


Figure 4.9.3 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Petroleum Engineering there are three research groups included in the evaluation: Drilling and Well, Natural Gas Technology and Reservoir Technology. In total 15 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 145 publications have been published during the period (cf. Table 4.9.4). This amounts to 2.7 % of the total publication output of the personnel included in the evaluation.

Table 4.9.4 Number of publications, 2009–2013, Department of Petroleum Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	15	145	68%
Drilling and Well	4	57	49%
Natural Gas Tech	3	34	74%
Reservoir Tech	8	54	83%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately two thirds of the publications of the groups have been published in journals and regular publishing series. Table 4.9.5 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.9.5 The most frequently used journals/series,* number of publications 2009–2013. Department of Petroleum Engineering.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Drilling and Well	SPE drilling & completion	7	Reservoir Tech	Energy & Fuels	12
	Annual Transactions - The Nordic Rheology Society	3		Journal of petroleum science and engineering	4
	International Conference on Offshore Mechanics and Arctic Engineering	3		SIAM Journal on Mathematical Analysis	3
Natural Gas Tech	Annual Transactions - The Nordic Rheology Society	9			

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.9.6 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. Overall, the field normalized citation rate is 84. In other words, the articles are cited approximately 20 % below the world average. This citation rate is also significantly lower than the national average for all groups included in the evaluation, which is 120. There are, however, large differences across the groups. The Reservoir Technology group contributes to most of the citations and has a field normalised citation index of 124. It should be noted that only a minority of the groups' publications have been published in NCR-indexed journals for which citation counts are available, and for one of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section).

Table 4.9.6 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Petroleum Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	57	183	23	100	84	88
Drilling and Well	16	11	2	103	37	52
Natural Gas Tech	9	14	7	-	-	-
Reservoir Tech	32	158	23	119	124	106

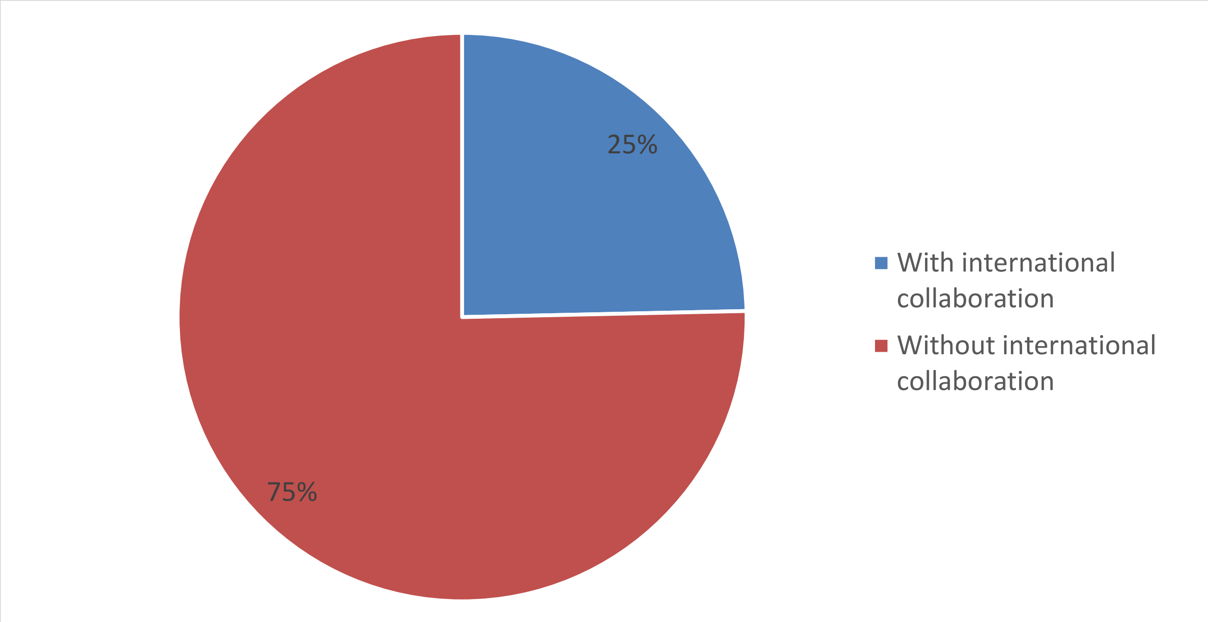
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 25 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.9.4. In contrast, the average for all units included in the evaluation is 40 %. It should be noted again, that the analysis is based on the NCR-indexed publications (n=73), and only gives an indication of the extent of international collaboration.

Figure 4.9.4 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 73). Department of Petroleum Engineering.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.10 University of Tromsø

Figure 4.10.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At the Department of Engineering and Safety at the University of Tromsø there is one research group included in the evaluation: Safety and Environment. In total 12 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 43 publications have been published during the period (cf. Table 4.10.1). This amounts to 0.8 % of the total publication output of the personnel included in the evaluation.

Table 4.10.1 Number of publications, 2009–2013, Department of Engineering and Safety.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
Safety and Environment	12	43	84%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, 84 % of the publications of the group have been published in journals and regular publishing series. Table 4.10.2 gives the most frequently used journals and series for the group – limited to journals with at least three publications during the period 2009-2013.

Table 4.10.2 The most frequently used journals/series,* number of publications 2009–2013. Department of Engineering and Safety.

Unit	Journal/series	No. of articles
Safety and Environment	Reliability Engineering & System Safety	3
	International Journal of Performability Engineering	3
	International Journal of Systems Assurance Engineering and Management	3

Data: CRIStin. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Only a minority of the publications appear in NCR-journals for which citation counts are available. Table 4.10.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. Overall, the field normalized citation rate is 74. In other words, the articles are cited approximately 25 % below the world average. However, it should be noted that the citation analysis is based on 11 articles, only, which limits the reliability of the citation indicators.

Table 4.10.3 Citation indicators, 2009–2012 publications indexed in NCR.* Department of Engineering and Safety.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
Safety and Environment	11	31	11	70	74	117

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

4.11 Østfold University College

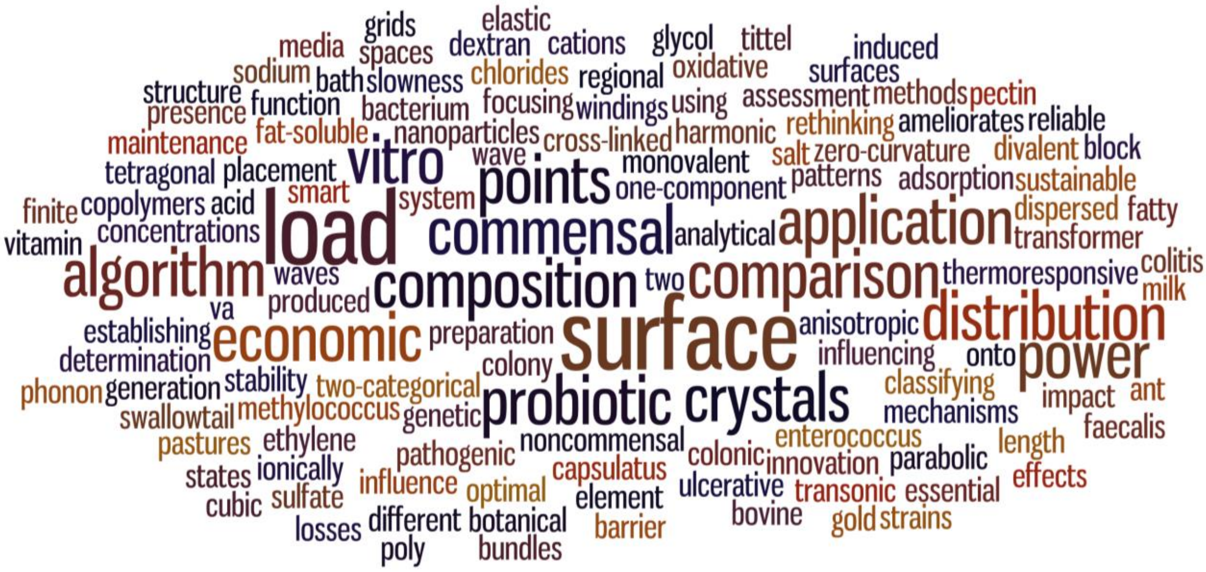


Figure 4.11.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin. Calculations: NIFU.

At Østfold University College, there are three research groups at the Faculty of Engineering included in the analysis: Biomedical technology; Innovation process and online teaching; and Smart Energy (there are two additional groups which are not included in the publication analysis). In total, 13 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institution are included (cf. the Method section).

Altogether, 17 publications have been published during the period (cf. Table 4.11.1).

Table 4.11.1 Number of publications, 2009–2013, Faculty of Engineering.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	13	17	88%
Biomedical technology	4	4	100%
Innovation process and online teaching	3	3	67%
Smart Energy	5	9	78%

Data: CRIStin. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Only a few of the articles have been published in NCR-indexed journals (cf. Table 4.11.2), therefore citation indicators and indicators of international collaboration have not been calculated.

