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Evaluation of natural sciences in Norway

Publication and citation analysis – a national profile

Henrik Karlstrøm and Dag W. Aksnes

NIFU

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Preface

This report presents a bibliometric analysis of research in natural sciences in Norway and is a background report for the evaluation of the area. The main intention is to provide a general overview of the national research profile, where both units encompassed by the evaluation and other units are included. Specific analyses of the units included in the evaluations are presented in separate reports. The report is written on the commission of the Research Council of Norway (RCN) by senior researcher Henrik Karlstrøm and research professor Dag W. Aksnes at the Nordic Institute for Studies in Innovation, Research and Education (NIFU).

Oslo, 23.03.23

Siri Brorstad Borlaug

Deputy head of research

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Summary

The report presents a bibliometric analysis of the part of natural sciences covered by the present evaluation (EVAL NAT). Overall, Norwegian researchers in the natural sciences contributed to more than 5100 publications in 2021. There has been a substantial growth in the publication output of Norwegian natural sciences during the recent 10-year period. Overall, the increase is 63% in terms of number of publications. Although there has also been a strong growth in the general Norwegian publication output during the period, the relative position of the field in the overall national research landscape is strengthened, measured by publication volume. In particular the publication volume has increased significantly in geosciences with a relative growth of 84%.

The Norwegian University of Science and Technology and the University of Oslo are by far the largest contributors to Norwegian natural science research publication output. Next follow the University of Bergen and UiT - The Arctic University of Norway. In addition to research carried out by higher education institutions, units in the institute sector make major contributions to Norwegian natural science research. Among these, the largest single unit by publication numbers is SINTEF.

In terms of citation rate, Norwegian natural science research performs reasonably well with a citation index of 115 (2018-2020). This means that the publications are cited 15 % above the world average. This is quite close to the total Norwegian average (all fields combined), which is 120. The publications in geosciences obtain the highest citation rate this three-year period.

There is extensive international research collaboration. In the natural sciences overall, 71 % of the publications had co-authors from other countries in 2019-2021. In other words, almost three out of four publications were internationally co-authored. This is significantly higher than the overall Norwegian average. The USA is the most important collaboration partner, and 17 % of the Norwegian articles within natural sciences also had co-authors from this nation.

1 Introduction

This report presents statistics and indicators of the scientific peer-reviewed publication output of Norwegian natural science. The report is primarily meant to function as a factual background report to the panels and committees involved in the evaluation of the research activities in Norway. Further assessments and considerations regarding the findings are therefore left to the evaluators.

Publication and citation analyses have relevance in the context of science policy and research evaluation. The relevance relies on the assumption that new knowledge – the principal objective of basic and applied research – to a large extent is disseminated to the research community through publications. Publications can thereby be used as indirect measures of knowledge production. Data on how much the publications have been referred to or cited in the subsequent scientific literature can in turn be regarded as an indirect measure of the scientific impact of the research.

The analysis in this paper encompasses data and analyses at the overall national level and of specific disciplines/areas within the natural sciences. Included are indicators on topics such as:

- Publication volume
- Citation impact indicators
- National and international collaboration measured through co-authorship

A fundamental issue when analysing fields bibliometrically concerns delineation and classification. For the evaluation in question, RCN has provided a thematic panel description. There is, however, no predefined bibliometric category system which corresponds to this specific division of panels. The analyses of disciplines/subfields within the natural sciences rely on a predefined classification system developed by the Norwegian Association of Higher Education Institutions (UHR), consisting of 87 different discipline/subfield categories with all areas of science.

The classification method involves journal-based subfield definitions and is further described in the next chapter. To make the analysis more relevant for the different evaluation panels, we have aggregated subfields into broader categories in order to correspond with the panel division of the disciplines encompassed by the evaluation. However, since the analysis is based on predefined discipline/subfield categories, there are limitations concerning this degree of correspondence.

In the analyses, the category systems described above, will be applied in a constituting way, meaning that the publication output will be delimited using this system, and the various categories distributed under the evaluations where they have relevance.

For analysis of publications from each administrative unit included in the evaluation, we refer to the separate reports for the units. In these reports, all publications of a specific department will be included, regardless of whether the publications are classified under a particular field in the publication databases. In the present report, only publications in the covered categories are included. This means for example that if a physics department has published in journals classified as mathematics, these publications are not included in the chapter covering physics.

The report is structured as follows:

- Chapter 2: Presents the data and the methodology applied in the study.
- Chapter 3: Provides an overall bibliometric analysis of the natural sciences in Norway. Here biology and biosciences are excluded as these fields are covered by the other corresponding report on the biosciences.
- Chapter 4: This chapter covers chemistry and materials science and engineering, which largely corresponds to the research evaluated by Panel 4, 6, 7, and 8:
    - Panel 4: Material and nano science and engineering.
    - Panel 6: Inorganic chemistry, physical chemistry, nuclear chemistry, and theoretical chemistry.
    - Panel 7: Organic chemistry, analytical chemistry, environmental chemistry, and biological chemistry.
    - Panel 8. Chemical technology, process chemistry, and metallurgy.
- Chapter 5: Covers geosciences which is relevant in respect to panel 9-12:
    - Panel 9: Meteorology, climatology and oceanography.
    - Panel 10: Cryosphere, hydrology, geomorphology, and remote sensing.
    - Panel 11: Marine geology, environmental geology, palaeontology, geotechnics.
    - Panel 12: Geodynamics, tectonics, seismology, volcanology, petrology, mineralogy and geomagnetism, and tectonics.
- Chapter 6: Covers physics and is of main relevance for panel 1-3:
    - Panel 1: Astrophysics, space physics, plasma physics.

    - Panel 2: Nuclear and particle physics, theoretical physics, and didactics.
    - Panel 3. Condensed matter physics, atom and molecular physics).
- Chapter 7: The final chapter covers electronics and cybernetics. This has partly relevance for:
    - Panel 5: Electronics, optics, sensors, medical physics and technology.

However, as is evident the match between chapters and panels is limited. The report contains a large number of tables and figures. Within the scope of this project, we have not been able to give detailed comments on all indicators presented. Rather, we give some examples of how the tables should be read and comment on major patterns. Hence, this is primarily a technical report providing background for the evaluation. As each chapter is intended as a stand-alone contribution which can be read independently of the other chapters, there is extensive use of repeating text.

Please note that the report does not include any extensive international comparisons and benchmarking. Such analyses will be provided in a later report: *A bibliometric analysis of Norwegian sciences. Trends and international comparisons.*

2 Data and methods

2.1 Data sources

2.1.1 The Cristin-database

The analysis is primarily based on the publicly accessible Cristin-database, which is a joint system for registration of scientific publications applied by Norwegian higher education institutions, research institutes and hospitals. The Cristin publication data (scientific/scholarly publications) are summarised in the Database for Statistics on Higher Education (DBH) and are used for the calculation of the performance-based budgeting of Norwegian higher education institutions and research institutes (see text box next page).

The Cristin database contains data on a variety of bibliographic parameters, including publication type, publication channel, and publication language. In addition, it includes individual data of the authors, such as their institutional affiliations, age and gender. Accordingly, statistics on many aspects of the publication activity can be provided.

The analysis in this report is limited to the publication categories included in the Norwegian performance-based funding system, 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. 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. Hence, the analysis covers the publications primarily directed towards the scientific community, but not other types of research disseminations. This needs to be taken into consideration when interpreting the results.

The performance-based basic funding system – publications

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 academic 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 (UHR). The table below shows the relative weights given the different types of publications at the two levels.

Table Publication weights

Publication type	Outlets at normal level (level 1)	Outlets at high level (level 2)
Articles in ISSN-titles (journals & 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 scientific publications. The definition is that a scientific 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. 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).

Co-authored publications are shared, and fractionalised publication points are calculated based on the number of author addresses. Publication points are used in the performance-based funding system for both the higher education sector and the institute sector and hospitals). The formula is identical across sectors.

2.1.2 The Web of Science database

In addition, the analysis is based on the Web of Science (WoS) Core collection database, covering the underlying sub databases: Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Emerging Sources Citation Index, Conference Proceedings citation indexes, and Book Citation Index. We have applied a local version of WoS maintained by the Norwegian Agency for Shared Services in Education and Research. This is a database covering more than 22,000 specialized and multidisciplinary scientific journals with peer review, in addition to a selection of scientific books and conference proceedings. Even if the coverage is not complete, the databases will include all major journals within natural sciences, medicine and technology and is generally regarded as constituting a satisfactory representation of the research within these fields (Aksnes & Sivertsen, 2019).

The WoS-database is applied for the calculation of citation indicators and for collecting publication data from units which do not apply the Cristin database such as companies and firms in the business sector. Although these units are not part of the evaluation, and they publish rarely in scientific journals, they have been included to obtain a complete national picture.

2.2 Methods

2.2.1 Field classification system

As described in the introduction, the analyses rely on a predefined classification system developed by the Norwegian Association of Higher Education Institutions (UHR), consisting of 87 different categories with all areas of science. The classification method involves journal-based subfield definitions, meaning that all articles in a given journal are assigned to the same field. Although such a journal-based field classification is not very accurate (Leydesdorff & Rafols, 2009), it provides a rough picture of the overall profile. For an overview of these categories and list of the journals which are included in each field we refer to the website: https://npi.hkdir.no/fagfeltoversikt

As noted above, subfields have been classified together as to correspond with the panel division of the disciplines encompassed by the evaluation. However, since the analysis is based on predefined categories, there are limitations concerning this degree of correspondence, see Table 2.1.

Tabell 2.1 Overview of the field, chapters and panel structure

Evaluation of natural sciences		
Cristin-field	Covered by chapter (the other report)	Main relevance for panel
Chemistry & materials science and engineering*	3, 4	4, 6, 7, 8
Geosciences**	3, 5	9-12
Physics	3, 6	1-3
Electronics and cybernetics	3, 7	5

*) Covers the former categories: Chemistry, Chemical engineering and Materials science and engineering.

**) Covers the former categories: Earth sciences and Applied geology, petroleum science and engineering.

In the field classification system of the Cristin database, publications in multidisciplinary journals like *Nature* and *PlosOne*, are not field classified but instead assigned specific categories for these journals. This is unfortunate as the publication volume of a particular subject or discipline is underestimated when publications in these journals are not included. As part of the project, we have therefore developed an algorithm allowing these publications to be attributed specific field categories. For this work, we have made use of the reference list of the publications and the field classification of the references in these. Publications in multidisciplinary journals have been reclassified according to the most referenced fields of these publications.

2.2.2 Publication output

The analysis is limited to the ten-year period 2012-2021, with the main emphasis on the recent years. The analysis is limited to the following publication types: full-papers (regular articles, proceedings articles) and review articles published in journals or books and books/monographs. Publications not covered by these categories are not included (for example material such as letters, editorials, corrections, book-reviews, meeting abstracts, etc.).

A main issue in all evaluative use of bibliometric indicators concerns the issue of counting methods. This is related to the fact that most publications have more than one author. Thus, the question arises weather these should be credited individual authors, institutions and countries. Over the years, a large number of indicators have been developed (Gauffriau, 2017). In citation analyses the issue is particularly urgent as citation frequencies generally are extremely skewed (Aksnes et al., 2012). The most common approaches are either “whole counting”, where a publication is fully credited all contributors or “fractionalized counting” where credit is divided proportionally. The Norwegian publication indicator is a compromise taking publication characteristics of fields into account and is developed internationally as Modified Fractional Counting (Sivertsen et al., 2019), but where other elements of the Norwegian publication indicator (weighting of journal/publisher level, and international collaboration) are omitted. Modified Fractional Counting was used in the recent version of RCN’s S&T Indicator report, and is also used in most of the analyses here, with the exceptions of analyses where adjusting for relative contribution is less relevant (e.g. analyses of international collaboration).

2.2.3 Citation indicators

It is commonly assumed that articles are more or less cited in accordance with the impact they have on further research. Based on this assumption, citations are often used as an indicator of scientific impact or influence, and thus as a partial measure of quality. Although citation analyzes are increasingly used in research performance analyses such indicators cannot replace an evaluation carried out by peers. This is due to the various limitations of citations indicators. Moreover, citations do not necessarily reflect societal usefulness or extra-scientific relevance.

The Web of Science database also includes information on how many times the articles have been referred to or cited in the subsequent scientific literature indexed in WoS. These data have been used to calculate citation indicators. In absolute counts, the units with the largest number of articles would of course also receive the highest number of citations – these units have more papers that can be cited. It is, however, common to use a size-independent measure to assess whether a unit's articles have been highly or poorly cited.

It is the individual articles and their citation counts that represent the basis for the citation indicators. In the citation indicators we have used accumulated citation counts (up to and including 2021) and calculated an overall (total) indicator for the whole period. This means that for the articles published in 2017, citations are counted over a 5-year period, while for the articles published in 2019, citations are counted over a 3-year period (or more precisely a 2–3-year period: the year of publication, 2020 and 2021). Articles from the most recent year (2021) are not included in the citation analysis as these have not been available in the literature for a sufficiently long time to be cited. We have used accumulated citation counts and calculated an overall (total) indicator for the whole period.

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 field in which the particular papers have been published.

One such indicator is the relative citation index *MNCS* showing whether a unit's scientific publications have been cited above or below the world average (=100). Here, each article is compared with the average paper in the respective field[1] and year by publication type[2]

[1] Subject field as defined by WoS, see overview: https://support.clarivate.com/ScientificandAcademicResearch/s/article/Web-of-Science-List-of-Subject-Classifications-for-All-Databases?language=en_US. In the 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 then calculated as the ratio between the average citation rate of the articles and the average subfield citation rate.

[2] See overview here: https://images.webofknowledge.com/images/help/WOS/hs_document_type.html

In addition to the MNCS indicator we have analysed the articles that are among the 10 per cent most cited in their fields: More specifically the number and the proportion of a unit’s publications that, compared with other publications in the same field and in the same year and by the same publication type, belong to the top 10% most frequently cited. The main objective is to analyse whether there are differences between the two sets of articles along various bibliometric variables.

2.2.4 Collaboration indicators

The fact that researchers co-author a scientific paper reflects collaboration, and co-authorship may be used as an indicator of such collaboration. 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. In this report, indicators of both international and institutional collaboration have been included.

3 Norwegian natural sciences – overall analysis

This chapter provides an overview of the total Norwegian publication output in the natural sciences covered by the evaluation (i.e., excluding disciplines such as biology, informatics and mathematics). We present combined figures based on the fields analysed separately in Chapters 4-7.

The analysis covers all publications with Norwegian contributors within these fields, not only publications from the units included in the evaluation. Overall, the evaluated units account for 58.8 % of all publishing within the natural sciences Norway. Thus, a quite large part of the publications within the area as it is delineated here are produced by units which are not part of the present evaluation. These are units which have decided not to participate in the evaluation or will participate in the next evaluation (mathematics, ICT and technology). In addition, publications are also produced by researchers affiliated with other units than the core departments and institutes in the natural sciences.

3.1 Publication output

3.1.1 General trend

Figure 3.1 shows the development of publication output for the natural sciences in the last decade. It shows an increase in the number of publications from 3 138 in 2012 to 5 113 in 2021. This corresponds to a relative growth of 63 %. Measured by fractionalised counts (modified author shares), the growth is less strong (+43%), an indication of increasingly collaborative authoring in the natural sciences during the period.

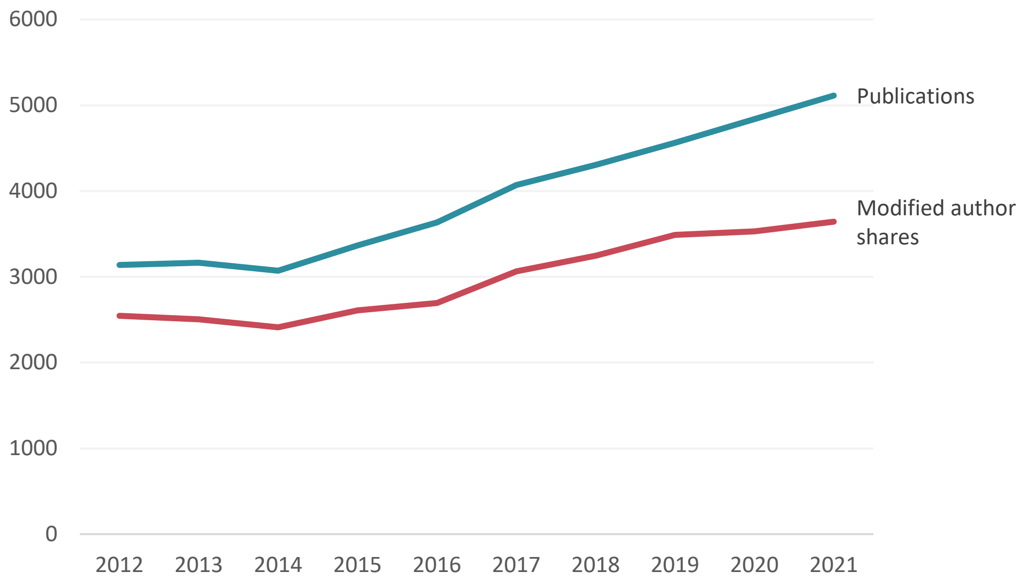

Figure 3.1. Publishing volume and sum of modified author shares for Norwegian natural sciences research 2012-2021.

