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Nordic Institute for Studies in
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Evaluation of technical-industrial institutes – Publication and citation analysis

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Preface

This report presents a bibliometric analysis of the technical-industrial institutes in Norway and is a background report for the evaluation of the institutes. It was commissioned by the Research Council of Norway and was written by Research Professor Dag W. Aksnes (project leader) at the Nordic Institute for Studies in Innovation, Research and Education (NIFU).

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Contents

Summary

This report provides a bibliometric analysis of the output of the technical-industrial (TI) institutes in terms of scientific publications. It focuses on the productivity of the institutes, their publication profiles, the scientific impact of their research as reflected in citation indictors as well as their collaboration patterns, analysed through co-authorship. It covers publications by the institutes' staff during the period 2009–2013, which are registered in the national Research Information System (CRIStin) and attributed to the institutes. This means that the analysis covers publications in officially recognised scientific publication channels but not other types of output such as grey literature and reports. Different categories of entry in the CRIStin database generate different numbers of 'publication points' and therefore amounts of funding in the Norwegian performance-based funding system.

Large differences in the volume of scientific publishing

The volume of scientific publishing varies greatly among the institutes. The SINTEF Foundation is the largest and accounts for 41 per cent of the scientific publishing of the TI institutes during the period 2011–2013, measured as publication points. If the associated institutes of the SINTEF Group – MARINTEK, SINTEF Petroleum Research and SINTEF Energy Research – are included SINTEF's share rises to 62 per cent. At the level of individual institutes rather than groups, SINTEF Materials and Chemistry and SINTEF Energy Research are the largest with 18 and 16 per cent of the total publication output of the TI institutes, respectively. They are followed by SINTEF ICT with 13 per cent and IFE with 10 per cent. The smallest institutes in terms of scientific publishing, Christian Michelsen Research (CMR), Tel-Tek and Norut Narvik, have proportions of 1 per cent each.

Publication productivity varies significantly

There are also significant differences among the institutes in the proportion of their R&D activities that results in scientific publications. This can be measured by dividing their publication points by the number of full-time equivalent (FTE) researchers they employ. In 2011–2013, SINTEF Energy Research had the highest ratio, 0.89 publication points per FTE researcher, followed by NORSAR with 0.78 and the Norwegian Computing Centre (NR) with 0.66. CMR, MATRINTEK and SINTEF Petroleum Research have the lowest publication productivities, with 0.19–0.24 publication points per FTE researcher. The figures reflect the heterogeneity of the research activities that the TIs perform. Some have a stronger focus on basic research, typically resulting in scientific publications. Others have a profile dominated by services and technology development, where scientific publishing is less relevant.

Growth in scientific publishing

There was a marked increase in the volume of scientific publishing during the period 2009–2013. Overall, the TI institutes increased their number of publication points by 26 per cent during the period. It is likely that the performance-based funding system, where scientific publishing counts as one of the indicators, has provided an incentive to increase publication activities.

Scientific specialisation

The scientific profiles of the institutes have been analysed using data on the subfield distribution of the publications. This analysis is based on publications indexed in Web of Science (WoS) only. Accordingly, it covers only a sub-set of the research output listed in CRIStin, i.e. the portion that has been published in journals indexed by Thomson Reuters, who produces the WoS.

The analysis shows that the TI institutes are very strongly specialised in Geological, Petroleum and Ocean engineering. We also find a strong specialisation in Energy and Fuels, Construction & building technology and Marine engineering. On the other hand, relatively speaking the institutes have little research output (a negative specialisation) within several other engineering subfields, such as Electrical & electronic engineering, Mechanical engineering and Nanoscience & Nanotechnology.

The TI institutes have contributed 55 per cent of the total Norwegian publication output in Geological engineering during the period 2009–2013. Their share is also very high in Construction & building technology (47%) and Metallurgy & metallurgical engineering (45%). These are subfields where the TI institutes play leading roles in the Norwegian R&D system. There are other areas such as Materials science, Electrochemistry, Petroleum engineering, and Energy & fuels where the institutes are large but less prominent contributors with shares in the range of 30–40 per cent of the national total.

Scientific impact measured through citations

Data on the extent to which publications have been referred to, or cited, in the subsequent scientific literature can be regarded as a proxy for the scientific impact of the research. The citation analysis is also limited to WoS indexed articles and covers the period 2009–2012. Overall, the TI institutes have a citation index of 120, which means that their articles have been cited 20 per cent more frequently than the field-normalised world average (100). This is marginally above the Norwegian average within Engineering science, which is 117. Accordingly, the TI institutes overall perform reasonably well when it comes to scientific impact measured through citations.

There are, however, large differences at the level of subfields. In two subfields, Petroleum engineering and Construction & building technology, the TI institutes are extremely highly cited: with citation indices of 340 and 293, respectively. The institutes also perform very well in Civil engineering (169) and Metallurgy & metallurgical engineering (147), where citation indices are far above the world average. On the other hand, there are many subfields where their citation indices are significantly below the world average, for example, Physics, condensed matter and Nanoscience & nanotechnology with citation indices of 44 and 59, respectively. Several of the subfields with high citation indices are areas in which the TI institutes are highly specialised, for example Petroleum engineering, Construction & building technology and Metallurgy & metallurgical engineering.

There are also large differences in citation indices among individual institutes. SINTEF Building and Infrastructure has the highest citation index with 192. Then follow Uni Research with 164, IRIS with 162 and MARINTEK with 140. These institutes perform very well in terms of citation rates. On the other hand, there are several institutes with citation rates significantly below the world average. In particular, the citation indices are rather low for Norut Narvik (49), Tel-Tek (71), NORSAR (74) and CMR (74).

When interpreting the figures, it is important to emphasise that citations mainly reflect intra-scientific use. Practical applications of research results will not necessarily be reflected in citation counts. Moreover, owing to various limitations and biases attached to citation indicators, they cannot replace a quality assessment carried out by peers.

Extensive collaboration

The analysis shows that the TI institutes are heavily involved in scientific collaboration. This is reflected through the fact that many publications have co-authors from external institutes, institutions and industry. Almost half of the publications have been published with co-authors from foreign institutions. There is also extensive national collaboration with particularly strong links between the TI institutes and the Norwegian University of Science and Technology (NTNU). In fact, approximately one third of the TIs' publications during 2011–2013 had co-authors from NTNU. Institutes within the SINTEF group account for the majority of these publications, but there are also many articles with co-authorship from other institutes. The University of Oslo (UiO) is by far the largest university in Norway and ranks as the second biggest institutional partner of the TI institutes. In total, 9 per cent of the publications had co-authors from Norwegian companies. The incidence of scientific publishing in industry is generally very low. This is partly due to the commercial interest related to research results, which means that the results often cannot be published, i.e. made public. Therefore, only a limited part of the institutes' collaboration with industry is reflected in co-authorship data.

Selected conclusions

In conclusion, the study has identified that the TI institutes have been successful in increasing their publication output during the period. However, the productivity measured per researcher is significantly lower for the TI institutes than for the other institutes within the institute sector in Norway. Despite the practical orientation of the institutes, they have been able to deliver research that is reasonably well cited. The institutes have research activities within a broad range of scientific fields, but at the same time a strong specialisation in some of them. The analysis suggests that the institutes generally perform particularly well in terms of scientific impact in fields where they also have a strong specialisation.

1 Introduction

1.1 Panel evaluation of the Norwegian technical-industrial research institutes

According to its statutes, one of main tasks the Research Council of Norway (RCN) is to "work to achieve a constructive distribution of tasks and cooperation between research institutions, and take strategic responsibility for the research institute sector".[1] RCN's five-year plan for the evaluation of research institutes states three overarching objectives for such evaluations:[2]

1. To provide knowledge for the institutes own strategic development efforts,
2. To strengthen the knowledge base for the efforts of the Research Council and the ministries to develop an effective, targeted research policy, and
3. To provide a basis for assessing the design of the Research Council funding instruments.

As part of its strategic responsibility for the institute sector, RCN evaluates the research institutes, and the time has now come to evaluate the Norwegian technical-industrial research institutes (hereinafter referred to as TI institutes):

- Christian Michelsen Research AS (CMR)
- Institute for Energy Technology (IFE):
  - IFE nuclear research activities
  - IFE other research activities
- International Research Institute of Stavanger AS (IRIS)
- Norwegian Marine Technology Research Institute AS (MARINTEK)
- Norwegian Geotechnical Institute (NGI)
- NORSAR
- Northern Research Institute AS (Norut) – Norut Tromsø
- Northern research Institute AS (Norut) – Norut Narvik
- Norwegian Computing Center (NR)
- SINTEF Energy Research AS
- SINTEF Petroleum Research AS
- SINTEF Foundation:
  - SINTEF Building and Infrastructure
  - SINTEF ICT

[1] Statutes of the Research Council of Norway.
[2] «Instituttevalueringer, Overordnet plan», Norges forskningsråd, 2013.

- SINTEF Materials and Chemistry
- SINTEF Technology and Society

- Tel-Tek
- Uni Research AS

For the purposes of the evaluation, the two largest institutes (IFE and SINTEF Foundation) have been divided into subunits to account for the fact that the 14 TI institutes are of very different size, meaning that the evaluation in total will assess 18 institute entities. The evaluation of the TI institutes thus encompasses institutes doing research spanning from industrial processes, materials and chemistry and ICT, to marine technology, energy, petroleum, nuclear technology, geoscience and technology and society.

The evaluation is a combination of i) an assessment of individual institutes and entities (and their particular framework conditions, strengths, weaknesses and possibilities); ii) an evaluation of technical-industrial research in Norway, including the institute sector's national and international interactions; and iii) an evaluation of the institute sector's changing framework conditions and the demands that are placed upon it. At the overall level, the evaluation embraces several important aspects of the Norwegian research system, and the future challenges and opportunities of the Norwegian TI institutes.

1.2 Supporting documentation for the evaluation

The evaluation of the TI institutes is conducted by an international panel of experts appointed by RCN, supported by a panel secretary contracted by RCN. The panel will conduct hearings with the institute entities, and does additionally have a vast amount of background material at its disposal, including:

1. Internal evaluations (self-assessments) by the institutes
2. Fact report on the institutes prepared by RCN
3. User survey
4. Impact analysis
5. Bibliometric analysis
6. Evaluation of basic and long-term research within technology conducted by RCN

RCN has procured a three-part assignment to produce items 3, 4 and 5 in this list. The assignment has been carried out by Technopolis Group in collaboration with Stiftelsen Nordisk institutt for studier av innovasjon, forskning og utdanning (NIFU) between January and May 2015. The assignment, led by Tomas Åström of Technopolis, has been carried out as three sub-projects. This report presents the results of the bibliometric analysis. The results of the other sub-projects are presented in separate reports.

1.3 The bibliometric analysis assignment

Publication and citation data have increasingly been applied as performance indicators in the context of science policy and research evaluation. The argument 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 therefore 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 aim of the current bibliometric analysis is to assess the scientific production and impact of the institutes' scientific publications through recognised publication channels, i.e. the ones that give publications points in the institutes' basic funding scheme, over the past three to five years. The analysis encompasses:

- Classification of publications in relevant categories and generation of a publication profile for individual institute entities
- Number of publications, publication points per scientific man-year, and distribution on scientific production on level 1 and level 2 (the "normal level" (level 1) and the higher level (level 2) which is given extra weight in the performance-based funding model and only includes the leading and most selective journals and publishers).
- Assessment of scientific impact through citation indices
- Analysis of scientific collaboration as measured through co-publications with authors in industry, other research institutes and higher education institutions; both national and international co-publications are included

Results are reported both at the level of institute entities and for the TI institutes as a group.

1.4 Report structure

The report is structured as follows: The next chapter presents the data and the methodology applied in the study. Then follows a chapter providing an overall analysis of the publication output at the included institutes. Separate chapters for each of the institutes are attached in the appendix. The appendix also includes a macro analysis of Norwegian engineering research in international comparison. A final appendix chapter provides a general introduction to bibliometric indicators, particularly focusing on analyses based on Thomson Reuters data.

2 Data and methods

Included in the analysis are the 18 institute entities listed above. Some of the institutes in scope include social science departments (Norut Tromsø, IRIS, and SINTEF Technology and Society). The social science activities of the institutes have been excluded from the publication analysis. At Uni Research, only the two departments, Uni CIPR and Uni Computing, are included. The general appendix chapter on Norwegian engineering science (Appendix 2) is, however, not limited to these units. Here, all Norwegian publishing in journals within engineering science is included. The analysis covers the five-year period 2009–2013.

2.1 Data sources

The study is based on three main data sources. One source 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. Another is the Web of Science by Thomson Reuters, the producer of the most used database for bibliometric purposes. Finally, the Key figure database at NIFU containing publication indicators for the institutes is applied.

The CRIStin database is the primary data source applied in the study. Publication data are available in CRIStin for the period 2011–13. For 2009 and 2010, we have used data from NIFU's Key figure database, also including data on scientific publications (Nøkkeltalldatabasen).

The analysis is limited to the publication categories included in the Norwegian performance-based funding of the research institutes (and the higher education institutions), namely monographs and contributions to anthologies (book articles) published at publishing houses classified as scientific/scholarly by the Norwegian Association of Higher Education Institutions (UHR), and articles in series and journals classified as scientific/scholarly by UHR. 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. Publications which are outside these channels are not included in our analysis. For example, unpublished PhD-dissertations, grey literature such as reports, as well as popular science articles. This needs to be taken into consideration when interpreting the results. For example, the research institutes typically have a significant amount of publishing through reports and other forms of grey literature.

The performance-based basic funding system

A part of the basic allocation is distributed between the institutes on basis of performance indicators. For the TI institutes the performance-based part of the basic allocations was 10 per cent in both 2013 and 2014. The performance-based part is (from 2014) distributed on the basis of the results achieved in the previous three years according to four indicators. These are: revenues from nationally commissioned research (45%), scientific publication (30%), international revenues (20%), and completed doctoral degrees (5%). In the period 2009-2013, there were two additional indicators, namely funding from the Research Council and collaboration with the higher education sector in terms of part-time positions. For each institute, the performance-based part is depending on both the institute's results on the different indicators, and the results achieved by the other institutes on the same indicators.

Source: The Research Council of Norway (2015). Technical-industrial institutes. Facts report - Key R&D indicators.

The funding formula for publication activity includes two dimensions. First, articles in journals and series (ISSN-titles), articles in books and books/monographs (ISBN-titles) are given different weights. Moreover, publication outlets are divided into two levels in order to avoid an incentive to productivity only. The outlets given extra weight are those defined to be the leading and most selective international journals, series and publishers (limited to about 20 per cent of the publications). The national councils in each discipline or field of research participate annually in determining and revising the highest level under the guidance of the Norwegian Association of Higher Education Institutions. [3] The table below shows the relative weights given the different types of publications at the two levels.

Table 2.1. Publication weights

Publication type	Outlets at normal level (level 1)	Outlets at high level (level 2)
Articles in ISSN-titles (journals and series)	1	3
Articles in ISBN-titles (books)	0.7	1
Books (ISBN-titles)	5	8

Note: Co-authored publications are shared among the participating institutions.

The formula only includes “scholarly publications”. The definition is that a scholarly publication must:

1. present new insight;
2. be presented in a form that allows the research findings to be verified and/or used in new research activity;

[3] http://dbh.nsd.uib.no/kanaler/

3. be written in a language and have a distribution that makes the publication accessible to most interested researchers;
4. appear in a publication channel (journal, series, book publisher) that has routines for external peer review. (Source: "Vekt på forskning" English translation, UHR 2007). [4]

Co-authored publications are shared, and fractionalised publication points are calculated based on the number of author addresses. Publications involving external collaboration (i.e. having co-authors from other institutions) are given extra weight and the publications points are multiplied by 1.25.

In the analysis of the report, we have used both the weighted indicator "publication points" and the number of unique publications (i.e. full counts). For example, the analysis of scientific collaboration (see below) is based on number of publications and not on publication points.

As a subsidiary data source we have used a database which NIFU has purchased from Thomson Reuters. 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 (the Web of Science Core collection). 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 NCR is used in order to analyse the specialisation profile of the institutes, their citation rates, as well as their international research collaboration (see below). In some of these analyses we are also drawing on aggregated bibliometric statistics at country and field/subfield level, which NIFU purchased from CWTS at Leiden University, the Netherlands. The latter data were used for the purpose of creating reference standards in the citation analyses, and for the general analyses in Appendix chapter 3. The aggregated data correspond to the NCR-dataset.

It is important to emphasise that only a part of the institutes' scientific publications are indexed in the NCR database. Generally, the engineering field is only moderately well covered by the database. This is due to the particular publication pattern of engineering research where proceedings play an important role; a significant part of this output will not be covered by the database. Overall, 59 per cent of the institutes' scientific publications appeared in NCR, but with significant variations across the individual institutes. These

[4] http://www.uhr.no/documents/Vekt_p__forskning__sluttrapport.pdf

differences partly reflect the research profile of the institutes. For example, natural scientific fields such as geophysics generally has a better coverage than engineering science and ICT.

Even if the coverage of the Web of Science database (and the NCR subset applied in the study) is not complete, the database will include all major journals within the natural sciences and technology. 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). For example, journals with very low citation frequencies and national journals are usually not included. Moreover, very recently launched journals may not be included. Thus, the analyses involving NCR are based on a limited part of the research output (even if it is probably the scientifically most important part). This is important to consider when interpreting the results, particularly for the institutes which only have relatively low proportions of their publications indexed in the database.

2.2 Methods

The analysis of the institutes includes all publications that have been published by the staff at the institutes during the period, and which are credited the institutes through the Norwegian performance-based funding system (i.e. the institute is listed as an author address). It should be noted that some of these publications are authored by people who no longer are employed. However, the analysis does not include publications published by a person before he/she became affiliated with their present place of employment. There is a delay between the time when the research is carried out to the appearance of the publication. For 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 institute level, and is not an evaluation of individual persons.

Uni Research has recently been included among the institutes which fulfil the criteria for obtaining core funding from the Research Council of Norway. Therefore, publication points are not available for this institute through the Key figure database. However, we have received publication lists from the institute, as well as data on number of researchers from RCN, and the relevant publications have been added to the database. We are accordingly able to include the institute in most of the analyses. We have also received additional data from SINTEF Technology and Society in order to exclude the social scientific part of the institute (the latter is classified as an entity under the group of social science institutes). For IFE we have received a personnel list enabling us to split the publications in two parts: i) nuclear research and ii) other research. However, for some of the analyses we are not able to provide separate figures for the two units.

The report contains indicators where the publication output of the institutes is analysed both collectively and individually. The publication volume is measured by publication points and number of unique publications. In order to assess the publication productivity of the institutes, the number of publication points is compared with the number of full-time equivalent (FTE) researchers they employ. Some of these indicators have already been published by the RCN in the annual reports of the TI institutes. Included among the indicators are also the proportion of publications appearing in level 2 channels and a list of the most frequently used journals and series. The national collaboration profile of the institutes is analysed using data on co-authorship. These indicators are all based on the complete publication output of the institutes.

Then there are some analyses based on the subset of the publications indexed in NCR. This includes analyses where the research output is classified by subject categories. The analysis relies 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).[5] In addition, NCR data are used for analysing international collaboration as well as collaboration with industry (data containing the required co-authorship information are only systematically available through NCR). In addition, NCR data are applied for constructing citation indicators. These are further described below.

2.3 Citation analyses

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. Only citations from journals in the Web of Science Core Collection (see above) are included. 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 very little cited or not cited at all.

In the study the institutes have received full credit for their citations – even when for example only one of several authors represents the respective institute. This is also the most common principle applied in international bibliometric analyses. There are however arguments for both full counting and fractionalisation of the citations. 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

[5] The content of the various categories is described here: http://ip-science.thomsonreuters.com/mjl/scope/scope_scie/#AA

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). The indicators are further described below.[6]

Relative citation index – journal

For the Relative citation index – journal we used the mean citation rate of the institute's journal package, calculated as the average citation rate of the journals in which the institute 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 institute 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 institute's articles and the average citation rate of its journal package. For example, an index value of 110 would mean that the institute'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 institute 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 institutes are usually active in more than one subfield (i.e. the journals they publish in are assigned to different subfields). For each institute we therefore calculated weighted

[6] We have not calculated the h-index. Although this indicator has become very popular among scientists, there are several problems with applying it. There are no field normalisation, which invalidate comparisons across disciplines and subfields. The indicator does not correct for career length, and disfavour younger scientists.

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 institute's articles and the average subfield citation rate. In this way, the indicator shows whether the institute's articles are cited below or above the world average of the subfield(s) in which the institute is active.

<u>Example</u>

The following example illustrates the principle involved in calculating relative citation indices. 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, a relative citation index is calculated for each article separately as a first step. Then the average index of all articles is calculated and used as indicator (cf. Lundberg 2007).

It is important to notice the differences between the field and journal adjusted relative citation index. An institute may have a publication profile where the majority of the articles are published in journals that are poorly cited within their fields (i.e. have low impact factors). This implies that the institute 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 (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*:

<u>Citation index: > 150:</u> Very high citation level.

<u>Citation index: 120-150:</u> High citation level, significantly above the world average.

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

<u>Citation index: 50-80:</u> Low citation level.

<u>Citation index: < 50:</u> Very low citation level.

It should be emphasised that the indicators cannot replace assessment carried out by peers. In the cases where an institute 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 an institute.

As described in the Appendix chapter 3, 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. During the work on the report, it has become apparent that some of the institutes only have relatively low proportions of their publications indexed in the database. This means that they publish a lot in journals, proceedings and books not indexed in the database. In turn, this may reflect the research profile of the institutes and the publishing characteristics of the fields in which they are active. In some field, the role of international journals is less important than in others. This is important to consider when interpreting the results, and one should be careful about 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 have not been available to us. Citations counts can also be retrieved 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. Google Scholar has no 'quality' test inherent in the way it collects citations – it simply counts any citation it can identify in a document that appears to be a report, book or journal and only counts the citation for as long as the citing document is visible on the World Wide Web. Therefore, this database has not been applied in the report.

3 Overall analysis of the institutes

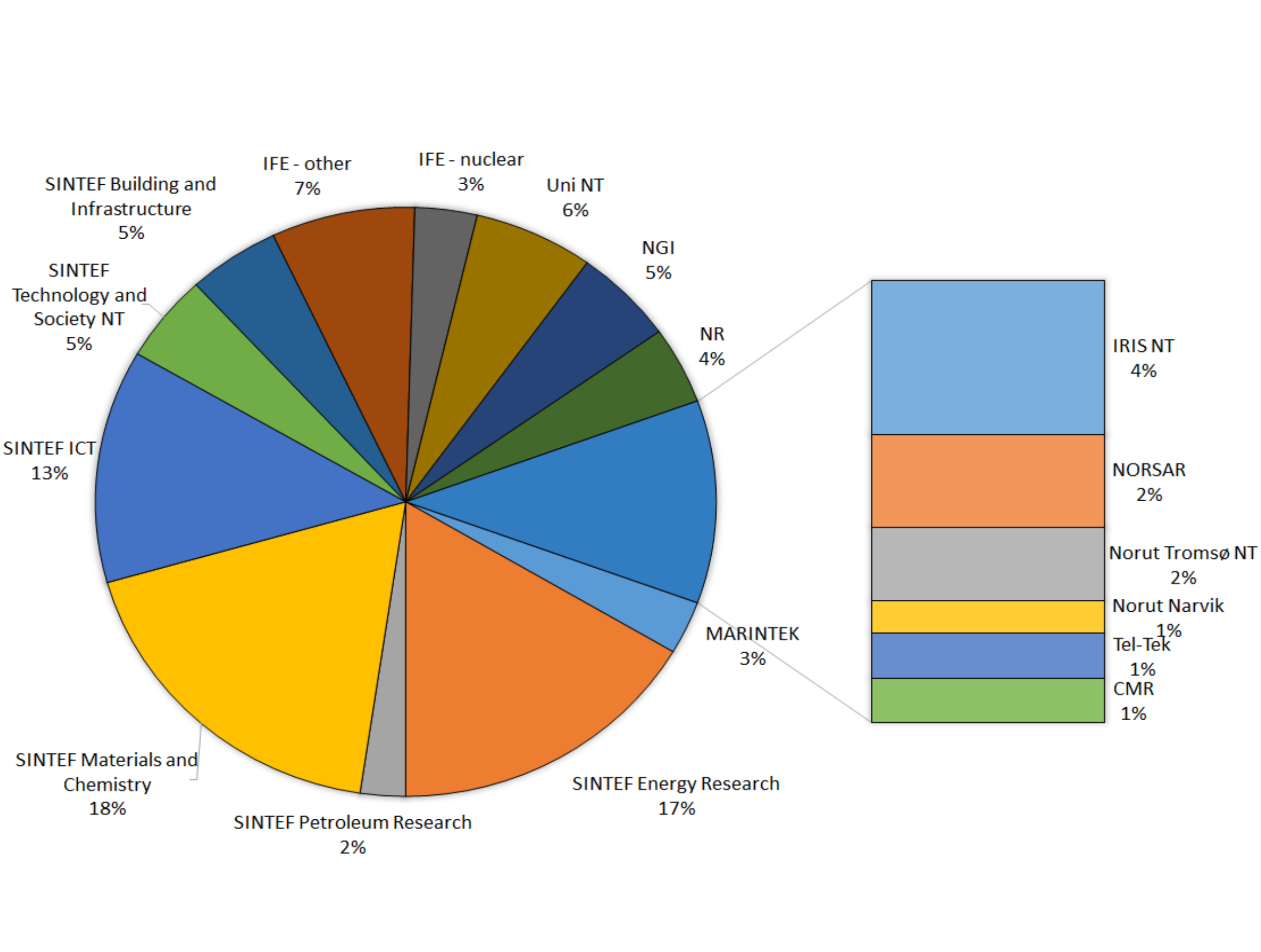
This chapter presents various analyses of the publication output of the TI institutes for the period 2009–2013. Included are analyses of the total scientific publication output and journal profile as well as citation and collaboration indicators. We present figures for the entire period and by year. Because more bibliographic details are available for the 2011–2013 publications, some of the analyses are limited to this period.

3.1 Scientific publishing

3.1.1 Scientific publishing measured by publication points

There are large differences among the institutes in the volume of scientific publishing. The SINTEF foundation is the major contributor and accounts for 41 per cent of the scientific publishing of the TI institutes measured as publication points during the period 2011–2013. When including the associated institutes of the SINTEF Group, MARINTEK, SINTEF Petroleum Research and SINTEF Energy Research, this proportion increases to 62 per cent. In Figure 3.1 the proportions of the individual institutes are shown. SINTEF Materials and Chemistry and SINTEF Energy Research are the largest single institutes with proportions of 18 and 16 percent, respectively, of the total. Then follows SINTEF ICT with a proportion of 13 per cent. IFE is the fourth largest institute with a proportion of 10 per cent (IFE - nuclear 3% and IFE – other 7%). The smallest institutes in terms of scientific publishing, CMR, Tel-Tek and Norut Narvik, have proportions of 1 per cent.

Figure 3.1 Proportion of publication points. TI institutes,* total 2011–2013.



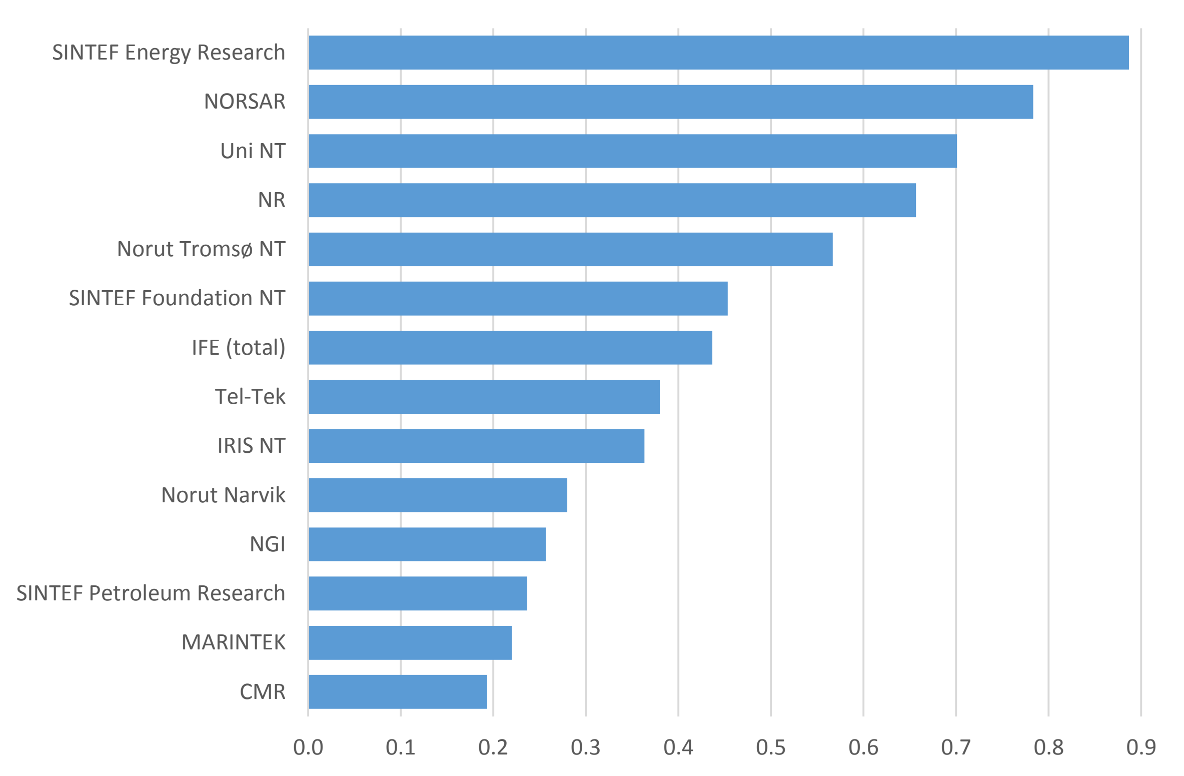
Source: Data: NIFU's Key figure database. Calculations: NIFU.

*) The figures for three of the institutes include the TI parts, only (abbreviation "NT") and for Uni, Uni CIPR and Uni Computing (Uni NT).

There are however large differences among the institutes in terms of the degree to which their R&D activities actually result in scientific publications. This can be measured by dividing the publication points by the number of full-time equivalent (FTE) researchers. In Figure 3.2 we have shown this indicator. In order to avoid random annual fluctuations, we have use the average for the three-year period 2011–2013 as basis for the comparisons. SINTEF Energy Research has the highest ratio, 0.89 publication points per FTE researchers, followed by NORSAR with 0.78 and NR with 0.66. Unfortunately, figures are not available for the individual institutes within the SINTEF foundation but overall the foundation has 0.45 publication points per FTE researchers. CMR, MATRINTEK and SINTEF Petroleum Research have the lowest publication productivity, with 0.19-0.24 publication points per FTE researchers. The average for the TI institutes is 0.44

The figures reflect the fact that the institutes are very heterogeneous in terms of their R&D activities. Some institutes have a stronger focus on basic research than others, typically leading them to produce larger numbers of scientific publications. Other have a profile dominated by services and technology development where scientific publishing is less relevant. It is important to take this into consideration when interpreting the figures.

Figure 3.2 Number of publication points per FTE researchers. TI institutes, average for the 2011-2013 period.