Table 4.11.2 Citation indicators, 2009–2012 publications indexed in NCR.* Faculty of Engineering.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal	Citation index – field	Journal profile
TOTAL	5	6	3	-	-	-

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

4.12 Institute for Energy Technology

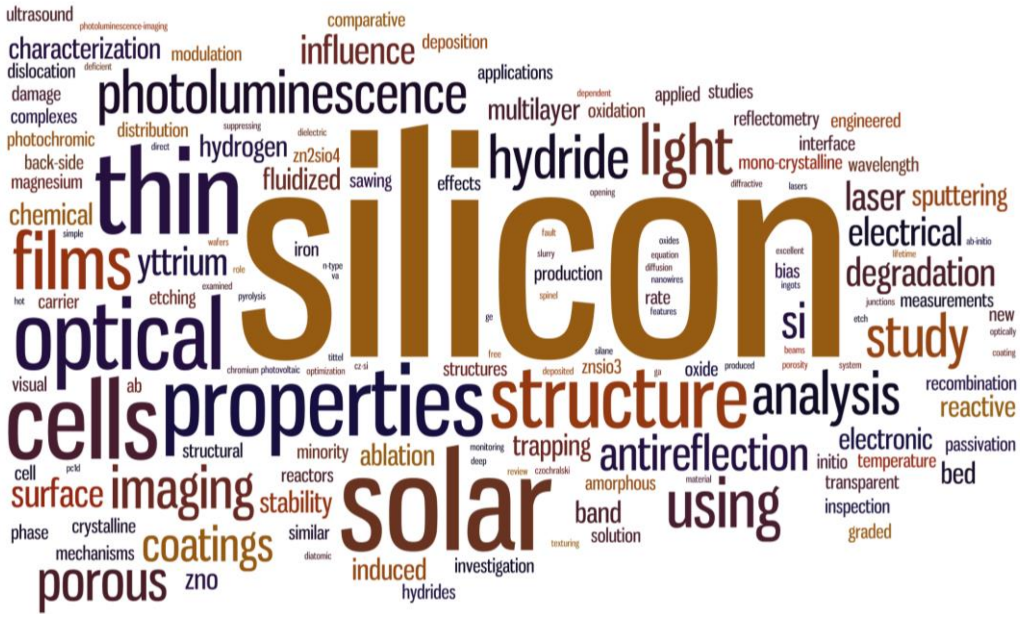


Figure 4.12.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

At the Institute for Energy Technology (IFE) there is one research unit included in the evaluation: Solar Energy Department. In total 8 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Altogether, 69 publications have been published during the period (cf. Table 4.12.1).

Table 4.12.1 Number of publications, 2009–2013, Institute for Energy Technology (IFE).

Unit	Number of persons included	Total number of publications	Publications in journals/series*
Solar Energy Dep	8	69	94%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Almost all the publications of the group have been published in journals and regular publishing series (94 %). Table 4.12.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013

Table 4.12.2 The most frequently used journals/series,* number of publications 2009–2013. Institute for Energy Technology (IFE).

Unit	Journal/series	No. of articles
Solar Energy Dep	Energy Procedia	12
	Journal of applied physics	10
	Solar energy materials and solar cells	5
	Thin solid films	5
	Journal of Alloys and Compounds	3
	Physica Status Solidi. C, Current topics in solid state physics	3

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.12.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. It should be noted that the citation analysis is based on 34 articles, only. The field normalized citation rate is 77. In other words, the articles are cited approximately 20 % below the world average. The citation rate is also clearly below the national average for all groups included in the evaluation, which is 120.

Table 4.12.3 Citation indicators, 2009–2012 publications indexed in NCR*. Institute for Energy Technology (IFE).

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
Solar Energy Dep	34	140	22	79	77	101

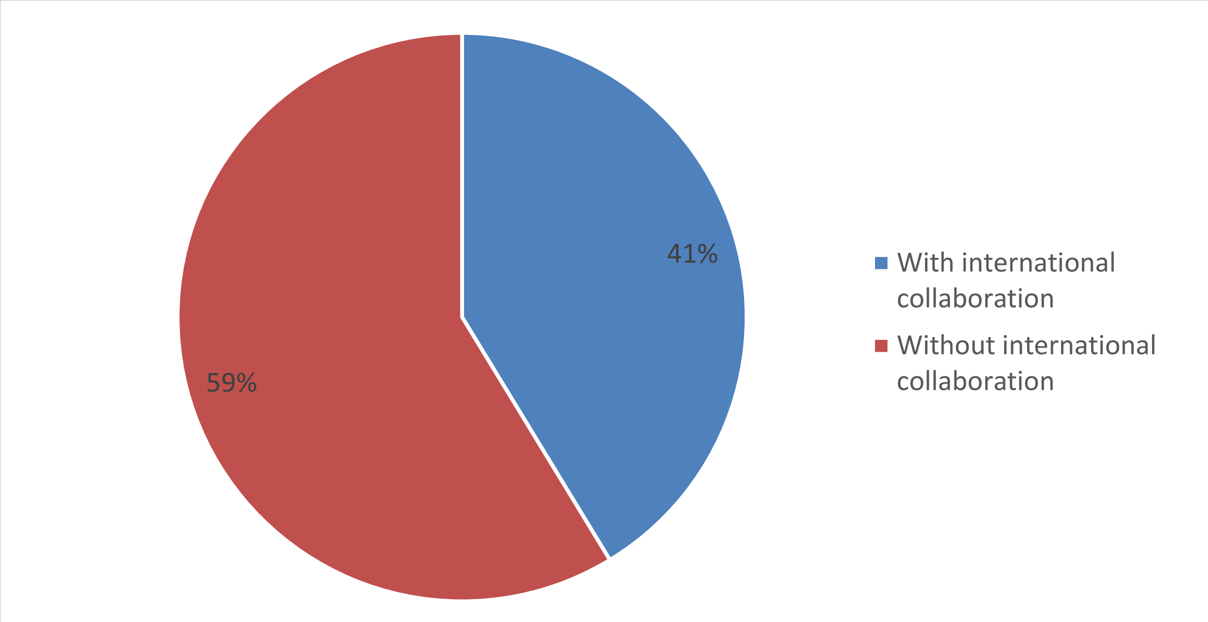
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 41 % of the group's publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.12.2. In contrast, the average for all units included in the evaluation is almost identical (40 %). It should be noted again, that the analysis is based on the NCR-indexed publications (n=46), and only gives an indication of the extent of international collaboration.

Figure 4.12.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=46). Institute for Energy Technology (IFE).



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.13 IRIS Energy

Figure 4.13.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

There are three research groups at IRIS Energy included in the evaluation: Drilling and Well Modelling; Enhanced Oil Recovery (EOR); and Reservoir. In total 27 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Table 4.13.1 shows publication indicators for the research groups. In the period 2009-2013, approximately 80 publications have been published.

Table 4.13.1 Number of publications, 2009–2013, IRIS Energy.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	27	81	91%
Drilling and Well Modelling	6	18	94%
Enhanced Oil Recovery	12	35	83%
Reservoir	8	30	100%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Almost all the publications of the groups have been published in journals and regular publishing series (91 %). Table 4.13.2 gives the most frequently used journals for the research groups – limited to journals with at least three publications during the period 2009–2013.

Table 4.13.2 The most frequently used journals/series*, number of publications 2009–2013. IRIS Energy

Unit	Journal/series	No. of articles
Drilling and Well Modelling	SPE Drilling & Completion	7
Enhanced Oil Recovery	Journal of Petroleum Science and Engineering	3
Reservoir	SPE Journal	8
	Computational Geosciences	5
	Monthly Weather Review	3
	Energy Policy	3

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Limited to journals with at least three publications during the time period.

Table 4.13.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. Despite a limited production, the institute performs well in terms of citation rates. In total, the field normalized citation index is 254. In other words, the articles are cited 150 % more than the world average. It should be noted, however, that one highly cited review article contributes significantly to this high citation rate (The Ensemble Kalman Filter in Reservoir Engineering - a Review, *SPE Journal*, 2009). All the research groups have field normalised citation indexes above the world average, highest for the Reservoir group (482), followed by Drilling and Well Modelling (123) and Enhanced Oil Recovery (EOR) (118).