The last decade has seen a large general increase in the number of scientific publications with Norwegian affiliated authors. Figure 3.2 shows the growth in scientific publishing in the natural sciences against the total growth of all Norwegian publishing (all fields combined). As can be seen, the growth in natural sciences publishing has been larger than the general growth in research output over the period. During the ten-year period the total Norwegian publication output increased by 47%, compared to 63% for natural sciences. Thus, the relative position of the natural sciences in the overall national research landscape is strengthened, measured by publication volume.

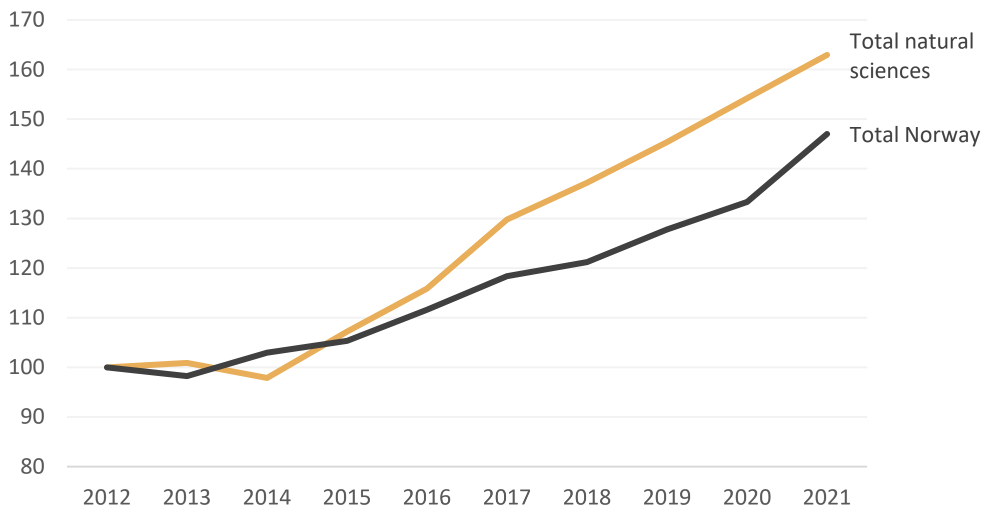

Figure 3.2. Relative growth in number of publications, natural sciences and total Norwegian publishing, 2012-2021. 2012=100.

3.1.2 Most publishing institutions

Table 3.1 shows the top five contributors to scientific publishing in the natural sciences in Norway by sector. Having 72.2 % of the total author contributions, the university and college sector is by far the biggest contributor to natural sciences publishing in Norway. The largest institutions by publishing volume are Norway's largest research institutions. Independent research institutes account for a quarter (26.2 %) of author contributions in the natural sciences, university hospitals and other health institutions contribute 1.4 % and various industry and public sector entities make up the remaining 0.2 % of natural sciences publications.

Table 3.1. Most publishing institutions in the natural sciences by sector and institution/institute, 2021

Sector	Institution	Publications	Modified author shares	Share of total
Health	Hospitals and health institutions	93	31.8	1.4 %
Research institutes	SINTEF	321	186.6	4.8 %
	Norwegian Geotechnical Institute	97	58.7	1.4 %
	Norwegian Institute of Marine Research	99	51.9	1.5 %
	Norwegian Meteorological Institute	110	50.7	1.6 %
	NORCE	118	44.4	1.7 %
	Other research institutes	1023	514.4	15.1 %
Universities and colleges	Norwegian University of Science and Technology	1488	982.9	22.0 %
	University of Oslo	1204	582.2	17.8 %

	University of Bergen	638	301.3	9.4 %
	UiT - The Arctic University of Norway	394	212.2	5.8 %
	University of Stavanger	223	147.3	3.3 %
	Other universities and colleges	931	478.4	13.8 %

3.1.3 Publishing venues

Figure 3.3 shows the most common journals for publishing natural sciences research in Norway in the most recent year, 2021. In total, these 15 journals account for 21 % of natural sciences publishing. 28.4 % of all natural sciences publications were published in journals that are placed on level 2 in the Norwegian journal classification system.

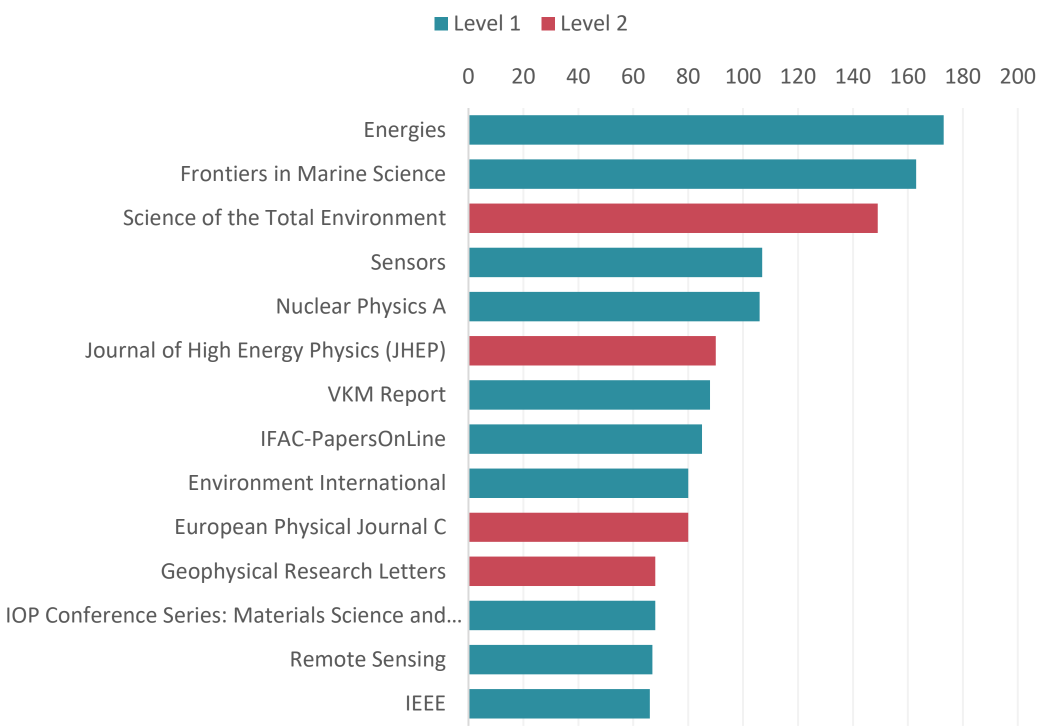

Figure 3.3. Most common publishing venues of natural sciences, 2021

3.1.4 Field distribution

There is not a complete overlap between the Norwegian journal classification system and that of Web of Science. Figure 3.4 shows how Norwegian natural sciences publications are distributed among research fields as classified by Web of Science. The most important WoS fields that fall under the natural sciences umbrella is Environmental sciences.

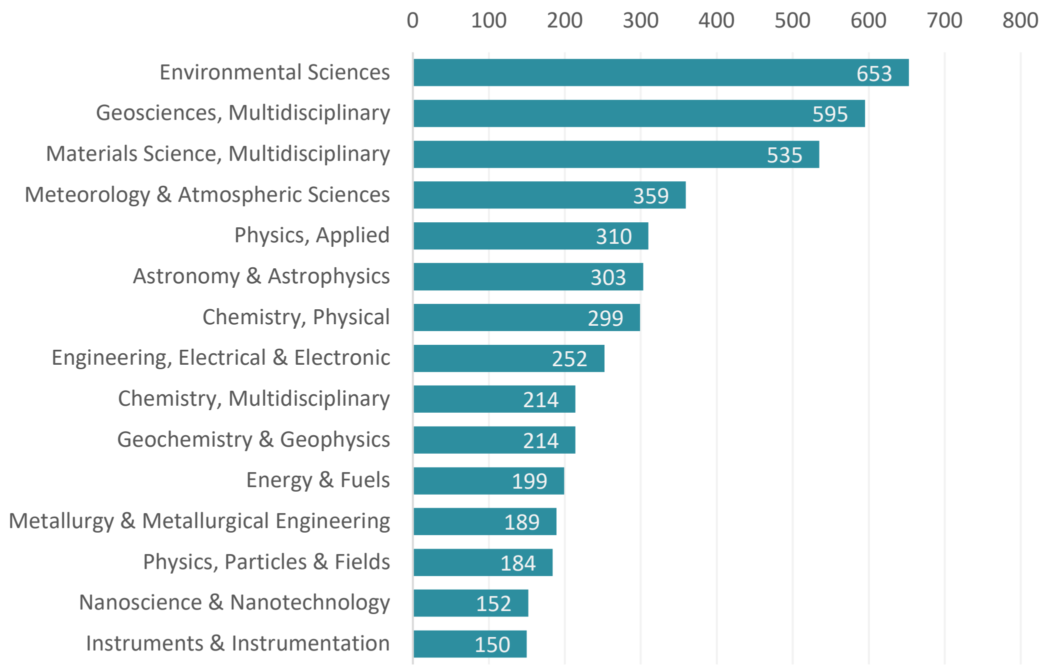

Figure 3.4. Web of Science subfield distribution of publications within natural science journals in the Norwegian journal classification system, 2021.

3.2 Citation indicators

There are many different indicators of the citation impact of a publication, but two of the most common are 1) Mean normalized citation score (MNCS), where the citation count of a publication is compared to the average number of citations received by publications within the same field and from the same year, and 2) citation percentile, which is a publication's percentile position in a list of all publications from a given field and publication year ordered by citation count.

Figure 3.5 shows the average MNCS for all natural sciences publishing in Norway 2012-2020, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

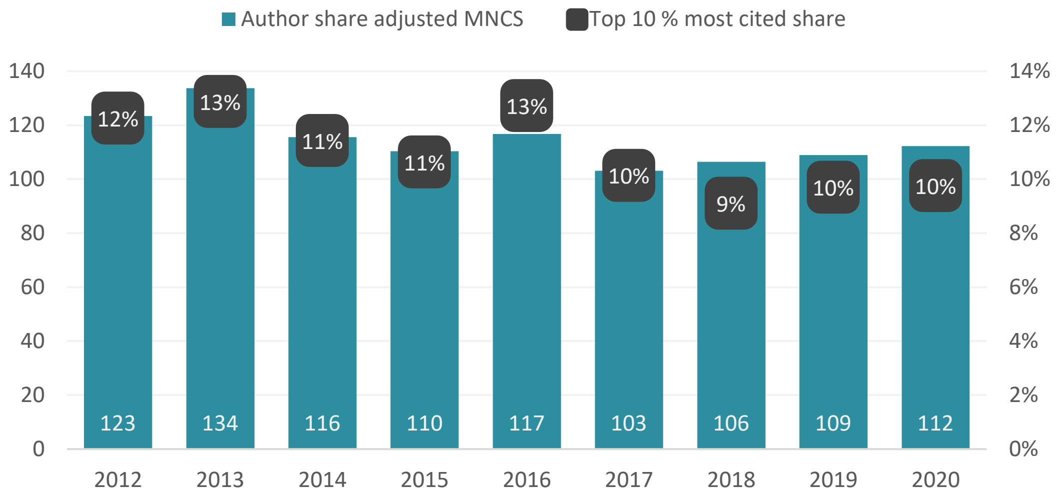

Figure 3.5. MNCS of natural science publications (left axis, 100 = global mean citation score for publications from same field and year) and share of publications among the 10 % most highly cited publication from same field and year (right axis), 2012-2020.

In general, Norwegian natural sciences research is above the global average for all years, with the average MNCS for the whole period being 115 and the share of author contributions that fall within the top 10 % most cited publications being 11 %. There are annual fluctuations for both indicators, but recent years are slightly lower than earlier in the period.

Figure 3.6 shows the MNCS for the 2018-2020 period for selected disciplines encompassed by the two present evaluations. In the natural sciences, the articles in geosciences have the highest citation index, 127. At the opposite end of the scale, we find chemistry with a citation index of 87.

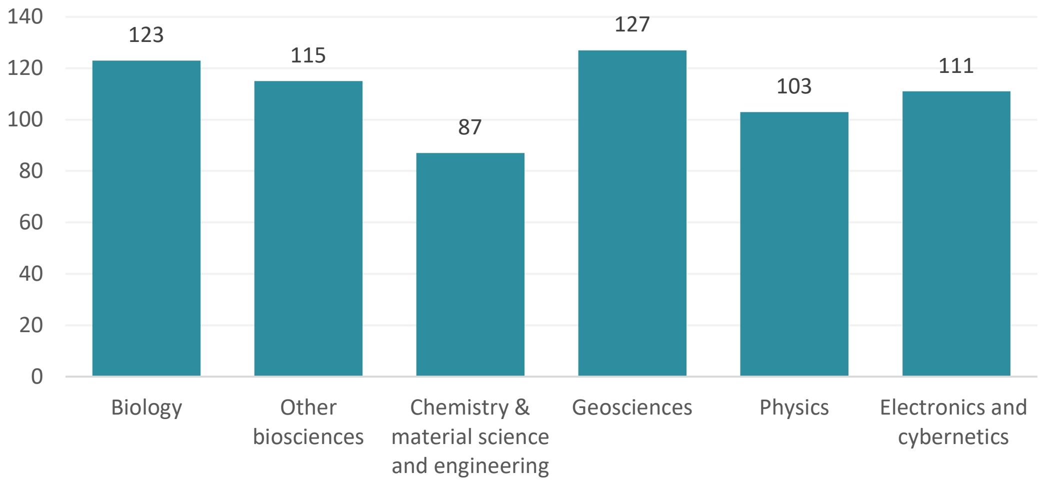

Figure 3.6. MNCS of disciplines encompassed by the two present evaluations, 2018—2020 figures.

Figure 3.7 shows the similar indicator for the publications that fall under the natural sciences category, but using the more fine-grained WoS-classification system (cf. Figure 3.4). Meteorology, textile research, particle physics, geology and astronomy all have citation impact scores well over the global average. Organic chemistry, condensed matter physics, coatings and film research and crystallography all have citation impact score under 70 (not shown in the figure).

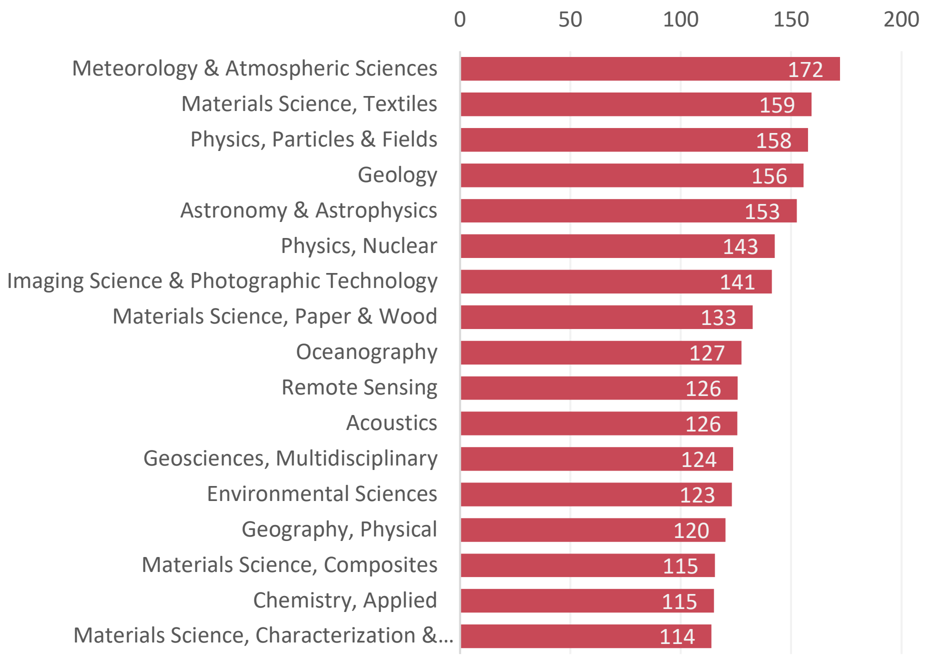

Figure 3.7. MNCS of 15 most impactful Web of Science subfields within Norwegian natural sciences publications, 2018-2021.

3.3 International collaboration

Which countries are the most important collaborative partners for Norway in the natural sciences? To answer this, the distribution of co-authorship by country has been analysed. Table 3.3 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. The USA is the most important collaboration nation. In total, 17% of the "Norwegian" articles had co-authors from the USA. Next follow Germany, UK and China, with proportions of 14%, 14%, and 10%, respectively.