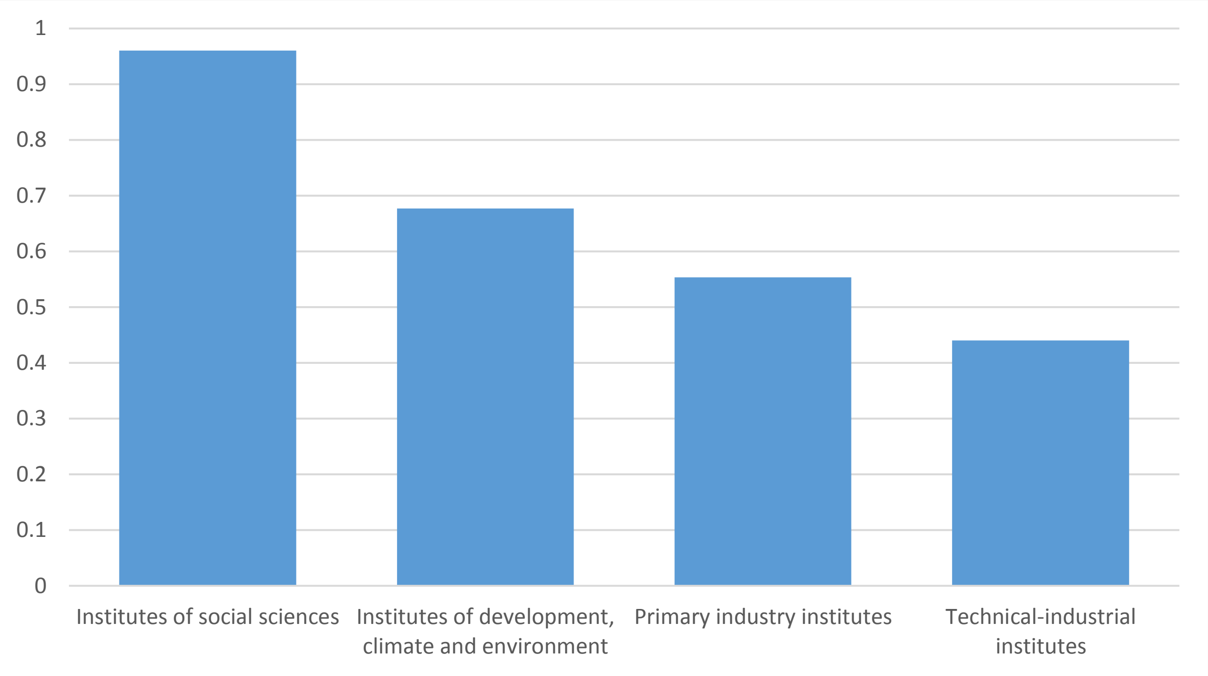


Source: Data: NIFU's Key figure database. Calculations: NIFU.

*) Figures not available for the individual institutes within the SINTEF foundation.

The incidence of scientific publishing at the TI institutes is, however, lower than at the other units within the institute sector in Norway. This is evident when comparing the productivity measured in publication points per FTE researchers. Figure 3.3 shows the average productivity for the 2011–2013 period for each institute arena, according to the classification of the Research Council of Norway. With an average of 0.44 publication points per FTE researchers, the TI institutes are positioned at the bottom, significantly below the average of the other institutes. Notably, the publication productivity of the social science institutes is more than twice as high (0.96). The low publication productivity of the TI institutes is also evident when comparing their proportions of input and output resources. According to the most recent official R&D statistics (2011) the TI institutes are responsible for 8 percent of total Norwegian R&D expenditure. In contrast, the institutes in 2011–2013 contributed 4 per cent of the publication output within the public research sector (if including the business enterprise sector, the proportion would have been even lower). Thus, these figures shows that scientific publishing is less frequent among the TI institutes and that only a limited part of their R&D activities results in such output. It should be noted, however, that the proportion of basic funding from the Research Council of Norway is lower for the TI institutes (5.9 % in 2013) than for the other institutes in the institute sector in Norway. This funding is important in respect to scientific publishing. Therefore, it may explain the lower publication ratios of the TI institutes.

Figure 3.3 Number of publication points per FTE researchers, average for the 2011–2013 period. Institute sector, classified according to arena



Source: Data: NIFU's Key figure database. Calculations: NIFU.

During the period 2009–2013, there has been a marked increase in the volume of scientific publishing. Overall, the TI institutes have increased their number of publication points by 26 per cent during the period. There was a particular strong growth from 2010 to 2011, cf. Table 3.1, but a slight decrease from 2012 to 2013. It is likely that the performance-based funding system, where scientific publishing counts as one of the indicators, has functioned as an incentive to increase publication activity.

At the level of the individual institutes, we find significant annual variations. Some of these changes, particularly for the smallest institutes, should probably be interpreted as random fluctuations than reflecting real temporal changes in the scientific publication activity. SINTEF Energy Research has increased its publication volume significantly during the period, almost doubling its publication points from 2009 to 2013 (most of the increase taking place from 2009 to 2010). There is also a strong growth for SINTEF Materials and Chemistry (78 per cent. None of the institutes has a distinct decreasing publication pattern.

Table 3.1. Number of publication points. TI institutes 2009–2013.

Institute	2009	2010	2011	2012	2013
CMR	4.3	1.6	5.9	14.8	8.9
IFE - total	78.5	82.9	109.2	96.5	79.2
IFE - nuclear	24.5	11.0	35.1	23.9	27.1
IFE - other	58.7	74.8	74.1	72.6	52.2
IRIS NT	30.7	20.5	35.5	35.2	32.5
MARINTEK	21.8	16.3	19.6	28.1	30.2
NGI	46.0	32.3	45.4	46.2	48.3
NORSAR	12.2	11.4	20.8	25.3	16.0
Norut Narvik	4.0	1.1	4.2	4.2	12.8
Norut Tromsø NT	22.4	16.1	16.6	22.0	10.4
NR	41.6	26.3	40.4	34.8	37.4
SINTEF Energy Research	76.9	86.0	142.7	147.9	147.9
SINTEF Petroleum Research	25.9	14.1	17.5	12.2	32.9
SINTEF Foundation (NT) total	261.0	305.9	333.5	371.0	322.9
SINTEF Building and Infrastructure	36.5	42.0	45.4	39.4	42.4
SINTEF ICT	98.8	123.7	109.5	134.8	95.7
SINTEF Materials and Chemistry	90.8	114.0	159.1	163.4	161.8
SINTEF Technology and Society NT	29.2	33.7	26.5	62.3	39.1
Tel-Tek	5.9	5.4	7.0	9.7	14.0
Uni NT*			45.7	55.8	63.9
Total**	631.1	619.8	798.5	848.0	793.2

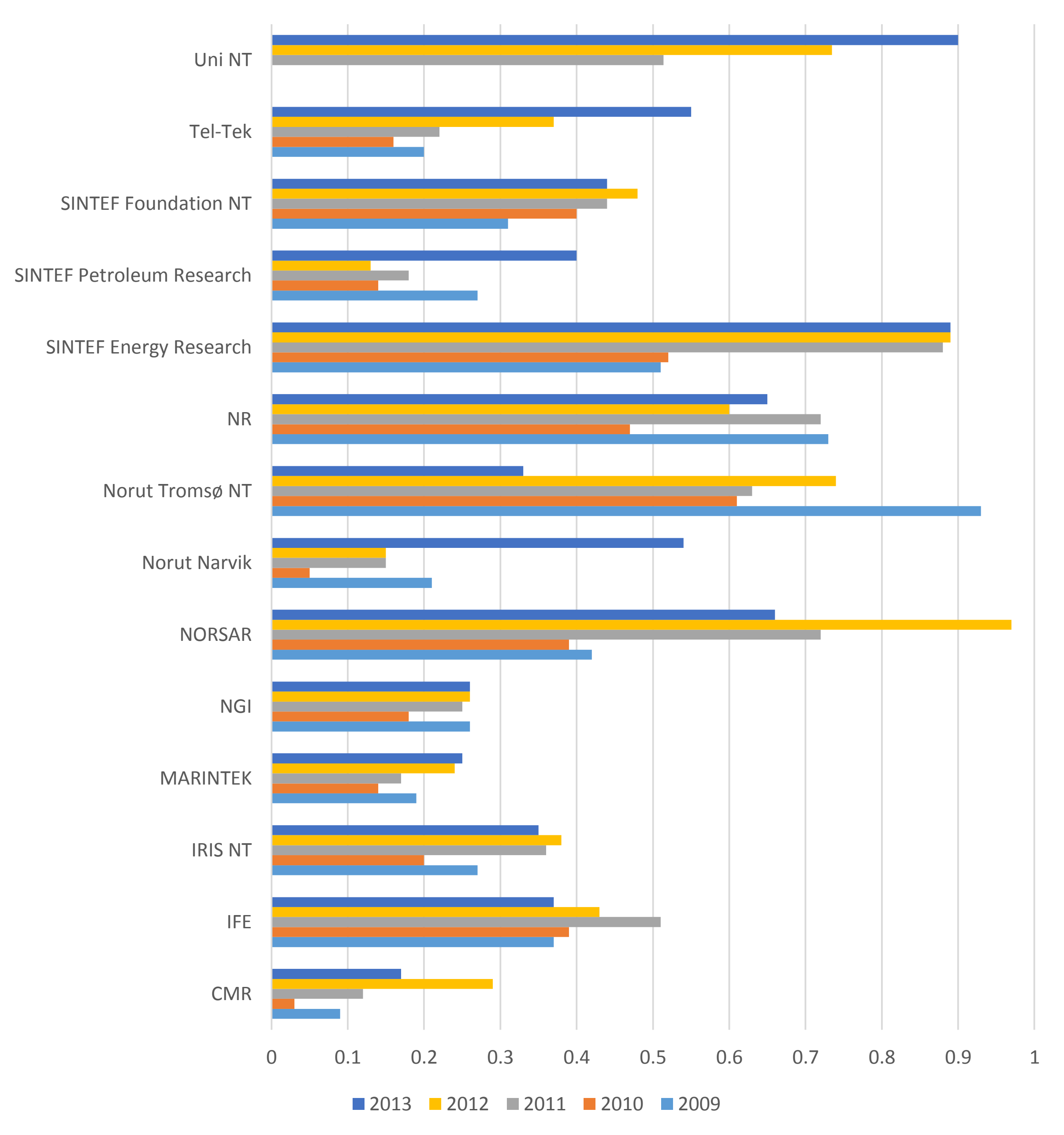
Source: Data: NIFU's Key figure database. Calculations: NIFU.

*) Figures not available for 2009 and 2010.

**) Excluding Uni NT.

Figure 3.4 shows the annual number of publication points per FTE researcher for the period 2009–2013. There are also quite large annual variations in these numbers for many of the institutes. Overall, the TI institutes have increased their productivity from 0.33 publication points per FTE researchers in 2009 to 0.44 in 2013. In other words, there has been a marked increase in the publication volume also when measured on FTE basis (33% increase).

Figure 3.4. Number of publication points per FTE researchers. TI institutes 2009–2013.



Source: Data: NIFU's Key figure database. Calculations: NIFU.
*) Figures not available for the individual institutes within the SINTEF foundation.

3.1.2 Scientific publishing by publication channels

As described in the previous chapter, the journals and publishers are classified into two levels in the performance-based funding model. The highest level (level 2) includes only the leading and most selective international journals and publishers (accounting for 20% of the publication output in each discipline, on average). Publications in these channels are given extra weight (cf Chapter 2). In our analysis, we identified the proportion of publications at level 2 for each institute and year. Table 3.2 shows the results of this analysis.

As can be seen, the overall proportion of level 2 publications by the TIs has been in the 20-24% range during the period 2009–2013. At the level of the individual institutes, we find large annual variations also on this indicator. The highest averages are found for Uni Research (38%) IRIS (33%) NORSAR (31%), SINTEF Materials and Chemistry (30%) and IFE nuclear (30%). SINTEF Technology and Society, Norut Narvik and SINTEF ICT have the lowest proportions, with 10, 13 and 14 per cent, respectively. Based on the premise that level 2 includes the leading and most selective international journals and publishers, high shares here indicate high ambitions when selecting journals for publication and a high quality of the research. On the other hand, it should be noted that in some fields, particular publication patterns where level 2 publishers are few or less relevant may explain why some institutes have low proportions of level 2 publications. Similarly, a lack of focus or awareness among the researchers of publishing in these journals and series may explain low figures. This needs to be taken into account when interpreting the indicator.

Table 3.2 Proportion of publications at "level-2". TI institutes 2009–2013.

	2009	2010	2011	2012	2013	Average 2009–13
CMR	20%	20%	13%	23%	43%	24%
IFE	20%	29%	21%	23%	28%	24%
IFE – nuclear*			36%	18%	36%	30%
IFE – other*			13%	25%	24%	21%
IRIS NT	32%	23%	34%	28%	49%	33%
MARINTEK	11%	22%	21%	15%	19%	17%
NGI	24%	16%	17%	26%	21%	21%
NORSAR	25%	20%	34%	47%	28%	31%
Norut Narvik	11%	0%	0%	40%	12%	13%
Norut Tromsø NT	28%	14%	28%	31%	20%	24%
NR	18%	14%	24%	13%	23%	18%
SINTEF Energy Research	28%	27%	20%	21%	22%	23%
SINTEF Petroleum Research	39%	41%	22%	12%	28%	29%
SINTEF Foundation NT	21%	21%	18%	24%	23%	21%
SINTEF Building and Infrastructure*			15%	25%	20%	20%
SINTEF ICT*			10%	18%	14%	14%
SINTEF Materials and Chemistry*			26%	33%	30%	30%
SINTEF Technology and Society NT*			13%	9%	8%	10%
Tel-Tek	10%	29%	11%	24%	10%	17%
Uni NT*			34%	38%	41%	38%
Total**	22%	22%	20%	24%	24%	22%

Source: Data: NIFU's Key figure database. Calculations: NIFU.

*) Figures not available for 2009 and 2010. Average based on 2011–2013 publications.

**) Excluding Uni NT.

The publications are distributed across a large number of different journals, series and publishers. Table 3.3 gives the annual publication counts for the most frequently used journals and series for the period 2009–2013 (limited to 20 publications from the TI institutes during the period). On the top of the list, we find the open access journal *Energy Procedia* with 214 articles. This journal was launched in 2009, and therefore there are few publications from 2009 and 2010. Then follows the series, *Lecture Notes in Computer Science*, with 110 articles. This is one of the largest series of computer science conference proceedings, which publishes a vast amount of articles annually. None of these journals are however indexed in the regular edition of the Web of Science database. The table also shows how the contribution in the various journals and series has developed during the period. From the list, one gets an overall impression of the research profile of the TI institutes.

Table 3.3 The most frequently used journals and series for the period 2009–2013, total number of publications from the TI institutes.

	Level	2009	2010	2011	2012	2013	Total
Energy Procedia	1	19	2	61	56	76	214
Lecture Notes in Computer Science	1	24	17	19	30	20	110
ISOPE - International Offshore and Polar Engineering Conference. Proceedings	1	3	7	16	13	9	48
International journal of hydrogen energy	2	7	12	7	12	8	46
International Conference on Offshore Mechanics and Arctic Engineering [proceedings]	1	3	1	4	20	15	43
Journal of Alloys and Compounds	1	8	1	17	8	5	39
Journal of Applied Physics	2	9	5	7	7	6	34
International Journal of Greenhouse Gas Control	2		3	8	12	11	34
Energy & Fuels	2	2	5	6	7	13	33
Environmental Science and Technology	2	3	2	11	9	7	32
The Journal of Physical Chemistry C	1	2	3	4	10	12	31
Light Metals	1			11	12	8	31
SPE Journal	2	3	11	5	4	4	27
Industrial & Engineering Chemistry Research	2		4	5	11	6	26
IEEE Transactions on Power Delivery	2	7	3	3	7	6	26
Computational Geosciences	1	2	5	8	8	3	26
Science et technique du froid	1		7		15	3	25
Journal of Crystal Growth	1	1	3	7	3	11	25
IFIP Advances in Information and Communication Technology	1		5	5	3	11	24
PLoS ONE	1	1	1	4	7	10	23
Energy and Buildings	2	3	3	7	4	6	23
Geophysics	2	8	2	3	6	4	23
Proceedings of SPIE, the International Society for Optical Engineering	1	4	11	2	1	3	21
ECS transactions	1	2	8	7	1	3	21

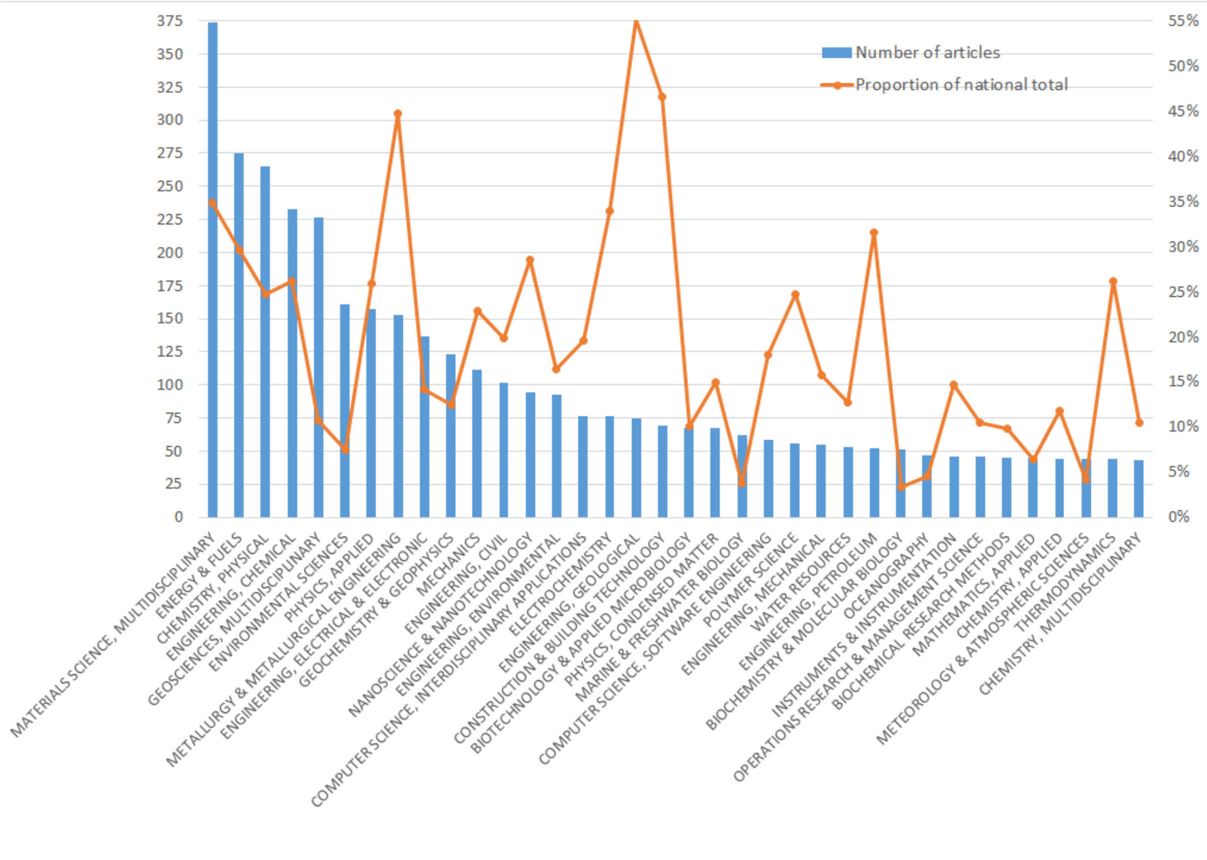
Source: Data: NIFU's Key figure database/CRIStin. Calculations: NIFU.

3.1.3 Scientific publishing by subfields

In order to provide further insight into the scientific profiles of the TI institutes, 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). Therefore, only the NCR-indexed articles are included in this analysis. 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 comparing the publication output at subfield levels.

Figure 3.5 shows the distribution of articles for the 5-year period 2009–2013. The results show that the TI institutes have publications within a broad range of areas, covering numerous subfields within technology, the natural sciences, health and medicine (e.g. material science, ICT, marine technology, energy, petroleum, nuclear technology, geosciences, chemistry, and physics.) The largest subfield in terms of number of articles is Material science – multidisciplinary (i.e. various topics within material science) with almost 375 articles. Then follow the subfields Energy and fuels with 275 articles and Chemistry, physical with 265 articles.

Figure 3.5 Scientific publishing at subfield levels, TI institutes. Number of articles 2009–2013 and proportion of the national total in the subfields.* NCR-indexed articles, only.

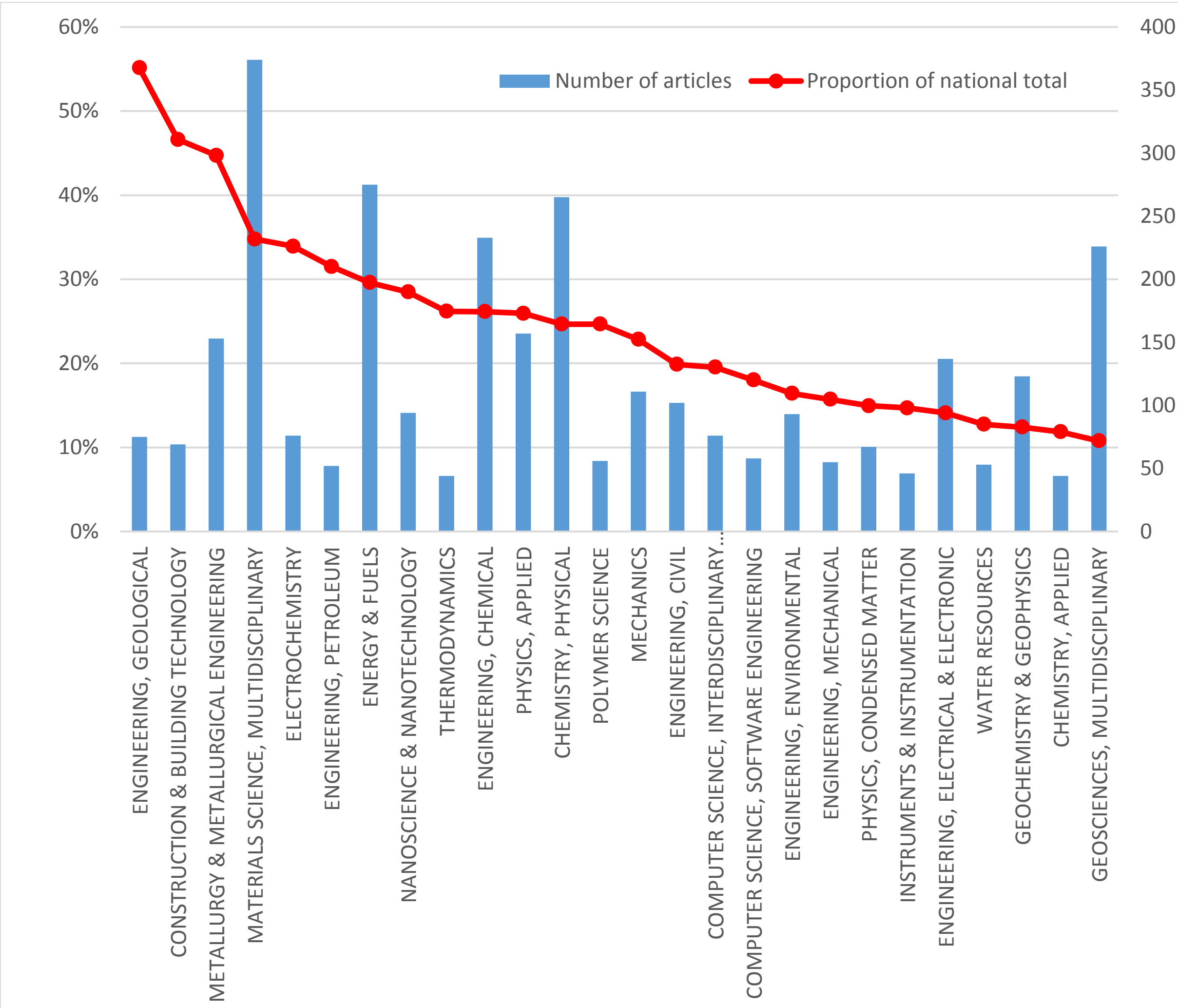


Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

*) Restricted to subfields with more than 40 articles during the time period.

Figure 3.5 also shows the TI institutes' share of the Norwegian total production of articles (red line). At subfield levels, this proportion varies significantly, from 55 per cent in Engineering, geological to 3 per cent In Biochemistry & molecular biology. In order to visualise which subfields the TI institutes are particular large contributors to Norwegian research, we in have ranked the subfields by decreasing proportions in Figure 3.6. In addition to Engineering, geological, the proportions are also particularly high in Construction & building technology (47%) and Metallurgy & metallurgical engineering (45%). Then follow Material science, multidisplinary (35%), Electrochemistry (34%), Engineering, petroleum (32%) and Energy & fuels (30%). There are nine subfields where the proportion is between 20 and 30 per cent. It should be noted, however, that the production in absolute terms (number of articles) varies significantly across the various subfields (blue bars).

Figure 3.6 Scientific publishing at subfield levels, TI institutes. Number of articles 2009–2013 and proportion of the national total in the subfields.* NCR-indexed articles, only.



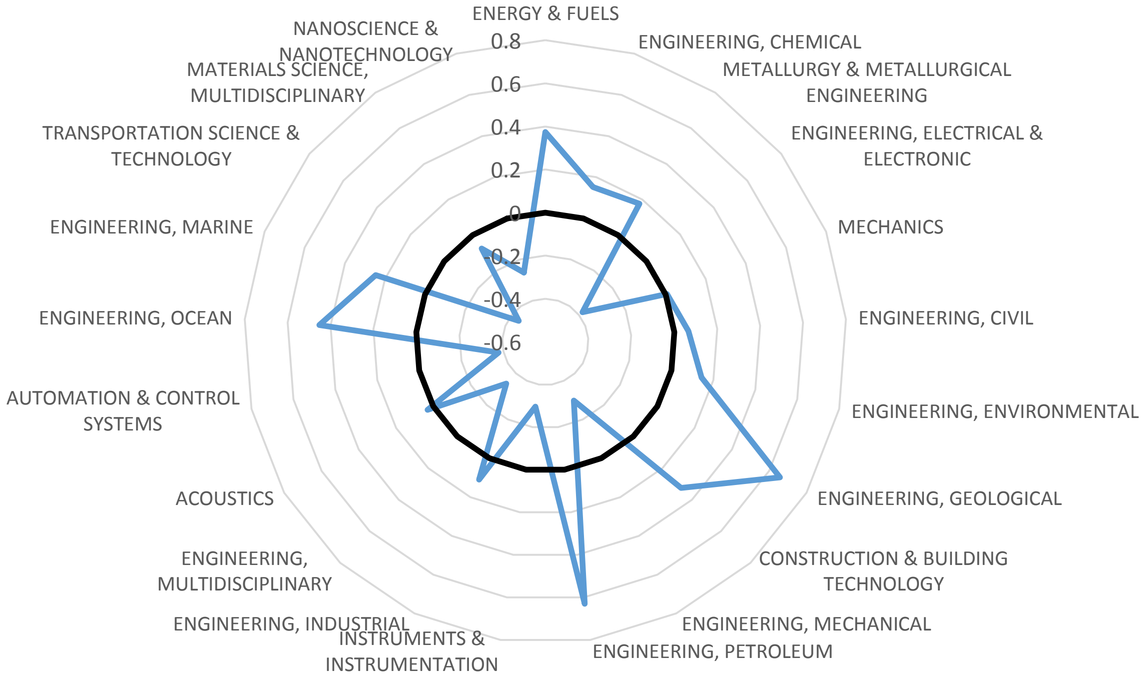
Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Restricted to subfields with more than 40 articles during the time period and more than 10 per cent of the national total.

The particular distribution of articles by subfields can be considered as the specialisation profile of the TI institutes. In order to assess its characteristics, we have analysed the distribution of publications by subfields. This analysis is also limited to the NCR-articles, as subfield classification is available for these articles, only. In figure 3.7 we have shown the so-called "relative specialization index", RSI.[7] Only technology subfields are included in this analysis (there are many articles classified in other subfields, e.g. within the natural sciences, cf. Figures 3.5 and 3.6). We have compared the relative profile with the global average distribution of articles within technology. Whether this is an adequate reference standard may be a matter of discussion. Nevertheless, we have used it to give an indication of the characteristics of the profile of specialisation.

As indicated by Figure 3.7, the TI institutes have a very strong specialisation in Geological engineering, Petroleum engineering and Ocean engineering (RSI = 0.66-0.45), compared to the global average (the black line in the figure). We also find strong specialisation in Energy and Fuels, Construction & building technology as well as Marine engineering, (RSI = 0.25-0.37). On the other hand, the TI institutes have little research output relatively speaking (a negative specialisation) within several fields, for example, Electrical & electronic engineering, Mechanical engineering and Nanoscience & Nanotechnology where the RSI is in the range -0.38-0.27.

[7] The relative specialization index (RSI) shows if the proportion of publications in a particular field is higher or lower compared to the average for all countries where RSI = 0. In other words it characterizes the internal balance between subfields, 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 3.7 Relative specialisation index in technology subfields, TI institutes, 2009–2013.* NCR-indexed articles, only.



Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Compared to the world average distribution in the selected subfields.

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 institutes 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 the articles have been highly or poorly cited. One such indicator is the relative citation index showing whether the scientific publications have been cited above or below the world average (=100).

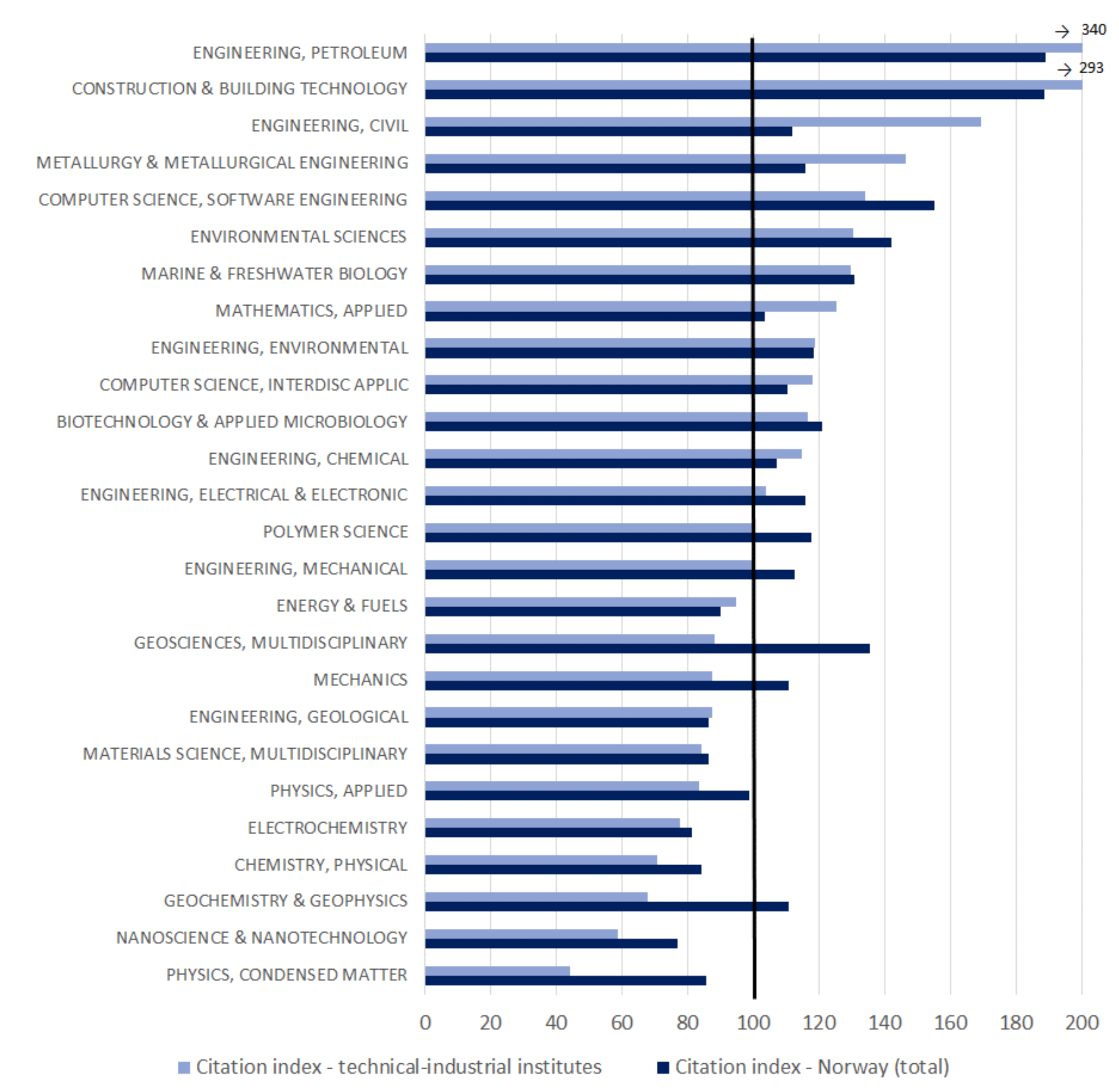
We have analysed the citation rate of the 2009–2012 publications. The analysis is based on the NCR-indexed articles, only. Overall, the TI institutes obtain a citation index of 120, which means that the articles have been cited 20 per cent more frequently than the field-normalised world average. This is marginally above the Norwegian average within

Engineering science (cf. Appendix 2), which is 117.[8] However, the citation index of the TI institutes is lower than the Norwegian total (all disciplines) for this period, which is approximately 130. Given the TI institutes' relatively strong orientation towards applied research and "non academic" activities it may be concluded that they perform reasonably well when it comes to scientific impact measured through citations.