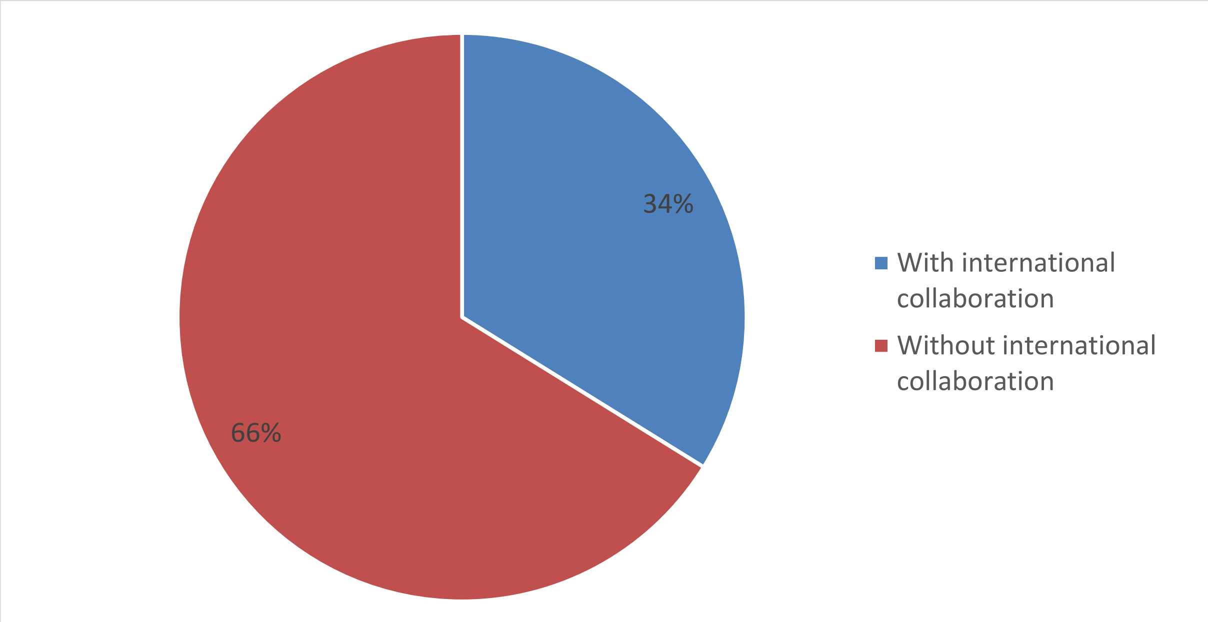
Table 4.13.3 Citation indicators, 2009–2012 publications indexed in NCR.* IRIS Energy.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	49	292	94	178	254	125
Drilling and Well Modelling	10	32	12	155	123	122
Enhanced Oil Recovery	22	88	25	106	118	114
Reservoir	18	173	94	271	482	147

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.
*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.
1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 34 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.13.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications only (n=65), and gives an indication of the extent of international collaboration

Figure 4.13.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=65). IRIS Energy.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.14 MARINTEK

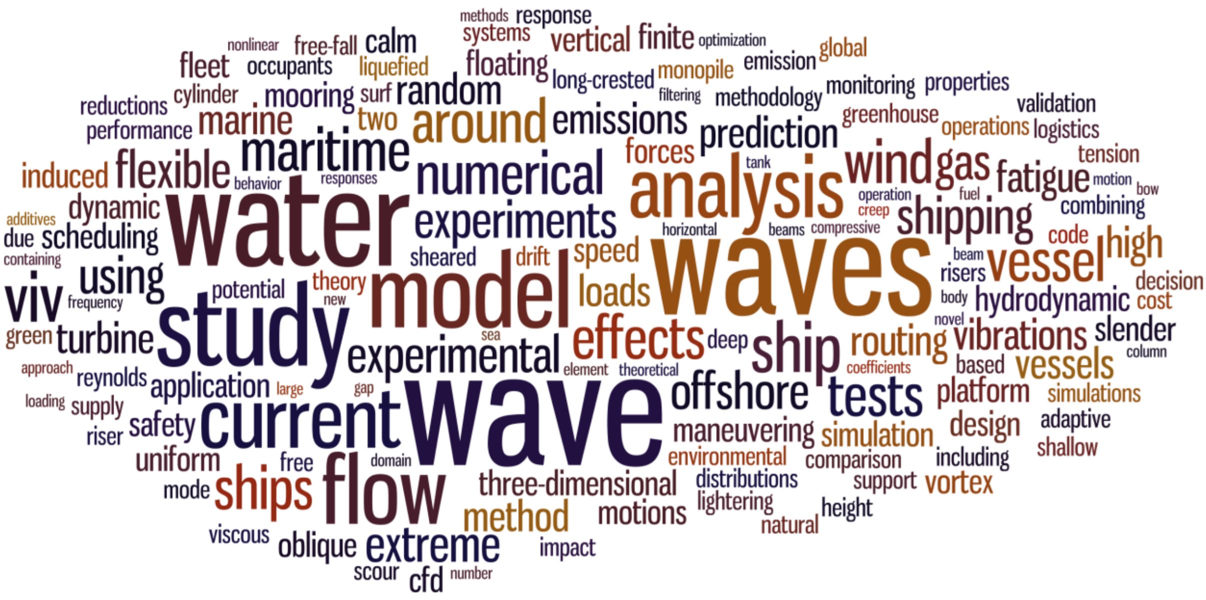


Figure 4.14.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

There are five research groups at MARINTEK included in the evaluation: Energy Systems; Hydrodymamics modelling; Logistics and operations research; Seakeeping and control; and Structural engineering. In total 49 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Table 4.14.1 shows some publication indicators for the five research groups. In the period 2009-2013, approximately 123 publications have been published.

Table 4.14.1 Number of publications, 2009–2013, MARINTEK.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	49	123	65%
Energy Systems	8	14	79%
Hydrodymamics modelling	12	56	54%
Logistics and operations research	8	17	94%
Seakeeping and control	11	17	65%
Structural engineering	10	23	65%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately two thirds of the publications of the groups have been published in journals and regular publishing series. Table 4.14.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.14.2 The most frequently used journals/series,* number of publications 2009–2013. MARINTEK.

Unit	Journal/series	No. of articles
Energy Systems	Energy Policy	3
Hydrodymamics modelling	International Conference on Offshore Mechanics and Arctic Engineering	16
Structural engineering	International Conference on Offshore Mechanics and Arctic Engineering	11

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.14.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the five groups together, the field normalized citation rate is 194. In other words, the articles are cited almost 100 % above the world average. It should be noted however, that only a minor fraction of the publications are indexed in NCR (23 articles, excluding 2013). We have not calculated relative citation indexes at group level due to the small number of indexed articles (cf. Method section).

Table 4.14.3 Citation indicators, 2009–2012 publications indexed in NCR.* MARINTEK.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	23	198	52	167	194	137
Energy Systems	5	25	14	-	-	-
Hydrodymamics modelling	9	110	52	-	-	-
Logistics and operations research	6	58	25	-	-	-
Seakeeping and control	3	3	2	-	-	-
Structural engineering	1	5	5	-	-	-

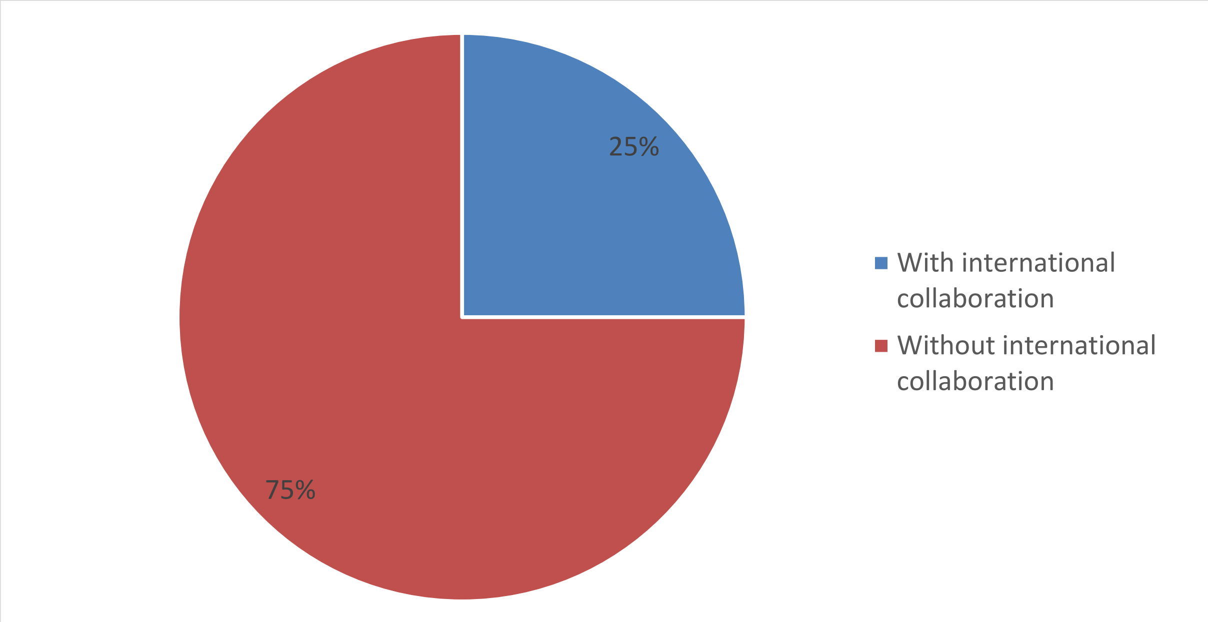
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 25 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.14.2. In contrast, the average for all units included in the evaluation is 40 %. It should be noted again, that the analysis is based on the NCR-indexed publications (n=36), and only gives an indication of the extent of international collaboration.

Figure 4.14.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=36). MARINTEK .