Of all the "Norwegian" publications within the field, 71% had co-authors from other countries as well. Thus, the extent of international collaboration is wide. Apparently, the large majority of the Norwegian research is carried out in collaboration with scientists from other countries.

Table 3.3. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
USA	2576	17 %	Canada	724	5 %
Germany	2155	14 %	Russia	652	4 %
UK	2059	14 %	Australia	622	4 %
China	1541	10 %	Japan	562	4 %
France	1415	9 %	India	550	4 %
Sweden	1193	8 %	Finland	535	4 %
Italy	1020	7 %	Belgium	434	3 %
Spain	868	6 %	Poland	394	3 %
Denmark	834	6 %	Austria	360	2 %
Netherlands	793	5 %			
Switzerland	731	5 %	Total	10721	71 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles.

The proportion of international collaboration differs somewhat across disciplines within the natural sciences. This is shown in Figure 3.8. However, in all fields, Norwegian research has a strong international orientation with extensive collaboration with researchers in other countries. Electronics and cybernetics is a deviating case, with less such collaboration. Still even in this discipline, half of the publications involved co-authorship with researchers from abroad.

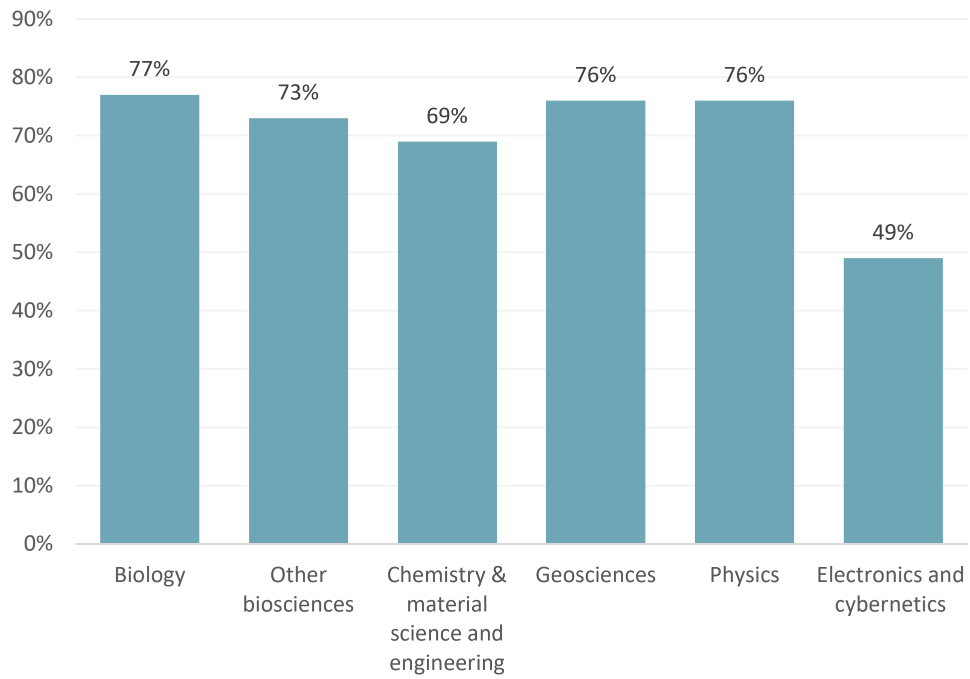

Figure 3.8. Proportion of international collaboration of disciplines encompassed by the two present evaluations, 2019—2021 figures.

3.4 National collaboration

Figure 3.9 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together.

Apparently, the clusters reflect both geographical and thematical proximities. For example, there are close links between the Norwegian University of Science and Technology and SINTEF, University of Bergen and NORCE; and the Arctic University of Norway and the University Centre in Svalbard.

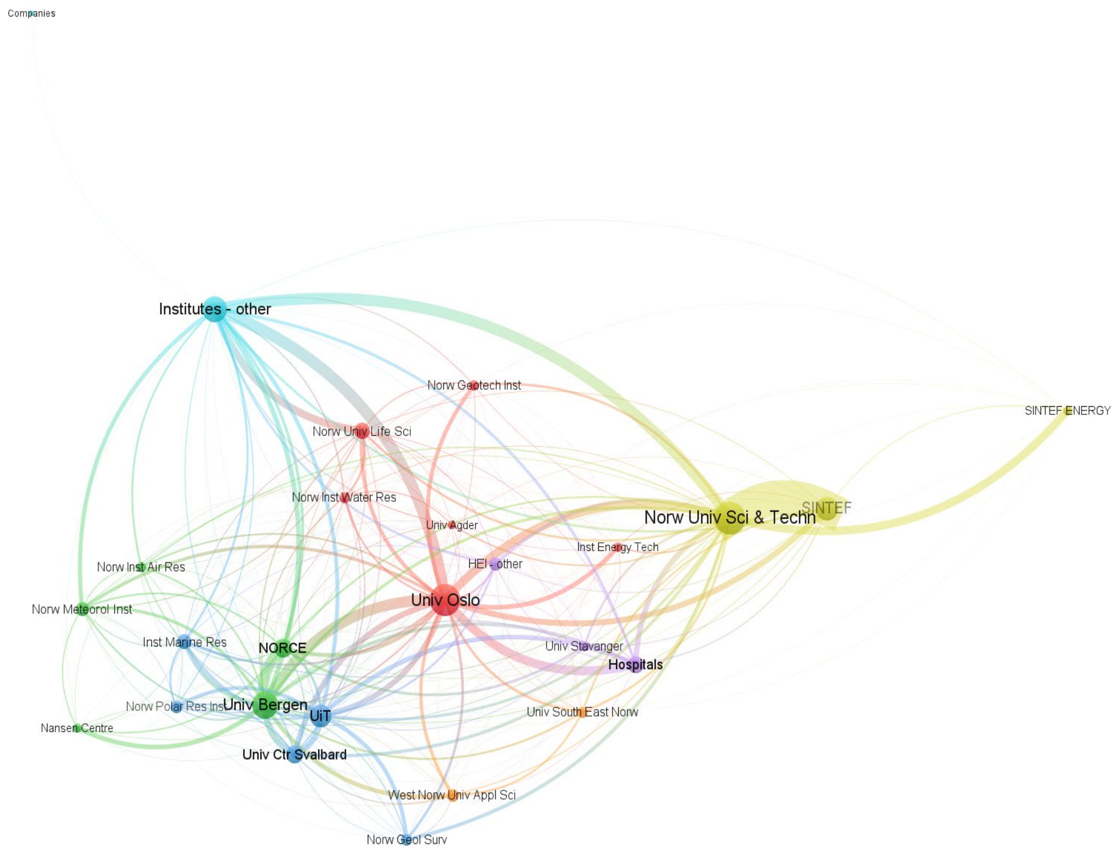

Figure 3.9. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021

3.5 Scientific publishing – number of researchers

This subchapter presents a short analysis of the number of authors contributing to the scientific publications. Included in the figures are authors affiliated with Norwegian institutions and institutes. This gives an overview of the size of the population which are active researchers and publish scientifically; how this varies across fields and develops over time. Thus, it provides a complementary view to the analysis of research personnel presented in a separate report to the evaluation. In order to provide a comparative view, we have also shown results for disciplines which are covered by the other evaluation.

It should be noted that the publication productivity at the level of individuals is highly skewed. A small proportion of researchers are extremely productive, while many have few publications. This pattern is common in all research fields. Moreover, some of the contributors may not have a research position (e.g. technicians, physicians, and students), and some of them may be researchers mainly publishing in other fields. In the analysis all individuals are included, but these facts should be taken into consideration when interpreting the results.

Figure 3.10 shows how the number has developed during the recent 10-year period. In 2021 the number of publication active individuals is highest 3,610 in biology in 2021 and even higher in other biosciences: 4,170 (some individuals will appear in several categories so the numbers should not be added). Geosciences follows with 2,920 individuals. The smallest disciplines are physics and electronics and cybernetics, but the latter field has passed physics the recent years.

There is a notable increase in number of individuals contributing to scientific publishing in all disciplines. In geosciences this number has increased by more than 1,600 persons during the 10-year period. Thus, the number of active researchers is much higher than in the past.

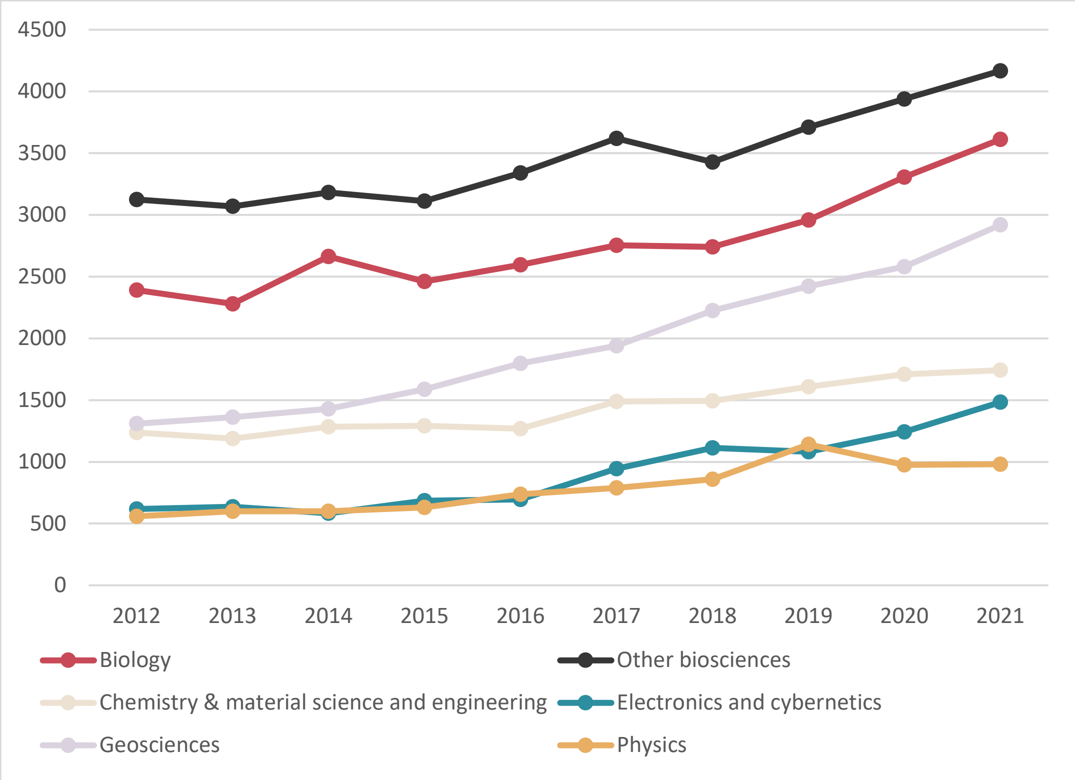

Figure 3.10. Number of individuals contributing to scientific publications by discipline and year, 2012-2021.

In relative terms, the number of individuals has increased with 140% in electronics and cybernetics and 123% in geosciences. Thus, these disciplines have a very strong growth and have more than doubled during the period. This is shown in Figure 3.11. The other disciplines shown in the figure, have a more moderate growth rate. The figure also shows calculations for the period 2017-2021. Generally, the increase in this period has been more limited in all disciplines.

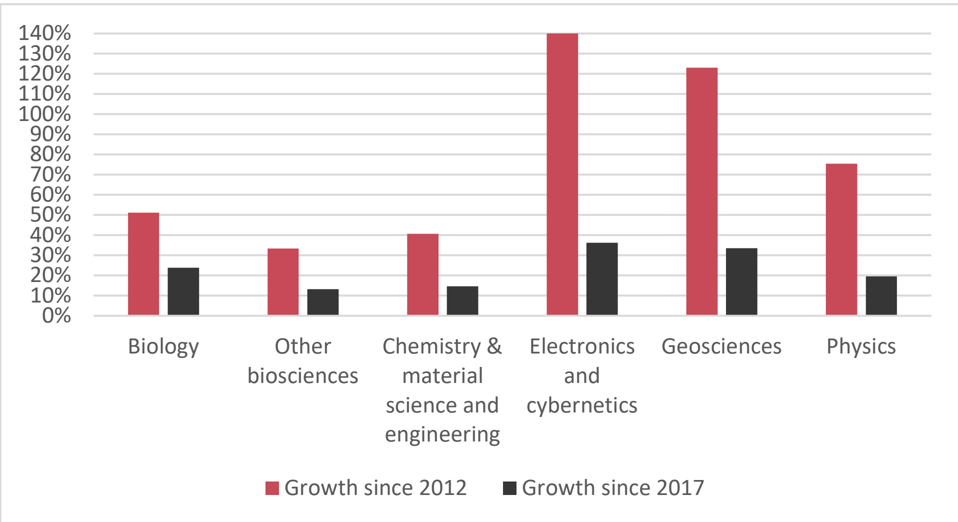

Figure 3.11. Relative growth in the number of individuals contributing to scientific publications by discipline, 2012-2021 and 2017-2021.

Figure 3.12 shows how the researchers are distributed across the two sectors represented in the evaluation: the HE- sector and the institute sector (contributions from other sectors are not included). As expected, a large majority of the individuals are affiliated with the HE-sector. This holds for all disciplines shown in the figure. However, the institute sector also plays a significant role, particularly in biology and geosciences.

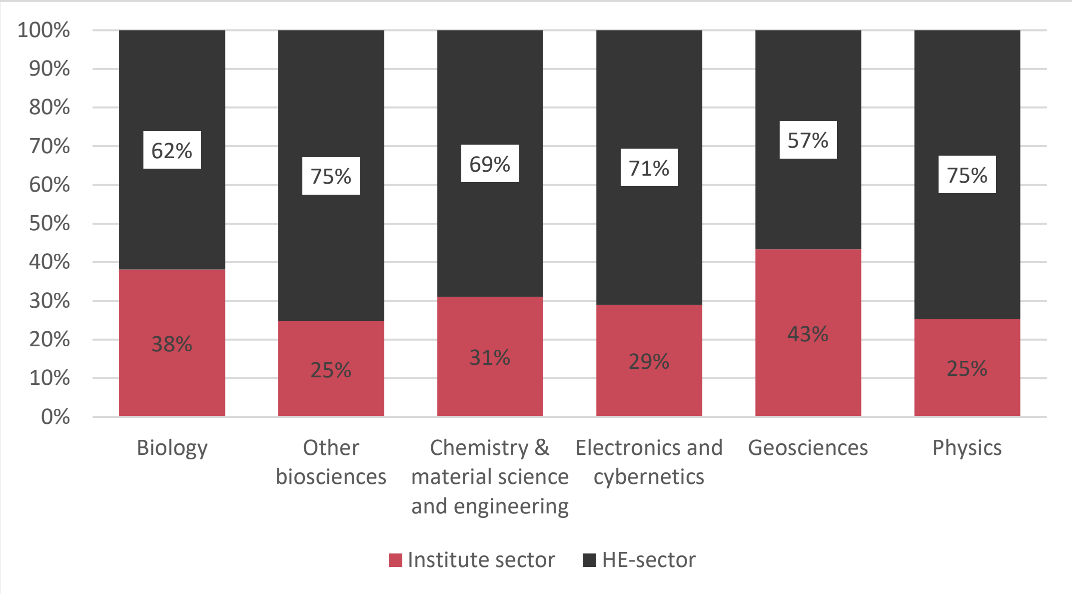

Figure 3.12. Proportion of individuals contributing to scientific publications per sector and discipline, 2021.

4 Chemistry & materials science and engineering

This chapter gives an overview of the Norwegian publication output in chemistry and materials science and engineering, as delineated in the classification system of the Norwegian Association of Higher Education Institutions (UHR) and National Academic Council for Chemistry, see: https://npi.hkdir.no/fagfeltoversikt/fagfelt?id=1157.

The analysis covers all publications with Norwegian contributors within this field, not only publications from the units included in the evaluation. Overall, the evaluated units account for 58.4 % of all chemistry and material sciences publishing in Norway. Thus, a considerable part of the publications within the field as it is delineated here are produced by units which are not part of the present evaluation. These are units which have decided not to participate in the evaluation or will participate in the next evaluation (mathematics, ICT and technology). In addition, publications are also produced by researchers affiliated with other units than the core departments and institutes in the field.

4.1 Publication output

4.1.1 General trend

Figure 4.1 shows the development of publication output for chemistry and materials science in the last decade. It shows an increase in the number of publications from 857 in 2012 to 1 291 in 2021, which corresponds to a relative growth of 51%. Measured by fractionalised counts (modified author shares), the growth is less strong (+22%), an indication of increasingly collaborative authoring in the field during the period. Most of the growth is appearing the recent five years, while the publication volume was relatively stable during the years 2012-2016.