Nevertheless, the overall citation index disguises important differences at subfield levels. This can be seen in Figure 3.8, where a citation index has been calculated for each subfield. In addition to indicators for the TI institutes, this figure also shows the corresponding national average within the respective subfields (which also includes the publications of the TI institutes). In two subfields, the publications of the TI institutes are extremely highly cited: Engineering, petroleum and Construction & building technology, with citation indices of 340 and 293, respectively. The TI institutes also perform very well in Engineering, civil (169) and Metallurgy & metallurgical engineering (147). Thus, in these fields the citation indices are far above the world average. On the other hand, there are many subfields where the citation index is significantly below the world average, for example, Physics, condensed matter and Nanoscience & nanotechnology with citation indices of 44 and 59, respectively. It should be noted also that the size of the subfields in terms of number of articles included, varies significantly. In some small fields, the citation rate may be strongly influenced by the presence or absence of particularly highly cited papers. Several of the subfields with high citation indices are also fields where the TI institutes have a high specialisation (cf. Figure 3.7), for example Engineering, petroleum, Construction & building technology and Metallurgy & metallurgical engineering – although there are also exceptions to this pattern, e.g. the subfield Energy & fuels.

[8] Within Engineering science, Norway ranks as number 11 among the 20 countries analyzed in the appendix. 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.

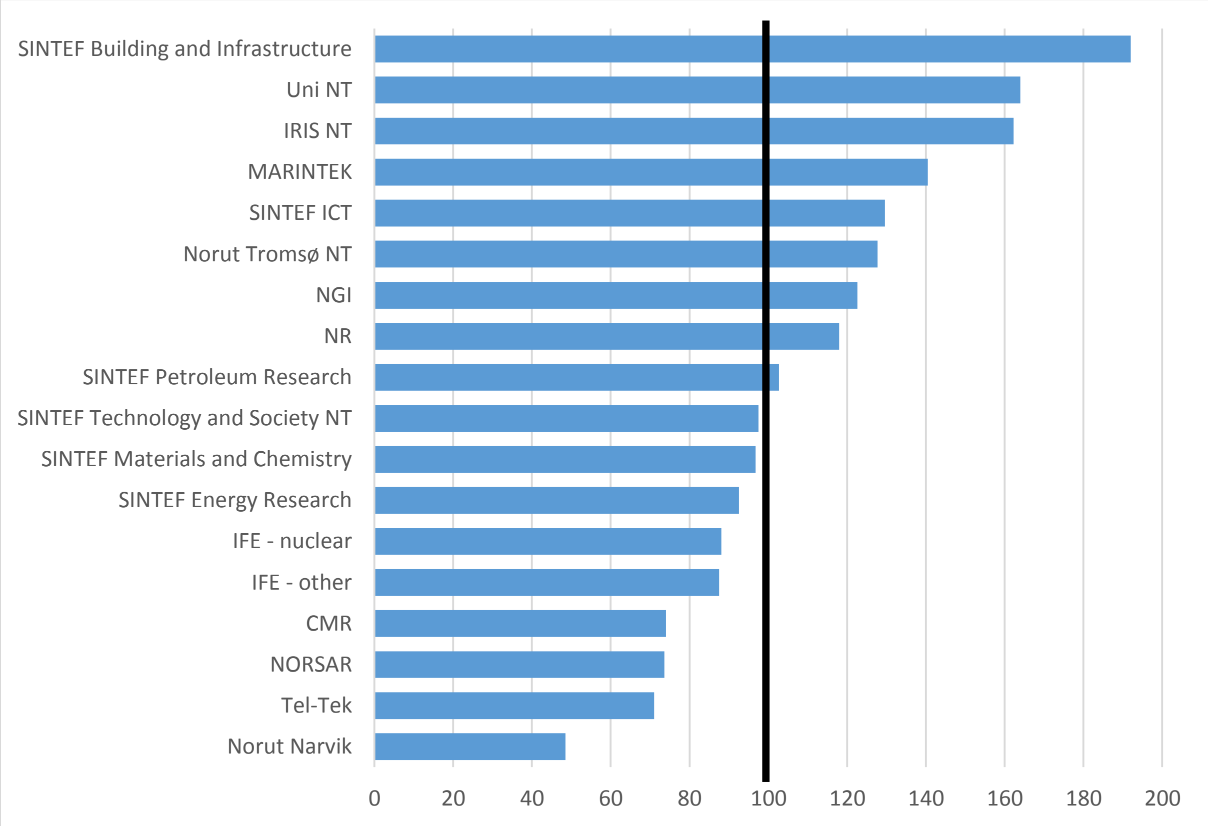
Figure 3.8 Relative citation index at subfield-levels (field normalised), TI institutes and national total 2009–2012.* NCR-indexed articles, only.



Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Based on the publications from the period and accumulated citations to these publications through 2013.Only subfields with more than 40 articles during the time period are shown in the figure. World average = 100.

There are also large differences in the citation index across the individual TI institutes. This is shown in Figure 3.9. SINTEF Building and Infrastructure obtains the highest citation index with 192. In other words, the articles have been cited 92 per cent more frequently than the world average. Then follow Uni Research with 164, IRIS with 162 and MARINTEK with 140. These institutes perform very well in terms of citation rates. On the other hand, there are several institutes with citation rates significantly below the world average; in particular, the citation index is rather low for Norut Narvik (49), Tel-Tek (71), NORSAR (74) and CMR (74). Nevertheless, it is important to recall that citations mainly reflect intra-scientific use. Practical applications and use of research results will not necessarily be reflected through citation counts. Therefore, bibliometric analyses can support evaluations, but not replace them. It is important to be aware of this limitation when interpreting the figures.

Figure 3.9 Relative citation index (field normalised), TI institutes 2009–2012.* NCR-indexed articles, only.



Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Based on the publications from the period and accumulated citations to these publications through 2013. World average = 100.

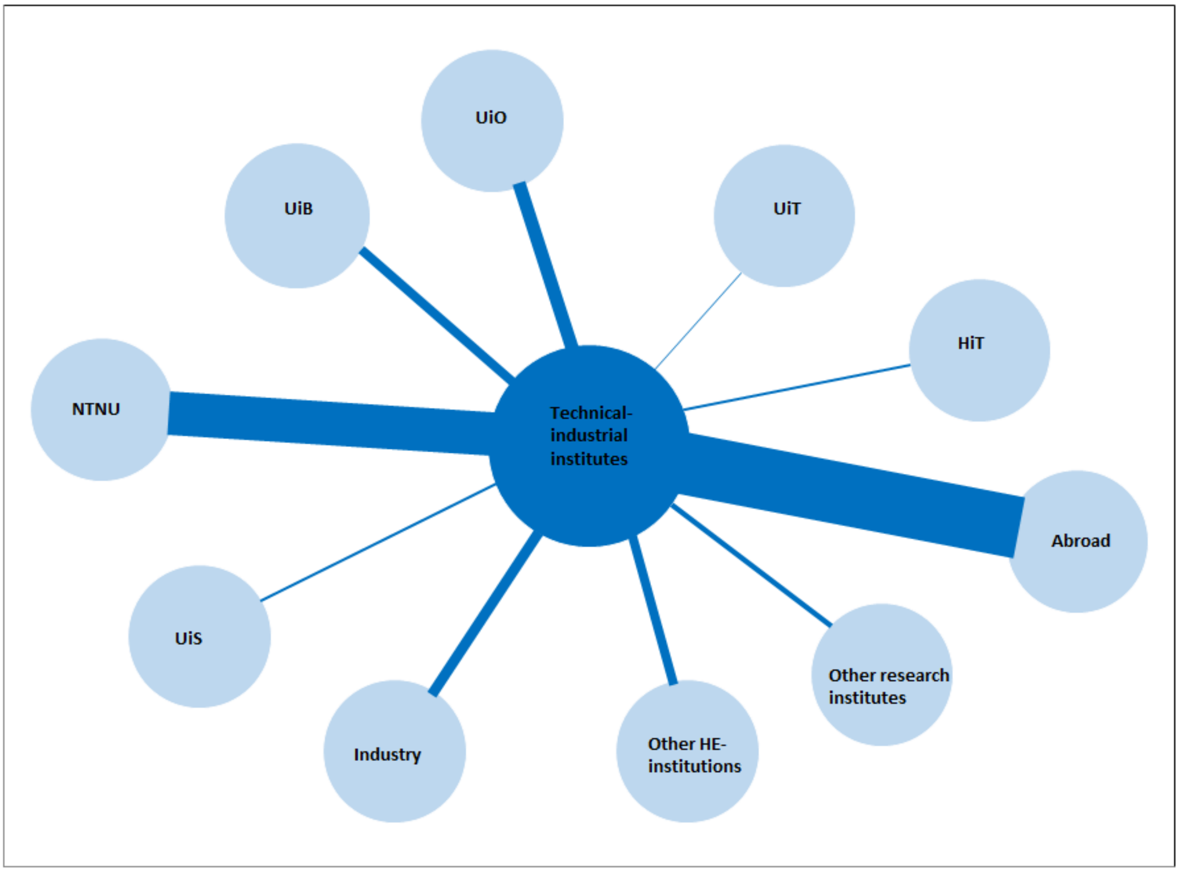
3.3 Scientific collaboration indicators

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. This chapter analyses the collaboration patterns of the TI institutes based on co-authorship data. Both national collaboration (publications having author addresses from other Norwegian institutions) and international collaboration (publications also having foreign author addresses) are analysed.

In Figure 3.10 we have illustrated the scientific collaboration profile of the TI institutes (based on the 2011–2013 publications. Only the largest institutions are shown separately). In the figure, the breadth of the lines is proportional to the number of collaborative articles with the TI institutes. Not surprisingly, there are very strong collaborative links between the TI institutes and the Norwegian University of Science and

Technology (NTNU). In fact, approximately one third of the publications also had co-authors from NTNU (1241 of a total of 3624 publications). The institutes within the SINTEF-group account for the majority of these publications, but there are also many co-publications between NTNU and other TI institutes. The University of Oslo (UiO) is by far the largest university in Norway and ranks as the second biggest institutional partner of the TI institutes. In total, 10 per cent of the publications of the institutes also had co-authors from UiO. The corresponding share for the University of Bergen (UiB) is 7 per cent. Then there are several institutions with a smaller amount of collaborative articles.

Figure 3.10 Graphical illustration of the collaboration profile of the TI institutes of (2011–2013).*



Source: NIFU's Key figure database, CRIStin. Calculations: NIFU.
*) Only the largest institutions in terms of publication output are shown separately in the figure. The breadth of the lines is proportional to the number of collaborative articles with the TI institutes. Legends: NTNU: Norwegian University of Science and Technology, UiB: University of Bergen, UiO: University of Oslo, UiT: University of Tromsø, UiS: University of Stavanger, HIT: Telemark University College. Industry: Norwegian industry/companies. Abroad: foreign institutions and industry.

In addition to the national collaboration, the TI institutes have strong foreign interactions. In fact, almost half (49%) of the publications also had co-authors from foreign institutions.

Figure 3.10 shows that the research institutes sometimes also collaborate with the industry. In total, 9 per cent of the publications had co-authors from Norwegian companies and industry. It should be noted, that only a very limited proportion of the R&D 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. Therefore, only a limited part of the institutes' collaboration with industry is reflected through co-authorship data.

The co-publication between Norwegian industry and the TI institutes is further analysed in Table 3.4, based on NCR-indexed articles, only. SINTEF Materials and Chemistry has the highest number of articles co-authored with industry. In relative terms, the figure is highest for SINTEF Petroleum Research and SINTEF Building and Infrastructure, where 27.5 per cent and 22.6 per cent of the publications, respectively, had co-authors from industry. On the other hand, several of the institutes have none or very few such publications.

Table 3.4. Collaboration with Norwegian industry 2011–2013. Number and proportion of the article production of the TI institutes with co-authors from Norwegian industry. NCR-indexed articles, only.

Unit	No. articles with co-authors from Norwegian industry	Prop. of articles with co-authors from Norwegian industry	Total no. of articles
SINTEF Petroleum Research	11	27.5%	40
SINTEF Building and Infrastructure	19	22.6%	84
NR	12	15.2%	79
SINTEF Materials and Chemistry	57	11.7%	488
IRIS NT	11	11.5%	96
NGI	15	10.6%	141
IFE - other	14	10.1%	138
MARINTEK	4	8.7%	46
Tel-Tek	2	8.0%	25
SINTEF Technology and Society NT	5	7.7%	65
SINTEF Energy Research	12	6.4%	188
CMR	2	6.1%	33
Norut Tromsø NT	2	4.8%	42
SINTEF ICT	6	4.3%	138
IFE - nuclear	4	3.5%	115
Uni NT	3	1.5%	202
NORSAR	0	0.0%	63
Norut Narvik	0	0.0%	23

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

Which countries are the most important collaboration partners for the TI institutes? In order to answer this question we analysed the distribution of co-authorship. Table 3.5 shows the frequencies of co-authorship for the countries that comprise the institutes' main collaboration partners in the period 2011–2013.

The USA is the most important collaboration partner, and 11 % of the articles also had co-authors from this nation. Then follows Germany with 8 per cent, UK with 7 per cent and Sweden with 6 per cent.

Table 3.5. Collaboration by country* 2011–2013. Number and proportion of the article production of the TI institutes with co-authors from the respective countries. NCR-indexed articles, only (N=1926).

Country	No. articles	Proportion	Country	No. articles	Proportion
USA	217	11.3%	Australia	39	2.0%
Germany	158	8.2%	Japan	33	1.7%
UK	137	7.1%	Poland	29	1.5%
Sweden	118	6.1%	Finland	28	1.5%
France	103	5.3%	Belgium	27	1.4%
Italy	68	3.5%	Austria	25	1.3%
Netherlands	68	3.5%	India	23	1.2%
Denmark	58	3.0%	Portugal	23	1.2%
China	50	2.6%	Russia	15	0.8%
Spain	49	2.5%	Greece	14	0.7%
Canada	47	2.4%	South Africa	13	0.7%
Switzerland	42	2.2%	Ukraine	13	0.7%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Only countries with more than 12 collaborative articles are shown in the table.

The incidence of international collaboration varies significantly across the individual TI institutes, cf. Table 3.6. A large majority (78-81%) of the articles (NCR-indexed) from NORSAR, IFE – nuclear and NGI had co-authors from foreign institutions. On the other hand, international collaboration reflected through co-authorship is much less frequent at Tel-Tek and SINTEF Technology and Society NT (12-25%).

Table 3.6. International collaboration 2011–2013. Number and proportion of the article production of the TI institutes with co-authors from other countries. NCR-indexed articles, only.

Unit	No. articles with co-authors from other countries	Prop. of articles with co-authors from other countries	Total no. of articles
NORSAR	51	81%	63
IFE - nuclear	91	79%	115
NGI	112	78%	144
Norut Narvik	14	61%	23
Uni NT	113	55%	204
IFE - other	74	54%	138
Norut Tromsø NT	22	52%	42
SINTEF Energy Research	88	47%	189
SINTEF ICT	61	44%	140
CMR	14	42%	33
SINTEF Materials and Chemistry	200	41%	491
IRIS NT	37	39%	96
NR	29	37%	79
SINTEF Petroleum Research	12	30%	40
SINTEF Building and Infrastructure	24	29%	84
MARINTEK	13	28%	47
SINTEF Technology and Society NT	17	25%	68
Tel-Tek	3	12%	25

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

4 Reflections

According to the terms of reference, the evaluation of the TI institutes has three main objectives. First, the evaluation shall be useful for the institutes' own strategic development efforts. This includes assessment of areas in which the TI institutes can improve and further develop. Second, the evaluation shall strengthen the knowledge base for the Research Council and the ministries in developing an effective, targeted research institute policy. Third, the evaluation is to provide a basis for assessing the funding instruments of the Research Council.

Hopefully, this publication analysis will be useful as background for assessing all three and particularly the two first objectives of the mandate. At the level of the individual institutes, the publication indictors provided may serve as basis for reflections on the publication profile of the institute and strategic actions related to the publishing activities. Issues that are relevant to consider are for example:

- Is the volume of scientific publishing at a satisfactorily level? What can be done to increase the volume and strengthen the publication profile in the future? How do the different groups and individuals within the institute perform when it comes to scientific publishing?
- What is the balance between the different publication types such as scientific journals, proceedings and reports? Is it possible or desirable to change the profile by increase the publishing activity in channels obtaining publication points in the performance-based funding system?
- Is the publication in the leading and most prestigious publication channels (level 2) at a satisfactory level? Should further actions be taken to increase the number of publications in these channels?
- How does the institute perform when it comes to citation impact? In which areas are the institute performing well, and what may be the possible reasons for low citation rates in some fields?
- To what extent is the institute involved in scientific collaboration, nationally and internationally? Should the collaboration profile of the institute be strengthened in the future by involving more external research partners?

Concerning the second mission of the mandate, the publication analysis has identified several issues that may be relevant to take into consideration. The TI institutes have increased their scientific publishing considerably during the period 2009–2013. This is reflected both in a growth in the publication volume and in the average productivity per researcher. This probably reflects a stronger focus on such publishing at the institutes, which is partly related to the application of the performance-based funding system where publication points are among the indicators. Nevertheless, the productivity measured per researcher is significantly lower for the TI institutes than for the other institutes within the institute sector in Norway. We leave it to the panel to judge whether this low productivity is a natural consequence of the research profile and mission of the institutes or whether it should be considered as a problem. This question will also have to be discussed on the background of the user survey, which constitutes a parallel background report to this evaluation. Anyhow, the figures suggest that there is potential for a further increase in the publication productivity.

The analysis shows that the TI institutes have research activities within a very broad range of scientific fields. They are important and large contributors to the Norwegian research activities within fields such as material science, petroleum research and geological engineering, marine technology, energy research, and construction and building research. The scientific profile is relevant background information when assessing the characteristics and research portfolio of the institutes individually and as a group.

Despite the practical orientation of the institutes, they have been able to deliver research that is cited slightly above the average for engineering research in Norway. Thus, they perform reasonably well also when it comes to the more intra-scientific use, which typically is reflected through citation counts. Nevertheless, it should be taken into consideration that the citation index in engineering research in Norway is somewhat below the national average in other fields. In some areas such as petroleum research, construction and building research, civil engineering and metallurgical engineering, the TI institutes have obtained very high impact. These are areas where the institutes have contributed to research of a high international standard, at least as this is reflected through citation indicators. On the other hand, there are also many fields where the citation impact of the research of the institutes apparently is rather poor. Similar large differences are found at the level of the individual institutes. These are relevant findings when assessing the quality of the research carried out at the institutes. However, scientific quality is a broader concept that what is reflected through citation counts. It should be recalled that practical applications and use of research results will not necessarily be reflected through citations. Due to various limitations and biases attached to citation indicators, they cannot replace an assessment carried out by peers.

It is interesting to note that the scientific impact of the institutes measured through citations, does not seem to be related to their size. The two largest units in terms of publication volume obtain citation indices below the world average and significantly below the average of the TI institutes. The small and medium-sized institutes have both high and low citation indices, although the tree smallest units perform less well. A similar pattern emerges when comparing the publication productivity of the staff with the citation indices. Institutes with a low publication productivity obtain both high and low citation rates. For example, MARINTEK is among the institutes with a low productivity but performs well in terms of citation rates. These findings reflect that it is possible to foster high quality research even when the unit is small or have a low productivity, but assumable this may presuppose a strong specialisation in the research activities.

It is also interesting to note that there is a weak correspondence only between the portion of level 2 publications and the citation indices. This is somewhat surprising as the level 2 channels generally are more cited than level 1 channels. For example an institute such as NORSAR has a very high level 2 proportion but nevertheless obtains a citation score significantly below the world average. This exemplifies the need of using a multiple set of indicators when assessing the research output of the institutes.

The analysis shows that the TI institutes are heavily involved in scientific collaboration. The institutes have a strong international orientation where almost half of the publications have been co-authored with scientists in other countries. Still, there are large differences across the individual TI institutes. A few institutes have rather low proportions of their publications co-authored with scientists from abroad. These institutes may consider how their foreign collaboration profile could be strengthened in the future.

Within the Norwegian R&D system there are very close collaborative links between the TI institutes and the Norwegian University of Science and Technology (NTNU). The analysis of collaboration may be used to assess the particular collaboration profile of the institutes and how they interact with other national and international R&D actors.

Appendix 1 Analysis of individual institutes

This chapter presents bibliometric indicators for each of the 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. Some of the overall results for each institute have already been presented in Chapter 3. These results will be referred to in the text, but are not included again in the tables and figures of the chapter.

A1.1 Christian Michelsen Research AS (CMR)

Figure A1.1 Most frequently appearing words in the publication titles, 2009-2013. CMR
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, CMR is one of the smallest institutes included and accounts for 1 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points shows large annual variations and have varied from 1.6 (2010) to 14.8 (2012) (cf. Table 3.1). CMR has the lowest publication productivity of all the TI institutes with an average of 0.19 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). The average of the TI institutes is 0.44. Thus, relatively little of the institute's activities result in scientific publications. However, the productivity shows an increasing trend, rising from 0.09 and 0.03 in 2009 and 2010 to 0.29 and 0.17 in 2012 and 2013.

Overall, the institute has published 66 scientific publication during the period 2009-2013. On average, 24 per cent of these publications appeared in level 2 channels, which is slightly above the average of the TI institutes.

Figure A1.1 above shows the most frequent words appearing in the publication titles of CMR. The figure illustrates some of the topics addressed in the research activities at CMR. Table A1.1 contains a list of the most frequently used journals – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the journal *Measurement science and technology* with 4 articles. The research of CMR has been published in a rather heterogeneous set of journals, spanning from a marine biology journal to a physics journal.

Table A1.1 The most frequently used journals/series*, number of publications 2009–2013. CMR.

Journal/series	No. of articles	Level (1/2)
Measurement science and technology	4	1
ICES Journal of Marine Science	4	1
Eurographics	3	2
Nuclear Instruments and Methods in Physics Research Section A : Accelerators, Spectrometers, Detectors and Associated Equipment	3	1
Computer graphics forum (Print)	3	2
Computers and Graphics	3	1

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

In order to provide further insights into the characteristics of the publication profile of CMR, we have classified the articles by subfield. This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. We find the two subfields, Computer science, software engineering and Instruments & instrumentation on the top of the list with nine articles each. Because the number of articles is below the threshold, citation indicators have not been calculated for the individual subfields.

Table A1.2. Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. CMR.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
COMPUTER SCIENCE, SOFTWARE ENGINEERING	9	–
INSTRUMENTS & INSTRUMENTATION	9	–
MARINE & FRESHWATER BIOLOGY	5	–
OCEANOGRAPHY	5	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.3 shows various citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 33 articles have been published which amounts to 65 per cent of the total scientific production of CMR during the period. The articles have been cited below the world average both when using a field and journal based normalisation method (citation index, 74 and 75, respectively). Thus, the impact of the research has not been particularly high when measured by number of citations.

Table A1.3 Citation indicators, 2009–2012 publications indexed in NCR.* CMR.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
33	65%	101	20	3.1	75	74

Source: Data: NIFU's Key figure database, CRIStin, 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.[9]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The institute is involved in extensive national collaboration. In the period 2011-2013, 94 per cent of the CMR publications have co-authors also from other Norwegian institutions and institutes (cf. Table A1.4). The University of Bergen is by far the most important collaborative institution and most of the publications (84%) have co-authors from this institution. In addition, two other units located in the Bergen area appear on the list: Haukeland University Hospital and Institute of Marine Research. It should be noted, however, that people with dual affiliations (e.g. CMR and University of Bergen) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 2 of 33 articles indexed in NCR have been co-authored with industry.

Table A1.4 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. CMR.

Institution/institute	No. of collaborative publications	Proportion of total
University of Bergen	43	84%
Haukeland University Hospital	7	14%
Norwegian University of Science and Technology	3	6%
Institute of Marine Research	3	6%
Other units	9	
Total number of collaborative publications with units in the Norwegian public research system	48	94%
Total number of publications	51	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

[9] Refers to the article: Korneliussen, RJ; Heggelund, Y; Eliassen, IK; Johansen, GO (2009). Acoustic species identification of schooling fish. ICES JOURNAL OF MARINE SCIENCE. 66, 1111-1118. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

The analysis also encompasses co-authorship with foreign institutions. These results show that 42 per cent of the CMR articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is slightly below the average of the TI institutes, which is 48 per cent. Table A.1.5 shows which countries CMR has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA, and almost a quarter of the publications have co-authors from this nation.

Table A1.5 Publications with co-authors from other countries. Number and proportion of total production, 2011-2013. CMR.

Country	No. of collaborative publications	Proportion of total
USA	8	24%
Austria	3	9%
Other countries	4	
Total number of publications with co-authors from other countries	14	42%
Total number of publications	33	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.2 Institute for Energy Technology (IFE) – nuclear research

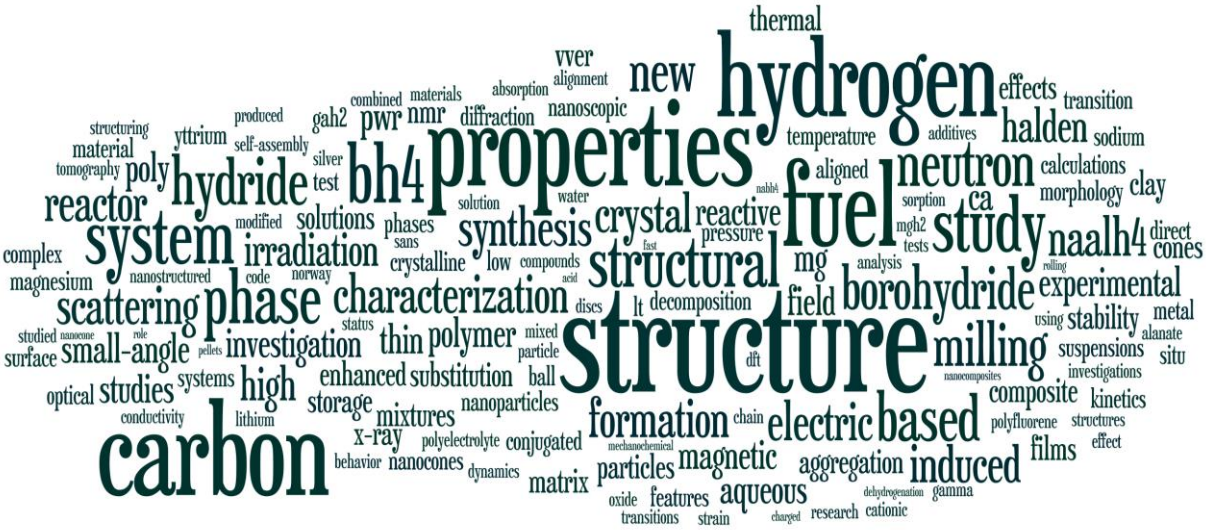


Figure A1.2 Most frequently appearing words in the publication titles, 2009-2013. IFE-nuclear research.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

This chapter provides an overview of the research at IFE published by the sectors classified within the nuclear research field in the evaluation (Nuclear safety and reliability (NUSP), Nuclear technology and physics (NTF), Isotope laboratories (Isotop)).

IFE nuclear research is the 11th largest unit included in the evaluation with a proportion of 3 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points shows large annual variations and have varied from 11 (2010) to 35 (2011) (cf. Table 3.1). The average of the period is 24 publication points. Figures on the publication productivity of the unit is not available. However, overall IFE has 0.44 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). This is identical to the average of the TI institutes.

Overall, the unit has published 189 scientific publications during the period 2009-2013. On average, 30 per cent of the publications in the period 2011-2013 appeared in level 2 channels. This is among the highest ratios of the institutes included in the evaluation. Thus, the unit has a significant number of publications in the most prestigious publication channels.

Figure A1.2 above shows the most frequent words appearing in the publication titles of IFE nuclear research. The figure illustrates some of the topics addressed in the research activities at the unit. Table A1.6 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find *Journal of Alloys and Compounds* with 23 articles followed by *The Journal of Physical Chemistry C* (16 articles) and *International journal of hydrogen energy* (11 articles).

Table A1.6 The most frequently used journals/series*, number of publications 2009–2013. IFE-nuclear research.

Journal/series	No. of articles	Level (1/2)
Journal of Alloys and Compounds	23	1
The Journal of Physical Chemistry C	16	1
International journal of hydrogen energy	11	2
Soft Matter	6	1
Physical Chemistry, Chemical Physics - PCCP	4	2
Physical Review B. Condensed Matter and Materials Physics	4	2
Langmuir	4	2
Macromolecules	4	2
Atomic Energy	4	1
Nanotechnology	4	2
Physical Review E. Statistical, Nonlinear, and Soft Matter Physics	3	1
Journal of Materials Chemistry	3	2
Journal of Solid State Chemistry	3	1
Revista Cubana de Física	3	1
Nuclear Technology	3	1

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

In order to provide further insights into the characteristics of the publication profile of IFE nuclear research, we have classified the articles by subfield. This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The two subfields, Chemistry, physical and Material science, multidisciplinary, have the highest article numbers, 85 and 77 articles, respectively. The latter category covers general and multidisciplinary journals within material science. The citation rate varies significantly across the different subfields listed. The publications within Metallurgy & metallurgical engineering have obtained the highest relative citation index with 232. In other words, the articles have been cited 132 per cent more than the field-normalised world average. In most of the fields, however, the citation rate of the publications is below this average.

Table A1.7 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. IFE-nuclear research.

Subfield*	No. of articles (2009-13)	Citation index –field** (2009-12)
CHEMISTRY, PHYSICAL	85	73
MATERIALS SCIENCE, MULTIDISCIPLINARY	77	98
METALLURGY & METALLURGICAL ENGINEERING	26	232
NANOSCIENCE & NANOTECHNOLOGY	25	68
PHYSICS, APPLIED	18	77
POLYMER SCIENCE	16	101
NUCLEAR SCIENCE & TECHNOLOGY	14	32
ENERGY & FUELS	14	80
PHYSICS, CONDENSED MATTER	14	–
ELECTROCHEMISTRY	11	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.8 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 121 articles have been published which amounts to 83 per cent of the total scientific production of IFE nuclear research during the period. Thus, the large majority of the publications have been published in indexed journals. The articles have been cited below the world average both when using a field and journal based normalisation method (citation index, 88 and 84, respectively). This means that IFE nuclear research in terms of citation rates, ranks at the lower end of the institutes included in the evaluation.

Table A1.8 Citation indicators, 2009–2012 publications indexed in NCR.* IFE-nuclear research.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
121	83%	755	34	6.2	84	88

Source: Data: NIFU's Key figure database, CRIStin, 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. [10]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

When it comes to national research collaboration, 38 per cent of the publications of IFE nuclear research have been published together with co-authors from other Norwegian

[10] Refers to the article: Riktor, MD; Sorby, MH; Chlopek, K; Fichtner, M; Hauback, BC (2009). The identification of a hitherto unknown intermediate phase CaB2Hx from decomposition of Ca(BH4)(2). JOURNAL OF MATERIALS CHEMISTRY. 19, 2754-2759. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

institutions and institutes (cf. Table A1.9). This figure is based on the 2011-2013 publication, only. The University of Oslo is the largest collaborative institution and 30 publications have co-authors from this institution (22%). Next follows Norwegian University of Science and Technology with 19 articles. It should be noted, however, that people with dual affiliations (e.g. IFE and University of Oslo) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 4 of 115 articles indexed in NCR have been co-authored with industry (cf. Table 3.4).

Table A1.9 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. IFE-nuclear research.

Institution/institute	No. of collaborative publications	Proportion of total
University of Oslo	30	22%
Norwegian University of Science and Technology	19	14%
SINTEF Foundation	13	10%
Other units	6	
Total number of collaborative publications with units in the Norwegian public research system	51	38%
Total number of publications	136	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 79 per cent of the IFE nuclear research articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is significantly above the average of the TI institutes, which is 48 per cent. Thus, the unit is involved in extensive international collaboration. Table A.1.10 shows which countries IFE nuclear research has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find France and Germany, and 20 per cent of the articles have co-authors from these countries.

Table A1.10 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. IFE-nuclear research.