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.15 Norwegian Geotechnical Institute

Figure 4.15.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

At the Norwegian Geotechnical Institute (NGI) there are three research groups included in the evaluation: Computational Geomechanics; Geosurveys; and Water and Resources. In total 35 people have delivered CVs. The analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Table 4.15.1 shows some publication indicators for the three research groups. In the period 2009-2013, 138 publications have been published. The Computational Geomechanics group is the largest both in terms of researchers included and publication output.

Table 4.15.1 Number of publications, 2009–2013, NGI.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	35	138	81%
Computational Geomechanics	15	55	67%
Geosurveys	13	36	83%
Water and Resources	7	52	94%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately 80 % of the publications of the groups have been published in journals and regular publishing series. Table 4.15.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.15.2 The most frequently used journals/series,* number of publications 2009–2013. NGI.

Unit	Journal/series	No. of articles
Computational Geomechanics	Geotechnique	3
	Natural hazards and earth system sciences	3
Geosurveys	Natural hazards and earth system sciences	6
Water and Resources	Environmental Science and Technology	23
	Journal of soils and sediments	4
	Environmental pollution	3
	Chemosphere	3
	Environmental toxicology and chemistry	3

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Limited to journals with at least three publications during the time period.

We have also analysed the citation rate of the journal publications (indexed in NCR). The results are given in Table 4.15.3. Water and Resources group performs very well in terms of citation rates with a field normalized citation index of 222. In other words, the articles have been cited 122 % above the corresponding world average. The group also publishes in journals that are higher than average cited (i.e. have high impact factor), which is reflected by a journal profile of 159. Also the Geosurveys group obtains a field normalised citation index clearly above the world average (151).

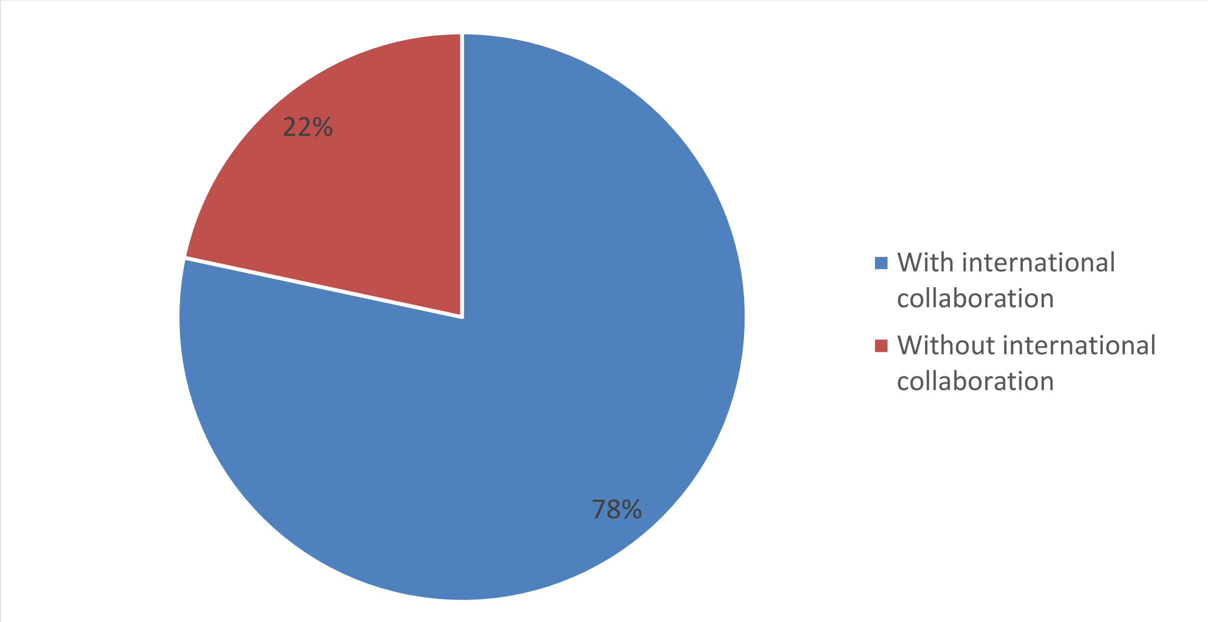
Table 4.15.3 Citation indicators, 2009–2012 publications indexed in NCR*. NGI

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	75	519	31	144	158	134
Computational Geomechanics	26	71	10	91	85	117
Geosurveys	18	72	12	194	151	118
Water and Resources	35	394	31	166	222	159

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.
*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.
1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

A large proportion of the groups' publications have been co-authored in collaboration with scientists from other countries (78 %). This is shown in Figure 4.15.2. In contrast, the average for all units included in the evaluation is 40 %.

Figure 4.15.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=97). NGI.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.16 SINTEF Building and Infrastructure

Figure 4.16.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

At SINTEF Building and Infrastructure there are two research groups included in the evaluation: Building Physics and Concrete Group. In total 29 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Table 4.16.1 shows some publication indicators for the two research groups. In the period 2009-2013, 163 publications have been published. The Building Physics group is the largest in terms of publication output (105 articles).

Table 4.16.1 Number of publications, 2009–2013, SINTEF Building and Infrastructure.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	29	163	69%
Building Physics	14	105	64%
Concrete Group	15	58	81%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

Approximately two thirds of the publications of the groups have been published in journals and regular publishing series. Table 4.16.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.16.2 The most frequently used journals/series,* number of publications 2009–2013. SINTEF Building and Infrastructure.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Building Physics	Energy and Buildings	12	Concrete Group	Cement and Concrete Research	8
	Journal of Building Physics	10		Nordic Concrete Research	6
	Solar Energy Materials and Solar Cells	5		Advances in Applied Ceramics: Structural, Functional & Bioceramics	3
	Advances in Materials Science and Engineering	3		Advances in Cement Research	3
	The Journal of Physical Chemistry C	3		Journal of the European Ceramic Society	3
	Wood Material Science & Engineering	3			
	Progress in organic coatings	3			

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.16.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. The research of the institute is very highly cited, particularly this holds for the Building Physics group. For the two groups together, the field normalized citation rate is 221. In other words, the articles are cited 121 % above the world average. The Building Physics group has a field normalised citation index of 256 and the Conrete Group 170. It should be noted, however, that only a minor fraction of the publications are indexed in NCR (53 articles, excluding 2013).The Building Physics group has published a review article with a very high citation count (Properties, requirements and possibilities of smart windows for dynamic daylight and solar energy control in buildings: A state-of-the-art review, *Solar Energy Materials and Solar Cells*, 2010).

Table 4.16.3 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Building and Infrastructure.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	53	582	108	191	221	126
Building Physics	31	397	108	217	256	124
Concrete Group	22	185	28	153	170	128

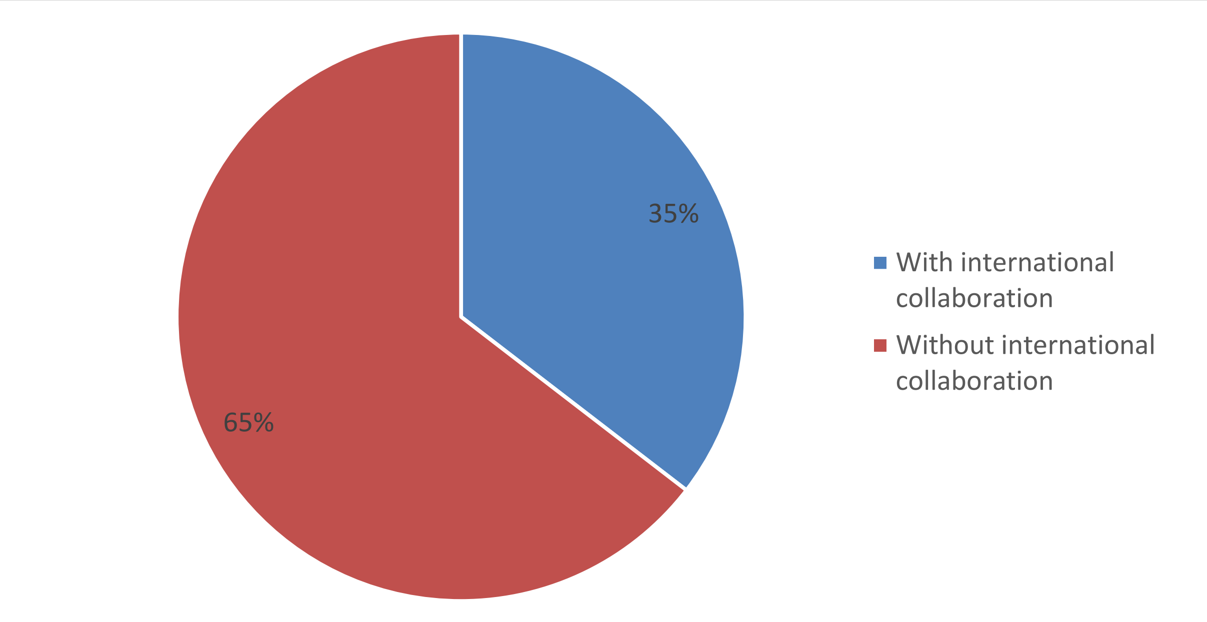
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 35 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.16.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications (n=79), and only gives an indication of the extent of international collaboration.