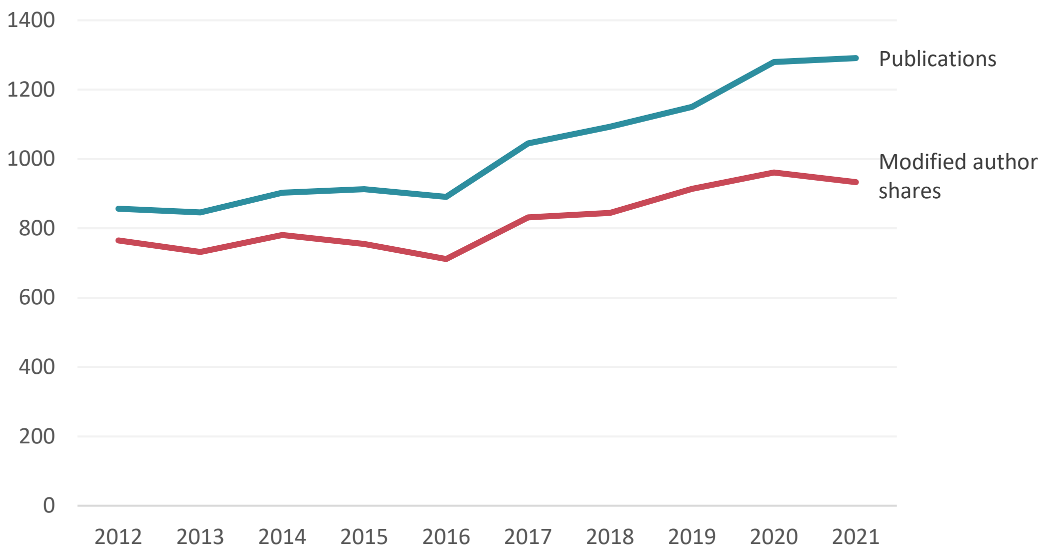

Figure 4.1. Publishing volume and sum of modified author shares for Norwegian chemistry and materials science and engineering research 2012-2021.

There has also been a general increase in the Norwegian publication output the recent decade. Figure 4.2 shows the growth in scientific publishing in chemistry and materials science against the general growth of all Norwegian publishing (all fields combined). As can be seen, the increase in chemistry and materials science publications closely aligns with the general growth trend of Norwegian scientific publishing. Thus, the growth rate of this field is almost equal to the average for all fields.

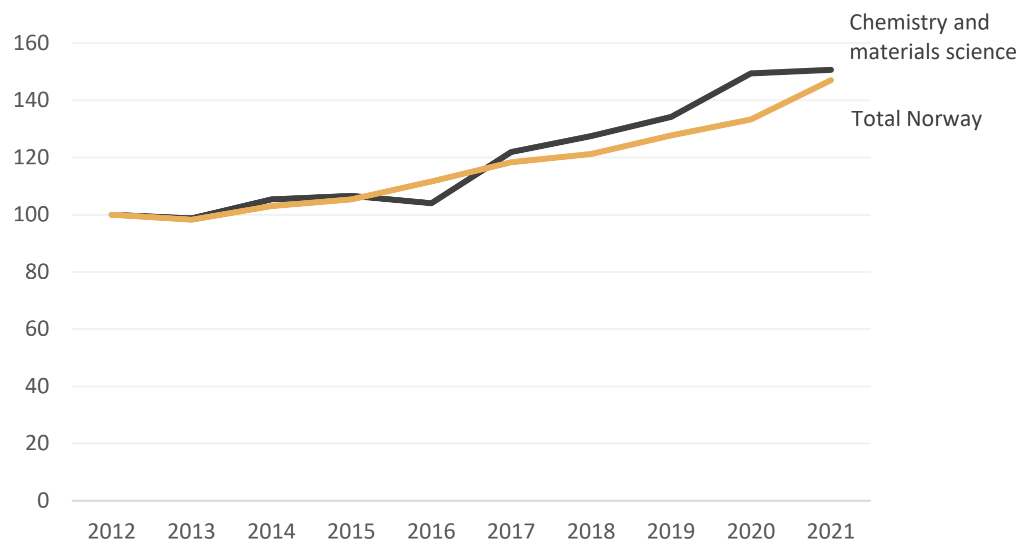

Figure 4.2. Relative growth in number of publications, chemistry and materials science and engineering and total Norwegian publishing, 2012-2021. 2012=100.

4.1.2 Most publishing institutions

Table 4.1 shows the top five contributors to scientific publishing in chemistry and materials science in Norway by sector, using 2021-figures. Having 76 % of the total author contributions, the university and college sector is the biggest contributor to chemistry and materials science publishing in Norway. Particularly large is the Norwegian University of Science and Technology, which accounts for 39 % of all publishing in chemistry and materials science alone. Independent research institutions account for 22 % of author contributions in the chemistry and materials science, university hospitals and other health institutions contribute with 2 %. Various industry and public sector entities make up a negligible share of chemistry and materials science publications.

Table 4.1. Most publishing institutions in chemistry and materials science and engineering, by sector, 2021.

Sector	Institution	Publications	Modified author shares	Share of total
Health	Hospitals and health institutions	30	11.0	2 %
Research institutes	SINTEF	193	104.7	12 %
	Institute for Energy Technology	49	28.2	3 %
	SINTEF Energy	22	12.7	1 %
	NOFIMA	10	7.6	1 %
	The Norwegian Institute of Bioeconomy Research	9	3.7	1 %
	Other research institutes	63	29.2	4 %
Universities and colleges	Norwegian University of Science and Technology	608	387.3	39 %
	University of Oslo	236	137.5	15 %
	University of Stavanger	94	69.6	6 %
	UiT - The Arctic University of Norway	66	40.5	4 %
	University of Bergen	51	30.3	3 %
	Other universities and colleges	130	72.3	8 %

4.1.3 Publishing venues

The publications are distributed across a large number of different journals. However, the frequency distribution is skewed, and some journals account for a substantial amount of the publication output. Figure 4.3 shows the most common journals for publishing chemistry and materials science research in Norway in 2021. In total, these 15 journals account for 28 % of chemistry and materials science publishing. 25.5 % of all chemistry and materials science publications were published in journals that are placed on level 2 in the Norwegian journal classification system.

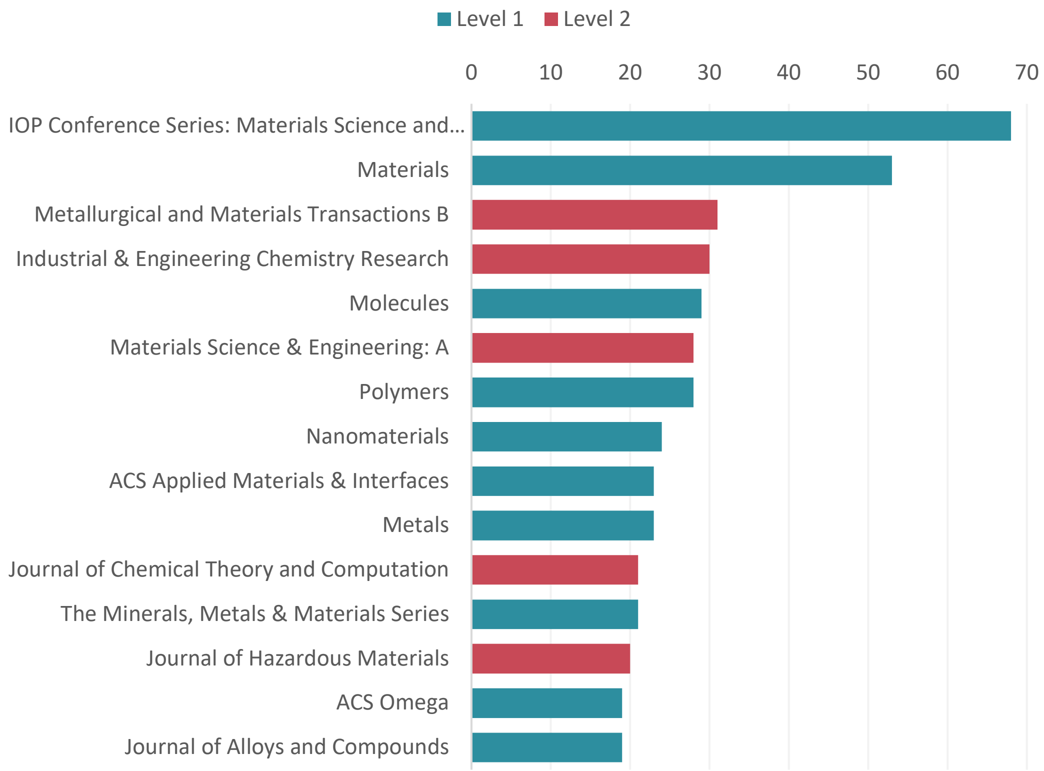

Figure 4.3. Most common publishing venues of chemistry and material sciences, 2021

4.1.4 Field distribution

Figure 4.4 shows how Norwegian chemistry and materials science publications are distributed among research fields as classified by Web of Science. This gives an impression of the field profile of Norwegian research, as defined in the project. The most important WoS fields that fall under the chemistry and materials science umbrella are Materials science, multidisciplinary and chemistry, physical.

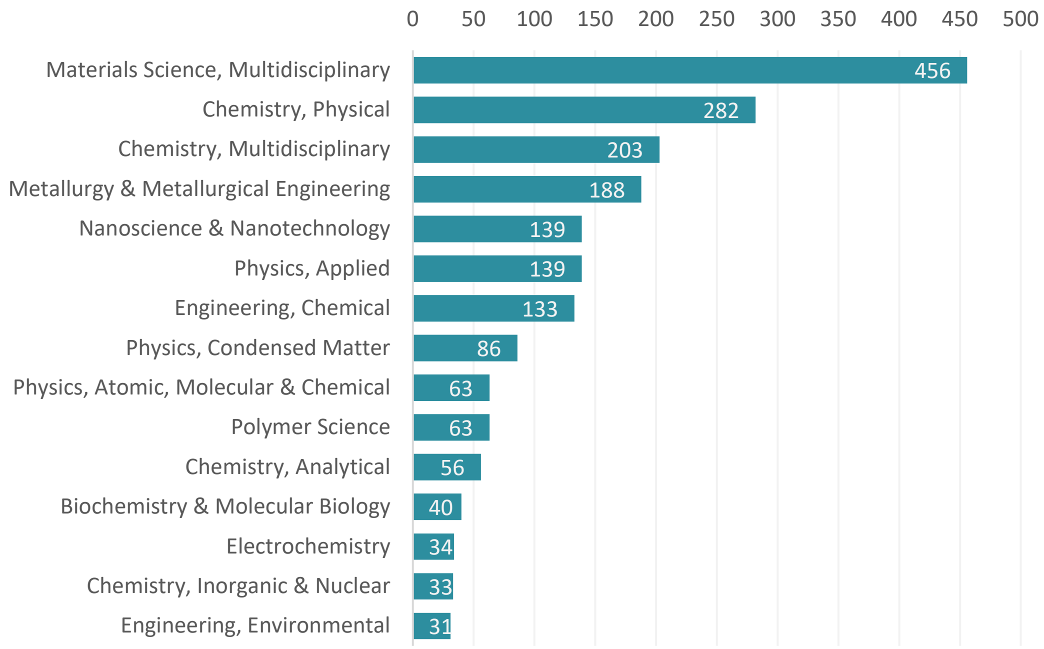

Figure 4.4. Web of Science field distribution of publications within chemistry and material sciences journals in the Norwegian journal classification system, 2021.

4.2 Citation indicators

There are many different indicators of the citation impact of a publication, but two of the most common are 1) Mean normalized citation score (MNCS), where the citation count of a publication is compared to the average number of citations received by publications within the same field and from the same year, and 2) citation percentile, which is a publication's percentile position in a list of all publications from a given field and publication year ordered by citation count.

Figure 4.5 shows the average MNCS for all chemistry and materials science publishing in Norway 2012-2020, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

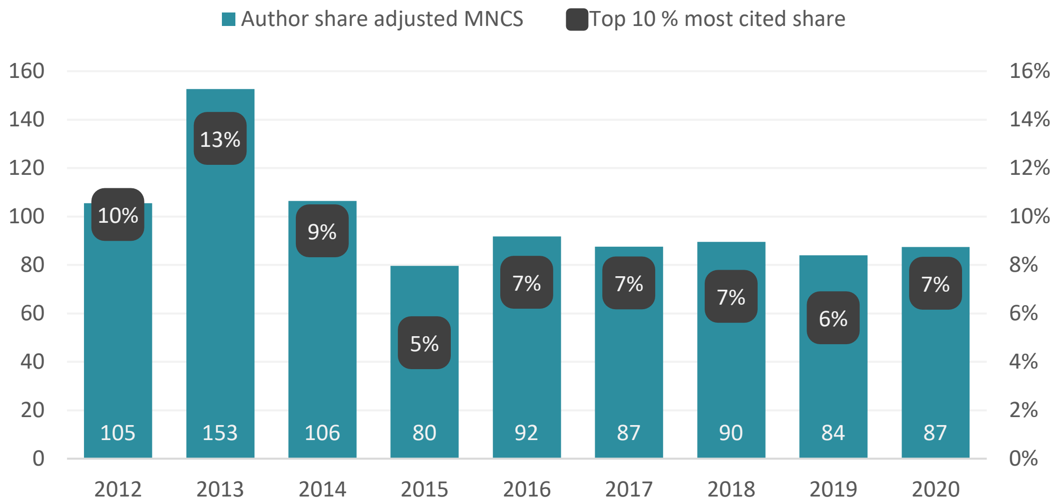

Figure 4.5. MNCS of chemistry and materials science and engineering, publications (left axis, 100 = global mean citation score for publications from same field and year) and share of publications among the 10 % most highly cited publication from same field and year (right axis), 2012-2020.

In general, Norwegian chemistry and materials science research is cited below the global average in recent years, with the average MNCS for all years being 98.3 and the share of author contributions that fall within the top 10 % most cited publications being 8 %. In terms of citation impact Norwegian chemistry and materials science research performs below the national average.

Figure 4.6 shows the similar indicator for the publications that fall under the category, but using the more fine-grained WoS-classification system (cf. Figure 4.4). Various forms of materials science have the highest citation impact, while organic chemistry and crystallography have the lowest, with an MNCS of 69.7 and 43.8, respectively (not shown in the figure).

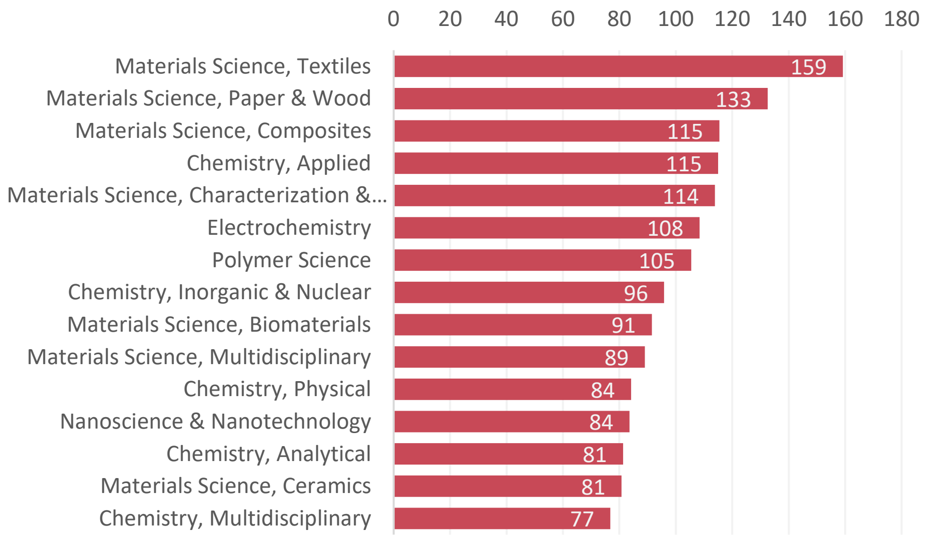

Figure 4.6. MNCS of 15 most impactful Web of Science subfields within Norwegian chemistry and material sciences publications, 2018-2020.

Table 4.2 shows which countries can be said to have publications with the highest average citation impact for the period 2018-2020, adjusted for the size of their author contributions to these publications. Only countries with at least 2 000 author shares have been included. While such rankings in the past were dominated by Western countries, Asian and Arabic countries have made their mark in recent years, due to major scientific investments, more international research collaboration, and hiring of esteemed foreign scientists. On the top of the list, we find Singapore. Norway is the 35th most impactful country in chemistry and materials science of a total consisting of the 63 largest countries.

Table 4.2. Author share adjusted MNCS of most impactful countries in chemistry and materials science, including Norway, 2018-2020.

Position	Country	Modified author shares	MNCS
1	Singapore	27100	206
2	Australia	50475	151
3	Saudi Arabia	23626	147
4	China	1342017	135
5	Switzerland	25968	130
6	USA	368967	127
7	Qatar	2367	121
8	Canada	48381	115
9	UK	83503	113
35	**Norway**	**6450**	**87**

4.3 International collaboration

Which countries are the most important collaborative partners for Norway in chemistry and materials science & engineering? To answer this, the distribution of co-authorship by country has been analysed. Table 4.3 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. China is the most important collaboration nation. In total, 12% of the "Norwegian" articles had co-authors from China. Next follow Germany, USA, and UK, with proportions of 10%, 9%, and 7%, respectively.