Country	No. of collaborative publications	Proportion of total
France	23	20%
Germany	23	20%
Sweden	19	17%
Denmark	16	14%
USA	13	11%
UK	11	10%
Switzerland	10	9%
Australia	9	8%
Italy	9	8%
Netherlands	6	5%
Hungary	6	5%
Other countries	47	
Total number of publications with co-authors from other countries	91	79%
Total number of publications	115	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.3 Institute for Energy Technology (IFE) – other research

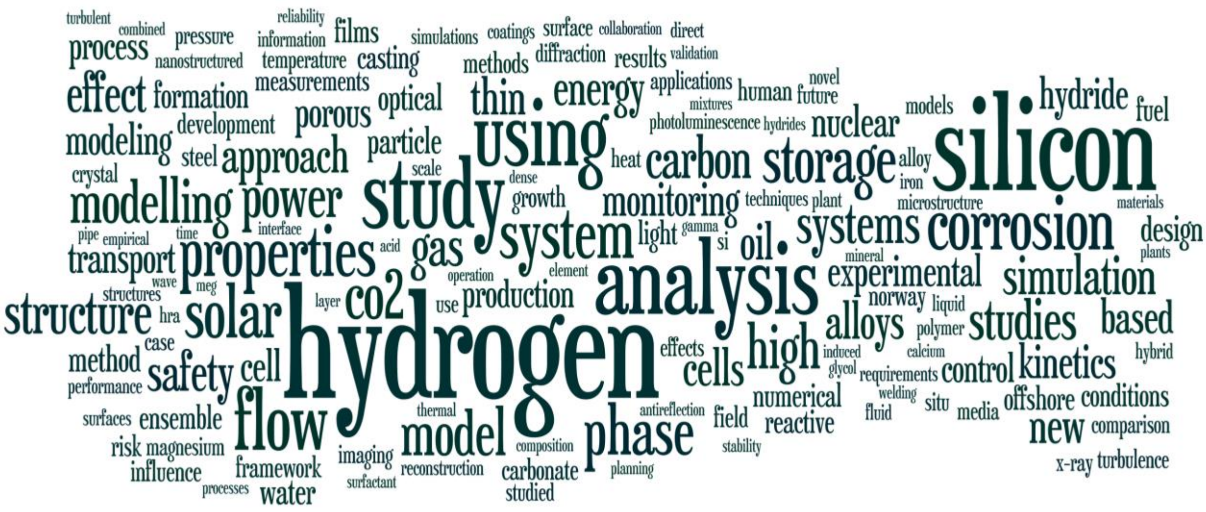


Figure A1.3 Most frequently appearing words in the publication titles, 2009-2013. IFE-other research.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

This chapter provides an overview of the research at IFE published by the sectors that not are included under the nuclear research field (Safety Man-Technology-Organisation (MTO), Petroleum technology (Petro), Energy and environmental technology (E&M)), i.e. "IFE other research".

IFE other research is the fourth largest unit included in the evaluation with a proportion of 7 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has varied from 53 to 75 in the period 2009-2013, with no distinct trend (cf. Table 3.1). The average of the period is 66 publication points. Figures on the publication productivity of the unit is not available. However, overall IFE has 0.44 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). This is identical to the average of the TI institutes.

Overall, the unit has published more than 430 scientific publications during the period 2009-2013. On average, 21 per cent of the publications in the period 2011-2013 appeared in level 2 channels. This is almost identical to the average of the TI institutes.

Figure A1.3 above shows the most frequent words appearing in the publication titles of IFE other research. The figure illustrates some of the topics addressed in the research activities at the unit. Table A1.11 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the open access journal *Energy Procedia* with 27 articles followed by *Journal of Alloys and Compounds* (17 articles) and the level 2 journal *Journal of Applied Physics* (15 articles).

Table A1.11 The most frequently used journals/series*, number of publications 2009–2013. IFE-other research.

Journal/series	No. of articles	Level (1/2)
Energy Procedia	27	1
Journal of Alloys and Compounds	17	1
Journal of Applied Physics	15	2
International journal of hydrogen energy	14	2
Journal of Crystal Growth	8	1
International Corrosion Conference Series	8	1
Physical Review E. Statistical, Nonlinear, and Soft Matter Physics	7	1
Energy Policy	5	1
International Journal of Multiphase Flow	5	1
Electrochimica Acta	5	2
Physica Status Solidi. C, Current topics in solid state physics	5	1
Solar Energy Materials and Solar Cells	5	2
ISOPE - International Offshore and Polar Engineering Conference. Proceedings	5	1
Corrosion	5	2
Thin Solid Films	5	1
Journal of Dispersion Science and Technology	4	1
Journal of Chemical Physics	4	1
Physics of Plasmas	4	1
Materials Science Forum	3	1
ECS Transactions	3	1
Human Factors and Ergonomics Society Annual Meeting Proceedings	3	1
Chemical Engineering Science	3	2
Conference record of the Photovoltaic Specialists Conference	3	1
Materials Research Society Symposium Proceedings	3	1

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

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

In order to provide further insights into the characteristics of the publication profile of IFE other research, we have classified the articles by subfield (cf. Table A1.12). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. On the top of the list, we find the two subfields Material science, multidisciplinary and Physics, applied with 62 and 41 articles, respectively. The first category covers general and multidisciplinary journals within material science. The citation rate varies significantly across the different subfields. The publications within Metallurgy & metallurgical engineering have obtained the highest relative citation index with 158. In other words, the articles have been cited 58 per cent more than the field-normalised world average. In most of the fields, however, the citation rate of the publications is below this average.

Table A1.12 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. IFE-other research.

Subfield*	No. of articles (2009-13)	Citation index –field** (2009-12)
MATERIALS SCIENCE, MULTIDISCIPLINARY	62	76
PHYSICS, APPLIED	41	62
CHEMISTRY, PHYSICAL	40	74
ENERGY & FUELS	37	91
METALLURGY & METALLURGICAL ENGINEERING	33	158
ELECTROCHEMISTRY	24	112
MECHANICS	18	55
PHYSICS, CONDENSED MATTER	16	23
PHYSICS, FLUIDS & PLASMAS	15	86
GEOSCIENCES, MULTIDISCIPLINARY	11	114
NUCLEAR SCIENCE & TECHNOLOGY	10	77
PHYSICS, MATHEMATICAL	10	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.13 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 195 articles have been published which amounts to 53 per cent of the total scientific production of IFE other research during the period. Thus, there is a significant number of publications not included in this analysis. For example, the articles appearing in *Energy Procedia* is not indexed in NCR. The articles have been cited below the world average both when using a field and journal based normalisation method (citation index, 88 and 86, respectively). This means that IFE other research in terms of citation rates, ranks at the lower end of the institutes included in the evaluation.

Table A1.13 Citation indicators, 2009–2012 publications indexed in NCR.* IFE-other research.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
195	53%	1160	41	5.9	86	88

Source: Data: NIFU's Key figure database, CRIStin, 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. [11]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

[11] Refers to the article: Ellison, PA; Gregorich, KE; Berryman, JS; Bleuel, DL; Clark, RM; Dragojevic, I; Dvorak, J; Fallon, P; Fineman-Sotomayor, C; Gates, JM; Gothe, OR; Lee, IY; Loveland, WD; McLaughlin, JP; Paschalis, S; Petri, M; Qian, J; Stavsetra, L; Wiedeking, M; Nitsche, H (2010). New Superheavy Element Isotopes: Pu-242(Ca-48, 5n)(285)114. PHYSICAL REVIEW LETTERS. 105. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

The analysis of the national research collaboration covering the period 2011-2013, shows that almost half of the publications of IFE other research have co-authors from other Norwegian institutions and institutes (cf. Table A1.14). The Norwegian University of Science and Technology and the University of Oslo are the two largest collaborative institutions and approximately 20 per cent of the publications have co-authors from each of these universities. It should be noted, however, that people with dual affiliations (e.g. IFE and University of Oslo) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 14 of 138 articles (10 %) indexed in NCR have been co-authored with industry. The majority of these articles involve co-authorship with Statoil.

Table A1.14 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. IFE-other research.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	54	21%
University of Oslo	50	20%
SINTEF Foundation	15	6%
University of Bergen	9	4%
Telemark University College	3	1%
SINTEF Petroleum Research	3	1%
Norwegian University of Life Sciences	3	1%
Other units	23	
Total number of collaborative publications with units in the Norwegian public research system	124	49%
Total number of publications	255	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 54 per cent of the IFE other research articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is above the average of the TI institutes, which is 48 per cent. Table A.1.15 shows which countries IFE other research has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA, and 14 per cent of the articles have co-authors from this nation.

Table A1.15 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. IFE-other research.

Country	No. of collaborative publications	Proportion of total
USA	20	14%
UK	9	7%
Ukraine	8	6%
South Africa	8	6%
Australia	7	5%
Netherlands	7	5%
Germany	6	4%
Sweden	6	4%
Other countries	40	
Total number of publications with co-authors from other countries	74	54%
Total number of publications	138	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.4 International Research Institute of Stavanger AS (IRIS)

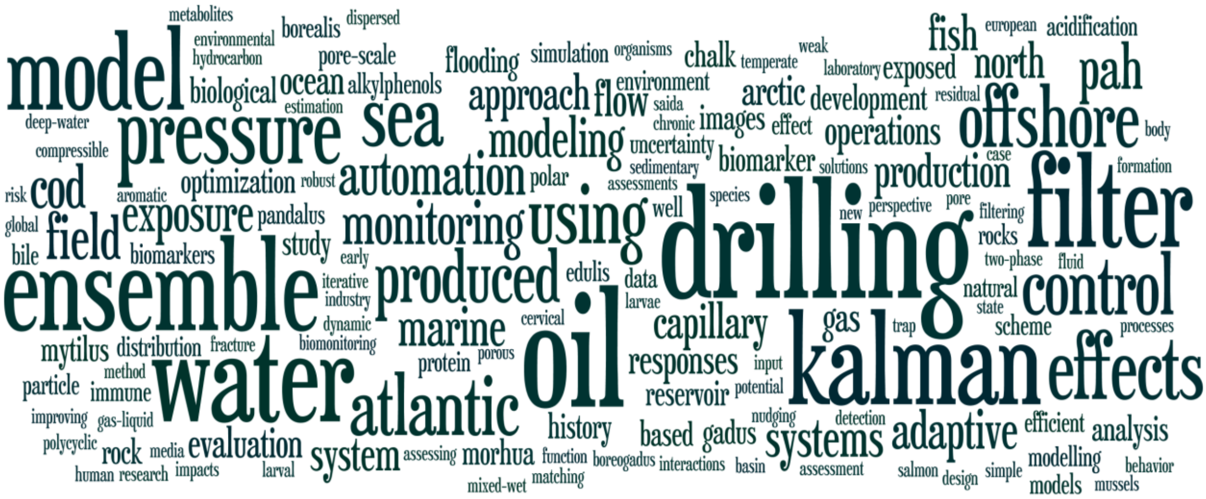


Figure A1.4 Most frequently appearing words in the publication titles, 2009-2013. IRIS NT.
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

This chapter provides an overview of the research at IRIS published by the departments included in the evaluation (e.g. excluding the social science department at IRIS). In terms of scientific publishing, IRIS is the 10th largest of the institutes included in the evaluation. IRIS has contributed 4 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 31 to 36 during the period 2009-2013, with no distinct trend (cf. Table 3.1), however, with 2010 as an outlier with only 21 publication points.

The staff at IRIS has published 0.36 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). This is slightly below the average of the TI institutes, which is 0.44.

Overall, the institute has published almost 180 scientific publications during the period 2009-2013. On average, 33 per cent of these publications appeared in level 2 channels. This is among the highest ratios of all the TI institutes. Thus, IRIS has a significant number of publications in the most prestigious publication channels.

Figure A1.4 above shows the most frequent words appearing in the publication titles of IRIS. The figure illustrates some of the topics addressed in the research activities at IRIS.

Table A1.16 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the journal *Marine Pollution Bulletin* with 12 articles, followed by *SPE Drilling & Completion* (12 articles) and *SPE journal* (11 articles).

Table A1.16 The most frequently used journals/series*, number of publications 2009–2013. IRIS NT.

Journal/series	No. of articles	Level (1/2)
Marine Pollution Bulletin	12	1
SPE Drilling & Completion	12	2
SPE Journal	11	2
Computational Geosciences	5	1
Journal of Petroleum Science and Engineering	5	2
Marine Environmental Research	5	1
Journal of Toxicology and Environmental Health	5	1
Monthly Weather Review	3	1
Marine Biology	3	1
Aquatic Toxicology	3	2
Journal of Process Control	3	2
Advances in Water Resources	3	1
Transport in Porous Media	3	2

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

In order to provide further insights into the characteristics of the publication profile of IRIS, we have classified the articles by subfield (cf. Table A1.17). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. On the top of the list, we find the three subfields, Petroleum engineering, Marine & freshwater biology and Environmental sciences with 25-27 articles. The citation rate varies significantly across the different subfields. The publications within Petroleum engineering have been extremely highly cited and have obtained a relative citation index of 438. In other words, the articles have been cited 338 per cent more than the field-normalised world average. In the other fields, the citation rate of the publications is closer this average.

Table A1.17 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. IRIS NT.

Subfield*	No. of articles (2009-13)	Citation index –field** (2009-12)
ENGINEERING, PETROLEUM	27	438
MARINE & FRESHWATER BIOLOGY	26	111
ENVIRONMENTAL SCIENCES	25	127
GEOSCIENCES, MULTIDISCIPLINARY	20	108
TOXICOLOGY	14	140
ENERGY & FUELS	12	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.18 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 101 articles have been published which amounts to 80 per cent of the total scientific production of IRIS during the period. Thus, the large majority of the publications have been published in indexed journals. The articles have been cited above the world average both when using a field and journal based normalisation method (citation index, 162 and 130, respectively). With a field-normalised index of 162, IRIS has the third highest citation rate of the TI institutes. The lower figure of the journal based indicator, implies that the articles have been published in journals with a higher than average citation rate (impact-factor). As seen above, the publications within Petroleum engineering contribute significantly to the high citation index of IRIS.

Table A1.18 Citation indicators, 2009–2012 publications indexed in NCR.* IRIS NT.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
101	80%	632	94	6.3	130	162

Source: Data: NIFU's Key figure database, CRIStin, 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. [12]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The institute is involved in extensive national collaboration. In the period 2011-2013, 68 per cent of the IRIS publications have co-authors also from other Norwegian institutions and institutes (cf. Table A1.19). The University of Stavanger is the largest collaborative institution and a third of the publications have co-authors from this institution. Then follow two units located in West-Norway: University of Bergen and Uni Research. It should be noted, however, that people with dual affiliations (e.g. IRIS and University of Stavanger) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 11 of 96 articles (12%) indexed in NCR have been co-authored with industry. Statoil accounts for the majority of these articles.

[12] Refers to the article: Aanonsen, SI; Naevdal, G; Oliver, DS; Reynolds, AC; Valles, B (2009). The Ensemble Kalman Filter in Reservoir Engineering-a Review. SPE JOURNAL. 14, 393-412. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Table A1.19 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. IRIS NT.

Institution/institute	No. of collaborative publications	Proportion of total
University of Stavanger	43	35%
University of Bergen	17	14%
Uni Research	13	11%
Norwegian Institute for Water Research	12	10%
Institute of Marine Research	8	7%
Norwegian University of Science and Technology	5	4%
University of Oslo	5	4%
Stavanger University Hospital	5	4%
SINTEF Foundation	5	4%
Other units	12	
Total number of collaborative publications with units in the Norwegian public research system	83	68%
Total number of publications	122	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 39 per cent of the IRIS articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is below the average of the TI institutes, which is 48 per cent. Table A.1.20 shows which countries IRIS has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA, and 17 per cent of the articles have co-authors from this nation.

Table A1.20 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. IRIS NT.

Country	No. of collaborative publications	Proportion of total
USA	16	17%
UK	5	5%
Sweden	5	5%
Netherlands	4	4%
Peoples R China	4	4%
Denmark	4	4%
Saudi Arabia	4	4%
Other countries	30	
Total number of publications with co-authors from other countries	37	39%
Total number of publications	96	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.5 Norwegian Marine Technology Research Institute AS (MARINTEK)

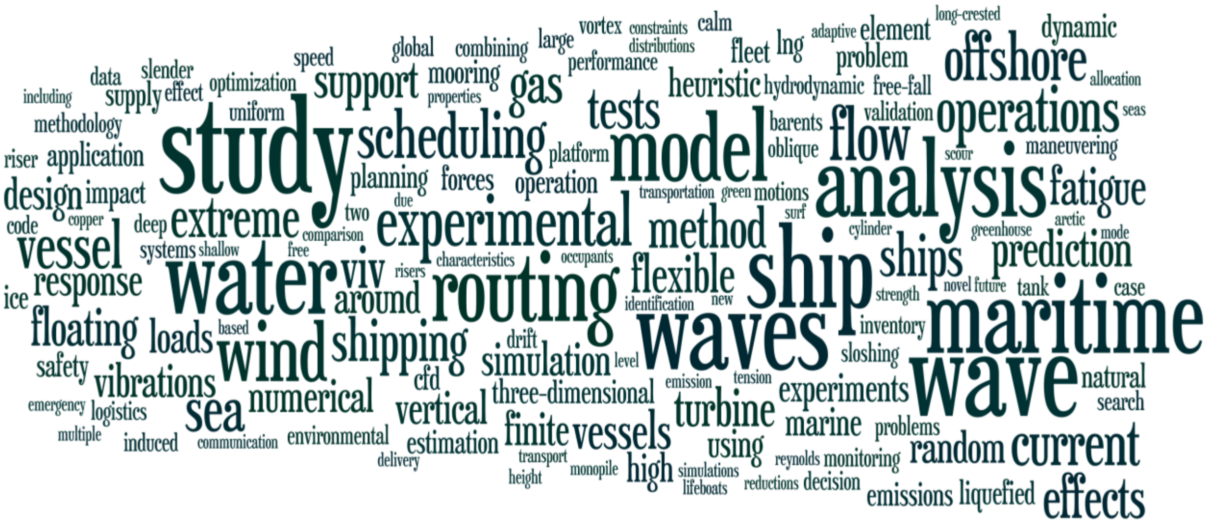


Figure A1.5 Most frequently appearing words in the publication titles, 2009-2013. MARINTEK.
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, MARINTEK is the 12th largest of the institutes included in the evaluation. MARINTEK has contributed 3 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 16 to 30 during the 2009-2013 period, with the highest numbers in the two recent years, 2013 and 2012 (cf. Table 3.1).

MARINTEK has the second lowest publication productivity of all the TI institutes with an average of 0.22 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). The average of the TI institutes is 0.44. Thus, relatively little of the institute's activities result in scientific publications. However, the productivity shows a slightly increasing trend, rising to 0.25 in 2013.

Overall, the institute has published almost 200 scientific publications during the period 2009-2013. On average, 17 per cent of these publications appeared in level 2 channels. This is somewhat below the average of the TI institutes, which is 22 per cent.

Figure A1.5 above shows the most frequent words appearing in the publication titles of MARINTEK. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.21 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find *Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering* with 37 articles.

Table A1.21 The most frequently used journals/series*, number of publications 2009–2013. MARINTEK.

Journal/series	No. of articles	Level (1/2)
International Conference on Offshore Mechanics and Arctic Engineering, proceedings	37	1
Journal of Offshore Mechanics and Arctic Engineering-Transactions of The Asme	4	2
Transportation Research Part C: Emerging Technologies	4	2
ISOPE - International Offshore and Polar Engineering Conference. Proceedings	4	1
International Conference on Ship Manoeuvring in Shallow and Confined Water	4	1
European Journal of Operational Research	4	2
Computers & Operations Research	4	2
Proceedings - International Conference on Port and Ocean Engineering under Arctic Conditions	3	1
Energy Policy	3	1
Computers & industrial engineering	3	1
Coastal Engineering	3	2

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

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

In order to provide further insights into the characteristics of the publication profile of MARINTEK, we have classified the articles by subfield. This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category for Operations research & management science accounts for the highest number of the articles (15 articles). These articles have also been cited significantly above the field-normalised average (citation index 190). Because the number of articles is below the threshold, citation indicators have not been calculated for the other subfields.

Table A1.22 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. MARINTEK.

Subfield*	No. of articles (2009-13)	Citation index –field** (2009-12)
OPERATIONS RESEARCH & MANAGEMENT SCIENCE	15	190
ENGINEERING, CIVIL	9	–
ENGINEERING, INDUSTRIAL	8	–
ENGINEERING, OCEAN	8	–
COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS	7	–
ENGINEERING, MECHANICAL	6	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

*) Limited to subfields with at least 5 articles during the period 2009-2013.

**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.23 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 40 articles have been published which amounts to 32 per cent of the total scientific production of MARINTEK during the period. Thus, only a rather limited part of the publication output of the institute is included in this analysis. This reduces the reliability of the citation indicators. MARINTEK has a large number of articles in proceedings which are not indexed in NCR. Nevertheless, the articles that are included have obtained a citation index clearly above the world average. With a field-normalised index of 140, MARINTEK has the fourth highest citation rate of the TI institutes.

Table A1.23 Citation indicators, 2009–2012 publications indexed in NCR.* MARINTEK.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
40	32%	255	52	6.4	131	140

Source: Data: NIFU's Key figure database, CRIStin, 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. [13]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that a large majority (71 %) the publications of MARINTEK have co-authors from other Norwegian institutions and institutes (cf. Table A1.24). Most of this collaboration involves The Norwegian University of Science and Technology (NTNU) and two thirds of the publications of MARINTEK have co-authors from this university. The follow institutes within the SINTEF Foundation. It should be noted, however, that people with dual affiliations (e.g. MARINTEK and NTNU) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 4 of 47 articles (9 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.

[13] Refers to the article: Onorato, M; Waseda, T; Toffoli, A; Cavaleri, L; Gramstad, O; Janssen, PAEM; Kinoshita, T; Monbaliu, J; Mori, N; Osborne, AR; Serio, M; Stansberg, CT; Tamura, H; Trulsen, K (2009). Statistical Properties of Directional Ocean Waves: The Role of the Modulational Instability in the Formation of Extreme Events. PHYSICAL REVIEW LETTERS. 102. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Table A1.24 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. MARINTEK.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	89	67%
SINTEF Foundation	10	8%
Other units	8	
Total number of collaborative publications with units in the Norwegian public research system	95	71%
Total number of publications	133	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 28 per cent of MARINTEK articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is below the average of the TI institutes, which is 48 per cent. Thus, compared to the other institutes, MARINTEK apparently is less involved in international research collaboration, as far as this is reflected trough co-authorship. However, it should be recalled that the analysis is based on a rather limited part of MARINTEK's production. Table A.1.25 shows which countries MARINTEK has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find Canada, and 13 per cent of the articles have co-authors from this nation.

Table A1.25 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. MARINTEK.

Country	No. of collaborative publications	Proportion of total
Canada	6	13%
South Africa	3	6%
Other countries	13	
Total number of publications with co-authors from other countries	13	28%
Total number of publications	47	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.6 Norwegian Geotechnical Institute (NGI)

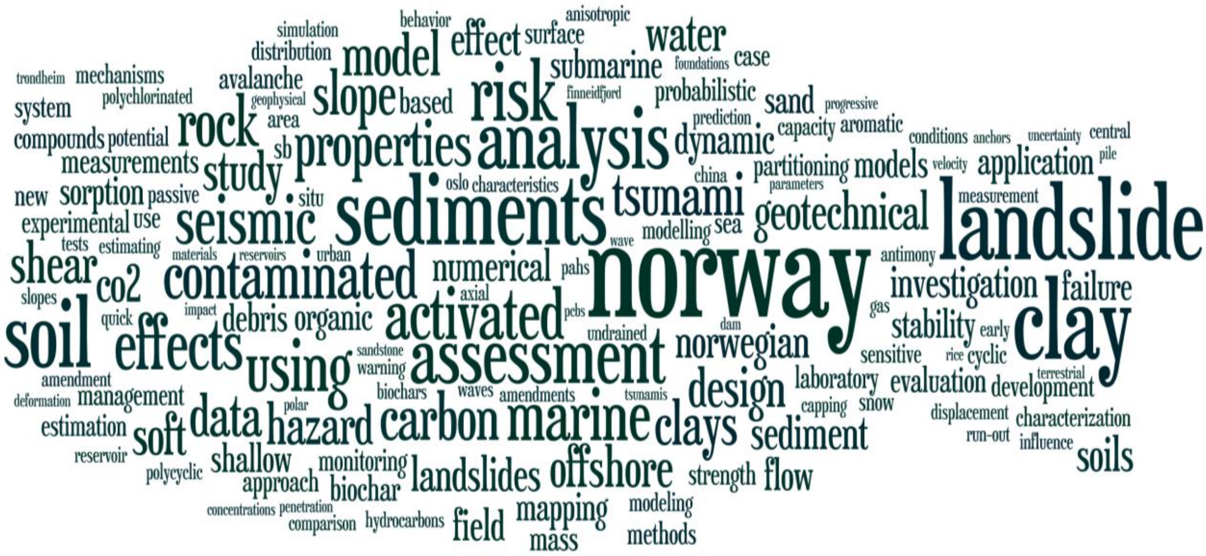


Figure A1.6 Most frequently appearing words in the publication titles, 2009-2013. NGI.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, NGI is the sixth largest of the institutes included in the evaluation. NGI has contributed 6 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been quite stable and in the range of 45-48 points in the 2009-2013 period, with the exception of a lower figure in 2010 (32 points) (cf. Table 3.1). The publication productivity is, however, lower than for most of the other TI institutes. During the 3-year period 2011-2013, the staff at NGI published 0.26 publication points per FTE researchers (cf. Figure 3.2). The average of the TI institutes is 0.44.

Overall, the institute has published more than 330 scientific publications during the period 2009-2013. On average, 21 per cent of these publications appeared in level 2 channels, which almost identical to the average of the TI institutes.

Figure A1.6 above shows the most frequent words appearing in the publication titles of NGI. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.26 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the level 2 journal *Environmental Science and Technology* with 30 articles, followed by the *Canadian geotechnical journal* (13 articles).

Table A1.26 The most frequently used journals/series*, number of publications 2009–2013. NGI.

Journal/series	No. of articles	Level (1/2)
Environmental Science and Technology	30	2
Canadian geotechnical journal (Print)	13	1
Natural hazards and earth system sciences	12	1
Energy Procedia	8	1
Landslides : Journal of the International Consortium on Landslides	8	1
Cold Regions Science and Technology	7	2
Journal of Geotechnical and Geoenvironmental Engineering	7	1
Chemosphere	6	1
Journal of Soils and Sediments	6	1
Geotechnique	5	1
Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards	5	1
Engineering Geology	5	1
Natural Hazards	4	1
Rock Mechanics and Rock Engineering	4	2
Geophysics	3	2
International Journal of Rock Mechanics And Mining Sciences	3	1
Environmental Pollution	3	1
Environmental Toxicology and Chemistry	3	1
Journal of Structural Geology	3	2
Geophysical Prospecting	3	1
Annals of Glaciology	3	1
Near Surface Geophysics	3	1
Journal of Geophysical Research	3	2
Journal of Environmental Monitoring	3	1

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

In order to provide further insights into the characteristics of the publication profile of NGI, we have classified the articles by subfield (cf. Table A1.27). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category for Multidisciplinary geosciences accounts for the highest number of the articles (83 articles), followed by Geological engineering (54 articles) and Environmental sciences (50 articles). The citation rate varies significantly across the different subfields. The publications classified as Environmental sciences have been very highly cited and have obtained a relative citation index of 224. In other words, the articles have been cited 124 per cent more than the field-normalised world average. In several of the fields, however, the citation rate of the publications is below this average.

Table A1.27 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. NGI.

Subfield*	No. of articles (2009-13)	Citation index –field** (2009-12)
GEOSCIENCES, MULTIDISCIPLINARY	83	71
ENGINEERING, GEOLOGICAL	54	99
ENVIRONMENTAL SCIENCES	50	224
ENGINEERING, ENVIRONMENTAL	36	210
GEOCHEMISTRY & GEOPHYSICS	21	69
METEOROLOGY & ATMOSPHERIC SCIENCES	17	87
WATER RESOURCES	16	116
ENGINEERING, CIVIL	13	93

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.28 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 157 articles have been published which amounts to 68 per cent of the total scientific production of NGI during the period. Thus, the majority of the publications have been published in indexed journals. The articles have been cited above the world average both when using a field and journal based normalisation method (citation index, 123 and 121, respectively). This means that the citation index of NGI is almost identical to the average of the TI institutes.

Table A1.28 Citation indicators, 2009–2012 publications indexed in NCR.* NGI.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
157	68%	999	52	6.4	121	123

Source: Data: NIFU's Key figure database, CRIStin, 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. [14]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that approximately half (46 %) the publications of NGI have co-authors from other Norwegian institutions and institutes (cf. Table A1.29). The collaboration encompasses several organisations. The University of Oslo appears as the most frequent collaborative partner with 43 joint articles (19 % of the total), followed by the The Norwegian University of Life Sciences with 34 articles (15 %). It should be noted, however, that people with dual affiliations (e.g. NGI and the University of Oslo) may list both addresses on the publications.

[14] Refers to the article: Ghosh, U; Luthy, RG; Cornelissen, G; Werner, D; Menzie, CA (2011). In-situ Sorbent Amendments: A New Direction in Contaminated Sediment Management. ENVIRONMENTAL SCIENCE & TECHNOLOGY. 45, 1163-1168. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 15 of 141 articles (11 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.) Here we find companies such as Lindum, Veritas and Statoil.

Table A1.29 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. NGI.

Institution/institute	No. of collaborative publications	Proportion of total
University of Oslo	43	19%
Norwegian University of Life Sciences	34	15%
Norwegian University of Science and Technology	17	7%
NORSAR	15	7%
University of Bergen	13	6%
Norwegian Institute for Agricultural and Environmental Research	8	3%
Norwegian Institute for Water Research	6	3%
University of Tromsø	5	2%
Uni Research	5	2%
University Centre in Svalbard	4	2%
Other units	15	
Total number of collaborative publications with units in the Norwegian public research system	105	46%
Total number of publications	230	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 78 per cent of the NGI articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is significantly above the average of the TI institutes, which is 48 per cent. Thus, the institute is involved in extensive international collaboration. Table A.1.30 shows which countries NGI has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find Sweden and the USA, and 23 and 18 per cent, respectively of the articles have co-authors from these countries.

Table A1.30 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. NGI.

Country	No. of collaborative publications	Proportion of total
Sweden	33	23%
USA	26	18%
Germany	16	11%
Canada	11	8%
UK	11	8%
Peoples R China	10	7%
Italy	6	4%
Switzerland	6	4%
France	5	3%
Poland	5	3%
Other countries	46	
Total number of publications with co-authors from other countries	112	78%
Total number of publications	144	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.7 NORSAR

Figure A1.7 Most frequently appearing words in the publication titles, 2009-2013. NORSAR.
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, NORSAR is among the smallest institutes included and accounts for 2 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has varied from 11 to 25 in the 2009-2013 period, with the highest numbers in the three most recent years (cf. Table 3.1). Thus, we see an increasing trend in the publication volume. NORSAR has the second highest publication productivity of all the TI institutes with an average of 0.78 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). The average of the TI institutes is 0.44. Thus, a larger portion of the research activities results in scientific publications than what is the case for most of the other institutes.

Overall, the institute has published 117 scientific publications during the period 2009-2013. On average, 31 per cent of these publications appeared in level 2 channels. This is among the highest ratios of the units included in the evaluation. Thus, the institute has a significant number of publications in the most prestigious publication channels.

Figure A1.7 above shows the most frequent words appearing in the publication titles of NORSAR. The figure illustrates some of the topics addressed in the research activities at NORSAR. Table A1.31 contains a list of the most frequently used journals – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the level 2 journal *Geophysical Journal International* with 11 articles, followed by the *Journal of Seismology* and *Geophysics*, each with 10 articles.

Table A1.31. The most frequently used journals/series*, number of publications 2009–2013. NORSAR.