Figure 4.16.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=79). SINTEF Building and Infrastructure.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.17 SINTEF Energy Research

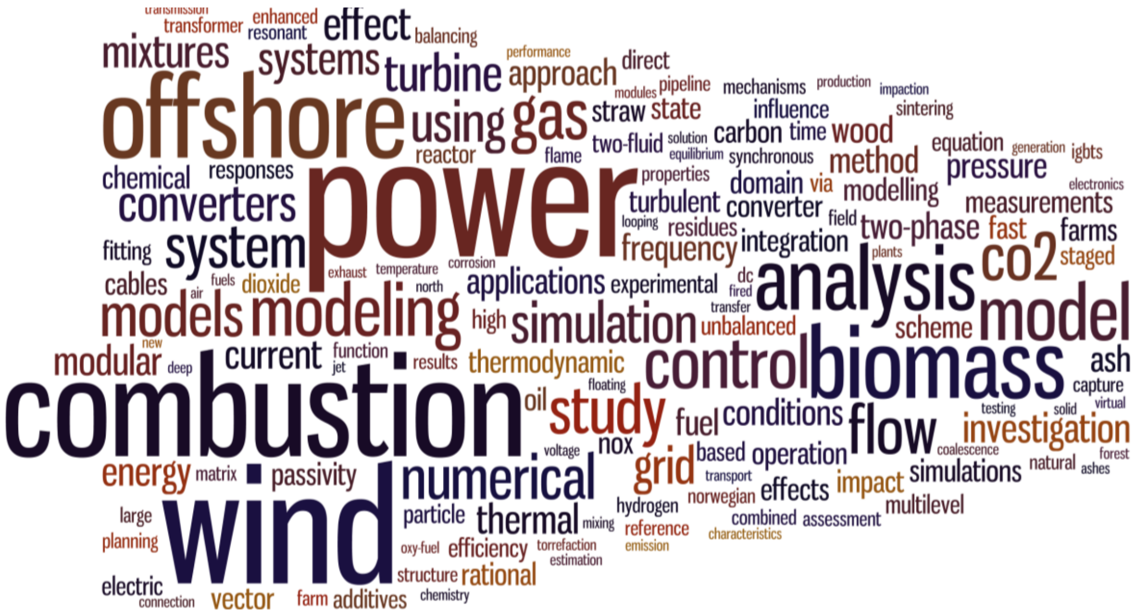


Figure 4.17.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

At SINTEF Energy Research there are four research groups included in the evaluation: Bioenergy; Combustion; Flow phenomena; Power conversion and transmission. In total, 38 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Table 4.17.1 shows some publication indicators for the research groups. In the period 2009-2013, 213 publications have been published. The Power conversion and transmission group is the largest both in terms of people included and publication output (97 articles).

Table 4.17.1 Number of publications, 2009–2013, SINTEF Energy Research.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	38	213	81%
Bioenergy	8	42	100%
Combustion	9	38	91%
Flow phenomena	6	36	90%
Power conversion and transmission	15	97	65%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, approximately 80 % of the publications of the groups have been published in journals and regular publishing series. Table 4.17.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.17.2 The most frequently used journals/series,* number of publications 2009–2013. SINTEF Energy Research.

Unit	Journal/series	No. of articles	Unit	Journal/series	No. of articles
Bioenergy	Energy & Fuels	19	Combustion	Journal of Fluid Mechanics	3
	Chemical Engineering Transactions	4	Flow phenomena	Energy Procedia	9
	Asia-Pacific Power and Energy Engineering Conf	3		Industrial & Engineering Chemistry Research	3
	Fuel	3	Power conversion and transmission	IEEE Transactions on Power Delivery	20
	Energy Procedia	3		Energy Procedia	10
Combustion	Energy Procedia	9		Wind Engineering : The International Journal of Wind Power	4
	Applied Energy	3		Wind Energy	3
	Combustion and Flame	3			

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.17.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. Overall, the institute has a field normalized citation rate of 121. In other words, the articles are cited approximately 20 % above the world average. This citation rate is on par with the national average for all groups included in the evaluation, which is 120. There are some minor differences across the groups. The Flow phenomena group has the highest field normalised citation index of (140). It should be noted that only a minority of the groups' publications have been published in NCR-indeed journals for which citation counts are available.

Table 4.15.7 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Energy Research.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	76	342	25	122	121	118
Bioenergy	20	106	25	123	109	100
Combustion	18	84	16	94	126	145
Flow phenomena	15	63	11	118	140	126
Power conversion and transmission	23	89	23	145	115	106

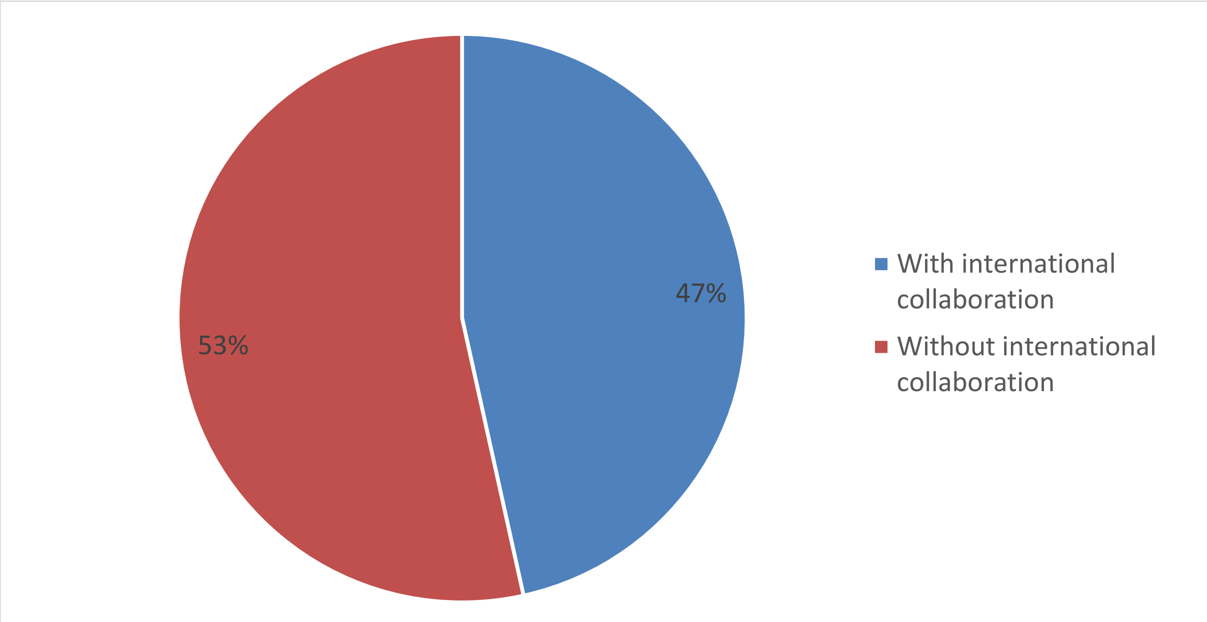
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 47 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.17.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications (n=101), and only gives an indication of the extent of international collaboration.

Figure 4.17.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n=101). SINTEF Energy Research.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.18 SINTEF Fisheries and Aquaculture

Figure 4.18.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

At SINTEF Fisheries and Aquaculture there are three research groups included in the evaluation: Fishing gear technology; Marine ICT; Processing technology. In total, 26 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Table 4.18.1 shows some publication indicators for the research groups. In the period 2009-2013, 71 publications have been published. The Processing technology group is the largest both in terms of people included and publication output (44 articles).

Table 4.18.1 Number of publications, 2009–2013, SINTEF Fisheries and Aquaculture.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
TOTAL	26	71	91%
Fishing gear technology	6	11	100%
Marine ICT	9	16	64%
Processing technology	11	44	100%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, approximately 90 % of the publications of the groups have been published in journals and regular publishing series. Table 4.18.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013. Therefore, for one of the groups there are no journals listed.

Table 4.18.2 The most frequently used journals/series,* number of publications 2009–2013. SINTEF Fisheries and Aquaculture.

Unit	Journal/series	No. of articles
Fishing gear technology	Fisheries Research	3
Processing technology	Food chemistry	6
	Journal of Agricultural and Food Chemistry	5
	Journal of Food Science	5

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Limited to journals with at least three publications during the time period.

Table 4.18.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. For the three groups together, the field normalized citation rate is 109. In other words, the articles are cited 9 % above the world average. This is slightly below the national average for all groups included in the evaluation (120). The Processing technology group has a citation index of 117. For two of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section).