Of all the "Norwegian" publications within the fields, 69% had co-authors from other countries as well. This is slightly below the average for the natural sciences, all fields combined (those included in this report), which is 71%.

Table 4.3. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
China	457	12 %	Netherlands	105	3 %
Germany	377	10 %	Japan	101	3 %
USA	328	9 %	Iran	99	3 %
UK	261	7 %	Poland	95	2 %
Sweden	219	6 %	Belgium	90	2 %
Italy	214	6 %	Switzerland	89	2 %
France	208	5 %	Australia	82	2 %
India	176	5 %	Canada	78	2 %
Spain	173	5 %	South Korea	78	2 %
Denmark	169	4 %			
Russia	138	4 %	Total	2624	69 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles.

4.4 National collaboration

Figure 4.7 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together.

There are very close links between the two main contributors, the Norwegian University of Science and Technology (NTNU) and SINTEF. In another cluster is

University of Oslo the largest unit with the strongest collaborative link to Institute of Energy Technology (IFE), in addition to SINTEF and NTNU.

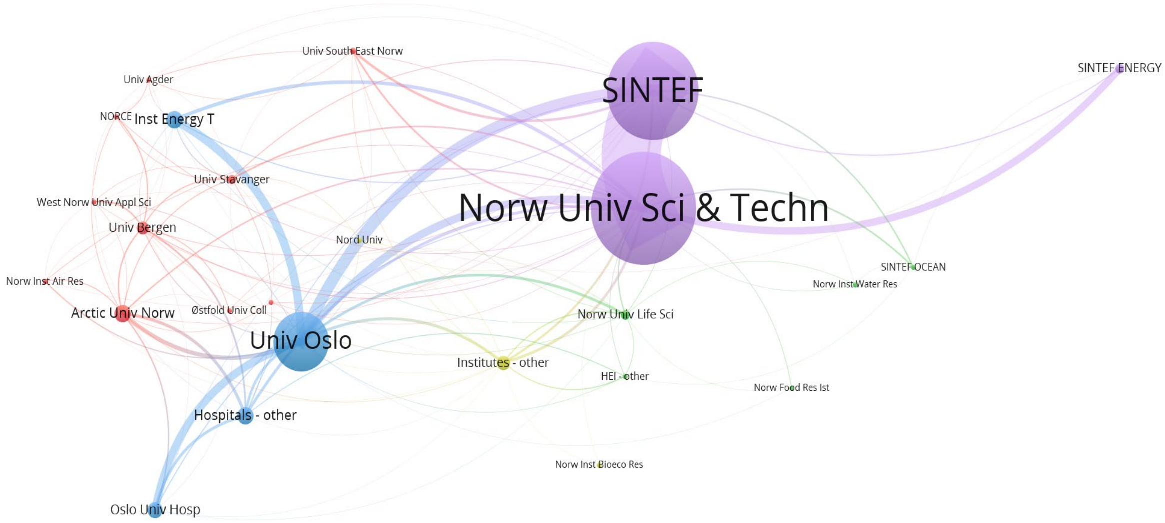

Figure 4.7. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021

5 Geosciences

This chapter gives an overview of the Norwegian publication output in geosciences, as delineated in the classification system of the Norwegian Association of Higher Education Institutions (UHR) and the National Academic Council for Geosciences, see: https://npi.hkdir.no/fagfeltoversikt/fagfelt?id=1155.

The analysis covers all publications with Norwegian contributors within this field, not only publications from the units included in the evaluation. Overall, the evaluated units account for 73.9 % of all publications in the field of geosciences in Norway. Thus, approximately one quarter of the publications within the field as it is delineated here are produced by units which are not part of the present evaluation. These are units which have decided not to participate in the evaluation or will participate in the next evaluation (mathematics, ICT and technology). In addition, publications are also produced by researchers affiliated with other units than the core departments and institutes in the field.

5.1 Publication output

5.1.1 General trend

Figure 5.1 shows the development of publication output for the geosciences in the last decade. The annual number of publications has increased significantly from 1 103 in 2012 to 2 034 in 2021, which corresponds to a relative growth of 84%. Measured by fractionalized counts (modified author shares) the growth is however less strong (+70 %), an indication of increasingly collaborative authoring in the geosciences in the period.

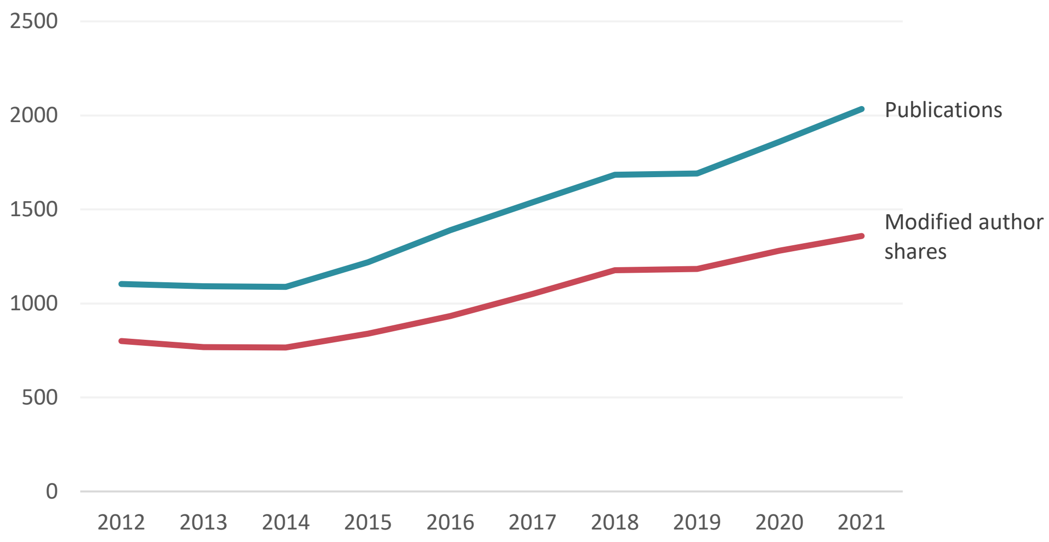

Figure 5.1. Publishing volume and sum of modified author shares for Norwegian geosciences research 2012-2021.

There has also been a general growth in the Norwegian publication output the recent decade. Figure 5.2 shows the growth in scientific publishing in the geosciences compared with the general increase of all Norwegian publishing (all fields combined). As can be seen, the growth in geosciences publishing outpaces the general publishing growth significantly in the period since 2015. The increase for the ten-year period is 84% and 47%, respectively. Thus, the relative position of the field in the overall national research landscape is strengthened, measured by publication volume.

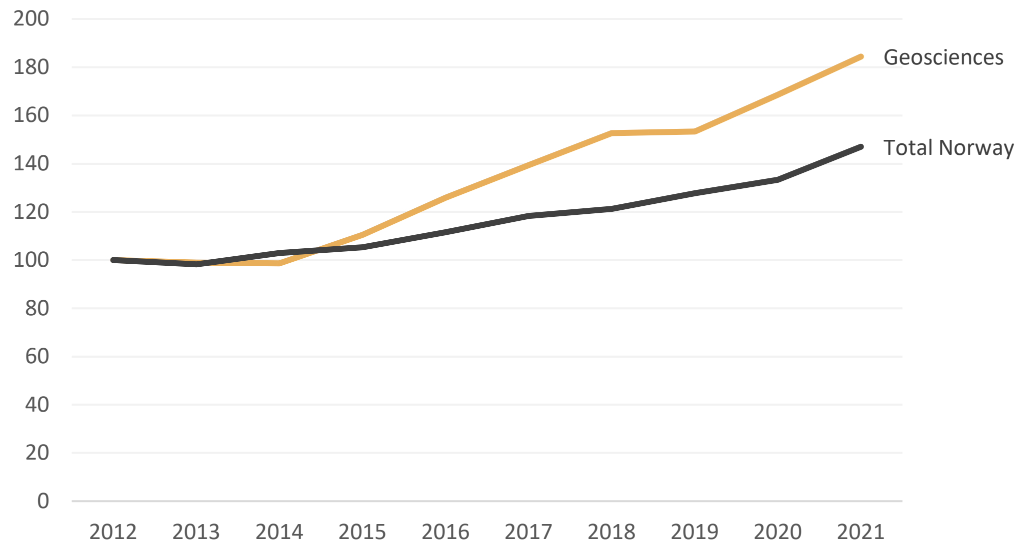

Figure 5.2. Relative growth in number of publications, geosciences and total Norwegian publishing, 2012-2021. 2012=100.

5.1.2 Most publishing institutions

Table 5.1 shows the top five contributors to scientific publishing in the geosciences in Norway by sector. Having 60 % of the total author contributions, the university and college sector is the biggest contributor to geosciences publishing in Norway. The distribution of publishing volume among the most productive institutions is in line with the general publishing distribution among the largest universities in Norway. Independent research institutes account for most of the rest of author contributions in the geosciences at 39 %. Various industry and public sector entities contribute together to 1 % of geosciences publications.

Table 5.1. Most publishing institutions in geosciences by sector, 2021.

Sector	Institution	Publications	Modified author shares	Share of total
Research institutes	Norwegian Institute of Marine Research	84	44.6	3 %
	Norwegian Meteorological Institute	95	43.9	3 %
	NORCE	105	39.8	4 %
	Norwegian Institute for Water Research	82	39.4	3 %
	Geological Survey of Norway	79	38.3	3 %
	Other research institutes	624	312.2	23 %
Universities and colleges	University of Oslo	410	193.3	15 %
	Norwegian University of Science and Technology	301	179.7	11 %
	University of Bergen	345	168.8	13 %
	UiT - The Arctic University of Norway	236	113.3	9 %
	Norwegian University of Life Sciences	92	42.5	3 %
	Other universities and colleges	282	138.6	10 %

5.1.3 Publishing venues

The publications are distributed across a large number of different journals. However, the frequency distribution is skewed, and some journals account for a substantial amount of the publication output. Figure 5.3 shows the most common journals for publishing geosciences re-search in Norway in the most recent year, 2021. In total, these 15 journals account for 38.8 % of geosciences publishing. 33.7 % of all geosciences publications were published in journals that are placed on level 2 in the Norwegian journal classification system.

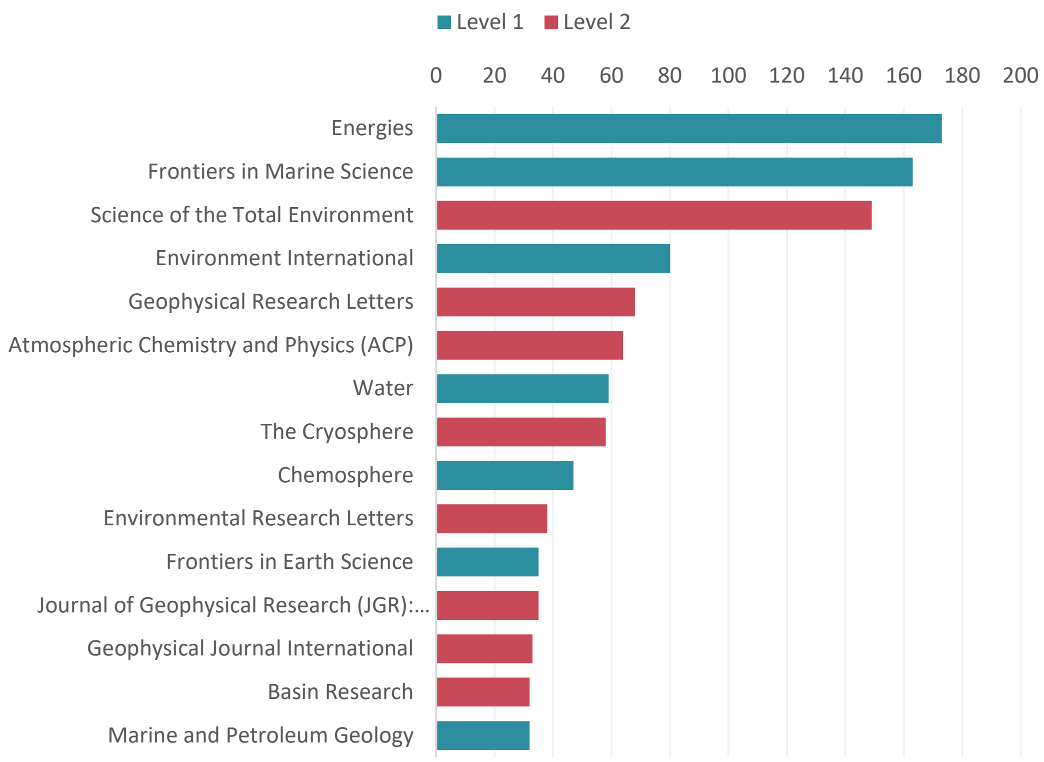

Figure 5.3. Most common publishing venues of geosciences, 2021.

5.1.4 Field distribution

Figure 5.4 shows how Norwegian geosciences publications are distributed among research fields as classified by Web of Science. This gives an impression of the field profile of Norwegian geosciences as defined in the project.

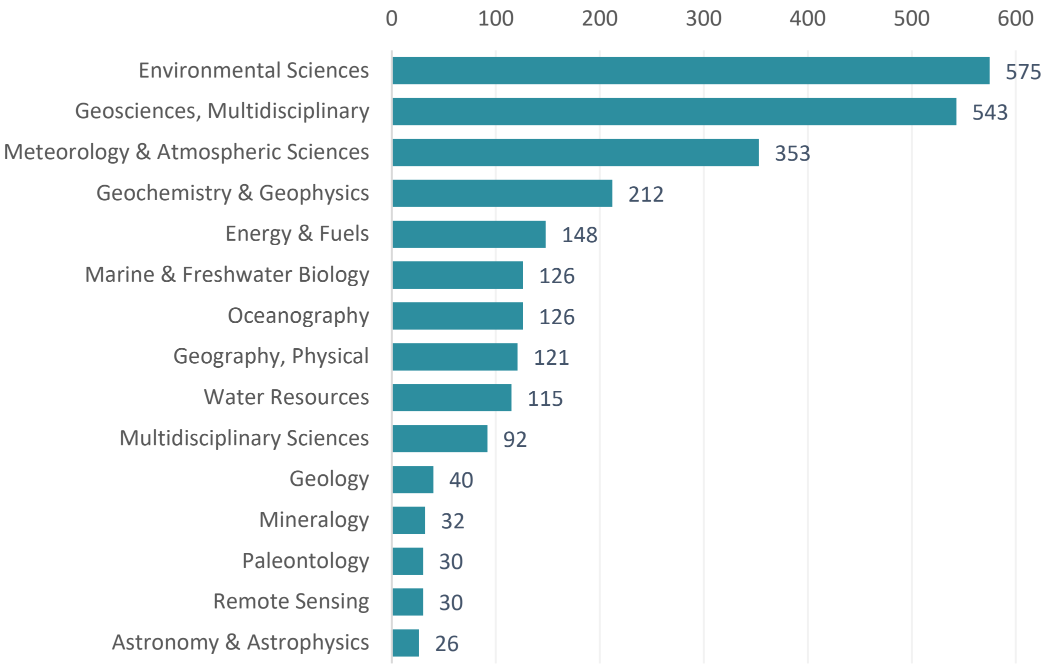

Figure 5.4. Web of Science field distribution of publications within geosciences journals in the Norwegian journal classification system, 2021.

5.2 Citation indicators

There are many different indicators of the citation impact of a publication, but two of the most common are 1) Mean normalized citation score (MNCS), where the citation count of a publication is compared to the average number of citations received by publications within the same field and from the same year, and 2) citation percentile, which is a publication's percentile position in a list of all publications from a given field and publication year ordered by citation count.