Journal/series	No. of articles	Level (1/2)
Geophysical Journal International	11	2
Journal of Seismology	10	1
Geophysics	10	2
Earthquake spectra	6	1
Bulletin of The Seismological Society of America (BSSA)	5	2
Earthquake engineering & structural dynamics (Print)	4	2
Pure and Applied Geophysics	4	1
Seismological Research Letters	4	1
EOS : Transactions	3	1
Tectonophysics	3	1
Soil Dynamics and Earthquake Engineering	3	1
First Break	3	1

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

In order to provide further insights into the characteristics of the publication profile of NORSAR, we have classified the articles by subfield (cf. Table A1.32). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category for Geochemistry & geophysics accounts for the highest number of the articles (50 articles). The citation rate varies across the different subfields. The publications classified as Geological engineering have been most frequently cited and have obtained a relative citation index of 102. In other words, the articles have been cited 2 per cent more than the field-normalised world average. This is still below the average of the TI institutes which is 120. In the other fields, the citation rate of the publications is below the world average.

Table A1.32 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. NORSAR.

Subfield*	No. of articles (2009-13)	Citation index –field** (2009-12)
GEOCHEMISTRY & GEOPHYSICS	50	56
ENGINEERING, GEOLOGICAL	16	102
ENGINEERING, CIVIL	15	76
GEOSCIENCES, MULTIDISCIPLINARY	13	92

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.33 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 63 articles have been published which amounts to 72 per cent of the total scientific production of NORSAR during the period. Thus, the majority of the publications have been published in indexed journals. The articles have been cited below the world average both when using a field and journal based normalisation method (citation index, 74 and 84, respectively). This means that the citation index of NORSAR is significantly below the average of the TI institutes and the impact of the research has not been particularly high when measured by number of citations.

Table A1.33 Citation indicators, 2009–2012 publications indexed in NCR.* NORSAR.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
63	72%	216	21	3.4	84	74

Source: Data: NIFU's Key figure database, CRIStin, 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. [15]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows approximately one third (37 %) of the publications of NORSAR have co-authors from other Norwegian institutions and institutes (cf. Table A1.34). NGI appears as the most frequent collaborative partner with 15 joint articles (17 % of the total), followed by the University of Oslo and the University of Bergen with 12 and 11 publications, respectively. It should be noted, however, that people with dual affiliations (e.g. NORSAR and the University of Oslo) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis.

Table A1.34 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. NORSAR.

Institution/institute	No. of collaborative publications	Proportion of total
NGI	15	17%
University of Oslo	12	14%
University of Bergen	11	13%
Norwegian University of Science and Technology	6	7%
Other units	7	
Total number of collaborative publications with units in the Norwegian public research system	32	37%
Total number of publications	86	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

[15] Refers to the article: Bommer, JJ; Douglas, J; Scherbaum, F; Cotton, F; Bungum, H; Fah, D (2010). On the Selection of Ground-Motion Prediction Equations for Seismic Hazard Analysis. SEISMOLOGICAL RESEARCH LETTERS. 81, 783-793. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

The institute is involved in extensive international collaboration. The analysis shows that 81 per cent of the NORSAR articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is significantly above the average of the TI institutes, which is 48 per cent. Table A.1.35 shows which countries NORSAR has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA and Germany, and 29 and 17 per cent, respectively, of the articles have co-authors from these countries.

Table A1.35 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. NORSAR.

Country	No. of collaborative publications	Proportion of total
USA	18	29%
Germany	11	17%
India	6	10%
UK	5	8%
France	5	8%
Spain	5	8%
Other countries	52	
Total number of publications with co-authors from other countries	51	81%
Total number of publications	63	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.8 Norut Narvik

Figure A1.8 Most frequently appearing words in the publication titles, 2009-2013. Norut Narvik.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, Norut Narvik is the smallest institute included and accounts for 1 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has varied from 1 to 4 in the period 2009-2012 but was rising to 13 in 2013 (cf. Table 3.1). The institute has an average of 0.28 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). The average of the TI institutes is 0.44.

Overall, the institute has published 47 scientific publications during the period 2009-2013. On average 13 per cent of these publications appeared in level 2 channels, which is below the average of the TI institutes (22 %). Thus, relatively few of the institute's publications appear in these most prestigious publication channels.

Figure A1.8 above shows the most frequent words appearing in the publication titles of Norut Narvik. The figure illustrates some of the topics addressed in the research activities at the institute. Table A1.1 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013.

Table A1.36. **The most frequently used journals/series*, number of publications 2009–2013. Norut Narvik.**

Journal/series	No. of articles	Level (1/2)
International Conference on Port and Ocean Engineering under Arctic Conditions Proceedings	5	1
Journal of Function Spaces and Applications	3	1
Nordic Concrete Research	3	1
Cold Regions Science and Technology	3	2

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

In order to provide further insights into the characteristics of the publication profile of Norut Narvik, we have classified the articles by subfield. This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. We find the subfield Applied mathematics on the top of the list with 7 articles. Because the number of articles is below the threshold, citation indicators have not been calculated for the individual subfields.

Table A1.37 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. Norut Narvik.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
MATHEMATICS, APPLIED	7	–
ENGINEERING, CIVIL	5	–
ENGINEERING, MULTIDISCIPLINARY	5	–
MATERIALS SCIENCE, MULTIDISCIPLINARY	5	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.38 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 20 articles have been published which amounts to 67 per cent of the total scientific production of Norut Narvik during the period. Thus, the majority of the publications have been published in indexed journals. The articles have been cited significantly below the world average both when using a field and journal based normalisation method (citation index, 49 and 61, respectively). This is the lowest citation rate of all the TI institutes. Accordingly, the impact of the research has not been high when measured by number of citations.

Table A1.38 Citation indicators, 2009–2012 publications indexed in NCR.* Norut Narvik.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
20	67%	24	8	1.2	61	49

Source: Data: NIFU's Key figure database, CRIStin, 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. [16]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that approximately one third (29 %) the publications of Norut Narvik have co-authors from other Norwegian institutions and institutes (cf. Table A1.39). Narvik University College appears as the most frequent collaborative partner, with 9 joint articles (26 % of the total). It should be noted, however, that people with dual affiliations (e.g. Norut Narvik and Narvik University College) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis.

Table A1.39 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. Norut Narvik.

Institution/institute	No. of collaborative publications	Proportion of total
Narvik University College	9	26%
Other units	3	
Total number of collaborative publications with units in the Norwegian public research system	10	29%
Total number of publications	34	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 61 per cent of the Norut Narvik articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is above the average of the TI institutes, which is 48 per cent. Table A.1.40 shows which countries Norut Narvik has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find Sweden and 39 per cent of the articles have co-authors from this country.

[16] Refers to the article: Lukkassen, D; Nguetseng, G; Nnang, H; Wall, P (2009). Reiterated homogenization of nonlinear monotone operators in a general deterministic setting. JOURNAL OF FUNCTION SPACES AND APPLICATIONS. 7, 121-152. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Table A1.40 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. Norut Narvik.

Country	No. of collaborative publications	Proportion of total
Sweden	9	39%
USA	4	17%
Portugal	4	17%
Other countries	5	
Total number of publications with co-authors from other countries	14	61%
Total number of publications	23	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.9 Norut Tromsø

Figure A1.9 Most frequently appearing words in the publication titles, 2009-2013. Norut Tromsø NT.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

This chapter provides an overview of the research at Norut Tromsø published by the departments included in the evaluation (e.g. excluding the social science department at Norut Tromsø). In terms of scientific publishing, Norut Tromsø is among the smallest institutes included in the evaluation. The institute has contributed 2 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 10 to 22 during the period 2009-2013.

The staff at Norut Tromsø has published 0.57 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). This is above the average of the TI institutes which is 0.44.

Overall, the institute has published almost 130 scientific publications during the period 2009-2013. On average, 24 per cent of these publications appeared in level 2 channels, which almost identical to the average of the TI institutes (22%).

Figure A1.9 above shows the most frequent words appearing in the publication titles of IRIS. The figure illustrates some of the topics addressed in the research activities at Norut Tromsø.

Table A1.41 contains a list of the most frequently used series and journals – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the level 2 journal *IEEE Transactions on Geoscience and Remote Sensing* with 13 articles, followed by the *Journal of Medical Internet Research* with 6 articles. The research of Norut Tromsø has been published in a rather heterogeneous set of journals.

Table A1.41 The most frequently used journals/series*, number of publications 2009–2013. Norut Tromsø NT.

Journal/series	No. of articles	Level (1/2)
IEEE Transactions on Geoscience and Remote Sensing	13	2
Journal of Medical Internet Research	6	2
Remote Sensing of Environment	5	2
Polar Record	4	1
Studies in Health Technology and Informatics	4	1
IEEE Engineering in Medicine and Biology Society. Conference Proceedings	3	1
ESA SP	3	1

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

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

In order to provide further insights into the characteristics of the publication profile of Norut Tromsø, we have classified the articles by subfield (cf. Table A1.42). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category for Remote sensing accounts for the highest number of the articles (13 articles), followed by Environmental sciences and Medical informatics, both with 12 articles. Because the number of articles is below the threshold in most of the subfields, citation indicators have only been calculated for the publications appearing in Environmental sciences. Here, the articles have been cited almost on par with the world average.

Table A1.42 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. Norut Tromsø NT.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
REMOTE SENSING	13	–
ENVIRONMENTAL SCIENCES	12	95
MEDICAL INFORMATICS	12	–
ECOLOGY	10	–
ENGINEERING, ELECTRICAL & ELECTRONIC	9	–
GEOCHEMISTRY & GEOPHYSICS	8	–
HEALTH CARE SCIENCES & SERVICES	8	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

*) Limited to subfields with at least 5 articles during the period 2009-2013.

**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.43 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 44 articles have been published which amounts to 48 per cent of the total scientific production of Norut Tromsø during the period. Thus, there is a significant number of publications not included in this analysis. The articles have been cited above the world average both when using a field and journal based normalisation method (citation index, 128 and 134, respectively). This is also slightly above the field normalised average of the TI institutes which is 120.

Table A1.43 Citation indicators, 2009–2012 publications indexed in NCR.* Norut Tromsø NT.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
44	48%	307	31	7.0	134	128

Source: Data: NIFU's Key figure database, CRIStin, 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. [17]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that approximately two third (65 %) of the publications of Norut Tromsø have co-authors from other Norwegian institutions and institutes (cf. Table A1.44). University of Tromsø appears as the most frequent collaborative partner with 35 joint articles (43 % of the total). It should be noted, however, that people with dual affiliations (e.g. Norut Tromsø and the University of Tromsø) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 2 of 42 articles indexed in NCR (5 %) have been co-authored with industry.

Table A1.44 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. Norut Tromsø NT.

Institution/institute	No. of collaborative publications	Proportion of total
University of Tromsø	35	43%
University Hospital of North Norway	12	15%
University of Oslo	6	7%
Norwegian Institute for Nature Research	5	6%
Norwegian University of Science and Technology	3	4%
Other units	8	
Total number of collaborative publications with units in the Norwegian public research system	53	65%
Total number of publications	82	100%

[17] Refers to the article: Chomutare, T; Fernandez-Luque, L; Arsand, E; Hartvigsen, G (2011). Features of Mobile Diabetes Applications: Review of the Literature and Analysis of Current Applications Compared Against Evidence-Based Guidelines. JOURNAL OF MEDICAL INTERNET RESEARCH. 13. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 52 per cent of the Norut Tromsø articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is slightly above the average of the TI institutes, which is 48 per cent. Table A.1.45 shows which countries Norut Tromsø has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA and 19 per cent of the articles have co-authors from this country.

Table A1.45 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. Norut Tromsø NT.

Country	No. of collaborative publications	Proportion of total
USA	8	19%
UK	6	14%
Sweden	5	12%
Other countries	14	
Total number of publications with co-authors from other countries	22	52%
Total number of publications	42	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.10 Norwegian Computing Center (NR)

Figure A1.10 Most frequently appearing words in the publication titles, 2009-2013. NR.
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, NR is the ninth largest of the institutes included in the evaluation. NR has contributed 4 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 26 to 42 during the 2009-2013 period, with no distinct trend (cf. Table 3.1).

NR has the third highest publication productivity of all the TI institutes with an average of 0.66 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). The average of the TI institutes is 0.44.

Overall, the institute has published 250 scientific publications during the period 2009-2013. On average, 18 per cent of these publications appeared in level 2 channels. This is somewhat below the average of the TI institutes which is 22 per cent.

Figure A1.10 above shows the most frequent words appearing in the publication titles of NR. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.46 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find *Lecture Notes in Computer Science* with 10 articles.

Table A1.46 The most frequently used journals/series*, number of publications 2009–2013. NR.

Journal/series	No. of articles	Level (1/2)
Lecture Notes in Computer Science	10	1
Environmetrics	6	1
PLoS ONE	5	1
International journal on advances in security	4	1
Scandinavian Journal of Statistics	4	2
Geophysics	4	2
Mathematical Geosciences	3	1
IFIP Advances in Information and Communication Technology	3	1
BMC Bioinformatics	3	2

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

In order to provide further insights into the characteristics of the publication profile of NR, we have classified the articles by subfield (cf. Table A1.47). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Statistics & probability accounts for the highest number of the articles (22 articles). Because the number of articles is below the threshold in most of the subfields, citation indicators have only been calculated for the publications appearing in Statistics & probability and Mathematics, interdisciplinary applications. Here, the articles have obtained very high citation indices with a field normalised citation index of 272 and 206, respectively. In other words, the articles have been cited more than twice as frequent the average articles within these fields.

Table A1.47 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. NR.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
STATISTICS & PROBABILITY	22	272
GEOSCIENCES, MULTIDISCIPLINARY	10	–
MATHEMATICS, INTERDISCIPLINARY APPLICATIONS	10	206
REMOTE SENSING	7	–
GEOCHEMISTRY & GEOPHYSICS	7	–
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	7	–
ENVIRONMENTAL SCIENCES	6	–
MULTIDISCIPLINARY SCIENCES	6	–
MATHEMATICAL & COMPUTATIONAL BIOLOGY	6	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.48 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 82 articles have been published which amounts to 45 per cent of the total scientific production of NR during the period. Thus, there is a significant number of publications not included in this analysis. The articles have been cited above the world average both when using a field and journal based normalisation method (citation index, 118 and 121, respectively). This is almost on par with the field normalised average of the TI institutes which is 120.

Table A1.48 Citation indicators, 2009–2012 publications indexed in NCR.* NR.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
82	45%	521	77	6.4	121	118

Source: Data: NIFU's Key figure database, CRIStin, 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. [18]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that approximately half (45 %) the publications of NR have co-authors from other Norwegian institutions and institutes (cf. Table A1.49). The collaboration encompasses several organisations. The University of Oslo appears as the most frequent collaborative partner with 45 joint articles (28 % of the total), followed by the Oslo University Hospital with 21 articles (13 %). It should be noted, however, that people with dual affiliations (e.g. NR and the University of Oslo) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 12 of 79 articles (15 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.) Here we find various companies where Statoil accounts for the highest number.

[18] Refers to the article: Jakobsen, JP; Czado, C; Frigessi, A; Bakken, H (2009). Pair-copula constructions of multiple dependence. INSURANCE MATHEMATICS & ECONOMICS. 44, 182-198. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Table A1.49 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. NR.

Institution/institute	No. of collaborative publications	Proportion of total
University of Oslo	45	28%
Oslo University Hospital	21	13%
Norwegian University of Science and Technology	13	8%
University of Bergen	5	3%
University of Tromsø	4	3%
Uni Research	4	3%
University of Stavanger	4	3%
SINTEF Foundation	3	2%
Norwegian Veterinary Institute	3	2%
Other units	16	
Total number of collaborative publications with units in the Norwegian public research system	72	45%
Total number of publications	159	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 37 per cent of the NR articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is below the average of the TI institutes, which is 48 per cent. Table A.1.50 shows which countries NR has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA, and 13 per cent of the articles have co-authors from this nation.

Table A1.50 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. NR.

Country	No. of collaborative publications	Proportion of total
USA	10	13%
Germany	6	8%
UK	5	6%
Other countries	18	
Total number of publications with co-authors from other countries	29	37%
Total number of publications	79	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.11 SINTEF Energy Research AS

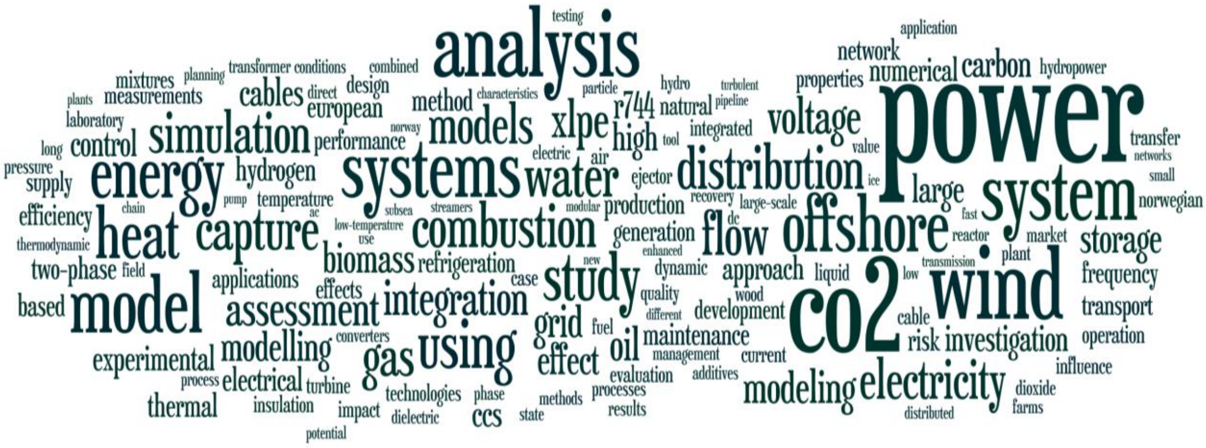


Figure A1.11 Most frequently appearing words in the publication titles, 2009-2013. SINTEF Energy Research.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, SINTEF Energy Research is the second largest of the institutes included in the evaluation. The institute has contributed 16 per cent of the total publication output of the TI institutes during the period 2011-2013. The publication volume has increased significantly during the period 2009-2011, with almost doubling the number of publication points (most of the increase taking place from 2009 to 2010). In 2013, the institute obtained 148 publication points (cf. Table 3.1).

SINTEF Energy Research also has a very high publication productivity, with an average of 0.89 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2).This is the highest rate of all the TI institutes. The average of these institutes is 0.44.

Overall, the institute has published almost 700 scientific publications during the period 2009-2013. On average, 23 per cent of these publications appeared in level 2 channels. This is almost identical to the average of the TI institutes.

Figure A1.11 above shows the most frequent words appearing in the publication titles of SINTEF Energy Research. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.51 contains a list of the most frequently used journals and series – limited to series with at least four publications during the period 2009–2013. On the top of the list, we find *Energy Procedia* with 84 articles followed by the *IEEE Transactions on Power Delivery* 26 articles.

Table A1.51 The most frequently used journals/series*, number of publications 2009–2013. SINTEF Energy Research.

Journal/series	No. of articles	Level (1/2)
Energy Procedia	84	1
IEEE Transactions on Power Delivery	26	2
Science et technique du froid	24	1
Energy & Fuels	21	2
IEEE transactions on dielectrics and electrical insulation	14	2
International Journal of Greenhouse Gas Control	12	2
IET Conference Publications	12	1
Conference on Electrical Insulation and Dielectric Phenomena. Annual Report	12	1
Chemical Engineering Transactions	9	1
CIRED Conference Proceedings	9	1
International journal of hydrogen energy	9	2
Applied Energy	8	1
International journal of refrigeration	7	2
Conference record of IEEE International Symposium on Electrical Insulation	7	1
IEEE Power & Energy Society General Meeting	6	1
Energy and Buildings	6	2
European transactions on electrical power	6	1
Proceedings of IEEE International Conference on Dielectric Liquids	6	1
Procedia Food Science	6	1
Applied Thermal Engineering	5	1
IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies	5	1
Fuel processing technology	5	1
Wind Engineering : The International Journal of Wind Power	5	1
Industrial & Engineering Chemistry Research	4	2
Wind Energy	4	2
Journal of Fluid Mechanics	4	2
ISOPE - International Offshore and Polar Engineering Conference. Proceedings	4	1
Energy	4	2

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

In order to provide further insights into the characteristics of the publication profile of SINTEF Energy Research, we have classified the articles by subfield (cf. Table A1.52). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category for Energy & fuels accounts for the highest number of the articles (99 articles), followed by Electrical & electronic engineering (65 articles). The citation rate varies across the different subfields. The publications classified as Civil engineering have been most frequently cited and have obtained a relative citation index of 185. In other words, the articles have been cited 85 per cent more than the field-normalised world average. In addition, the publications within Thermodynamics have been highly cited with an index value of 150. In some of the other fields, the citation rate of the publications is significantly below the world average.

Table A1.52 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. SINTEF Energy Research.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
ENERGY & FUELS	99	78
ENGINEERING, ELECTRICAL & ELECTRONIC	65	83
ENGINEERING, CHEMICAL	60	134
PHYSICS, APPLIED	25	45
THERMODYNAMICS	25	150
MECHANICS	24	56
ENGINEERING, MECHANICAL	21	134
CHEMISTRY, PHYSICAL	17	50
ENGINEERING, ENVIRONMENTAL	14	50
ENGINEERING, CIVIL	13	185
WATER RESOURCES	11	–
ENVIRONMENTAL SCIENCES	10	–
MATHEMATICS, APPLIED	10	–
PHYSICS, FLUIDS & PLASMAS	10	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.53 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 193 articles have been published which amounts to 41 per cent of the total scientific production of SINTEF Energy Research during the period. Thus, there is a significant number of publications not included in this analysis. For example, the articles appearing in *Energy Procedia* is not indexed in NCR.

The indexed articles have been cited below the world average both when using a field and journal based normalisation method (citation index, 93 and 92, respectively). This is also below the field normalised average of the TI institutes which is 120.

Table A1.53 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Energy Research.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
193	41%	936	46	4.8	92	93

Source: Data: NIFU's Key figure database, CRIStin, 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. [19]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

[19] Refers to the article: Kvamsdal, HM; Jakobsen, JP; Hoff, KA (2009). Dynamic modeling and simulation of a CO2 absorber column for post-combustion CO2 capture. CHEMICAL ENGINEERING AND PROCESSING. 48, 135-144. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

The analysis of the national research collaboration covering the period 2011-2013, shows that half the publications of SINTEF Energy Research have co-authors from other Norwegian institutions and institutes (cf. Table A1.54). The Norwegian University of Science and Technology (NTNU) is by far the most frequent collaborative partner with 236 joint publications (45 % of the total). It should be noted, however, that people with dual affiliations (e.g. SINTEF Energy Research and NTNU) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 12 of 88 articles (6 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.)

Table A1.54 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. SINTEF Energy Research.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	236	45%
SINTEF Foundation	15	3%
University of Oslo	5	1%
SINTEF Petroleum Research	4	1%
University of Bergen	3	1%
Other units	17	
Total number of collaborative publications with units in the Norwegian public research system	262	50%
Total number of publications	523	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. These results show that 47 per cent of the SINTEF Energy Research articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is almost identical with the average of the TI institutes, which is 48 per cent. Table A.1.50 shows which countries SINTEF Energy Research has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find Sweden, and 9 per cent of the articles have co-authors from this nation.

Table A1.55 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. SINTEF Energy Research.

Country	No. of collaborative publications	Proportion of total
Sweden	17	9%
USA	12	6%
Serbia	9	5%
France	8	4%
Germany	7	4%
Finland	7	4%
Poland	6	3%
Canada	5	3%
Other countries	42	
Total number of publications with co-authors from other countries	88	47%
Total number of publications	189	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.12 SINTEF Petroleum Research AS

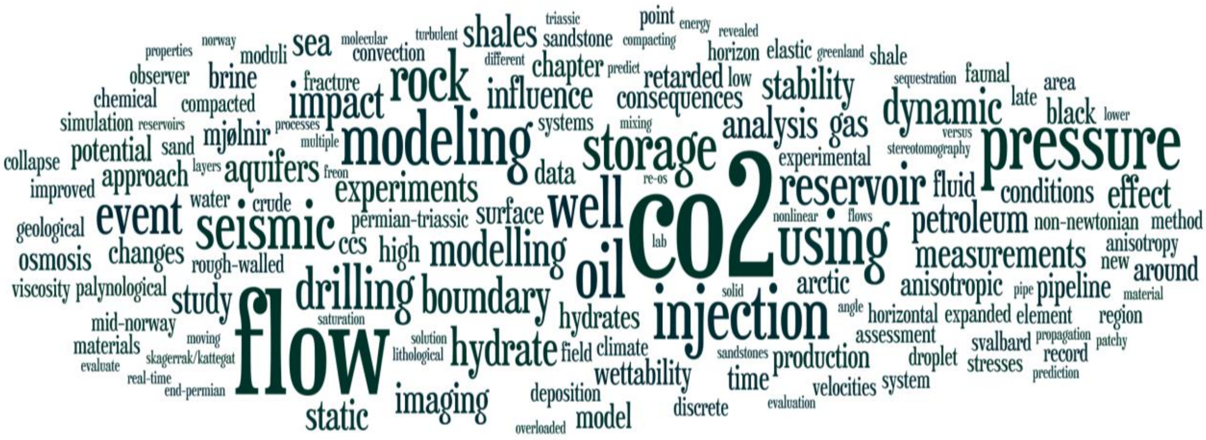


Figure A1.12 Most frequently appearing words in the publication titles, 2009-2013. SINTEF Petroleum Research.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, SINTEF Petroleum Research is among the smaller institutes included in the evaluation. The institute has contributed 2 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points shows quite large annual variations and has varied from 12 (2012) to 33 (2013) (cf. Table 3.1), within no distinct trend. SINTEF Petroleum Research has the third lowest publication productivity of all the TI institutes with an average of 0.24 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). The average of the TI institutes is 0.44. Thus, relatively little of the institute's activities result in scientific publications.

Overall, the institute has published approximately 140 scientific publications during the period 2009-2013. On average, 29 per cent of these publications appeared in level 2 channels, which is above the average of the TI institutes (22 %).

Figure A1.12 above shows the most frequent words appearing in the publication titles of SINTEF Petroleum Research. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.56 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find *Energy Procedia* with 16 articles.

Table A1.56 The most frequently used journals/series*, number of publications 2009–2013. SINTEF Petroleum Research.

Journal/series	No. of articles	Level (1/2)
Energy Procedia	16	1
Energy & Fuels	6	2
Geophysics	5	2
Geophysical Prospecting	4	1
Society of Exploration Geophysicists. Expanded Abstracts with Biographies	4	1
Earth and Planetary Science Letters	4	2
Palaeogeography, Palaeoclimatology, Palaeoecology	3	1
Physical Review E. Statistical, Nonlinear, and Soft Matter Physics	3	1
Journal of Petroleum Science and Engineering	3	2
Journal of Membrane Science	3	2

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

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

In order to provide further insights into the characteristics of the publication profile of SINTEF Petroleum Research, we have classified the articles by subfield (cf. Table A1.57). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Geochemistry & geophysics accounts for the highest number of the articles (20 articles). The citation rate varies across the different subfields. The publications classified as Multidisciplinary geoscience have been most frequently cited and have obtained a relative citation index of 142. In other words, the articles have been cited 42 per cent more than the field-normalised world average. In some of the other fields, the citation rate of the publications is below the world average.

Table A1.57 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. SINTEF Petroleum Research.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
GEOCHEMISTRY & GEOPHYSICS	20	73
ENGINEERING, CHEMICAL	15	124
GEOSCIENCES, MULTIDISCIPLINARY	15	142
ENERGY & FUELS	14	55
GEOGRAPHY, PHYSICAL	6	–
MECHANICS	5	–
ENGINEERING, GEOLOGICAL	5	–
ENGINEERING, PETROLEUM	5	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

*) Limited to subfields with at least 5 articles during the period 2009-2013.

**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.58 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 61 articles have been published which amounts to 62 per cent of the total scientific production of SINTEF Petroleum Research during the period. Thus, the majority of the publications have been published in indexed journals. The articles have been cited on par with the field-normalised world average (citation index 103), while the journal normalised indicator is below average (citation index 78). This implies that the articles have been published in journals with a higher than average citation rate (impact-factor).

Table A1.58 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Petroleum Research.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
61	62%	468	58	7.7	78	103

Source: Data: NIFU's Key figure database, CRIStin, 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. [20]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that two third of the publications of SINTEF Petroleum Research have co-authors from other Norwegian institutions and institutes (cf. Table A1.59). The Norwegian University of Science and Technology (NTNU) is by far the most frequent collaborative partner with 35 joint publications (38 % of the total). It should be noted, however, that people with dual affiliations (e.g. SINTEF Petroleum Research and NTNU) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 11 of 40 articles (28 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.). Statoil accounts for the majority of these articles.

[20] Refers to the article: Pradhan, S; Hansen, A; Chakrabarti, BK (2010). Failure processes in elastic fiber bundles. REVIEWS OF MODERN PHYSICS. 82, 499-555. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Table A1.59 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. SINTEF Petroleum Research.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	35	38%
SINTEF Foundation	8	9%
University of Stavanger	6	7%
University of Oslo	5	5%
University of Bergen	4	4%
IFE	4	4%
SINTEF Energy Research	4	4%
Tel-Tek	3	3%
Other units	8	
Total number of collaborative publications with units in the Norwegian public research system	61	67%
Total number of publications	91	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. The results show that 30 per cent of the SINTEF Petroleum Research articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is below the average of the TI institutes, which is 48 per cent. Table A.1.60 shows which countries SINTEF Petroleum Research has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA, and 8 per cent of the articles have co-authors from this nation.

Table A1.60 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. SINTEF Petroleum Research.

Country	No. of collaborative publications	Proportion of total
USA	3	8%
France	2	5%
Denmark	2	5%
Other countries	10	
Total number of publications with co-authors from other countries	12	30%
Total number of publications	40	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.13 SINTEF Building and Infrastructure

Figure A1.13 Most frequently appearing words in the publication titles, 2009-2013. SINTEF Building and Infrastructure.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, SINTEF Building and Infrastructure is the eight largest of the institutes included in the evaluation. The institute has contributed 5 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 37 to 45 during the 2009-2013 period, with no distinct trend (cf. Table 3.1). Figures on the publication productivity of the individual institutes within the SINTEF Foundation are not available.

Overall, the institute has published more than 330 scientific publications during the period 2009-2013. On average, 20 per cent of the 2011-2013 publications appeared in level 2 channels. This is almost identical to the average of the TI institutes.

Figure A1.13 above shows the most frequent words appearing in the publication titles of SINTEF Building and Infrastructure. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.61 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the level 2 journal *Energy and Buildings,* with 17 articles, followed by Norwegian journal *Vann* (15 articles).

Table A1.61 The most frequently used journals/series*, number of publications 2009–2013. SINTEF Building and Infrastructure.

Journal/series	No. of articles	Level (1/2)
Energy and Buildings	17	2
Vann	15	1
Nordic Concrete Research	13	1
Journal of Building Physics	10	2
Cement and Concrete Research	9	1
Tunnelling and Underground Space Technology	5	1
Solar Energy Materials and Solar Cells	5	2
Arkitektur N. The Norwegian Review of Architecture	5	1
Advances in Applied Ceramics: Structural, Functional and Bioceramics	3	1
Progress in organic coatings	3	1
RILEM Bookseries	3	1
Building and Environment	3	1
Rock Mechanics and Rock Engineering	3	2
Bulletin of Engineering Geology and the Environment	3	2
Journal of the European Ceramic Society	3	2
Wood Material Science & Engineering	3	1
The Journal of Physical Chemistry C	3	1
Advances in Materials Science and Engineering	3	1
Advances in Cement Research	3	2

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

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

In order to provide further insights into the characteristics of the publication profile of SINTEF Building and Infrastructure, we have classified the articles by subfield (cf. Table A1.62). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Construction & building technology accounts for the highest number of the articles (58 articles). The citation rate varies significantly across the different subfields. In several of the subfields shown, the citation index is extremely high. For example, the articles classified as Construction & building technology have obtained a relative citation index of 325. In other words, the articles have been cited 225 per cent more than the field-normalised world average.