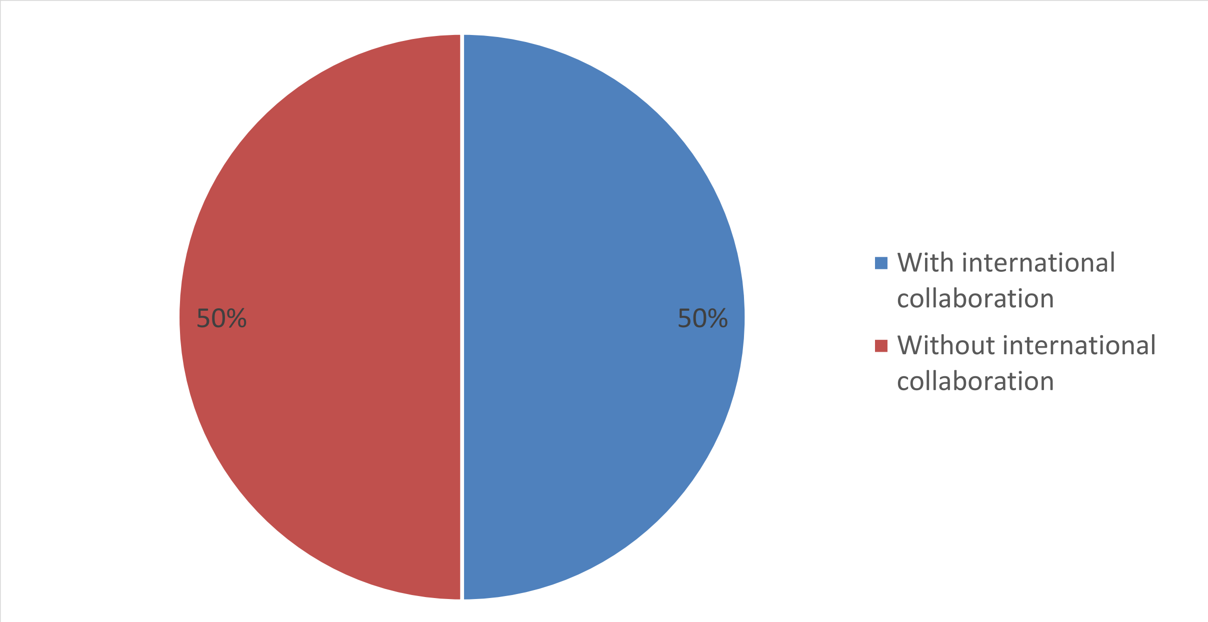
Table 4.18.3 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Fisheries and Aquaculture.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
TOTAL	42	232	22	115	109	118
Fishing gear technology	4	17	9	-	-	-
Marine ICT	4	9	5	-	-	-
Processing technology	34	206	22	118	117	123

Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.
*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.
1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 50 % of the groups' publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.18.2. In contrast, the average for all units included in the evaluation is 40 %. The analysis is based on the NCR-indexed publications (n=54), and only gives an indication of the extent of international collaboration.

Figure 4.18.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 54). SINTEF Fisheries and Aquaculture.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

4.19 SINTEF Materials and Chemistry

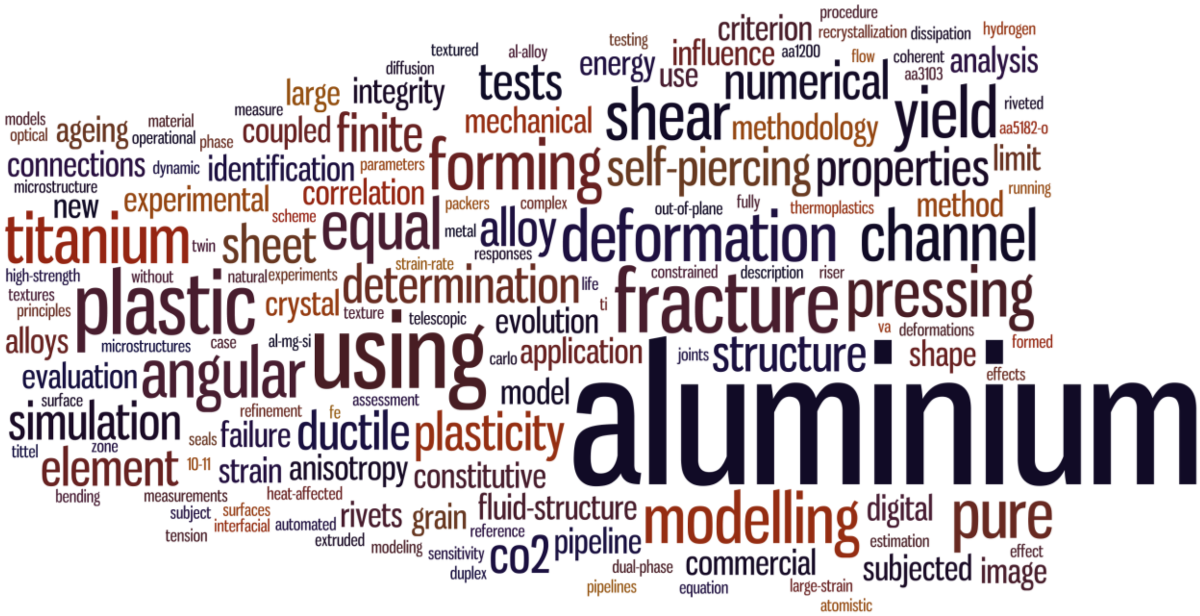


Figure 4.19.1 Most frequently appearing words in the included publication titles, 2009-2013.
Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

At SINTEF Materials and Chemistry there is one research group included in the evaluation: Material- and Structural Mechanics. In total, 12 people have delivered CVs. This analysis is based on the publication output of these persons, where only publications that have been accredited the institute are included (cf. the Method section).

Table 4.19.1 shows some publication indicators for the research groups. In the period 2009-2013, 34 publications have been published.

Table 4.19.1 Number of publications, 2009–2013, SINTEF Materials and Chemistry.

Unit	Number of persons included	Total number of publications	Publications in journals/series*
Material- and Structural Mechanics	12	34	94%

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.
*) Publications in scientific journals and in series published on a regular basis (excl. independent proceedings and books).

In total, 94 % of the publications of the group have been published in journals and regular publishing series. Table 4.19.2 gives the most frequently used journals and series for the groups – limited to journals with at least three publications during the period 2009-2013.

Table 4.19.2 The most frequently used journals/series,* number of publications 2009–2013. SINTEF Materials and Chemistry.

Unit	Journal/series	No. of articles
Material- and Structural Mechanics	Materials & Design	4
	Computers & Structures	3

Data: CRIStin/NIFU's Key figure database. Calculations: NIFU.

*) Limited to journals with at least three publications during the time period.

Table 4.19.3 shows some citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. The field normalized citation rate is 107. In other words, the articles are cited 9 % above the world average. This is slightly below the national average for all groups included in the evaluation (120).

Table 4.19.3 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Materials and Chemistry.

Unit	Number of articles	Number of citations	Max cited article	Citation index – journal[1]	Citation index – field[2]	Journal profile[3]
Material- and Structural Mechanics	20	125	18	120	107	106

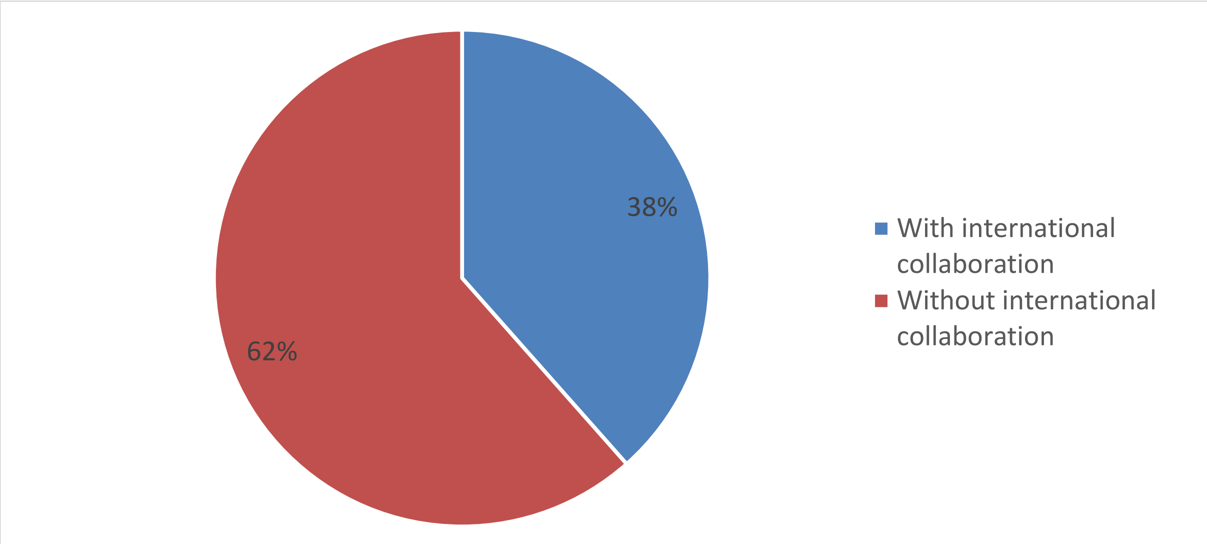
Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

*) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. Max cited article refers to the citation count of the most cited article.

1) Journal average = 100. 2) World average field = 100. 3) Average journal profile = 100. Ref. Method section.