Figure 5.5 shows the average MNCS for all geosciences publishing in Norway 2012-2020, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

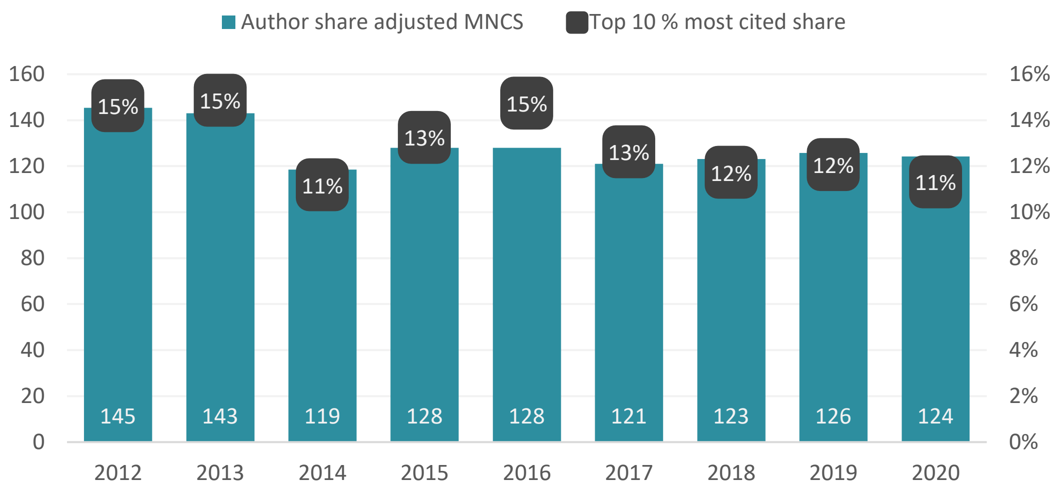

Figure 5.5. MNCS of geosciences, publications (left axis, 100 = global mean citation score for publications from same field and year) and share of publications among the 10 % most highly cited publication from same field and year (right axis), 2012-2020.

In general, Norwegian geosciences research is above the global average for all years, with the average MNCS-score for all years being 128.6 and the share of author contributions that fall within the top 10 % most cited publications being 12.9 %. The world average is, however, not a very ambitious reference standard, and most Western countries have citation indexes significantly above this average. Still, in terms of citation impact Norwegian geoscience research performs above also the national average.

Figure 5.6 shows the similar indicator for the publications that fall under the geosciences category, but using the more fine-grained WoS-classification system (cf. Figure 5.4). Several subfields are well above the global average, with meteorology and geology having particularly high citation impact. Mineralogy is the only subfield where citation impact is below the global average.

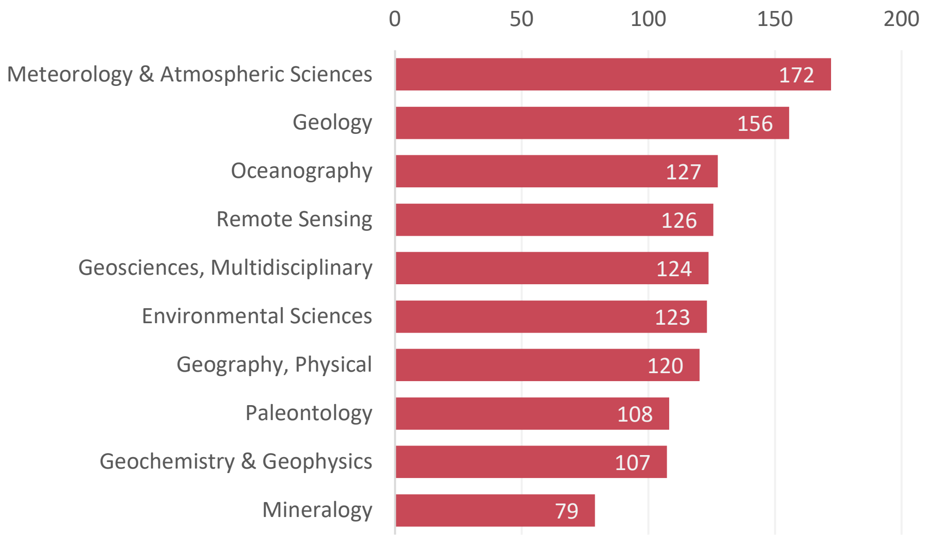

Figure 5.6. MNCS scores of Web of Science subfields within Norwegian geosciences publications, 2018-2020.

Table 5.2 shows which countries can be said to have publications with the highest average citation impact for the period 2018-2020, adjusted for the size of their author contributions to these publications. Only countries with at least 2 000 author shares have been included. While such rankings in the past were dominated by Western countries, Asian and Arabic countries have made their mark in recent years, due to major scientific investments, more international research collaboration, and hiring of esteemed foreign scientists. On the top of the list, we find Singapore. Norway is the 7th most impactful country in geosciences of a total consisting of the 57 largest countries.

Table 5.2. Author share adjusted MNCS of most impactful countries in geosciences, including Norway, 2018-2020

Position	Country	Modified author shares	MNCS
1	Singapore	3122	153
2	Vietnam	3224	142
3	UK	46289	139
4	Netherlands	15259	139
5	Switzerland	12308	138
6	Australia	34427	128
7	**Norway**	**9464**	**127**
8	Austria	6643	126
9	Denmark	6546	125
10	Belgium	7657	122

5.3 International collaboration

Which countries are the most important collaborative partners for Norway in geosciences? To answer this, the distribution of co-authorship by country has been analysed. Table 5.3 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. The USA is the most important collaboration nation. In total, 22% of the "Norwegian" articles had co-authors from the US. Next follow UK, Germany, and France, with proportions of 20%, 18%, and 12%, respectively.

Of all the "Norwegian" publications within the fields, 76% had co-authors from other countries as well. This is above the average for the natural sciences, all fields combined (those included in this report), which is 71%.

Table 5.3. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
USA	1438	22 %	Switzerland	423	6 %
UK	1324	20 %	Spain	421	6 %
Germany	1201	18 %	Finland	318	5 %
France	805	12 %	Russia	306	5 %
China	707	11 %	Japan	294	4 %
Sweden	608	9 %	Belgium	237	4 %
Netherlands	528	8 %	Austria	216	3 %
Denmark	523	8 %	Poland	197	3 %
Canada	483	7 %	South Africa	164	3 %
Italy	469	7 %			
Australia	424	6 %	Total	4992	76 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles.

5.4 National collaboration

Figure 5.6 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together.

We observe that the four traditional universities are the main node in four different clusters. There are string links between the Norwegian University of Science and Technology and SINTEF; University of Bergen and NORCE; Arctic University of Norway and the University Centre in Svalbard.

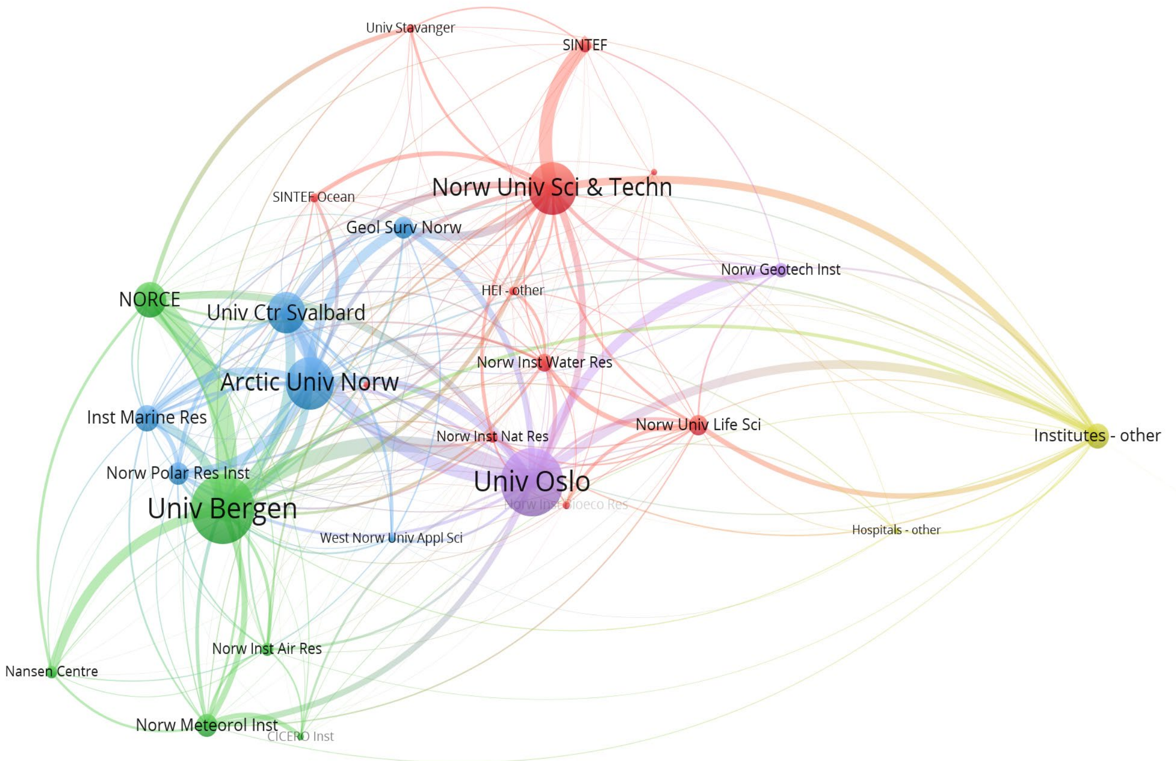

Figure 5.7. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021

6 Physics

This chapter gives an overview of the Norwegian publication output in physics, as delineated in the classification system of the Norwegian Association of Higher Education Institutions (UHR) and the National Academic Council of Physics, see: https://npi.hkdir.no/fagfeltoversikt/fagfelt?id=1037.

The analysis covers all publications with Norwegian contributors within this field, not only publications from the units included in the evaluation. Overall, the evaluated units account for 75.3 % of all publications in the field of physics in Norway. Thus, approximately one quarter of the publications within the field as it is delineated here are produced by units which are not part of the present evaluation. These are units which have decided not to participate in the evaluation or will participate in the next evaluation (mathematics, ICT and technology). In addition, publications are also produced by researchers affiliated with other units than the core departments and institutes in the field.

6.1 Publication output

6.1.1 General trend

Figure 6.1 shows the development of publication output for physics in the last decade. The number of publications has increased from 629 in 2012 to 4 912 in 2021, this corresponds to a relative growth of 45%. However, the number has decreased the two recent years and the output in 2019 is 15 % higher than in 2021. Measured by fractionalised counts (modified author shares) the growth over the ten-year period is less strong (+21 %), an indication of increasingly collaborative authoring in physics in the period.

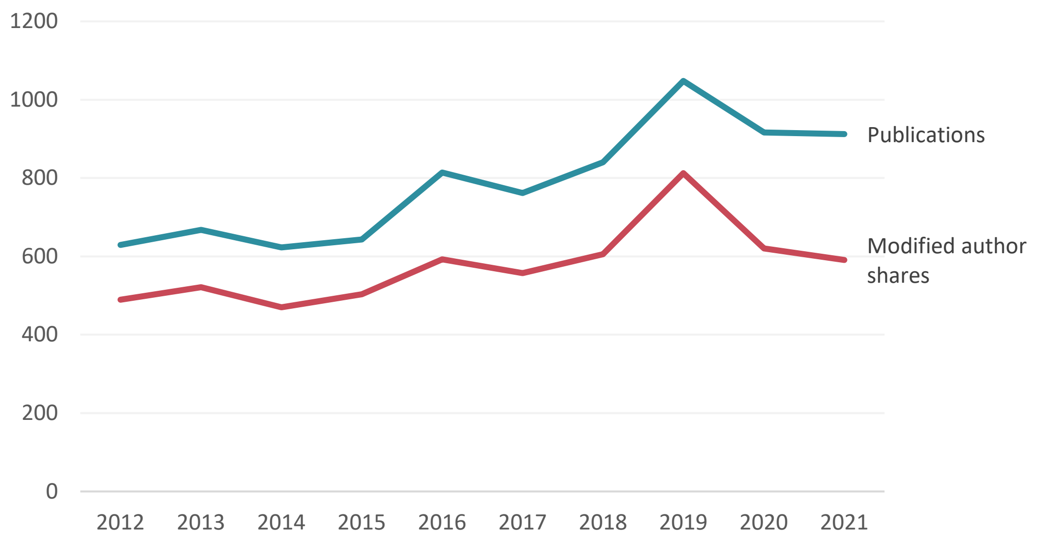

Figure 6.1. Publishing volume and sum of modified author shares for Norwegian physics research 2012-2021.

There has also been general growth in scientific publishing in Norway. Figure 6.2 shows the growth in scientific publishing in physics against the general growth of all Norwegian publishing. As can be seen, the field of physics has experienced a growth pattern more or less in line with the general development in Norwegian scientific publishing over the past decade.

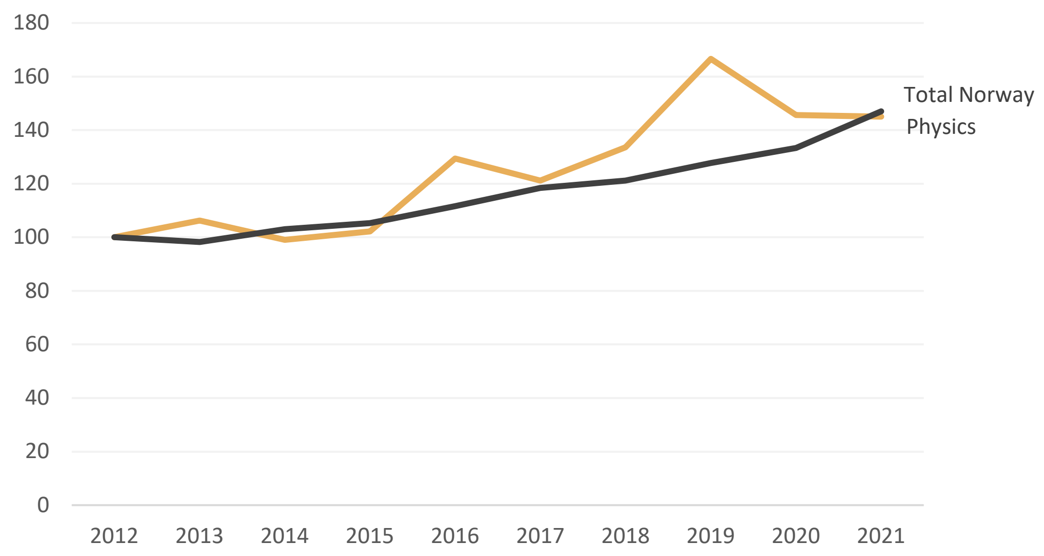

Figure 6.2. Relative growth in number of publications, physics and total Norwegian publishing, 2012-2021. 2012=100.

6.1.2 Most publishing institutions

Table 6.1 shows the top five contributors to scientific publishing in physics in Norway by sector. Physics research in Norway is dominated by universities, which account for 89 % of the total author contributions. University of Oslo is by far the largest institution in terms of publication output. It is notable that Western Norway University of Applied Sciences is among the most productive research institutions within physics. This partly reflects researchers being involved in CERN-collaboration projects. Such papers also contribute substantially to the publication measure of University of Oslo and University of Bergen. However, when using fractionalised measure (modified author shares) the impact of these papers is significantly reduced. Independent research institutions account for 10 % of author contributions in physics, while university hospitals and other health institutions and various industry and public sector entities make up the remaining 1 % of physics publications.

Table 6.1. Most publishing institutions in physics by sector, 2021.

Sector	Institution	Publications	Modified author shares	Share of total
Research institutes	SINTEF	31	19.1	2 %
	Norwegian Geotechnical Institute	20	13.7	2 %
	NORCE	8	4.8	1 %
	Norwegian Meteorological Institute	8	4.6	1 %
	Institute for Energy Technology	9	4.3	1 %
	Other	48	26.3	4 %
Universities and colleges	University of Oslo	453	189.4	35 %
	Norwegian University of Science and Technology	191	125.1	15 %
	University of Bergen	216	90.4	17 %
	Western Norway University of Applied Sciences	68	17.0	5 %
	University of South-Eastern Norway	65	11.7	5 %
	Other	152	82.2	12 %

6.1.3 Publishing venues

The publications are distributed across a large number of different journals. However, the frequency distribution is skewed, and some journals account for a substantial amount of the publication output. Figure 6.3 shows the most common journals for publishing physics research in Norway in the most recent year, 2021. In total, these 15 journals account for 65,9 % of physics publishing. 42,1 % of all physics publications were published in journals that are placed on level 2 in the Norwegian journal classification system.