Table A1.62 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. SINTEF Building and Infrastructure.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
CONSTRUCTION & BUILDING TECHNOLOGY	58	325
ENGINEERING, CIVIL	35	342
MATERIALS SCIENCE, MULTIDISCIPLINARY	31	196
ENERGY & FUELS	27	288
ENGINEERING, ENVIRONMENTAL	13	53
ENVIRONMENTAL SCIENCES	12	41
PHYSICS, APPLIED	6	–
CHEMISTRY, ANALYTICAL	6	–
GEOSCIENCES, MULTIDISCIPLINARY	5	–
NANOSCIENCE & NANOTECHNOLOGY	5	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.63 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 90 articles have been published which amounts to 37 per cent of the total scientific production of SINTEF Building and Infrastructure during the period. Thus, there is a significant number of publications not included in this analysis. The articles which are indexed have, however, been very highly cited, both when using a field and journal based normalisation method (citation index, 192 and 160, respectively). This is the highest overall citation rate of all the TI institutes (cf. Figure 3.9). Thus, the impact of the research carried out at SINTEF Building and Infrastructure has been very high when measured by number of citations. The lower figure of the journal based indicator, implies that the articles have been published in journals with a higher than average citation rate (impact-factor).

Table A1.63 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Building and Infrastructure.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
90	37%	805	108	8.9	160	192

Source: Data: NIFU's Key figure database, CRIStin, 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. [21]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

[21] Refers to the article: Baetens, R; Jelle, BP; Gustavsen, A (2010). 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. 94, 87-105. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

The analysis of the national research collaboration covering the period 2011-2013, shows that 71 per cent of the publications of SINTEF Building and Infrastructure have co-authors from other Norwegian institutions and institutes (cf. Table A1.64). The Norwegian University of Science and Technology (NTNU) is by far the most frequent collaborative partner with 137 joint publications (65 % of the total). It should be noted, however, that people with dual affiliations (e.g. SINTEF Building and Infrastructure and NTNU) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 19 of 84 articles (23 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.). Here we find companies such as Norcem and Weber Leca.

Table A1.64 Publications with co-authors from Norwegian higher education institutions and other research institutes.* Number and proportion of total production, 2011-2013. SINTEF Building and Infrastructure.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	137	65%
Nofima	4	2%
SINTEF Petroleum Research	3	1%
Other units	16	
Total number of collaborative publications with units in the Norwegian public research system	150	71%
Total number of publications	212	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

*) Publications co-authored with researchers at other institutes within the SINTEF-foundation are not included in this analysis.

The analysis also encompasses co-authorship with foreign institutions. The results show that 29 per cent of the SINTEF Building and Infrastructure articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is below the average of the TI institutes, which is 48 per cent. Table A.1.65 shows which countries SINTEF Building and Infrastructure has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the USA and Belgium, and 6 per cent of the articles have co-authors from each of these nations.

Table A1.65 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. SINTEF Building and Infrastructure.

Country	No. of collaborative publications	Proportion of total
USA	5	6%
Belgium	5	6%
Germany	4	5%
Italy	4	5%
Switzerland	4	5%
Other countries	21	
Total number of publications with co-authors from other countries	24	29%
Total number of publications	84	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.14 SINTEF ICT

Figure A1.14 Most frequently appearing words in the publication titles, 2009-2013. SINTEF ICT.
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, SINTEF ICT is the third largest of the institutes included in the evaluation. The institute has contributed 13 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 96 to 135 during the 2009-2013 period (cf. Table 3.1). Figures on the publication productivity of the individual institutes within the SINTEF Foundation are not available.

Overall, the institute has published more than 850 scientific publications during the period 2009-2013. On average, 14 per cent of the 2011-2013 publications appeared in level 2 channels, which is below the average of the TI institutes (22 %). Thus, relatively few of the institute's publications appear in these most prestigious publication channels.

Figure A1.14 above shows the most frequent words appearing in the publication titles of SINTEF ICT. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.66 contains a list of the most frequently used journals and series – limited to series with at least four publications during the period 2009–2013. On the top of the list, we find *Lecture Notes in Computer Science,* with 94 articles.

Table A1.66. **The most frequently used journals/series*, number of publications 2009–2013. SINTEF ICT.**

Journal/series	No. of articles	Level (1/2)
Lecture Notes in Computer Science	94	1
CEUR Workshop Proceedings	15	1
Proceedings of SPIE, the International Society for Optical Engineering	12	1
Lecture Notes in Business Information Processing	12	1
Journal of Micromechanics and Microengineering	11	1
Information and Software Technology	9	2
Studies in Health Technology and Informatics	9	1
Journal of Systems and Software	7	2
Nuclear Instruments and Methods in Physics Research Section A : Accelerators, Spectrometers, Detectors and Associated Equipment	7	1
IEEE International Conference on Intelligent Robots and Systems. Proceedings	7	1
Proceedings / IEEE International Conference on Robotics and Automation	6	1
Optics Express	6	2
Elsevier IFAC Publications / IFAC Proceedings series	6	1
Energy Procedia	6	1
SPE Journal	6	2
Lecture Notes in Informatics	6	1
Communications in Computer and Information Science	5	1
IFIP Advances in Information and Communication Technology	5	1
International Symposium on Empirical Software Engineering and Measurement	5	1
Software & Systems Modeling	5	2
IEEE Software	5	2
Computer	4	2
Chemical Engineering and Processing	4	1
IEEE Transactions on Nuclear Science	4	1
IEEE Engineering in Medicine and Biology Society. Conference Proceedings	4	1
Design, Automation and Test in Europe	4	1
Computational Geosciences	4	1
Industrial & Engineering Chemistry Research	4	2
International Journal of Secure Software Engineering	4	1

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

*) Limited to journals/series with at least four publications during the time period.

In order to provide further insights into the characteristics of the publication profile of SINTEF ICT, we have classified the articles by subfield (cf. Table A1.67). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Computer science, software engineering accounts for the highest number of the articles (46 articles). The citation rate varies significantly across the different subfields. The publications classified as Computer science, interdisciplinary applications have obtained the highest relative citation index with 228. In other words, the articles have been cited 128 per cent more than the field-normalised world average. In two of the subfields (Nanoscience & nanotechnology and Materials science, multidisciplinary), the citation rate of the publications is significantly below this average.

Table A1.67 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. SINTEF ICT.

Subfield*	No. of articles (2009-13)	Citation index –field** (2009-12)
COMPUTER SCIENCE, SOFTWARE ENGINEERING	46	142
ENGINEERING, ELECTRICAL & ELECTRONIC	33	106
INSTRUMENTS & INSTRUMENTATION	27	148
MATERIALS SCIENCE, MULTIDISCIPLINARY	21	42
ENGINEERING, CHEMICAL	16	89
COMPUTER SCIENCE, INFORMATION SYSTEMS	16	108
MECHANICS	15	155
NANOSCIENCE & NANOTECHNOLOGY	14	24
COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS	14	228
ENERGY & FUELS	12	–
COMPUTER SCIENCE, THEORY & METHODS	12	–
NUCLEAR SCIENCE & TECHNOLOGY	11	–
ACOUSTICS	10	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.68 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 163 articles have been published which amounts to 25 per cent of the total scientific production of SINTEF ICT during the period. Thus, there is a significant number of publications not included in this analysis. This reduces the reliability of the citation indicators. The articles which are indexed have, however, been cited above the average of the TI institutes (cf. Figure 3.9). The institute obtains a field-normalised citation index of 130, and a journal-normalised index of 141.

Table A1.68. Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF ICT.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
163	25%	800	47	4.9	141	130

Source: Data: NIFU's Key figure database, CRIStin, 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. [22]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

[22] Refers to the article: Bazilevs, Y; Hsu, MC; Zhang, Y; Wang, W; Liang, X; Kvamsdal, T; Brekken, R; Isaksen, JG (2010). A fully-coupled fluid-structure interaction simulation of cerebral aneurysms. COMPUTATIONAL MECHANICS. 46, 3-16. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

The analysis of the national research collaboration covering the period 2011-2013, shows that 55 per cent of the publications of SINTEF ICT have co-authors from other Norwegian institutions and institutes (cf. Table A1.69). The Norwegian University of Science and Technology (NTNU) is the most frequent collaborative partner with 135 joint publications (25 % of the total), followed by the University of Oslo with 90 articles (17 %). It should be noted, however, that people with dual affiliations (e.g. SINTEF ICT and NTNU) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 6 of 138 articles (4 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.).

Table A1.69 Publications with co-authors from Norwegian higher education institutions and other research institutes.* Number and proportion of total production, 2011-2013. SINTEF ICT.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	135	25%
University of Oslo	90	17%
Vestfold University College	22	4%
University of Bergen	11	2%
Uni Research	7	1%
MARINTEK	6	1%
IFE	4	1%
UNIK - University Graduate Centre	4	1%
SINTEF Fisheries and Aquaculture	3	1%
NR	3	1%
University of Stavanger	3	1%
Other units	22	
Total number of collaborative publications with units in the Norwegian public research system	294	55%
Total number of publications	537	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

*) Publications co-authored with researchers at other institutes within the SINTEF-foundation are not included in this analysis.

The analysis also encompasses co-authorship with foreign institutions. The results show that 44 per cent of the SINTEF ICT articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is slightly below the average of the TI institutes, which is 48 per cent. Table A.1.70 shows which countries SINTEF ICT has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the UK and the USA, and 16 and 15 per cent, respectively of the articles have co-authors from each of these nations.

Table A1.70 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. SINTEF ICT.

Country	No. of collaborative publications	Proportion of total
UK	22	16%
USA	21	15%
Spain	14	10%
Germany	13	9%
Italy	13	9%
France	11	8%
Switzerland	8	6%
Sweden	6	4%
Finland	6	4%
Romania	5	4%
Other countries	38	
Total number of publications with co-authors from other countries	61	44%
Total number of publications	140	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.15 SINTEF Materials and Chemistry

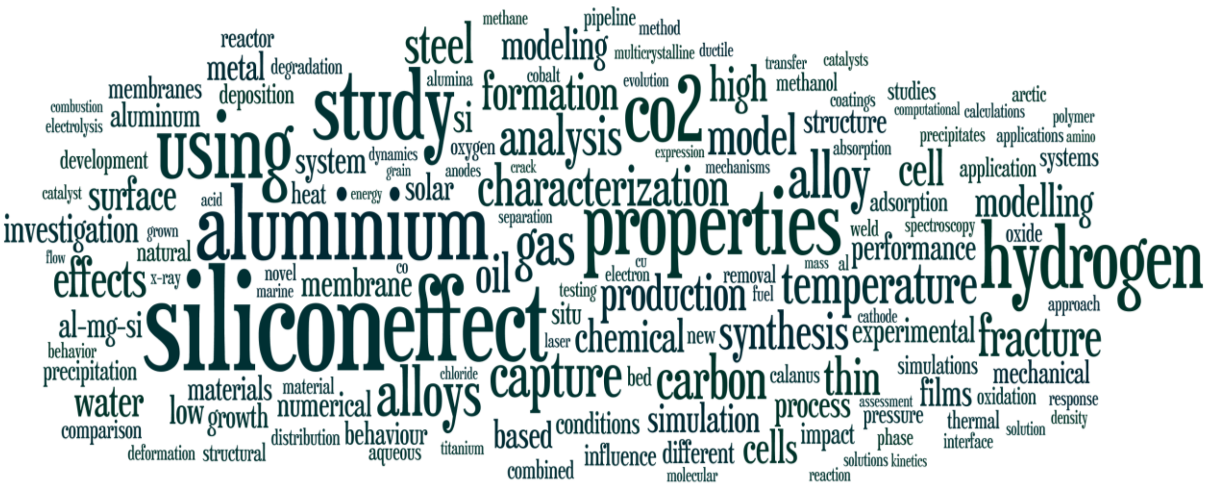


Figure A1.15 Most frequently appearing words in the publication titles, 2009-2013. SINTEF Materials and Chemistry.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, SINTEF Materials and Chemistry is the largest of the institutes included in the evaluation. The institute has contributed 18 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 91 to 163 during the 2009-2013 period (cf. Table 3.1). There is an increasing trend and the highest numbers have been obtain in the three most recent years. Figures on the publication productivity of the individual institutes within the SINTEF Foundation are not available.

Overall, the institute has published 950 scientific publications during the period 2009-2013. On average, 30 per cent of the 2011-2013 publications appeared in level 2 channels. This is among the highest ratios of the units included in the evaluation. Thus, the institute has a significant number of publications in the most prestigious publication channels.

Figure A1.15 above shows the most frequent words appearing in the publication titles of SINTEF Materials and Chemistry. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.71 contains a list of the most frequently used journals and series – limited to series with at least six publications during the period 2009–2013. On the top of the list, we find *Energy Procedia,* with 55 articles.

Table A1.71 The most frequently used journals/series*, number of publications 2009–2013. SINTEF Materials and Chemistry.

Journal/series	No. of articles	Level (1/2)
Energy Procedia	55	1
ISOPE - International Offshore and Polar Engineering Conference. Proceedings	33	1
Light Metals	31	1
Journal of Crystal Growth	21	1
Journal of Applied Physics	18	2
ECS Transactions	17	1
International journal of hydrogen energy	15	2
Industrial & Engineering Chemistry Research	15	2
Journal of the Electrochemical Society	15	2
Microporous and Mesoporous Materials	14	2
The Journal of Physical Chemistry C	14	1
Applied and Environmental Microbiology	13	2
Materials Science Forum	13	1
International Journal of Greenhouse Gas Control	12	2
Metallurgical and Materials Transactions. A	12	2
Materials Science & Engineering: A	11	2
Catalysis Today	11	2
Metallurgical and materials transactions. B, process metallurgy and materials processing science	11	2
Chemical Engineering Science	10	2
Powder Technology	9	1
Journal of Catalysis	8	2
Materials & Design	8	1
Philosophical Magazine	8	1
Journal of Membrane Science	8	2
Physical Review B. Condensed Matter and Materials Physics	7	2
Surface and Interface Analysis	7	1
Computational materials science	7	1
Physica status solidi. A, Applied research	7	1
JOM: The Member Journal of TMS	7	1
Journal of Alloys and Compounds	7	1
Acta Materialia	7	2
Marine Pollution Bulletin	7	1
ISIJ International	6	1
Scripta Materialia	6	2
International Conference on Offshore Mechanics and Arctic Engineering [proceedings]	6	1
Corrosion	6	2
Engineering Fracture Mechanics	6	2
Topics in catalysis	6	1

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

*) Limited to journals/series with at least six publications during the time period.

In order to provide further insights into the characteristics of the publication profile of SINTEF Materials and Chemistry, we have classified the articles by subfield (cf. Table A1.72). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Materials science, multidisciplinary accounts for the highest number of the articles (195 articles), followed by Physical chemistry (126 articles). The citation rate varies significantly across the different subfields. Of the largest subfields in terms of number of articles, the highest citation indices are obtained in Metallurgy & metallurgical engineering and Chemical engineering. Here the articles are cited 38 and 34 per cent, respectively, more than the field-normalised world average. In several of the subfields, the citation rate is below the world average.

Table A1.72 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. SINTEF Materials and Chemistry.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
MATERIALS SCIENCE, MULTIDISCIPLINARY	195	76
CHEMISTRY, PHYSICAL	126	75
METALLURGY & METALLURGICAL ENGINEERING	99	138
ENGINEERING, CHEMICAL	92	134
PHYSICS, APPLIED	75	67
NANOSCIENCE & NANOTECHNOLOGY	50	65
ENERGY & FUELS	43	69
MECHANICS	38	87
PHYSICS, CONDENSED MATTER	38	56
ELECTROCHEMISTRY	37	62
CHEMISTRY, APPLIED	32	134
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	31	120
ENVIRONMENTAL SCIENCES	29	103
POLYMER SCIENCE	28	91
MATERIALS SCIENCE, COATINGS & FILMS	27	75
MICROBIOLOGY	26	94
CRYSTALLOGRAPHY	24	155
CHEMISTRY, MULTIDISCIPLINARY	20	100
PHYSICS, ATOMIC, MOLECULAR & CHEMICAL	19	196
ENGINEERING, ENVIRONMENTAL	18	92
ENGINEERING, MECHANICAL	14	86
TOXICOLOGY	13	–
MARINE & FRESHWATER BIOLOGY	11	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.73 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 491 articles have been published which amounts to 71 per cent of the total scientific production of SINTEF Materials and Chemistry, during the period. Thus, the large majority of the publications have been published in indexed journals. The articles have been cited on par with the world average both when using a field and journal based normalisation method (citation index, 97 and 98, respectively). This is below the average of the TI institutes (cf. Figure 3.9).

Table A1.73 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Materials and Chemistry.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
491	71%	3262	158	6.6	98	97

Source: Data: NIFU's Key figure database, CRIStin, 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. [23]

1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that 77 per cent of the publications of SINTEF Materials and Chemistry have co-authors from other Norwegian institutions and institutes (cf. Table A1.74). The Norwegian University of Science and Technology (NTNU) is by far the most frequent collaborative partner with 338 joint publications (58 % of the total), followed by the University of Oslo with 91 articles (13 %). It should be noted, however, that people with dual affiliations (e.g. SINTEF Materials and Chemistry and NTNU) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 57 of 488 articles (12 %) indexed in NCR have been co-authored with industry (cf. Table 3.4.). Here we find companies such as Statoil, Hydro, and many others.

[23] Refers to the article: Dietzel, PDC; Besikiotis, V; Blom, R (2009). Application of metal-organic frameworks with coordinatively unsaturated metal sites in storage and separation of methane and carbon dioxide. JOURNAL OF MATERIALS CHEMISTRY. 19, 7362-7370. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Table A1.74 Publications with co-authors from Norwegian higher education institutions and other research institutes.* Number and proportion of total production, 2011-2013. SINTEF Materials and Chemistry.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	398	58%
University of Oslo	91	13%
IFE	21	3%
SINTEF Energy Research	13	2%
Vestfold University College	11	2%
University of Stavanger	7	1%
University of Bergen	7	1%
SINTEF Fisheries and Aquaculture	6	1%
Telemark University College	5	1%
IRIS	5	1%
Norwegian Institute for Water Research	4	1%
Institute of Marine Research	4	1%
SINTEF Petroleum Research	4	1%
National Institute of Nutrition and Seafood Research	3	0%
Norwegian University of Life Sciences	3	0%
Other units	18	
Total number of collaborative publications with units in the Norwegian public research system	528	77%
Total number of publications	689	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

*) Publications co-authored with researchers at other institutes within the SINTEF-foundation are not included in this analysis.

The analysis also encompasses co-authorship with foreign institutions. The results show that 41 per cent of the SINTEF Materials and Chemistry articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is below the average of the TI institutes, which is 48 per cent. Table A.1.75 shows which countries SINTEF Materials and Chemistry has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find Germany and France, and 8 and 6 per cent, respectively of the articles have co-authors from each of these countries.

Table A1.75 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. SINTEF Materials and Chemistry.

Country	No. of collaborative publications	Proportion of total
Germany	37	8%
France	29	6%
UK	25	5%
USA	22	4%
Netherlands	19	4%
Sweden	16	3%
Denmark	16	3%
Peoples R China	16	3%
Italy	15	3%
Australia	14	3%
Japan	13	3%
Spain	10	2%
Portugal	6	1%
Other countries	39	
Total number of publications with co-authors from other countries	200	41%
Total number of publications	491	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.16 SINTEF Technology and Society

Figure A1.16 Most frequently appearing words in the publication titles, 2009-2013. SINTEF Technology and Society NT.

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

This chapter provides an overview of the research at SINTEF Technology and Society published by the departments included in the evaluation (e.g. excluding the social science part of the institute). In terms of scientific publishing, SINTEF Technology and Society is the seventh largest of the institutes included in the evaluation. The institute has contributed 5 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been in the range of 27 to 39 during the period 2009-2013 (cf. Table 3.1), however, with 2012 as an outlier with 62 publication points. Figures on the publication productivity of the individual institutes within the SINTEF Foundation are not available.

Overall, the institute has published 300 scientific publications during the period 2009-2013. On average, 10 per cent of the 2011-2013 publications appeared in level 2 channels. This is the lowest ratio of all the units included in the evaluation. Thus, the institute has relatively few publications in the most prestigious publication channels.

Figure A1.16 above shows the most frequent words appearing in the publication titles of SINTEF Technology and Society. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.76 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the series *IFIP Advances in Information and Communication Technology* with 16 articles, followed by *NTNU Engineering Series* (13 articles).

Table A1.76 The most frequently used journals/series*, number of publications 2009–2013. SINTEF Technology and Society NT.

Journal/series	No. of articles	Level (1/2)
IFIP Advances in Information and Communication Technology	16	1
NTNU Engineering Series	13	1
Lecture Notes in Computer Science	7	1
IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control	6	1
Proceedings : European Transport Conference	6	1
MITAT. Minimally invasive therapy & allied technologies	6	1
Energy Procedia	5	1
Safety Science	4	2
International Journal of Computer Assisted Radiology and Surgery	4	1
Surgical Endoscopy	4	2
Reliability Engineering & System Safety	4	2
Neurosurgery	3	2
Springer Series in Reliability Engineering	3	1
European Journal of Operational Research	3	2
Journal of Acoustical Society of America	3	2
Transport Policy	3	1
Chemical Engineering Transactions	3	1
Ultrasound in Medicine and Biology	3	1
Accident Analysis and Prevention	3	1

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

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

In order to provide further insights into the characteristics of the publication profile of SINTEF Technology and Society, we have classified the articles by subfield (cf. Table A1.77). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Surgery accounts for the highest number of the articles (25 articles), followed by Acoustics and Operations research & management science (14 articles). The citation rate varies across the different subfields. The publications classified as Operations research & management have been most frequently cited and have obtained a relative citation index of 160. In other words, the articles have been cited 60 per cent more than the field-normalised world average. In two of the fields shown, the citation rate of the publications is below the world average.

Table A1.77 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. SINTEF Technology and Society NT.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
SURGERY	25	83
ACOUSTICS	14	122
OPERATIONS RESEARCH & MANAGEMENT SCIENCE	14	160
RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING	11	67
ENGINEERING, INDUSTRIAL	9	–
PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH	9	–
ENGINEERING, ELECTRICAL & ELECTRONIC	7	–
TRANSPORTATION	7	–
ENERGY & FUELS	6	–
ENGINEERING, BIOMEDICAL	6	–
ERGONOMICS	6	–
CLINICAL NEUROLOGY	6	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.78 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 86 articles have been published which amounts to 41 per cent of the total scientific production of SINTEF Technology and Society during the period. Thus, there is a significant number of publications not included in this analysis. The articles have been cited on par with the world average using a field based normalisation method (citation index 98). This is below the average of the TI institutes, which is 120 (cf. Figure 3.9).

Table A1.78 Citation indicators, 2009–2012 publications indexed in NCR.* SINTEF Technology and Society NT.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
86	41%	426	47	5.0	114	98

Source: Data: NIFU's Key figure database, CRIStin, 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. [24]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

[24] Refers to the article: Bazilevs, Y; Hsu, MC; Zhang, Y; Wang, W; Liang, X; Kvamsdal, T; Brekken, R; Isaksen, JG (2010). A fully-coupled fluid-structure interaction simulation of cerebral aneurysms. COMPUTATIONAL MECHANICS. 46, 3-16. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

The analysis of the national research collaboration covering the period 2011-2013, shows that 67 per cent of the publications of SINTEF Technology and Society have co-authors from other Norwegian institutions and institutes (cf. Table A1.79). The Norwegian University of Science and Technology (NTNU) is far the most frequent collaborative partner with 119 joint publications (59 % of the total), followed by St. Olav's Hospital with 23 articles (12 %). It should be noted, however, that people with dual affiliations (e.g. SINTEF Technology and Society and NTNU) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 5 of 65 articles (8 %) indexed in NCR have been co-authored with industry (cf. Table 3.4).

Table A1.79 Publications with co-authors from Norwegian higher education institutions and other research institutes.* Number and proportion of total production, 2011-2013. SINTEF Technology and Society NT.

Institution/institute	No. of collaborative publications	Proportion of total
Norwegian University of Science and Technology	119	59%
St Olav's Hospital	23	11%
NTNU Social Research	6	3%
University of Oslo	5	2%
Other units	21	
Total number of collaborative publications with units in the Norwegian public research system	135	67%
Total number of publications	202	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

*) Publications co-authored with researchers at other institutes within the SINTEF-foundation are not included in this analysis.

The analysis also encompasses co-authorship with foreign institutions. The results show that 25 per cent of the SINTEF Technology and Society articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is significantly below the average of the TI institutes, which is 48 per cent. Thus, compared to the other institutes, SINTEF Technology and Society apparently is less involved in international research collaboration, as far as this is reflected trough co-authorship. Table A.1.80 shows which countries SINTEF Technology and Society has collaborated most frequently with, using co-authorship as a measure. On the top of the list, we find the UK, and 7 per cent of the articles have co-authors from this nation.

Table A1.80 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. SINTEF Technology and Society NT.

Country	No. of collaborative publications	Proportion of total
UK	5	7%
Germany	3	4%
Finland	3	4%
Other countries	18	
Total number of publications with co-authors from other countries	17	25%
Total number of publications	68	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.17 Tel-Tek

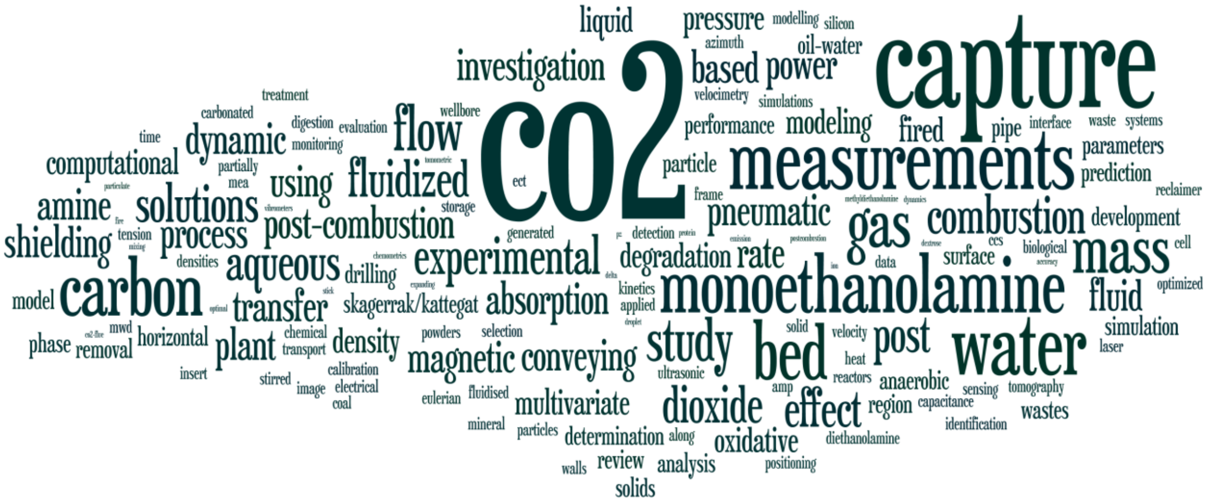


Figure A1.17 Most frequently appearing words in the publication titles, 2009-2013. Tel-Tek.
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

In terms of scientific publishing, Tel-Tek is one of the smallest institutes included and accounts for 1 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points shows large annual variations and have varied from 5 (2010) to 14 (2013) (cf. Table 3.1). The institute has an average of 0.38 publication points per FTE researchers during the 3-year period 2011-2013 (cf. Figure 3.2). This is close to the average of the TI institutes, which is 0.44.

Overall, the institute has published 84 scientific publications during the period 2009-2013. On average, 17 per cent of these publications appeared in level 2 channels, which is somewhat below the average of the TI institutes (22 per cent)

Figure A1.17 above shows the most frequent words appearing in the publication titles of Tel-Tek. The figure illustrates some of the topics addressed in the research activities at Tel-Tek. Table A1.81 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the journal *Energy Procedia* with 24 articles.

Table A1.81 The most frequently used journals/series*, number of publications 2009–2013. Tel-Tek.

Journal/series	No. of articles	Level (1/2)
Energy Procedia	24	1
Journal of Chemical and Engineering Data	6	1
Powder Technology	5	1
Particulate Science and Technology	5	1
Industrial & Engineering Chemistry Research	4	2
European Journal of Scientific Research	3	1
The International Journal of Energy and Environment	3	1

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

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

In Table A1.82 we have classified the articles by subfields. This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Chemical Engineering accounts for the highest number of the articles (22 articles). These articles obtained a relative citation index of 75. In other words, the articles have been cited 25 per cent less than the field-normalised world average.

Table A1.82 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. Tel-Tek.

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
ENGINEERING, CHEMICAL	22	75
CHEMISTRY, MULTIDISCIPLINARY	6	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

*) Limited to subfields with at least 5 articles during the period 2009-2013.

**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

Table A1.83 shows various overall citation indicators based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 27 articles have been published which amounts to 54 per cent of the total scientific production of Tel-Tek during the period. Thus, there is a significant number of publications not included in this analysis. The articles have been cited below the world average using a field based normalisation method (citation index 71). This is also below the average of the TI institutes, which is 120 (cf. Figure 3.9).

Table A1.83 Citation indicators, 2009–2012 publications indexed in NCR.* Tel-Tek.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
27	54%	102	33	3.8	99	71

Source: Data: NIFU's Key figure database, CRIStin, 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. [25]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that almost all (92 %) of the publications of Tel-Tek have co-authors from other Norwegian institutions and institutes (cf. Table A1.84). The Telemark University College is by far the most frequent collaborative partner with 56 joint publications (85 % of the total). It should be noted, however, that people with dual affiliations (e.g. Tel-Tek and Telemark University College) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 2 of 25 articles (8 %) indexed in NCR have been co-authored with industry (cf. Table 3.4).

Table A1.84 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. Tel-Tek.

Institution/institute	No. of collaborative publications	Proportion of total
Telemark University College	56	85%
University of Oslo	3	5%
SINTEF Petroleum Research	3	5%
Other units	10	
Total number of collaborative publications with units in the Norwegian public research system	61	92%
Total number of publications	66	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. The results show that 12 per cent of the Tel-Tek articles indexed in NCR during the period 2011-2013 have co-authors from abroad. This is significantly below the average of the TI institutes, which is 48 per cent. Thus, compared to the other institutes, Tel-Tek apparently is less involved in international research collaboration, as far as this is reflected trough co-authorship. Table A.1.85 shows which countries Tel-Tek has collaborated most frequently with, using co-authorship as a measure.

[25] Refers to the article: Amundsen, TG; Oi, LE; Eimer, DA (2009). Density and Viscosity of Monoethanolamine plus Water plus Carbon Dioxide from (25 to 80) degrees C. JOURNAL OF CHEMICAL AND ENGINEERING DATA. 54, 3096-3100. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.

Table A1.85 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. Tel-Tek.

Country	No. of collaborative publications	Proportion of total
China	2	8%
Other countries	2	
Total number of publications with co-authors from other countries	3	12%
Total number of publications	25	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

A1.18 Uni Research AS

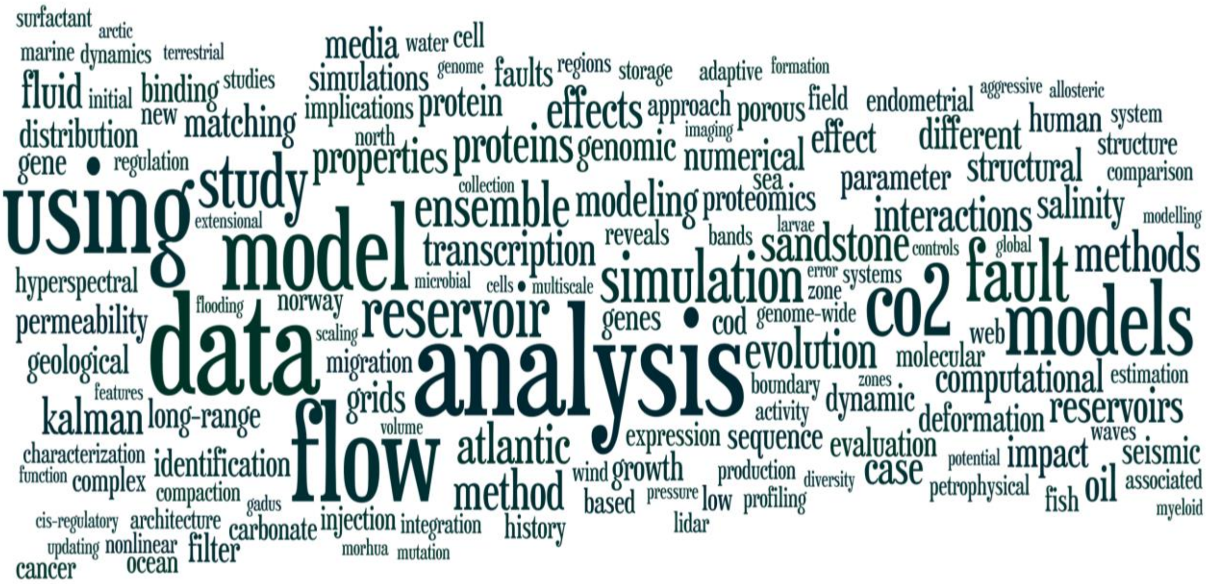


Figure A1.18 Most frequently appearing words in the publication titles, 2009-2013. Uni NT (total).
Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

This chapter provides an overview of the research at Uni Research published by the departments included in the evaluation (Uni CIPR and Uni Computing, termed "Uni NT"). The institute has recently been included among the TI institutes. Therefore, a complete set of publication indicators is not available for the institute (cf. Chapter 2).