In total, 38 % of the group's publications have been co-authored in collaboration with scientists from other countries. This is shown in Figure 4.19.2. In contrast, the average for all units included in the evaluation is 40 %.

Figure 4.19.2 International collaboration. Proportion of publications with and without co-authors from other countries. 2009–2013 publications indexed in NCR (n= 26). SINTEF Materials and Chemistry.



Source: Data: Thomson Reuters/National Citation Report (NCR). Calculations: NIFU.

5 Appendix: General introduction to bibliometric indicators

Publication and citation data have increasingly been applied as performance indicators in the context of science policy and research evaluation. The basis for the use of bibliometric indicators is that new knowledge – the principal objective of basic and applied research – is disseminated to the research community through publications. Publications can thereby be used as indirect measures of knowledge production. Data on how much the publications have been referred to or cited in the subsequent scientific literature can in turn be regarded as an indirect measure of the scientific impact of the research. In this chapter we will provide a general introduction to bibliometric indicators, particularly focusing on analyses based on the *Web of Science* database.[3]

5.1 The Web of Science database

The *Web of Science* database covers a large number of specialised and multidisciplinary journals within the natural sciences, medicine, technology, the social sciences and the humanities. The coverage varies between the different database products. According to the website of the Thomson Reuters company, the online product *Web of Science* covering the three citation indexes *Science Citation Expanded*, *Social Sciences Citation Index*, and *Arts & Humanities Citation Index* includes more than 12,000 journals. Compared to the large volume of scientific and scholarly journals that exist today, this represents a limited part. The selection of journals is based on a careful examination procedure in which a journal must meet particular requirements in order to be included (Testa, 2012). Even if its coverage is not complete, the database will include all major journals within the natural sciences, medicine and psychology and technology and is generally regarded as constituting a satisfactory representation of international mainstream scientific research (Katz & Hicks, 1998). With respect to the social sciences and humanities the coverage is more limited, and this issue will be further discussed below.

From a bibliometric perspective, a main advantage of the *Web of science* database is that it fully indexes the journals that are included. Moreover, all author names, author addresses and references are indexed. Through its construction it is also well adapted for bibliometric analysis. For example, country names and journal names are standardised, controlled terms. It is also an advantage that it is multidisciplinary in contrast to most other similar databases which cover just one or a few scientific disciplines.

[3] This introduction is based on Aksnes (2005).

5.2 Citation indicators

Citations represent an important component of scientific communication. Already prior to the 19th century it was a convention that scientists referred to earlier literature relating to the theme of the study (Egghe & Rousseau, 1990). The references are intended to identify earlier contributions (concepts, methods, theory, empirical findings, etc.) upon which the present contribution was built, and against which it positions itself. Thus, it is a basic feature of the scientific article that it contains a number of such references and that these references are attached to specific points in the text.

The *Web of Science* database was originally developed for information retrieval purposes, to aid researchers in locating papers of interest in the vast research literature archives (Welljams-Dorof, 1997). As a subsidiary property it enabled scientific literature to be analysed quantitatively. Since the 1960s the *Science Citation Index* and similar bibliographic databases have been applied in a large number of studies and in a variety of fields. The possibility for citation analyses has been an important reason for this popularity. As part of the indexing process, Thomson Reuters systematically registers all the references of the indexed publications. These references are organised according to the publications they point to. On this basis each publication can be attributed a citation count showing how many times each paper has been cited by later publications indexed in the database. Citation counts can then be calculated for aggregated publications representing, for example, research units, departments, or scientific fields.

5.3 What is measured through citations?

Because citations may be regarded as the mirror images of the references, the use of citations as indicators of research performance needs to be justified or grounded in the referencing behaviour of the scientists (Wouters, 1999). If scientists cite the work they find useful, frequently cited papers are assumed to have been more useful than publications which are hardly cited at all, and possibly be more useful and thus important in their own right. Thus, the number of citations may be regarded as a measure of the article's usefulness, impact, or influence. The same reasoning can be used for aggregated levels of articles. The more citations they draw, the greater their influence must be. Robert K. Merton has provided the original theoretical basis for this link between citations and the use and quality of scientific contribution. In Merton's traditional account of science, the norms of science oblige researchers to cite the work upon which they draw, and in this way acknowledge or credit contributions by others (Merton, 1979). Such norms are upheld through informal interaction in scientific communities and through peer review of manuscripts submitted to scientific journals.

Empirical studies have shown that the Mertonian account of the normative structure of science covers only part of the dynamics. For the citation process, this implies that other incentives occur, like the importance of creating visibility for one's work, and being selective in referencing to create a distance between oneself and others. Merton himself already pointed out the ambivalence of the norms, for example that one should not hide one's results from colleagues in one's community, but also not rush into print before one's findings are robust. Merton also identified system level phenomena like the "Matthew effect": to whom who has shall be given more. Clearly, a work may be cited for a large number of reasons including tactical ones such as citing a journal editor's work as an attempt to enhance the chances of acceptance for publication. Whether this affects the use of citations as performance indicators is a matter of debate (Aksnes, 2003b).

The concept of quality has often been used in the interpretation of citation indicators. Today, however, other concepts – particularly that of "impact" – are usually applied. One reason is that quality is often considered as a diffuse or at least multidimensional concept. For example, the following description is given by Martin and Irvine (1983): "'Quality' is a property of the publication and the research described in it. It describes how well the research has been done, whether it is free from obvious 'error' […] how original the conclusions are, and so on." Here, one sees reference to the craft of doing scientific research, and to the contribution that is made to the advance of science.

The impact of a publication, on the other hand, is defined as the "actual influence on surrounding research activities at a given time." According to Martin and Irvine it is the impact of a publication that is most closely linked to the notion of scientific progress – a paper creating a great impact represents a major contribution to knowledge at the time it is published. If these definitions are used as the basis it is also apparent that impact would be a more suitable interpretation of citations than quality. For example, a 'mistaken' paper can nonetheless have a significant impact by stimulating further research. Moreover, a paper by a recognised scientist may be more visible and therefore have more impact, earning more citations, even if its quality is no greater than those by lesser known authors (Martin, 1996).

5.4 Some basic citation patterns

De Solla Price showed quite early that recent papers are more cited than older ones (Price, 1965). Nevertheless, there are large individual as well as disciplinary differences. The citation counts of an article may vary from year to year. Citation distributions are extremely skewed. This skewness was also early identified by Solla Price (Price, 1965). The large majority of the scientific papers are never or seldom cited in the subsequent scientific literature. On the other hand some papers have an extremely large number of citations (Aksnes, 2003a; Aksnes & Sivertsen, 2004).

Citation rates vary considerably between different subject areas. For example, on average papers in molecular biology contain many more references than mathematics papers (Garfield, 1979b). Accordingly, one observes a much higher citation level in molecular biology than in mathematics. Generally, the average citation rate of a scientific field is determined by different factors, most importantly the average number of references per paper. In addition, the percentage of these references that appears in *Web of Science*-indexed journals, the average age of the references, and the ratio between new publications in the field and the total number of publications, are relevant.

5.5 Limitations

In addition to the fundamental problems related to the multifaceted referencing behaviour of scientists, there are also more specific problems and limitations of citation indicators. Some of these are due to the way the *Web of Science* database is constructed. First of all, it is important to emphasise that only references in *Web of Science* indexed literature count as "citations". For example, when articles are cited in non-indexed literature (e.g. a trade journal) these are not counted. This has important consequences. Research of mainly national or local interest, for example, will usually not be cited in international journals. Moreover, societal relevance, such as contributions of importance for technological or industrial development, may not be reflected by such counts. Because it is references in (mainly) international journals which are indexed, it might be more appropriate to restrict the notion of impact in respect to citation indicators to impact on international or "mainstream" knowledge development.

There is also a corresponding field dimension. For example, LePair (1995) has emphasised that "In technology or practicable research bibliometrics is an insufficient means of evaluation. It may help a little, but just as often it may lead to erroneous conclusions." For similar reasons the limitations of citation indicators in the social sciences and humanities are generally more severe due to a less centralised or a different pattern of communication. For example, the role of international journals is less important, and publishing in books is more common: older literature has a more dominant role and many of the research fields have a "local" orientation. In conclusion, citation analyses are considered to be most fair as an evaluation tool in the scientific fields where publishing in the international journal literature is the main mode of communication.

Then there are problems caused by more technical factors such as discrepancies between target articles and cited references (misspellings of author names, journal names, errors in the reference lists, etc.), and mistakes in the indexing process carried out by Thomson Reuters (see Moed, 2002; Moed & Vriens, 1989). Such errors affect the accuracy of the citation counts to individual articles but are nevertheless usually not taken into account in bibliometric analyses (although their effect to some extent might "average out" at aggregated levels).