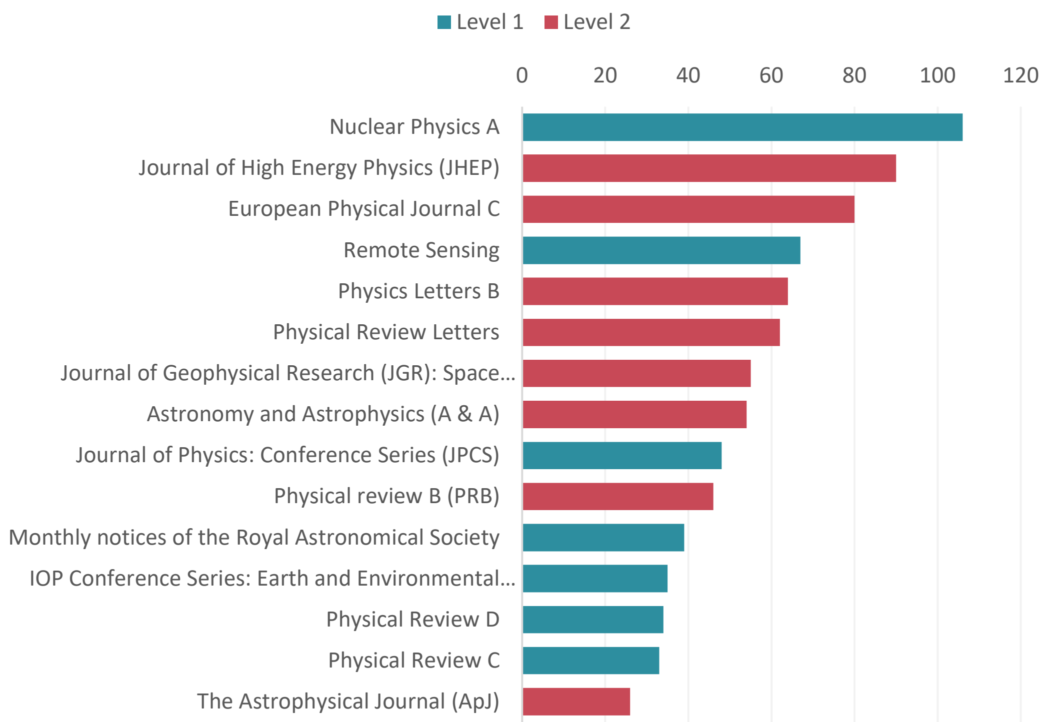

Figure 6.3. Most common publishing venues of physics, 2021.

6.1.4 Field distribution

There is not a complete overlap between the Norwegian journal classification system and that of Web of Science. Figure 6.4 shows how Norwegian physics publications are distributed among research fields as classified by Web of Science. This gives an impression of the field profile of Norwegian physics, as defined in the project. The by far largest category is Astronomy and astrophysics.

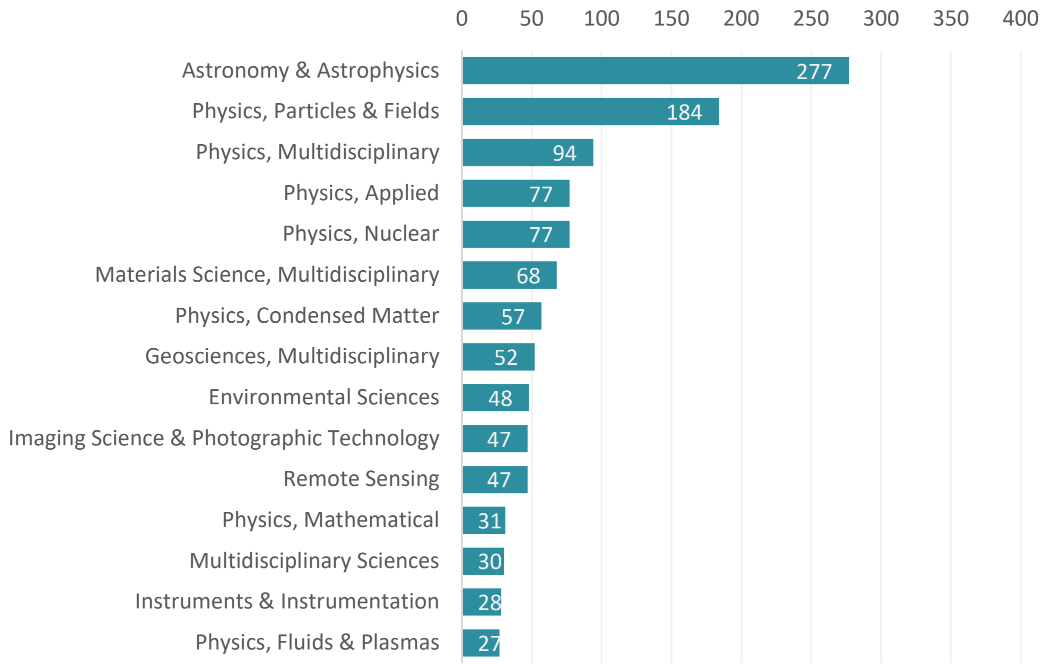

Figure 6.4. Web of Science field distribution of publications within physics journals in the Norwegian journal classification system, 2021.

6.2 Citation indicators

There are many different indicators of the citation impact of a publication, but two of the most common are 1) Mean normalized citation score (MNCS), where the citation count of a publication is compared to the average number of citations received by publications within the same field and from the same year, and 2) citation percentile, which is a publication's percentile position in a list of all publications from a given field and publication year ordered by citation count.

Figure 6.5 shows the average MNCS for all physics publishing in Norway 2012-2021, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

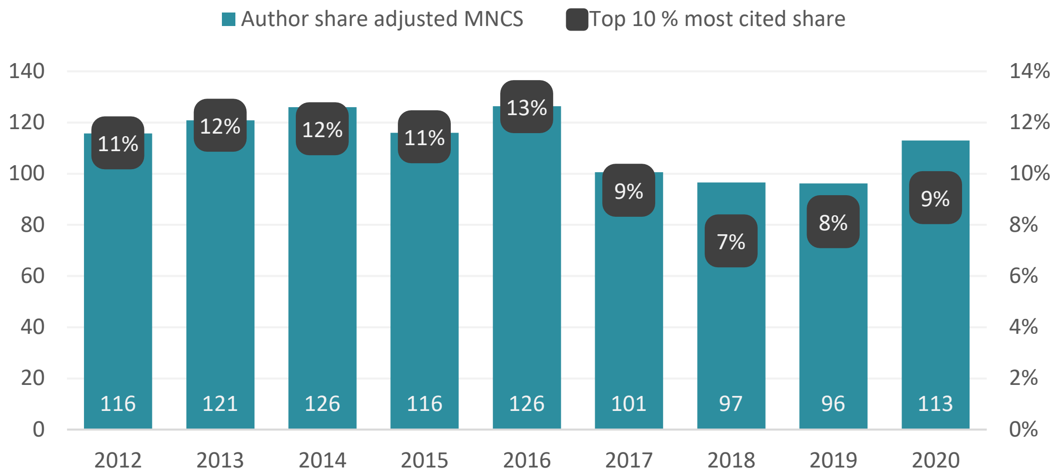

Figure 6.5. MNCS of physics, publications (left axis, 100 = global mean citation score for publications from same field and year) and share of publications among the 10 % most highly cited publication from same field and year (right axis), 2012-2020.

In general, Norwegian physics research is above the global average for all years, with the average MNCS for all years being 112,4 and the share of author contributions that fall within the top 10 % most cited publications being 10,3 %. There is a drop in citation impact from the year 2017 onwards, albeit with a rising trend in the recent years. The MNCS for the recent three-year period is 103. Thus, in terms of citation impact Norwegian physics research performs on par with the global average the recent period.

Figure 6.6 shows the similar indicator for the publications that fall under the physics category, but using the more fine-grained WoS-classification system (cf. Figure 6.4). Publications within particle physics obtain the highest citation index. This can be partly explained by the Norwegian contribution to CERN-papers. Astronomy and nuclear physics also have notably higher citation impact than the global average. At the other end, we find applied and condensed matter physics, which are substantially below the global average.

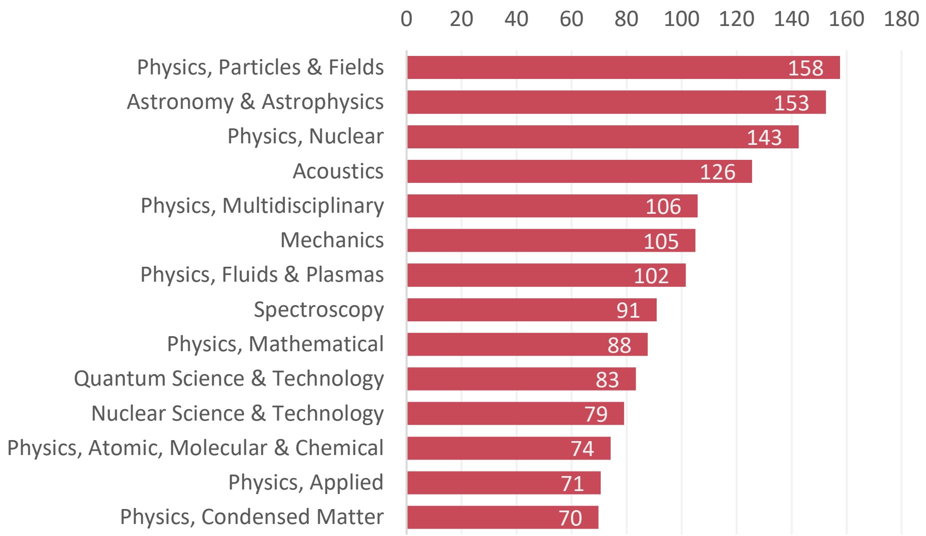

Figure 6.6. MNCS scores of Web of Science subfields within Norwegian physics publications, 2018-2020.

Table 6.2 shows which countries can be said to have publications with the highest average citation impact for the period 2018-2020, adjusted for the size of their author contributions to these publications. Only countries with at least 2 000 author shares have been included. While such rankings in the past were dominated by Western countries, Asian and Arabic countries have made their mark in recent years, due to major scientific investments, more international research collaboration, and hiring of esteemed foreign scientists. On the top of the list, we find Singapore. Norway is the 25th most impactful country in physics globally of a total consisting of the 58 largest countries.

Table 6.2. Author share adjusted MNCS of most impactful countries in physics, including Norway, 2018-2020

Position	Country	Modified author shares	MNCS
1	Singapore	10485	193
2	Australia	23461	154
3	Switzerland	24962	147
4	Saudi Arabia	9933	145
5	USA	254784	142
6	Netherlands	15948	137
7	UK	67658	133
8	Italy	67587	123
9	Germany	103473	122
25	**Norway**	**4594**	**103**

6.3 International collaboration

Which countries are the most important collaborative partners for Norway in physics? To answer this, the distribution of co-authorship by country has been analysed. In order to reduce the effect of "CERN-publications which have an extremely large number of contributors, the analysis is limited to articles with less than 50 authors. Table 6.3 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. The USA is the most important collaboration nation. In total, 24% of the "Norwegian" articles had co-authors from the US. Next follow Germany, UK, and France, with proportions of 18%, 15%, and 13%, respectively.

Of all the "Norwegian" publications within the fields, 76% had co-authors from other countries as well. This is above the average for the natural sciences, all fields combined (those included in this report), which is 71%.

Table 6.3. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
USA	582	24 %	Japan	123	5 %
Germany	434	18 %	Canada	113	5 %
UK	360	15 %	Denmark	98	4 %
France	313	13 %	Finland	93	4 %
Sweden	264	11 %	Netherlands	89	4 %
Italy	243	10 %	Belgium	79	3 %
China	236	10 %	Poland	78	3 %
Spain	189	8 %	Australia	77	3 %
Switzerland	176	7 %	South Korea	76	3 %
Russia	170	7 %			
India	137	6 %	Total	1810	76 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles. In this analysis publications with more than 50 authors have been excluded.

6.4 National collaboration

Figure 6.6 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together. This analysis has been limited to publications with less than 50 authors, as CERN publications otherwise would dominate the picture.

In physics the extent of national collaboration is more limited. University of Bergen is the unit with most extensive national links, in particular to the University of Oslo and West Norway University of Applied Sciences. The Norwegian University of Science and Technology (NTNU) is closely connected to SINTEF which is not labelled in the figure for visibility reasons (blue dot next to NTNU)

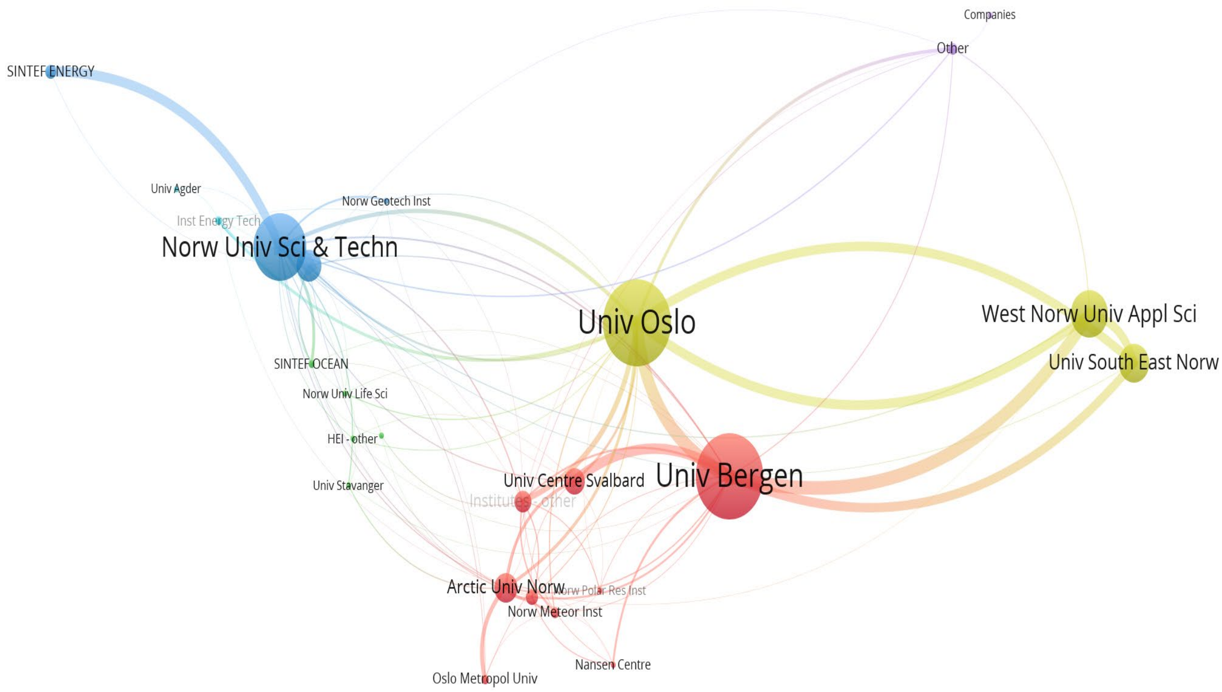

Figure 6.6. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021*

*) In this analysis publications with more than 50 authors have been excluded.

7 Electronics and cybernetics

This chapter gives an overview of the Norwegian publication output in electronics and cybernetics, as delineated in the classification system of the Norwegian Association of Higher Education Institutions (UHR) and the he National Publication Committee for MNT, see: https://npi.hkdir.no/fagfeltoversikt/fagfelt?id=1046.

The analysis covers all publications with Norwegian contributors within this field, not only publications from the units included in the evaluation. Overall, the evaluated units account for 14.1 % of all publications in the field of electronics and cybernetics in Norway. Thus, the large majority of the publications within the field are produced by units which are not part of the present evaluation. Many of the core research units in the field are not included in the present evaluation and most of these units will probably participate in in the next evaluation (mathematics, ICT and technology).

7.1 Publication output

7.1.1 General trend

Figure 7.1 shows the development of publication output for electronics and cybernetics in the last decade. In total the number of publications has increased from 551 in 2012 to 878 in 2021, which corresponds to a relative growth of 59%. The figure also shows fractionalized counts measured as modified author shares. Here the growth rate is almost identical to the one of total publications, an indication that the collaboration patterns in the field in terms of number of authors has not changed.

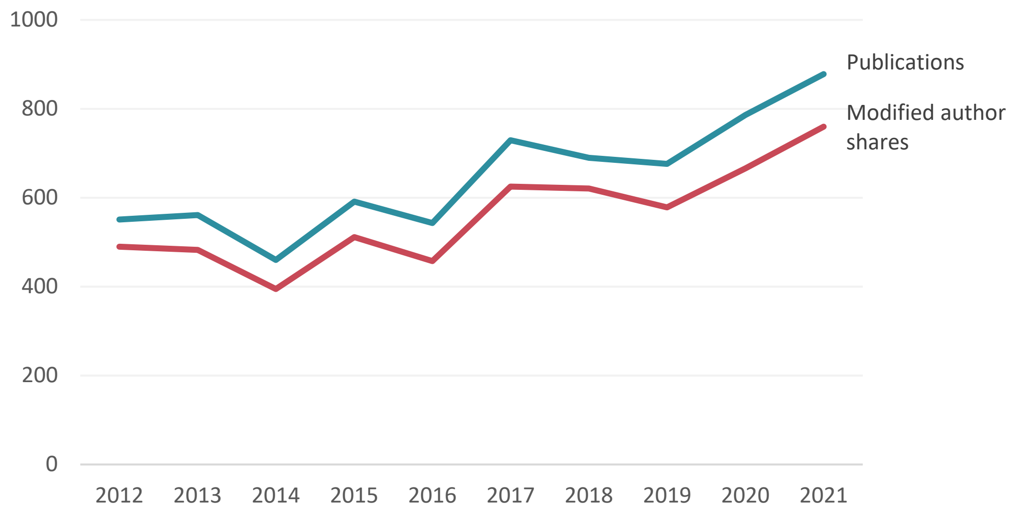

Figure 7.1. Publishing volume and sum of modified author shares for Norwegian electronics and cybernetics research 2012-2021.