In terms of scientific publishing, Uni NT is the fifth largest of the institutes included in the evaluation. The institute has contributed 6 per cent of the total publication output of the TI institutes during the period 2011-2013. The number of annual publication points has been rising from 46 in 2010 to 64 in 2013.

Overall, the institute has published approximately 350 scientific publications during the period 2009-2013. On average, 38 per cent of the 2011-2013 publications appeared in level 2 channels. This is the highest ratio of all the units included in the evaluation. Thus, the institute has many publications in the most prestigious publication channels.

Figure A1.18 above shows the most frequent words appearing in the publication titles of Uni NT. The figure illustrates some of the topics addressed in the research activities at the institute.

Table A1.86 contains a list of the most frequently used journals and series – limited to series with at least three publications during the period 2009–2013. On the top of the list, we find the journal *Computational Geosciences* with 17 articles, followed by *Plos ONE* (12 articles).

Table A1.86 The most frequently used journals/series*, number of publications 2009–2013. Uni NT (total).

Journal/series	No. of articles	Level (1/2)
Computational Geosciences	17	1
PLoS ONE	12	1
Journal of Structural Geology	9	2
Nucleic Acids Research	9	2
Ocean Dynamics	8	1
SPE Journal	8	2
Marine and Petroleum Geology	8	1
American Association of Petroleum Geologists Bulletin	7	2
International Journal of Numerical Analysis & Modeling	7	1
Bioinformatics	7	2
Journal of Petroleum Science and Engineering	6	2
Energy Procedia	6	1
Aquatic Toxicology	5	2
Proteomics	5	2
Computers & Geosciences	5	1
Journal of the Geological Society	5	1
Advances in Water Resources	5	1
BMC Bioinformatics	4	2
Marine Ecology Progress Series	4	2
Energy & Fuels	3	2
Monthly Weather Review	3	1
Journal of Computational Physics	3	1
Norsk Geologisk Tidsskrift	3	1
Journal of Biological Chemistry	3	2
International Journal of Greenhouse Gas Control	3	2
Photogrammetric Record	3	1
BMC Genomics	3	1
PloS Computational Biology	3	1
Proceedings of the National Academy of Science of the United States of America	3	2
Transport in Porous Media	3	2
Sedimentology	3	2
Studies in Corpus Linguistics	3	1
Proteins: Structure, Function, and Genetics	3	1
SPE Reservoir Engineering and Evaluation	3	1

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

In order to provide further insights into the characteristics of the publication profile of Uni NT we have classified the articles by subfield (cf. Table A1.87). This categorisation is based on journal categories and is limited to articles indexed in the Web of Science database NCR. In other words, the classification is based on the journal titles and not the actual topic of the research papers. The category Geosciences, multidisciplinary accounts for the highest number of the articles (62 articles), followed by Biochemistry & molecular biology (36 articles). The citation rate varies significantly across the different subfields. The few publications classified within Petroleum engineering have been extremely highly cited. These articles obtained a relative citation index of 717. In other words, the articles have been cited 617 per cent more than the field-normalised world average. In some of the subfields, the citation rate is below the world average.

Table A1.87 Number of journal articles indexed in NCR and relative citation index by subfield (journal categories) 2009-2013. Uni NT (total).

Subfield*	No. of articles (2009-13)	Citation index – field** (2009-12)
GEOSCIENCES, MULTIDISCIPLINARY	62	87
BIOCHEMISTRY & MOLECULAR BIOLOGY	36	195
BIOCHEMICAL RESEARCH METHODS	26	117
COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS	25	64
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	22	116
OCEANOGRAPHY	20	62
MULTIDISCIPLINARY SCIENCES	18	360
GENETICS & HEREDITY	17	131
ENERGY & FUELS	15	50
MARINE & FRESHWATER BIOLOGY	14	–
MATHEMATICAL & COMPUTATIONAL BIOLOGY	14	155
MATHEMATICS, APPLIED	14	142
ENGINEERING, PETROLEUM	13	717
GEOCHEMISTRY & GEOPHYSICS	11	–

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.
*) Limited to subfields with at least 5 articles during the period 2009-2013.
**) Based on the publications indexed in NCR from the period 2009–2012 and the accumulated citations to these publications through 2013. World average field = 100. Ref. Method section. Figures only shown for subfields with 10 or more articles during the period 2009-12.

As Uni CIPR and Uni Computing are rather heterogeneous in their research activities, we have calculated overall citation indicators for each of the departments. Table A1.88 shows various overall citation indicators for UNI CIPR based on the journal articles (indexed in NCR) published in the period 2009–2012. In total, 100 articles have been published which amounts to 82 per cent of the total scientific production of CIPR, during the period. Thus, the large majority of the publications have been published in indexed journals. The articles have been cited above the world average both when using a field and journal based normalisation method (citation index, 151 and 118, respectively). The lower figure of the journal based indicator, implies that the articles have been published in journals with a higher than average citation rate (impact-factor). Only one of the TI institutes has a higher citation rate than CIPR (cf. Figure 3.9).

Table A1.88 Citation indicators, 2009–2012 publications indexed in NCR.* Uni CIPR.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
100	82%	548	94	5.5	118	151

Source: Data: NIFU's Key figure database, CRIStin, 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. [26]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

Table A1.89 shows similar citation indicators for Uni Computing. Also this department obtains a high field normalised citation indicator (166) and only one of the TI institutes has higher citation rate (cf. Figure 3.9).

Table A1.89 Citation indicators, 2009–2012 publications indexed in NCR.* Uni Computing.

Number of articles indexed in NCR	Prop of production indexed in NCR	Tot number of citations	Max cited article	Avg number of citations per paper	Citation index – journal[1]	Citation index – field[2]
130	92%	1927	208	14.8	116	166

Source: Data: NIFU's Key figure database, CRIStin, 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. [27]
1) Journal average = 100. 2) World average field = 100. Ref. Method section.

The analysis of the national research collaboration covering the period 2011-2013, shows that 79 per cent of the publications of Uni NT have co-authors from other Norwegian institutions and institutes (cf. Table A1.90). The University of Bergen (UiB) is by far the most frequent collaborative partner with 165 joint publications (71 % of the total). It should be noted, however, that people with dual affiliations (e.g. Uni and UiB) may list both addresses on the publications. These articles will therefore be identified as involving national collaboration in the analysis. In addition to publications with Norwegian public institutions, 3 of 202 articles (1 %) indexed in NCR have been co-authored with industry (cf. Table 3.4).

[26] Refers to the article: Aanonsen, SI; Naevdal, G; Oliver, DS; Reynolds, AC; Valles, B (2009). The Ensemble Kalman Filter in Reservoir Engineering-a Review. SPE JOURNAL. 14, 393-412. It should be recalled that the citation counts of the articles are higher today, since the analysis only includes citations up to and including 2013 and only citations from articles in WoS Core Collection. Generally, articles from the first years of the period analyzed will dominate the list of most cited articles, as these have been available for a longer time in the literature to be cited.
[27] Refers to the article: Portales-Casamar, E; Thongjuea, S; Kwon, AT; Arenillas, D; Zhao, XB; Valen, E; Yusuf, D; Lenhard, B; Wasserman, WW; Sandelin, A (2010). JASPAR 2010: the greatly expanded open-access database of transcription factor binding profiles. NUCLEIC ACIDS RESEARCH. 38, D105-D110.

Table A1.90 Publications with co-authors from Norwegian higher education institutions and other research institutes. Number and proportion of total production, 2011-2013. Uni NT (total).

Institution/institute	No. of collaborative publications	Proportion of total
University of Bergen	165	71%
Haukeland University Hopsital	16	7%
University of Oslo	15	6%
IRIS	11	5%
University Centre in Svalbard	9	4%
Institute of Marine Research	8	3%
Oslo University Hospsital	7	3%
SINTEF Foundation	7	3%
Norwegian University of Science and Technology	6	3%
NGI	5	2%
NR	4	2%
University of Tromsø	4	2%
National Institute of Nutrition and Seafood Research	4	2%
Norwegian University of Life Sciences	3	1%
Other units	18	
Total number of collaborative publications with units in the Norwegian public research system	184	79%
Total number of publications	234	100%

Source: Data: NIFU's Key figure database, CRIStin. Calculations: NIFU.

The analysis also encompasses co-authorship with foreign institutions. The results show that 31 per cent of the CIPR articles indexed in NCR during the period 2011-2013 have co-authors from abroad. The corresponding figure for Computing is 69 per cent. Thus, CIPR is apparently less involved in international research collaboration, as far as this is reflected trough co-authorship. The average of the TI institutes is 48 per cent. Table A.1.91 and A.1.92 show which countries the departments have collaborated most frequently with, using co-authorship as a measure.

Table A1.91 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. Uni CIPR.

Country	No. of collaborative publications	Proportion of total
USA	11	14%
Germany	4	5%
France	4	5%
Other countries	13	
Total number of publications with co-authors from other countries	24	31%
Total number of publications	77	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

Table A1.92 Journal articles indexed in NCR with co-authors from other countries. Number and proportion of total production, 2011-2013. Uni Computing.

Country	No. of collaborative publications	Proportion of total
USA	26	20%
Germany	26	20%
UK	24	19%
Netherlands	18	14%
Austria	11	9%
France	10	8%
Spain	7	6%
Denmark	5	4%
Belgium	5	4%
Japan	5	4%
Other countries	40	
Total number of publications with co-authors from other countries	88	69%
Total number of publications	127	100%

Source: Data: NIFU's Key figure database, CRIStin, Thomson Reuters, National Citation Report (NCR). Calculations: NIFU.

Appendix 2 Norwegian engineering science in an international context

This chapter presents various bibliometric indicators on the performance of Norwegian research within engineering science.[28] The chapter is based on *all* publications within the field *Engineering science* not only the TI institutes. Moreover, 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.

A2.1 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 A2.1, 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). Industry accounts for 9 % of 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 partly due to the commercial interests related to the research results, which means that the results often cannot be published, i.e. made public.

[28] This chapter is basically a reprint of an analysis carried out as part of the ongoing evaluation of the engineering science in Norway (Aksnes, forthcoming). It is included as it contains some additional analyses that may be of interest in respect to the evaluation of the TI institutes.

Table A2.1 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.

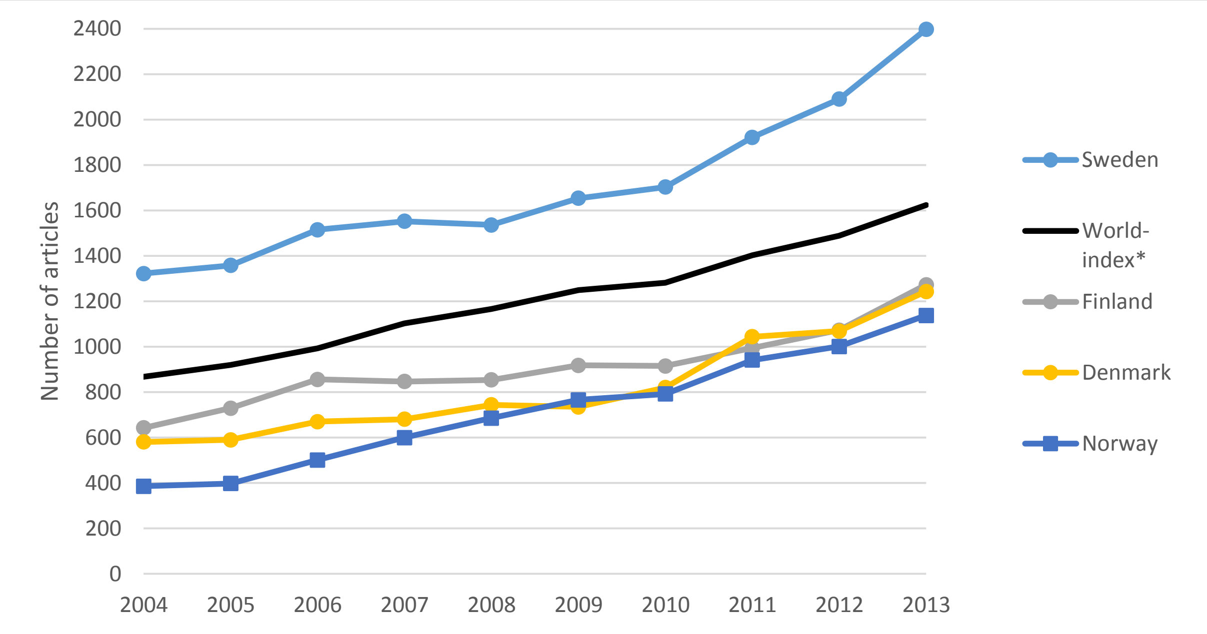
**) The SINTEF foundation consists of the following institutes: SINTEF Building and Infrastructure, SINTEF ICT, SINTEF Materials and Chemistry, SINTEF Technology and Society

In Figure A2.1 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).

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 A2.1 Scientific publishing in Engineering science 2004-2013 in four Nordic countries. Number of articles.

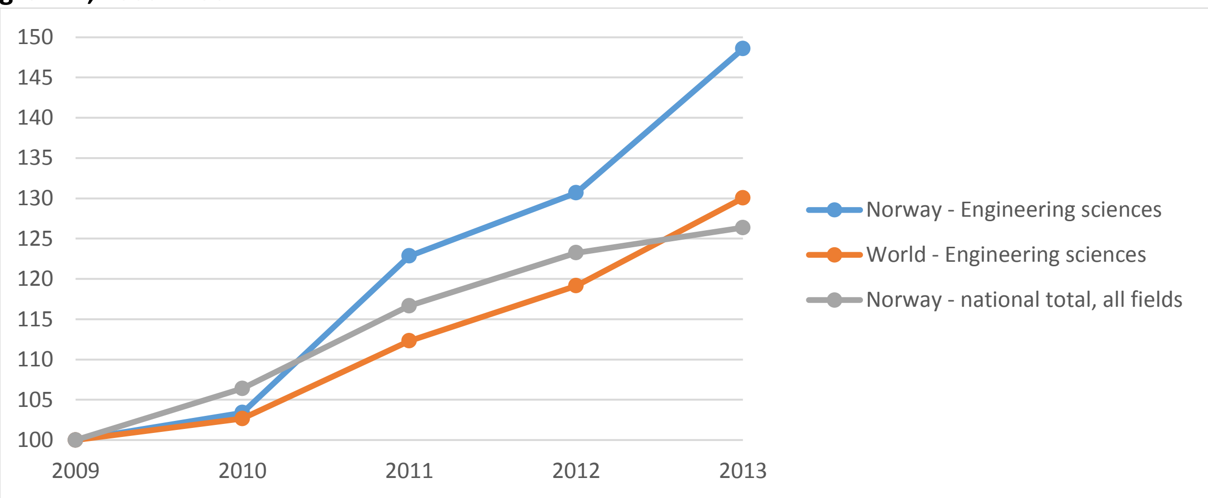


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

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

Figure A2.2 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 A2.2 Scientific publishing in Engineering science and Norwegian total 2009-2013. Relative growth, 2009 =100.

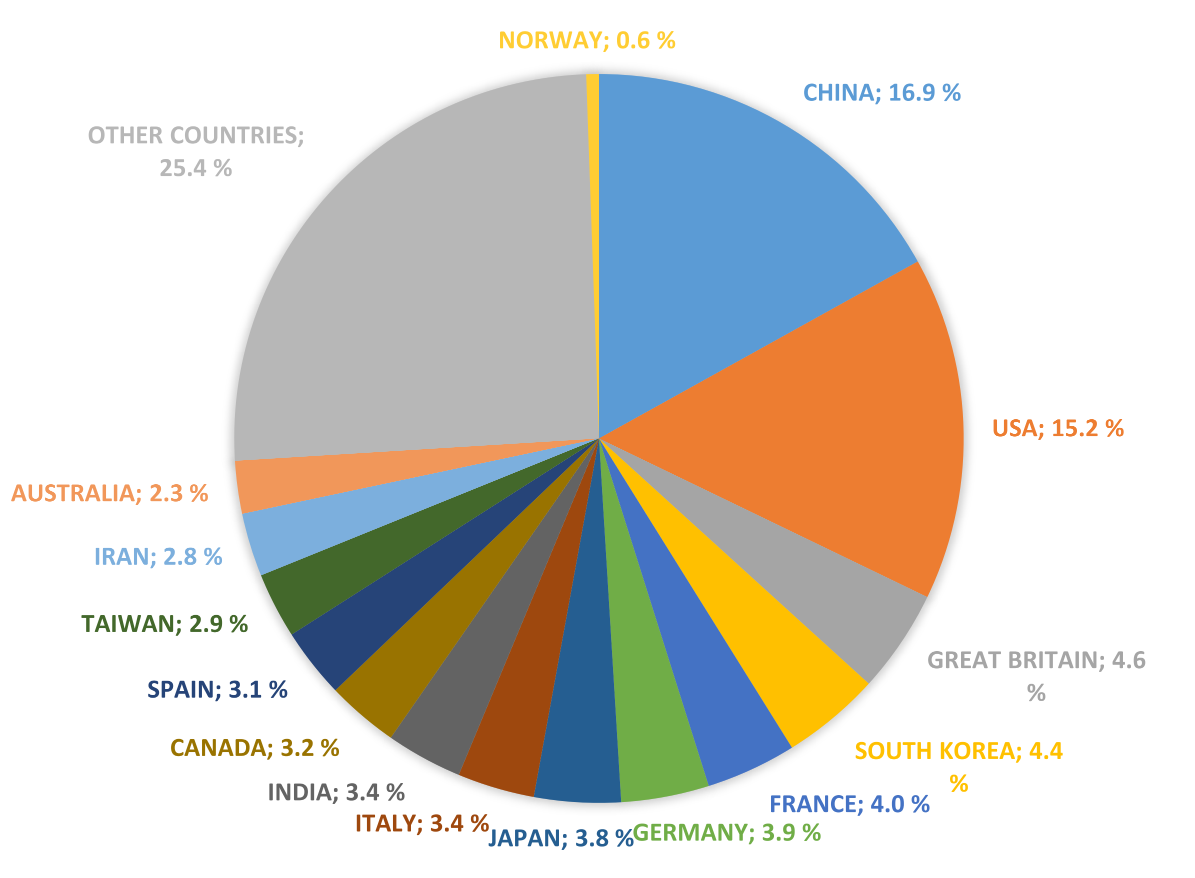


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

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 A2.3 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 A2.3 Scientific publishing in 2013 in selected countries, Proportion of world production in Engineering science.



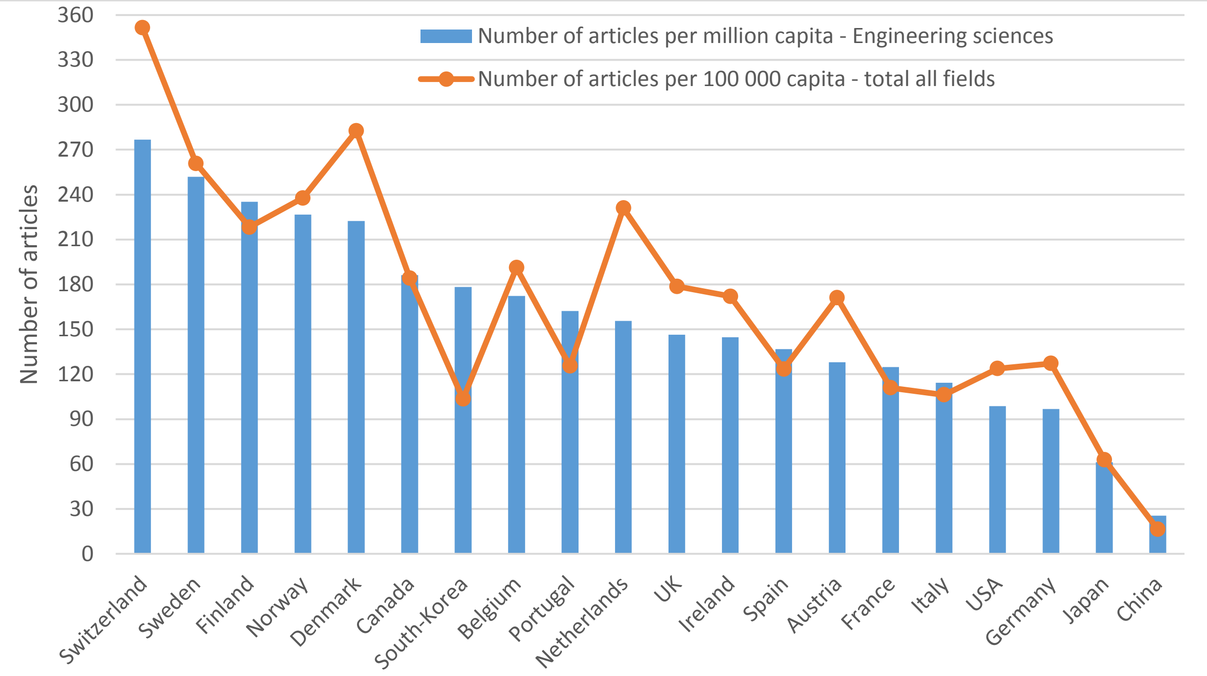
Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

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 A2.4 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 A2.4 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 A2.4 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

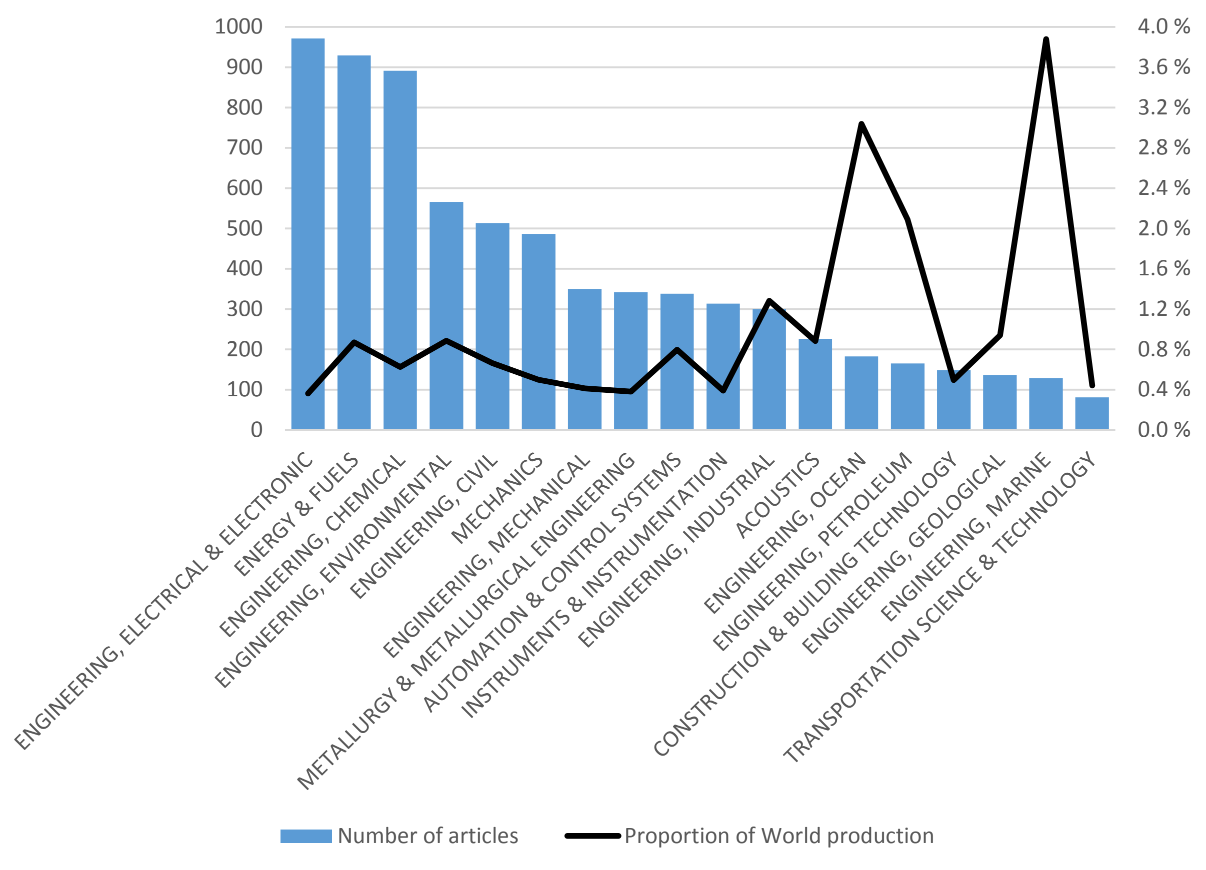
Metallurgy & Metallurgical Engineering: Includes journals that cover the numerous chemical and physical processes used to isolate a metallic element from its naturally occurring state, refine it, and convert it into a useful alloy or product. Topics in this category include corrosion prevention and control, 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 A2.5 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 A2.5 Scientific publishing in Engineering subfields, Norway, total number of articles for the period 2009–2013 and proportion of the World production.

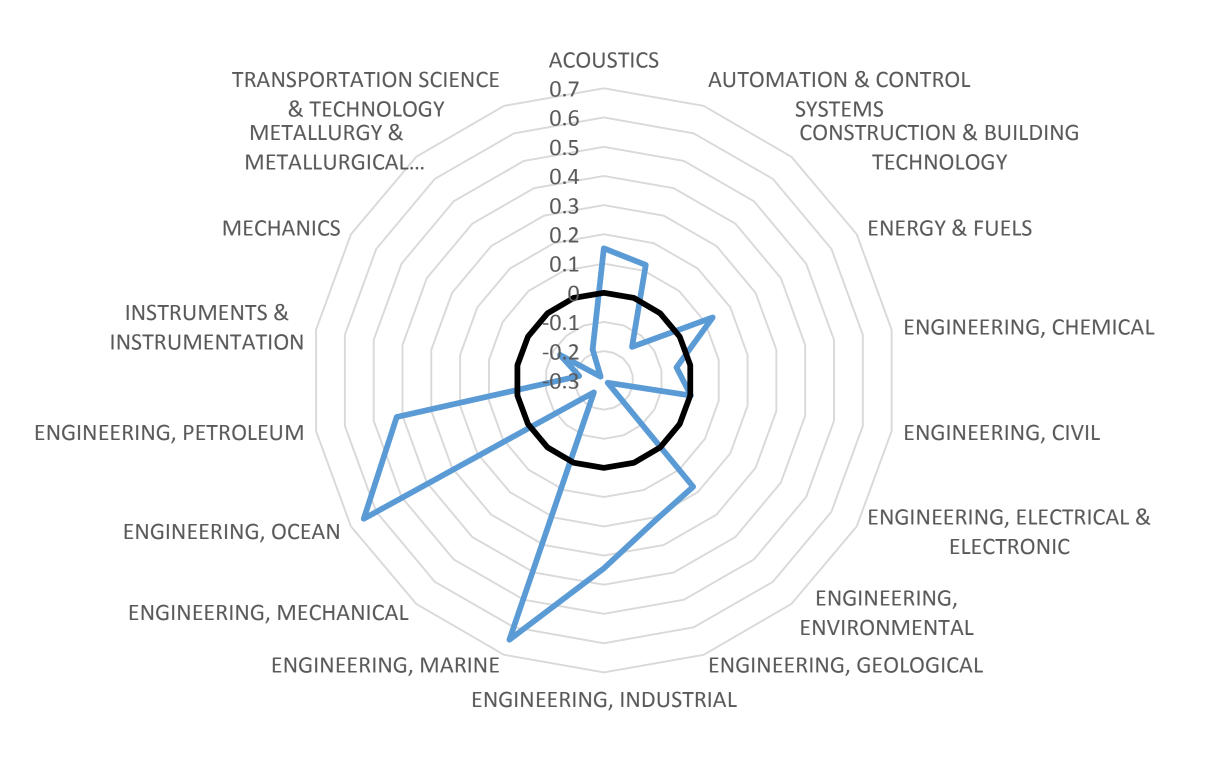


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

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 A2.6 we have shown the so-called "relative specialization index", RSI.[29] 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.

[29] 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.

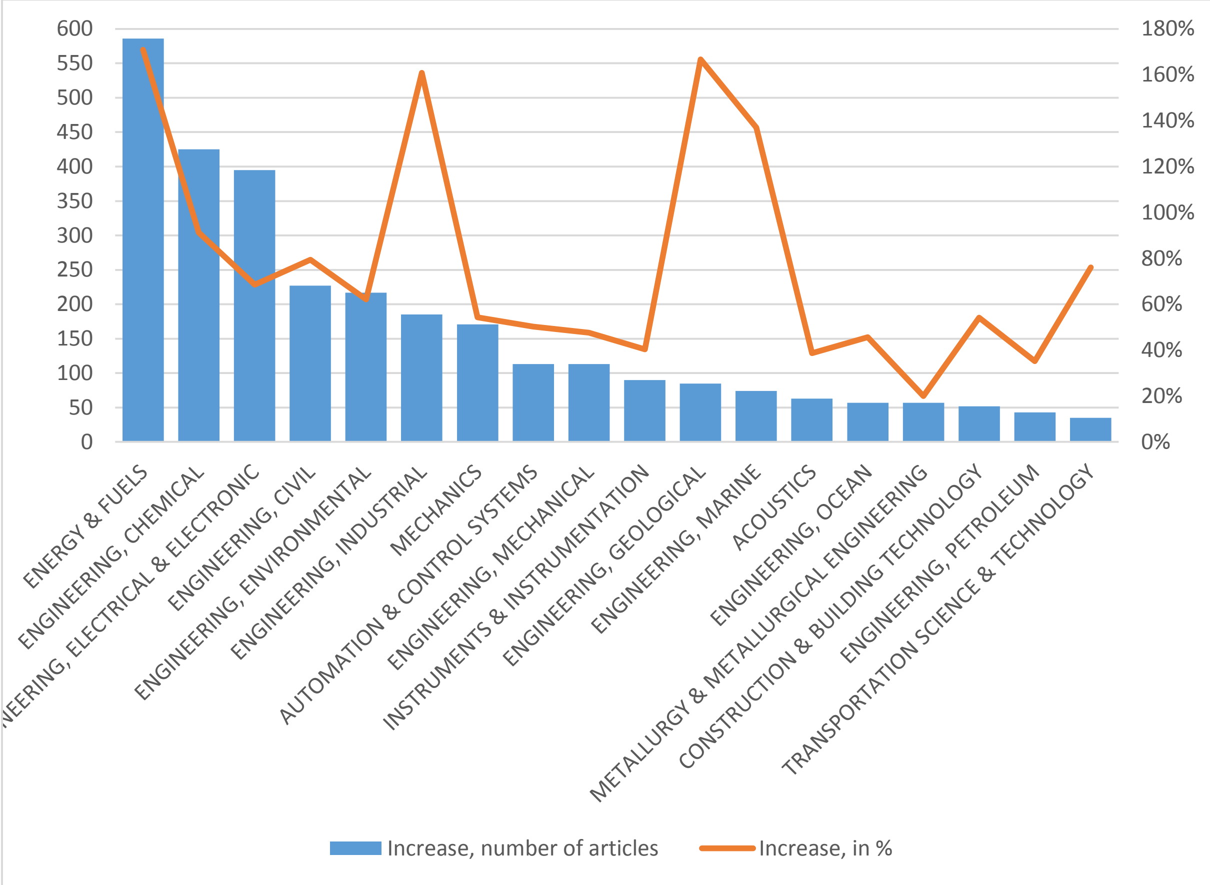
Figure A2.6 Relative specialisation index for Norway in Engineering sciences, 2009-2013.



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 A2.7 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 A2.7 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 A2.2. 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 A2.2 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 A2.2 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 across 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 A2.3 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.

At 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 A2.3 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.