While some of the problems are of a fundamental nature, inherent in any use of citations as indicators, other may be handled by the construction of more advanced indicators. In particular, because of the large differences in the citation patterns between different scientific disciplines and subfields, it has long been argued by bibliometricians that relative indicators and not absolute citation counts should be used in cross-field comparisons (Schubert & Braun, 1986; Schubert & Braun, 1996; Schubert, Glänzel, & Braun, 1988; Vinkler, 1986). For example, it was early emphasised by Garfield that: "Instead of directly comparing the citation counts of, say, a mathematician against that of a biochemist, both should be ranked with their peers, and the comparison should be made between rankings" (Garfield, 1979a). Moed et al. (1985) similarly stressed that: "if one performs an impact evaluation of publications from various fields by comparing the citation counts to these publications, differences between the citation counts cannot be merely interpreted in terms of (differences between) impact, since the citation counts are partly determined by certain field-dependent citation characteristics that can vary from one field to another".

A fundamental limitation of citation indicators in the context of research assessments is that a certain time period is necessary for such indicators to be reliable, particularly when considering smaller number of publications. Frequently, in the sciences a three-year period is considered as appropriate (see e.g. Moed et al., 1985). But for the purpose of long-term assessments more years are required. At the same time, an excessively long period makes the results less usable for evaluation purposes. This is because one then only has citation data for articles published many years previously. Citation indicators are not very useful when it comes to publications published very recently, a principal limitation of such indicators being that they cannot provide an indication of present or future performance except indirectly: past performance correlates with future performance (Luukkonen, 1997). It should be added, however, that this time limitation does not apply to the bibliometric indicators based on publication counts.

5.6 Bibliometric indicators versus peer reviews

Over the years a large number of studies have been carried out to ascertain the extent to which the number of citations can be regarded as a measure of scientific quality or impact. Many studies have also found that citation indicators correspond fairly well, especially in the aggregate, with various measures of research performance or scientific recognition which are taken as reflecting quality. On the other hand, there have been several studies challenging or criticising such use of citations.

One approach to the question is represented by studies analysing how citations correlate with peer reviews. In these studies judgements by peers have been typically regarded as a kind of standard by which citation indicators can be validated. The idea is that one should find a correlation if citations legitimately can be used as indicators of scientific performance (which assumes that peer assessment can indeed identify quality and performance without bias – a dubious assumption). Generally, most of the studies seem to have found an overall positive correspondence although the correlations identified have been far from perfect and have varied among the studies (see e.g. Aksnes & Taxt, 2004, Aksnes, 2006).

Today most bibliometricians emphasise that a bibliometric analysis can never function as a substitute for a peer review. Thus, a bibliometric analysis should not replace an evaluation carried out by peers. First a peer-evaluation will usually consider a much broader set of factors than those reflected through bibliometric indicators. Second, this is due to the many problems and biases attached to such analyses. As a general principle, it has been argued that the greater the variety of measures and qualitative processes used to evaluate research, the greater is the likelihood that a composite measure offers a reliable understanding of the knowledge produced (Martin, 1996).

At the same time, it is generally recognised that peer reviews also have various limitations and shortcomings (Chubin & Hackett, 1990). For example, van Raan (2000) argues that subjectivity is a major problem of peer reviews: The opinions of experts may be influenced by subjective elements, narrow mindedness and limited cognitive horizons. An argument for the use of citation indicators and other bibliometric indicators is that they can counteract shortcomings and mistakes in the peers' judgements. That is, they may contribute to fairness of research evaluations by representing "objective" and impartial information to judgements by peers, which would otherwise depend more on the personal views and experiences of the scientists appointed as referees (Sivertsen, 1997). Moreover, peer assessments alone do not provide sufficient information on important aspects of research productivity and the impact of the research activities (van Raan, 1993).

Citations and other bibliometric indicators have been applied in various ways in research evaluation. For example, such indicators are used to provide information on the performance of research groups, departments, institutions or fields. According to van Raan (2000), "the application of citation analysis to the work – the oeuvre – of a group as a whole over a longer period of time, does yield in many situations a strong indicator of scientific performance, and, in particular, of scientific quality". As a qualifying premise it is emphasised, however, that the citation analysis should adopt an advanced, technically highly developed bibliometric method. In this view, a high citation index means that the assessed unit can be considered as a scientifically strong organisation with a high probability of producing very good to excellent research.

In this way a bibliometric study is usually considered as complementary to a peer evaluation. Van Raan has accordingly suggested that in cases where there is significant deviation between the peers' qualitative assessments and the bibliometric performance measures, the panel should investigate the reasons for these discrepancies. They might then find that their own judgements have been mistaken or that the bibliometric indicators did not reflect the unit's performance (van Raan, 1996).[4]

In conclusion, the use of citations as performance measures have their limitations, as all bibliometric indicators have. But a citation analysis when well designed and well interpreted will still provide valuable information in the context of research evaluation.

[4] Van Raan (1996) suggests that in cases were conflicting results appear, the conclusion may depend on the type of discrepancy. If the bibliometric indicators show a poor performance but the peer's judgement is positive, then the communication practices of the group involved may be such that bibliometric assessments do not work well. By contrast, if the bibliometric indicators show a good performance and the peers' judgement is negative, then it is more likely that the peers are wrong.

Performance, quality and excellence can also be assessed through peer review, but in spite of their widespread use, these have problems as well. A combination of methods, or better, mutual interplay on the basis of findings of each of the methods, is more likely to provide reliable evaluation results.

5.7 Co-authorship as an indicator of collaboration[5]

The fact that researchers co-author a scientific paper reflects collaboration, and co-authorship may be used as an indicator of such collaboration. Computerised bibliographic databases make it possible to conduct large-scale analyses of scientific co-authorship. Of particular importance for the study of scientific collaboration is the fact that the Thomson Reuters indexes all authors and addresses that appear in papers, including country as a controlled term.

By definition a publication is co-authored if it has more than one author, internationally co-authored if it has authors from more than one country. Compared to other methodologies, bibliometrics provides unique and systematic insight into the extent and structure of scientific collaboration. A main advantage is that the size of the sample that can be analysed with this technique can be very large and render results that are more reliable than those from case studies. Also, the technique captures non-formalised types of collaboration that can be difficult to identify with other methodologies.

Still, there are limitations. Research collaboration sometimes leads to other types of output than publications. Moreover, co-authorship can only be used as a measure of collaboration if the collaborators have put their names on a joint paper. Not all collaboration ends up in co-authorship and the writing of co-authored papers does not necessarily imply close collaboration (Katz & Martin, 1997; Luukkonen, Persson, & Sivertsen, 1992; Melin & Persson, 1996). Thus, international co-authorship should only be used as a partial indicator of international collaboration (Katz and Martin 1997). As described above there are also particular limitations with the *Web of Science* database, represented by the fact that regional or domestic journals, books, reports etc. are not included.

Smith (1958) was among the first to observe an increase in the incidence of multi-authored papers and to suggest that such papers could be used as a rough measure of collaboration among groups of researchers (Katz and Martin 1997). In a pioneering work, Derek de Solla Price also showed that multiple authorship had been increasing (Price, 1986). These findings have later been confirmed by a large number of similar studies (e.g. (Merton & Zuckerman, 1973; National Science Board, 2002). In the natural sciences and medicine the single-author paper is, in fact, becoming an exception to the norm. In the case of Norway, 86 % of *Web of Science*-indexed papers were co-authored in 2000, compared to 66 % in 1981.

[5] This section is based on Wendt, Slipersæter, & Aksnes (2003).

Scientific collaboration across national borders has also significantly increased over the last decades. According to Melin and Persson (1996) the number of internationally co-authored papers has doubled in about fifteen years. In Norway 60 % of the articles published by Norwegian researchers now has foreign co-authors compared to 16 % in 1981. Similar patterns can be found in most countries. Bibliometric analysis thus provides evidence to the effect that there is a strong move towards internationalisation in science and that the research efforts of nations are becoming more and more entwined.

The move toward internationalisation is also reflected in the publishing practices of scientists: English has increasingly become the lingua franca of scientific research, and publishing in international journals is becoming more and more important, also in the areas of social science and the humanities.

As might be expected, nations with big scientific communities have far more collaborative articles than have smaller countries (Luukkonen, Tijssen, Persson, & Sivertsen, 1993), though one finds a trend to the effect that the proportion of internationally co-authored papers increases along with decreasing national volume of publications (see e.g. Luukkonen, Persson et al. 1992, National Science Board 2002), hence international collaboration is relatively more important in smaller countries. This is probably a consequence of researchers from small countries often having to look abroad for colleagues and partners within their own speciality. Size is, however, not the only factor with bearing on the extent of international collaboration; access to funding, geographical location, and cultural, linguistic and political barriers are other important factors (Luukkonen, Persson et al. 1992, Melin and Persson 1996).

Bibliometric techniques allow analysis of structures of international collaboration. For almost all other countries, the United States is the most important partner country; this reflects this country's pre-eminent role in science. In 1999, 43 % of all published papers with at least one international co-author had one or more U.S. authors. For Western Europe the share of U.S. co-authorship ranged from 23 % to 35 % of each country's internationally co-authored papers (National Science Board 2002). Generally, one also finds that most countries have much collaboration with their neighbouring countries (e.g. collaboration among the Nordic countries). Over the last decade we find a marked increase in co-authorship among western European countries; this probably mainly reflects the EU framework programmes.

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