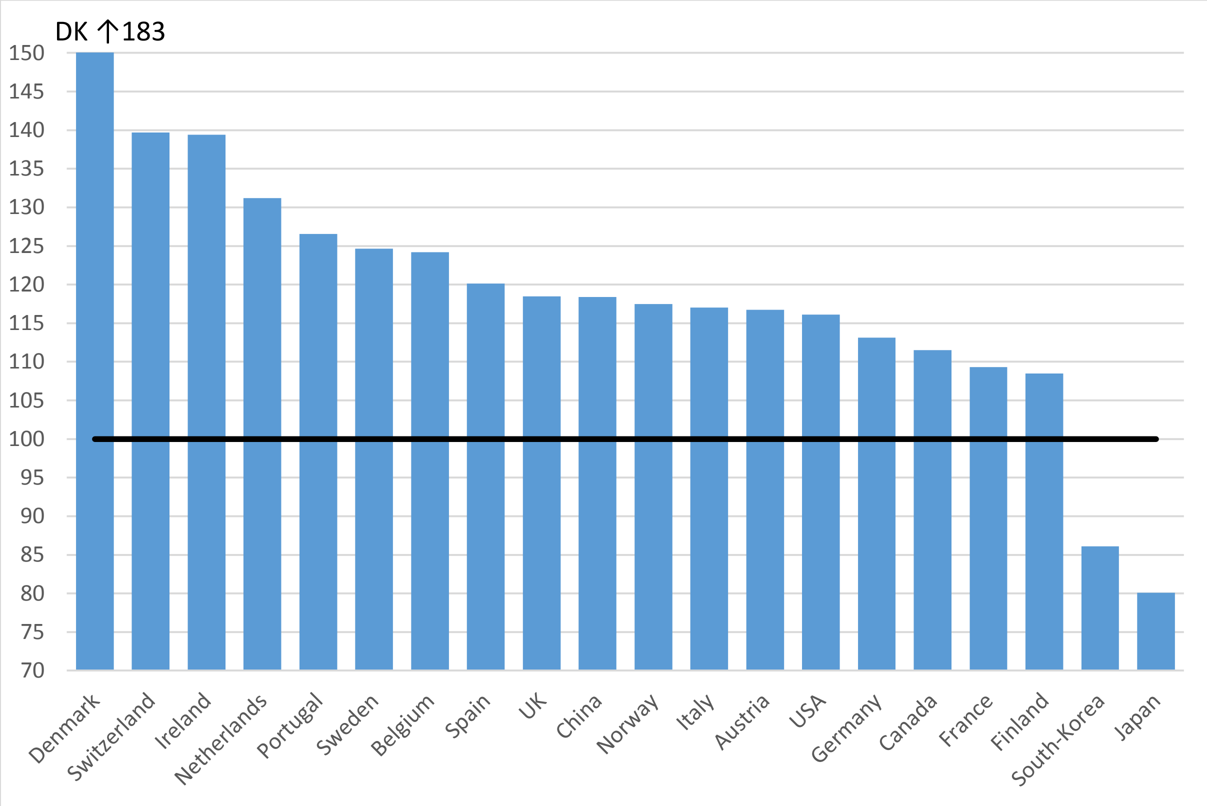
*) Includes the following publication types: articles, review papers, proceedings papers, and letters.

A2.2 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 A2.8 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.

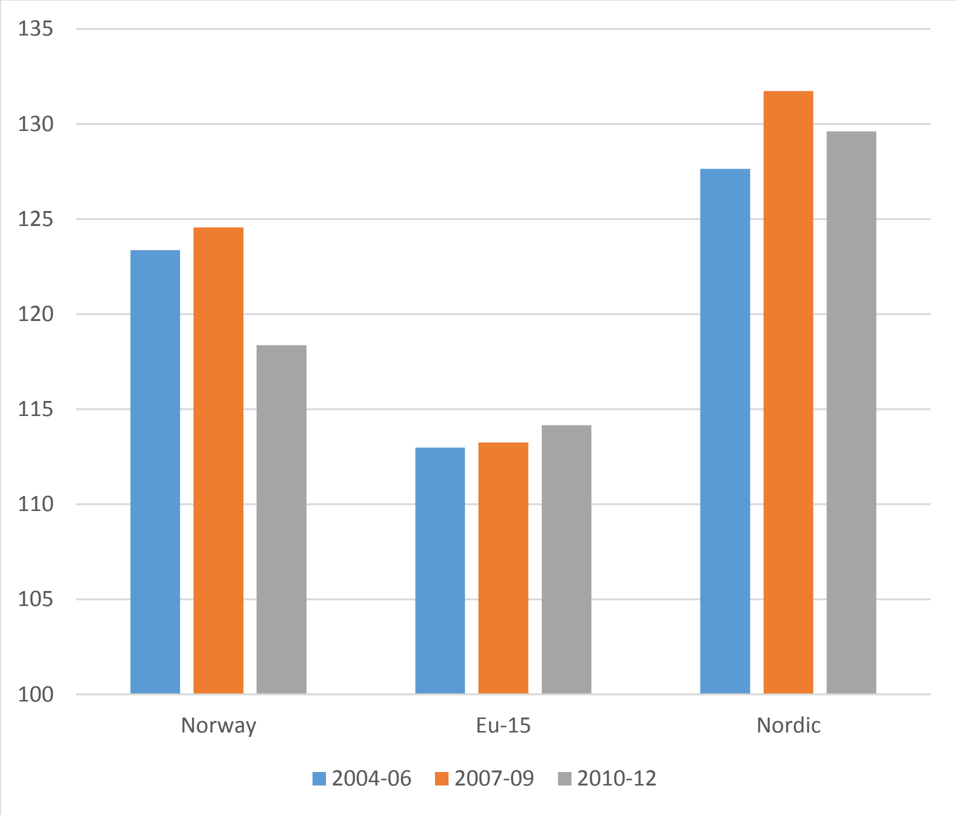
Figure A2.8 Relative citation index in Engineering sciences for selected countries (2009–2012).*



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 A2.9 (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 A2.9 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.



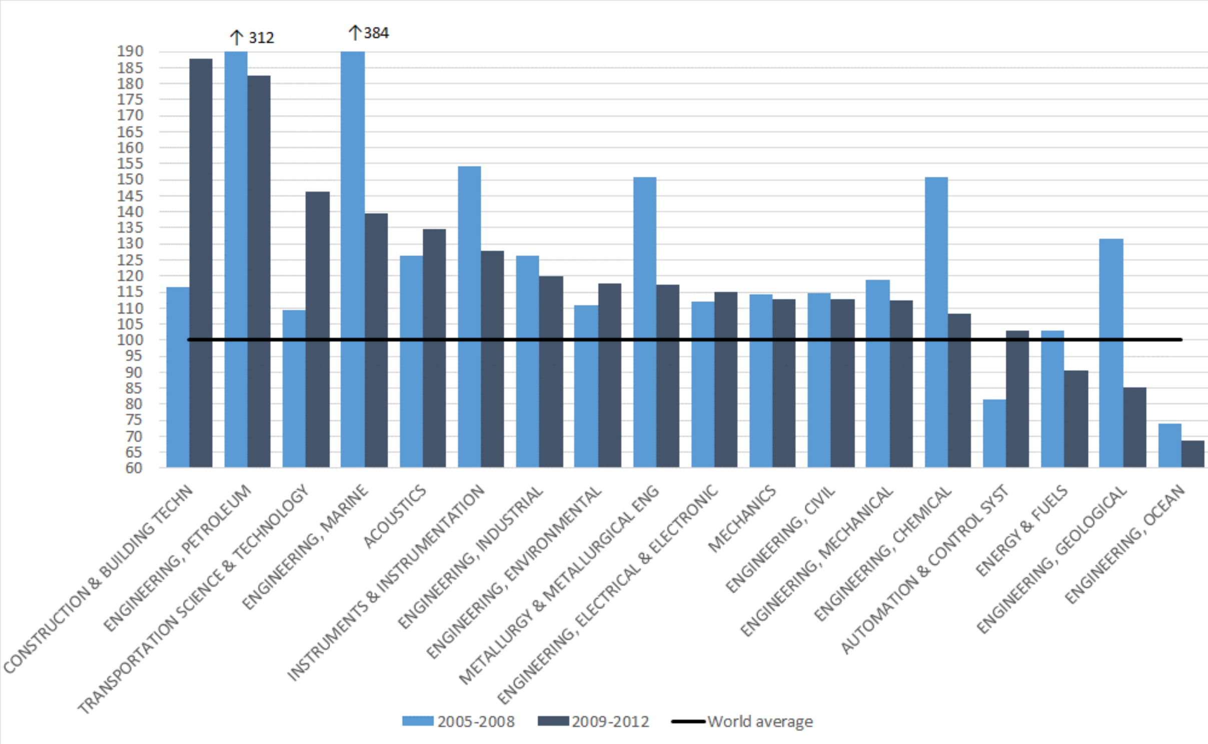
Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

*) 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 A2.10 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 indices of 188 and 183, respectively. Norway also performs very well in Transportation science & technology and Marine engineering (citation indices above 135). Lowest citation rate is found for Ocean engineering (69), Geological engineering (85) and Energy & fuels (91). Thus, in these fields the citation indices are 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 A2.10 Relative citation index in Engineering science subfields, 2005-2008 and 2009–2012.*

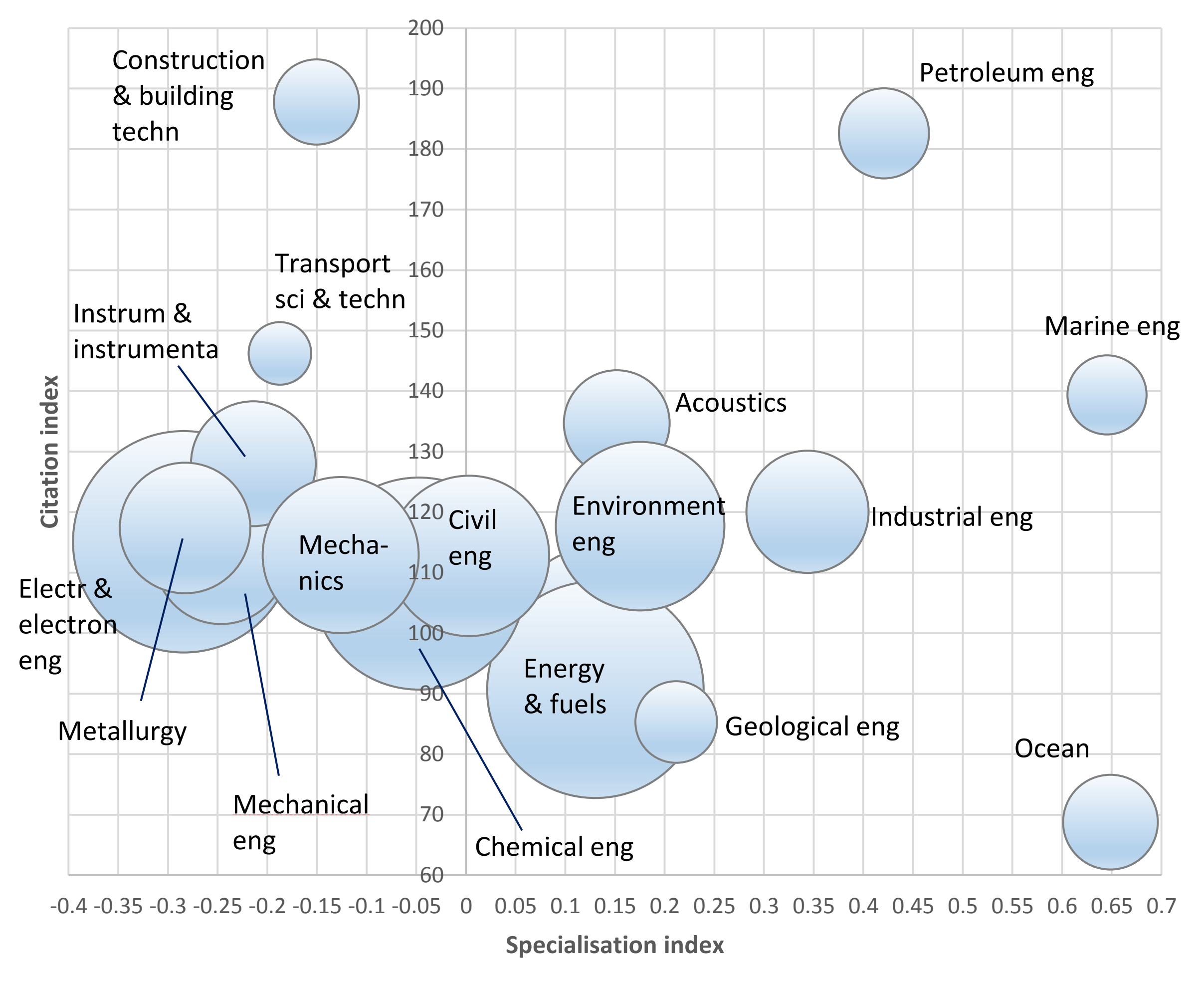


Source: Data: Thomson Reuters/CWTS Web of Science. Calculations: NIFU.

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

In Figure A2.11 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 A2.11 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.

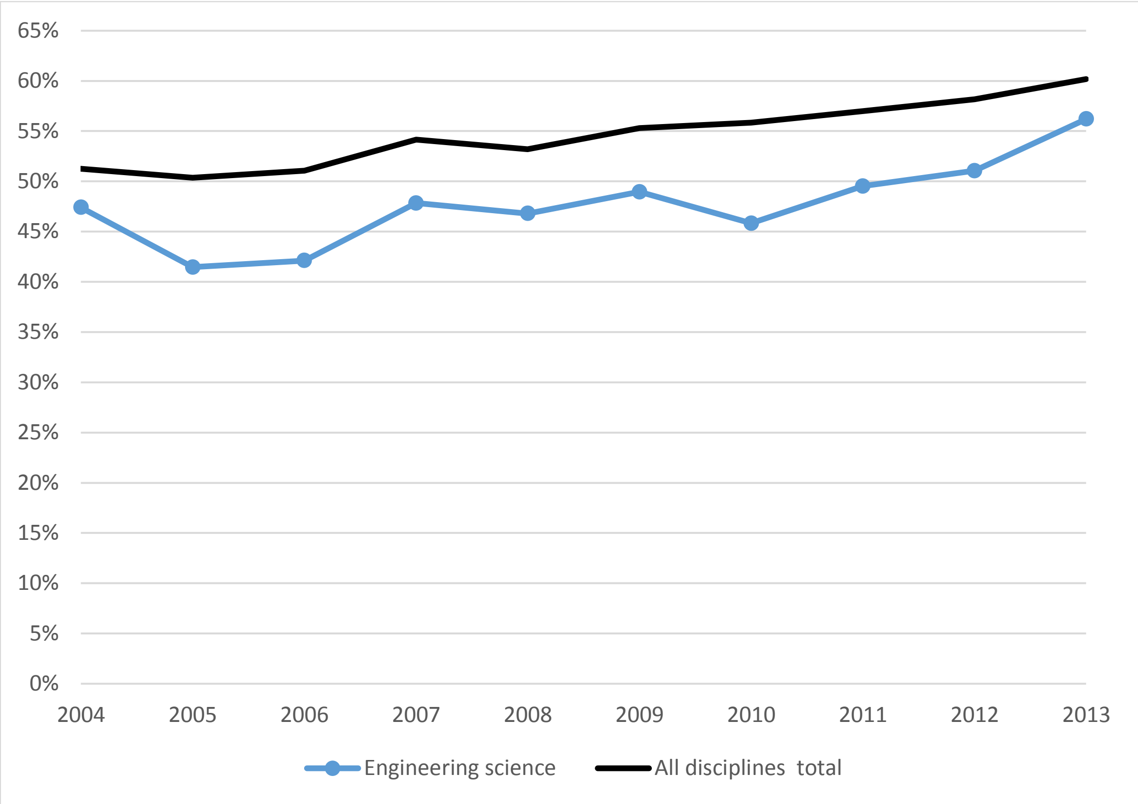
A2.3 Collaboration indicators

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 A2.12 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 A2.12 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 A2.4 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 *A2*.4 Collaboration by country* 2009–2013. Number and proportion of the Norwegian article production in Engineering sciences with co-authors from the respective countries.

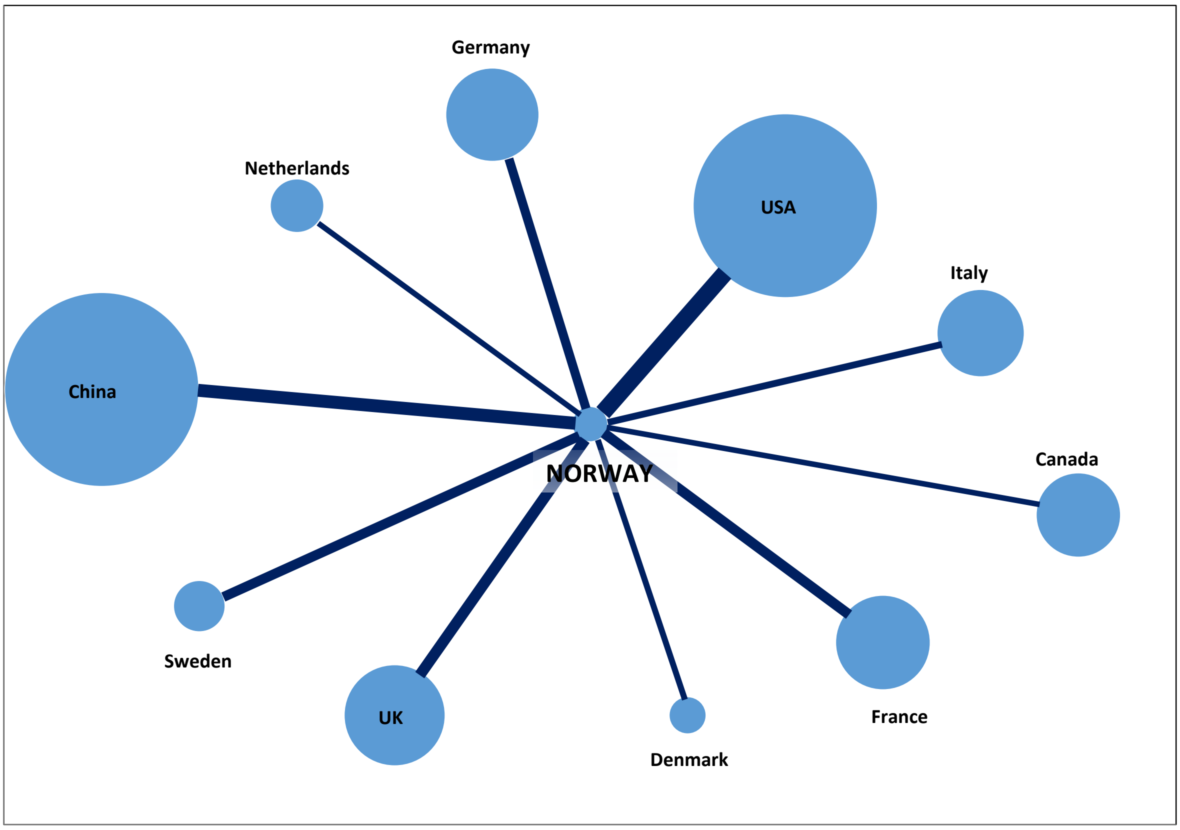
Country	No. articles	Proportion	Country	No. articles	Proportion
USA	450	9.7 %	Finland	96	2.1 %
China	344	7.4 %	Australia	82	1.8 %
UK	296	6.4 %	Russia	81	1.7 %
France	269	5.8 %	India	76	1.6 %
Sweden	263	5.7 %	Belgium	71	1.5 %
Germany	232	5.0 %	Japan	66	1.4 %
Italy	181	3.9 %	Poland	59	1.3 %
Denmark	160	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 A2.12 we have illustrated the international collaboration profile of Norwegian Engineering science graphically for the 10 most important collaborative partners.

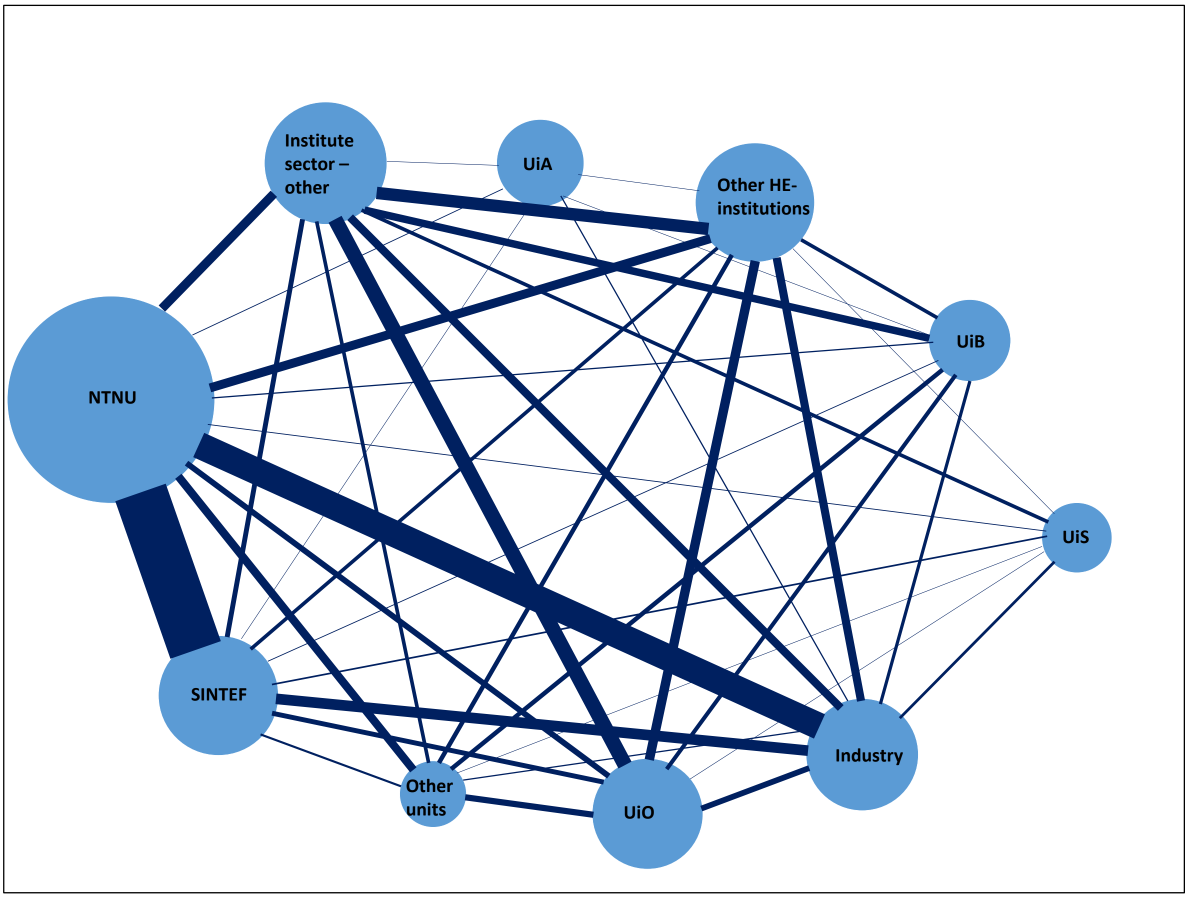
Figure A2.12 Graphical illustration of the international collaboration profile* of Norwegian Engineering science (2009-2013).



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 A2.13 (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 A2.13 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 A2.13 are given in Table A2.5. 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 A2.5 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.

Appendix 3 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.[30]

A3.1 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.

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

A3.2 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.

A3.3 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).

A3.4 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.

A3.5 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.

A3.6 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).[31]

[31] 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.

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. 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.

A3.7 Co-authorship as an indicator of collaboration[32]

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

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

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.

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.

References

Aksnes, D. W. (2003a). Characteristics of highly cited papers. *Research Evaluation, 12*(3), 159-170.

Aksnes, D. W. (2003b). A macro study of self-citation. *Scientometrics, 56*(2), 235-246.

Aksnes, D. W. (2005). Citations and their use as indicators in science policy. Studies of validity and applicability issues with a particular focus on highly cited papers. Dissertation for the doctoral degree, University of Tewente, Enschede, The Netherlands.

Aksnes, D. W. (2006). Citation rates and perceptions of scientific contribution. *Journal of the American Society for Information Science and Technology (JASIST), 57*(2), 169-185.

Aksnes, D.W. & Hessen D.O. (2009) The structure and development of polar research (1981-2007). A publication-based approach. *Arctic, Antarctic, and Alpine Research*, 41 (2), 155-163.

Aksnes, D. W., & Sivertsen, G. (2004). The effect of highly cited papers on national citation indicators. *Scientometrics, 59*(2), 213-224.

Aksnes, D. W., & Taxt, R. E. (2004). Peer reviews and bibliometric indicators. A comparative study at a Norwegian university. *Research Evaluation, 13*(1), 33-41.

Aksnes, D. W., Frølich, N & Slipersæter, S. (2008). Science policy and the driving forces behind the internationalisation of science: the case of Norway. *Science and Public Policy* 35(6), 445-457.

Chubin, D. E., & Hackett, E. J. (1990). *Peerless Science. Peer Review and U.S. Science Policy*. Albany: State University of New York Press.

Egghe, L., & Rousseau, R. (1990). Introduction to Informetrics. Quantitative Methods in Library, Documentation and Information Science. Amsterdam: Elsevier Science Publishers.

Garfield, E. (1979a). Citation Indexing - Its Theory and Application in Science, Technology and Humanities. New York: John Wiley & Sons.

Garfield, E. (1979b). Is citation analysis a legitimate evaluation tool? *Scientometrics, 1*(4), 359-375.

Hicks, D. (2004). The four literatures of social science. In H. F. Moed, W. Glänzel & U. Schmoch (Eds.), *Handbook of Quantitative Science and Technology research* (pp. 473-496). Dordrecht: Kluwer Academic Publisheres.

Katz, S. J., & Martin, B. R. (1997). What is research collaboration? *Research Policy*, 26(1), 1-18.

Katz, S. J., & Hicks, D. (1998). *Indicators for Systems of Innovation* (No. IDEA 12-98). Oslo: STEP-group.

lePair, C. (1995). Formal evaluation methods: Their utility and limitations. *International Forum on Information and Documentation, 20*(4), 16-24.

Lundberg J. (2007). Lifting the crown – citation z-score. *Journal of Informetrics*, 1 (2), 145 – 54.

Luukkonen, T., Persson, O., & Sivertsen, G. (1992). Understanding patterns of international scientific collaboration. *Science, Technology and Human Values*, 17(1), 101-126.

Luukkonen, T., Tijssen, R. J. W., Persson, O., & Sivertsen, G. (1993). The measurement of international scientific collaboration. *Scientometrics*, 28(1), 15-36.

Luukkonen, T. (1997). Quantitative Techniques in Evaluation in Western Europe. In M. S. Fankel & J. Cave (Eds.), *Evaluating Science and Scientists. An East-West Dialoge on Research Evaluation in Post-Communist Europe.* Budapest: Central European University Press.

Martin, B. R. (1996). The use of multiple indicators in the assessment of basic research. *Scientometrics, 36*(3), 343-362.

Martin, B. R., & Irvine, J. (1983). Assessing basic research: Some partial indicators of scientific progress in radio astronomy. *Research Policy, 12*, 61-90.

Melin, G., & Persson, O. (1996). Studying research collaboration using co-authorships. *Scientometrics,* 36(3), 363-377.

Merton, R. K., & Zuckerman, H. (1973). Age, aging and age structure in science. In R. K. Merton (Ed.), *The Sociology of Science*. Chicago: The University of Chicago Press.

Merton, R. K. (1979). Foreword. In E. Garfield (Ed.), Citation Indexing - Its Theory and Application in Science, Technology, and Humanities. New York: John Wiley & Sons.

Moed, H. F. (2002). The impact-factors debate: the ISI's uses and limits. *Nature, 415*, 731-732.

Moed, H. F. (2005). *Citation Analysis in Research Evaluation*. Dordrecht: Springer.

Moed, H. F., Burger, W. J. M., Frankfort, J. G., & van Raan, A. F. J. (1985). The application of bibliometric indicators: Important field- and time-dependent factors to be considered. *Scientometrics, 8*(3-4), 177-203.

Moed, H. F., & Velde, J. G. M. v. d. (1993). *Bibliometric profiles of academic chemistry research in the Netherlands* (No. 93-08). Leiden: Center for Science and Technology Studies (CWTS).

Moed, H. F., & Vriens, M. (1989). Possible inaccuracies occuring in citation analysis. *Journal of Information Science, 15*, 95-107.

National Science Board. (2002). *Science and Engineering Indicators - 2002*. Arlington: National Science Foundation.

Nederhof, A. J., & van Raan, A. F. J. (1993). A bibliometric analysis of six economics research groups: A comparison with peer review. *Research Policy*, 22, 353-368.

Price, D. J. d. S. (1965). Networks of Scientific Papers. *Science, 149*, 510-515.

Price, D. J. d. S. (1986). *Little science, big science -- and beyond*. New York: Columbia University Press.

Schubert, A., & Braun, T. (1986). Relative indicators and relational charts for comparative assessment of publication output and citation impact. *Scientometrics, 9*(5-6), 281-291.

Schubert, A., & Braun, T. (1996). Cross-field normalization of scientometric indicators. *Scientometrics, 36*(3), 311-324.

Schubert, A., Glänzel, W., & Braun, T. (1988). Against Absolute Methods: Relative Scientometric Indicators and Relational Charts as Evaluation Tools. In A. F. J. Van Raan (Ed.), *Handbook of Quantitative Studies of Science and Technology*. Amsterdam: Elsevier.

Seglen, P. O. (2001). Evaluating Biology. A Scientometric Study of a University Department. Oslo: NIFU. Skriftserie 6/2001.

Sivertsen, G. (1997). Ethical and Political Aspects of Using and Interpreting Quantitative Indicators. In M. S. Frankel & J. Cave (Eds.), *Evaluating Science and Scientists: An East-West Dialogue on Research Evaluation in Post-Communist Europe*. Budapest: Central European University Press.

Sivertsen, G. (2006). A bibliometric Model for Performance Based Budgeting of Research Instituions. Paper presented at the 9th International Conference on Science & Technology Indicators. 07-09 September 2006, Leuven, Belgium.

Sivertsen, G., & Aksnes, D. W. (2000a). Hva slags forskningsnasjon er Norge? *Forskningspolitikk*(1. URL: http://www.nifu.no/Fpol/1-2000/art3.html).

Sivertsen, G., & Aksnes, D. W. (2000b). Norge som forskningsnasjon II. *Forskningspolitikk*, 2000(3).

Smith, M. (1958). The trend toward multiple authorship in psychology. *American Psychologist*, 13, 596-599

Testa, J. (2012). The Thomson Reuters journal selection process. URL: http://wokinfo.com/essays/journal-selection-process/

Van Raan, A. F. J. (1993). Advanced bibliometric methods to assess reseach performance and scientific development: basic principles and recent practical applications. *Research Evaluation, 3*(3), 151-166.

Van Raan, A. F. J. (1996). Advanced bibliometric methods as quantitative core of peer review based evaluation and forsight exercises. *Scientometrics, 36*(3), 397-420.

Van Raan, A. F. J. (2000). The Pandora's Box of Citation Analysis: Measuring Scientific Excellence—The Last Evil? In B. Cronin & H. B. Atkins (Eds.), *The Web of Knowledge. A Festschrift in Honor of Eugene Garfield* (pp. 301-319). Medford: ASIS.

Vinkler, P. (1986). Evaluation of some methods for the relative assessment of scientific publications. *Scientometrics, 10*(3-4), 157-177.

Welljams-Dorof, A. (1997). Quantitative Citation Data as Indicators in Science Evaluations: A Primer on Their Appropriate Use. In M. S. Frankel & J. Cave (Eds.), *Evaluating Science and Scientists. An East-West Dialogue on Research Evaluation in Post-Communist Europe.* Budapest: Central European University Press.

Wendt, K., Slipersæter, S., & Aksnes, D. W. (2003). Internationalisation of Research. In Å. Gornitzka, M. Gulbrandsen & J. Trondal (Eds.), *Internationalisation of Research and Higher Education. Emerging Patterns of Transformation*. Oslo: Norwegian Institute for Studies in Research and Higher Education. Report 2/2003.

Wouters, P. (1999). *The Citation Culture.* PhD-thesis, University of Amsterdam, Amsterdam.