There has also been general growth in scientific publishing in Norway. In order to see whether electronics and cybernetics research differs from the general development, Figure 7.2 shows the growth in scientific publishing in the field against the total growth of all Norwegian publishing. As can be seen, the growth in electronics and cybernetics publishing generally tracks the general growth in research output over the period. As can be seen, the field of electronics and cybernetics has experienced a growth pattern more or less in line with the general development in Norwegian scientific publishing over the past decade.

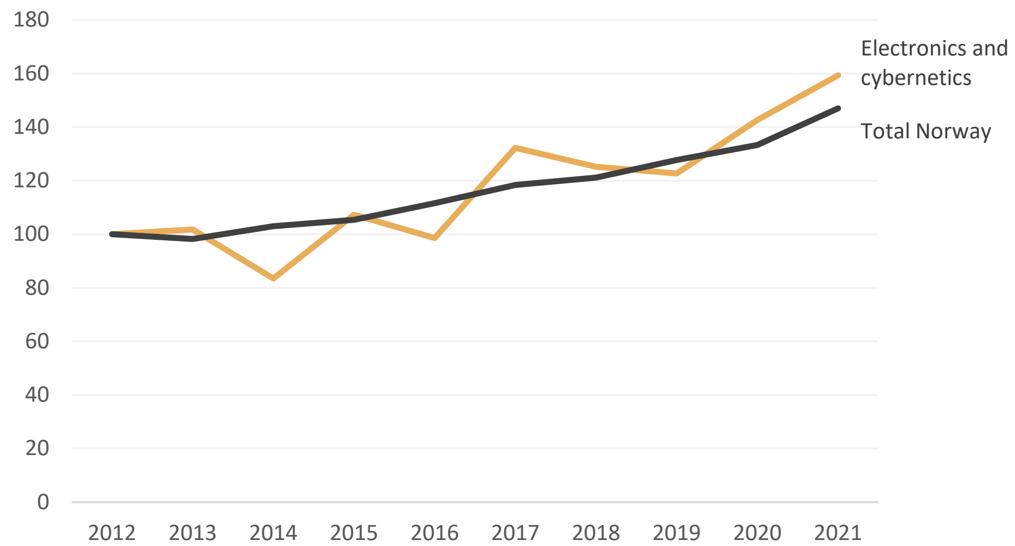

Figure 7.2. Relative growth in number of publications, electronics and cybernetics and total Norwegian publishing, 2012-2021. 2012=100.

7.1.2 Most publishing institutions

Table 7.1 shows the top five contributors to scientific publishing electronics and cybernetics in Norway by sector. Having 76 % of the total author contributions, the university and college sector is the biggest contributor to electronics and cybernetics publishing in Norway. Independent research institutions account for 20 % of author contributions in electronics and cybernetics, and university hospitals and other health institutions contribute with 4 %.

Table 7.1. Most publishing institutions in electronics and cybernetics by sector, 2021.

Sector	Institution	Publications	Modified author shares	Share of total
Health	Hospitals and health institutions	42	14.0	4 %
Research institutes	SINTEF	59	39.4	5 %
	Norwegian Defence Research Establishment	26	19.1	2 %
	Institute for Energy Technology	15	11.2	1 %
	SINTEF Energy	15	7.7	1 %
	Norwegian Institute of Public Health	12	3.9	1 %
	Other research institutes	103	49.4	9 %
Universities and colleges	Norwegian University of Science and Technology	388	290.8	34 %
	University of Agder	91	66.5	8 %
	University of South-East Norway	83	65.9	7 %
	University of Oslo	105	62.0	9 %
	UiT - The Arctic University of Norway	43	29.7	4 %
	Other universities and colleges	172	100.1	15 %

7.1.3 Publishing venues

The publications are distributed across a large number of different journals and publishers. However, the frequency distribution is skewed, and some outlets account for a substantial amount of the publication output. Figure 7.3 shows the most common journals for publishing electronics and cybernetics research in Norway in the most recent year, 2021. In total, these 15 journals account for 56 % of electronics and cybernetics publishing. 12 % of all electronics and cybernetics publications were published in journals that are placed on level 2 in the Norwegian journal classification system.

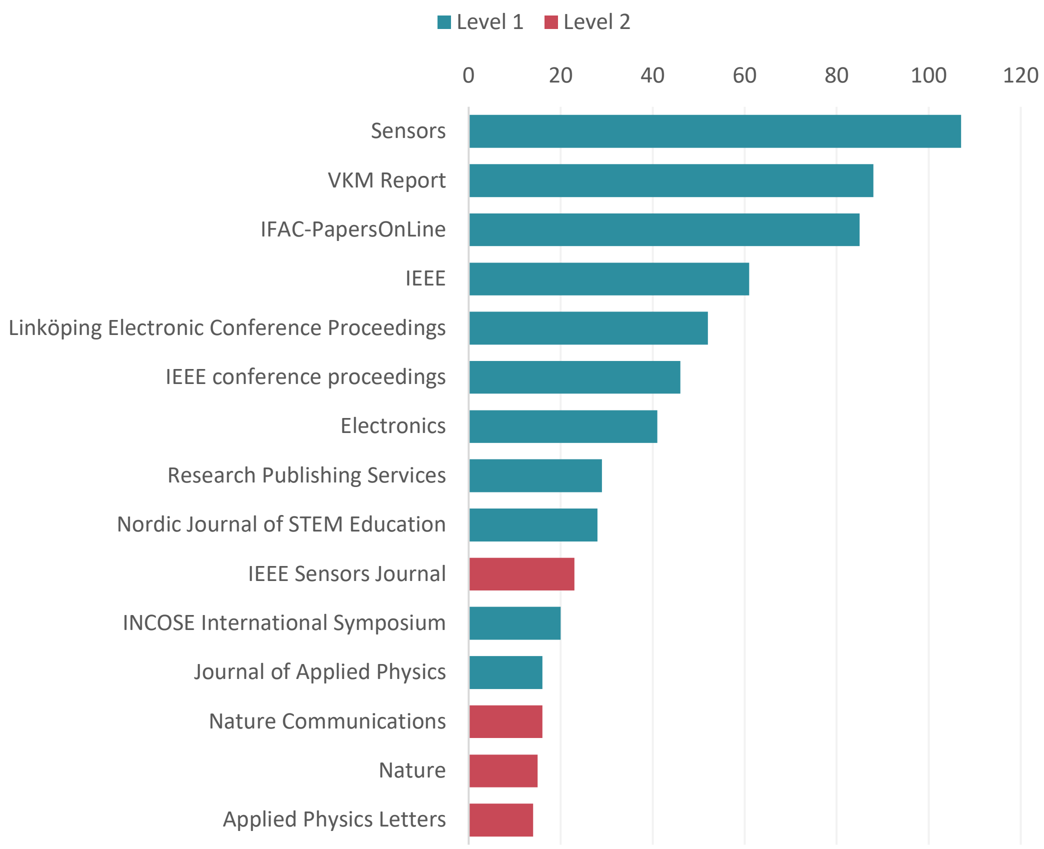

Figure 7.3. Most common publishing venues of electronics and cybernetics, 2021.

7.1.4 Field distribution

There is not a complete overlap between the Norwegian journal classification system and that of Web of Science. Figure 7.4 shows how Norwegian electronics and cybernetics publications are distributed among research fields as classified by Web of Science.

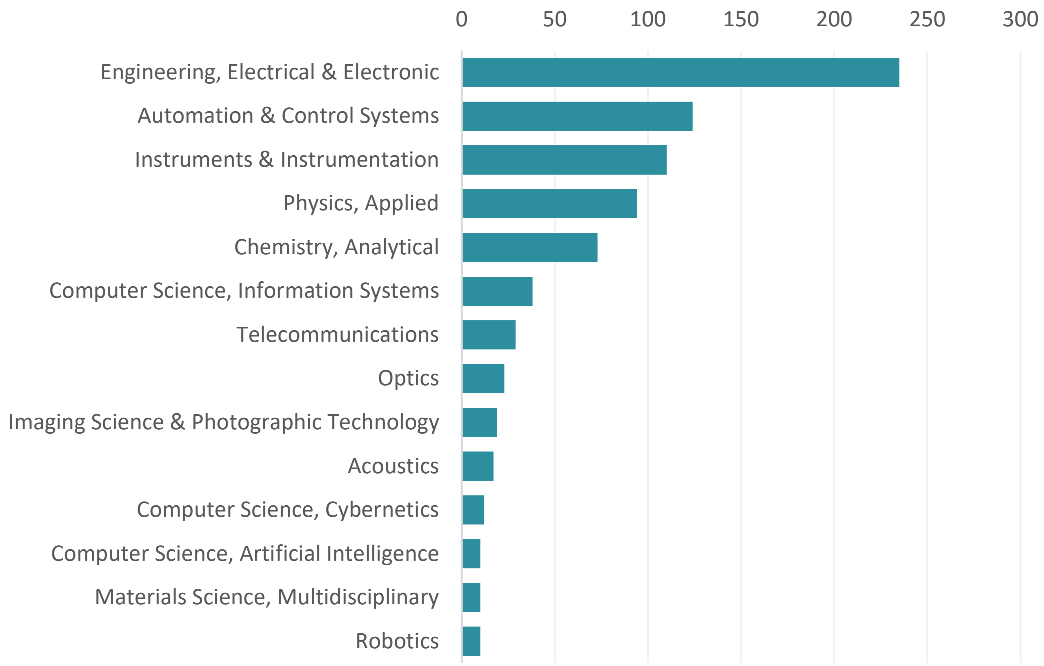

Figure 7.4. Web of Science field distribution of publications within electronics and cybernetics journals in the Norwegian journal classification system, 2021.

7.2 Citation indicators

There are many different indicators of the citation impact of a publication, but two of the most common are 1) Mean normalized citation score (MNCS), where the citation count of a publication is compared to the average number of citations received by publications within the same field and from the same year, and 2) citation percentile, which is a publication's percentile position in a list of all publications from a given field and publication year ordered by citation count.

Figure 7.5 shows the average MNCS for all electronics and cybernetics publishing in Norway 2012-2020, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

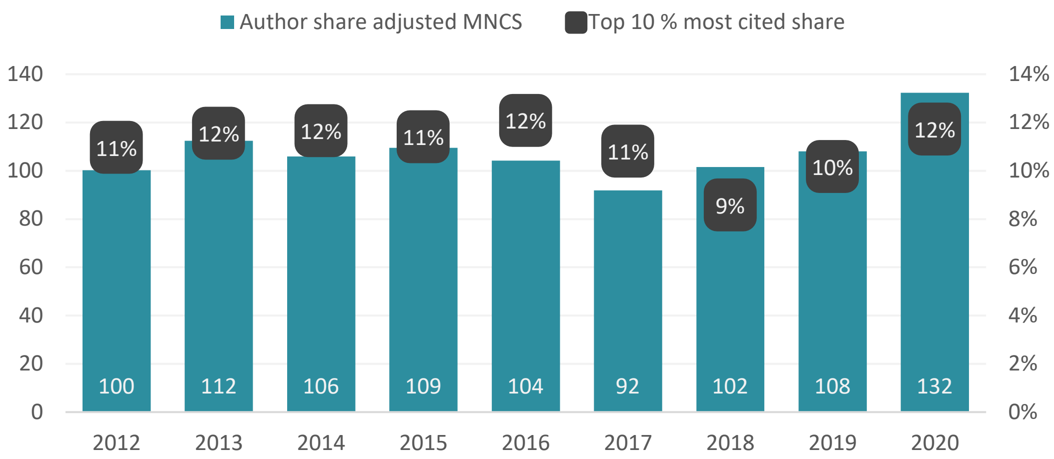

Figure 7.5. MNCS of electronics and cybernetics, publications (left axis, 100 = global mean citation score for publications from same field and year) and share of publications among the 10 % most highly cited publication from same field and year (right axis), 2012-2020.

In general, Norwegian electronics and cybernetics research is above the global average for all years, with the average MNCS for all years being 107,3 and the share of author contributions that fall within the top 10 % most cited publications being 11 %. Both indicators have seen some swing over the period, but with robust growth in the last years. In terms of citation impact Norwegian electronics and cybernetics research performs somewhat below the national average, particularly on the MNCS-indicator.

Web of Science does not have a category for electronics and cybernetics. We have constructed a macro category for this field from the subfields Imaging science and photographic technology, Electrical and electronic engineering, Optics and Computer science and cybernetics. Figure 7.6 shows the MNCS indicator for the publications that fall under these four subfields, using the more fine-grained WoS-classification system (cf. Figure 7.4). Imaging science and electrical and electronic engineering are above the global average, while optics and computer science are somewhat below.

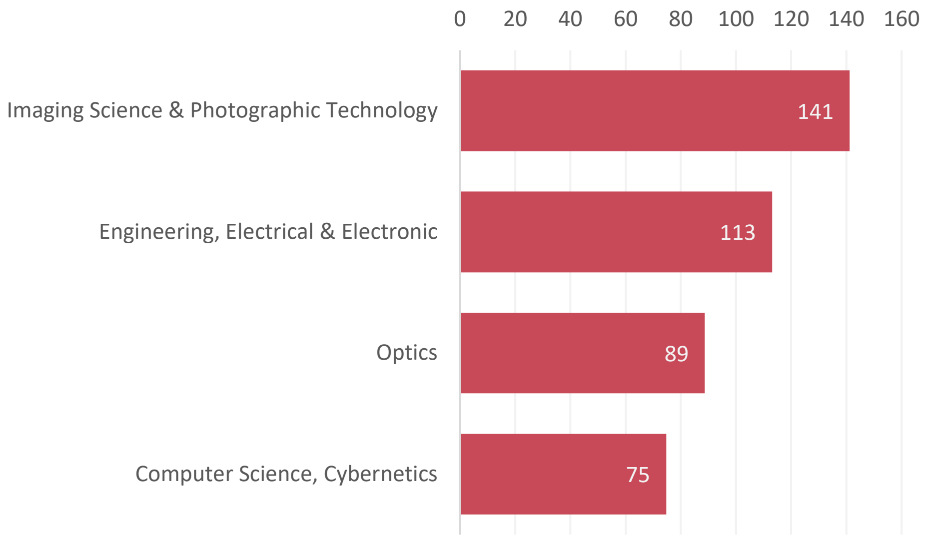

Figure 7.6. MNCS scores of Web of Science subfields within Norwegian electronics and cybernetics publications, 2018-2020.

Table 7.2 shows which countries can be said to have publications with the highest average citation impact for the period 2018-2020, adjusted for the size of their author contributions to these publications. Only countries with at least 2 000 author shares have been included. While such rankings in the past were dominated by Western countries, Asian and Arabic countries have made their mark in recent years, due to major scientific investments, more international research collaboration, and hiring of esteemed foreign scientists. On the top of the list we find Singapore. Norway is the 14th most impactful country in electronics and cybernetics globally of a total consisting of the 54 largest countries.

Table 7.2. Author share adjusted MNCS of most impactful countries in electronics and cybernetics, including Norway, 2018-2020

Position	Country	Modified author shares	MNCS
1	Singapore	11602	162
2	Australia	21219	145
3	USA	178265	144
4	Switzerland	9991	140
5	Denmark	6868	131
6	UK	41899	128
7	Saudi Arabia	7129	125
8	Belgium	8596	124
9	Sweden	8316	122
14	**Norway**	**3506**	**111**

7.3 International collaboration

Which countries are the most important collaborative partners for Norway in the field? To answer this, the distribution of co-authorship by country has been analysed. Table 7.3 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. The USA is the most important collaboration nation. In total, 10% of the "Norwegian" articles had co-authors from the US. Next follow Germany, China, and UK, with proportions of 6-5%.

Of all the "Norwegian" publications within the fields, 49% had co-authors from other countries as well. This is significantly below the average for the natural sciences, all fields combined (those included in this report), which is 71%. It is also below the corresponding national average for engineering (all fields combined), which is 57%.

Table 7.3. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
USA	228	10 %	Canada	50	2 %
Germany	143	6 %	Denmark	44	2 %
China	141	6 %	Japan	44	2 %
UK	114	5 %	Switzerland	43	2 %
Sweden	102	4 %	Australia	39	2 %
Italy	94	4 %	Russia	38	2 %
India	90	4 %	Brasil	35	1 %
France	89	4 %	Austria	33	1 %
Spain	85	4 %	Belgium	28	1 %
Netherlands	71	3 %			
Finland	61	3 %	Total	1149	49 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles.

7.4 National collaboration

Figure 7.6 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together.

The collaborative patters in the field consist of different clusters, one related to health where various hospitals are main contributors. The Norwegian University of Science and Technology collaborates most closely with SINTEF. One cluster (in blue) encompasses the University of Bergen, NORCE, the Norwegian University of Life Sciences, and several other institutes in the institute sector.

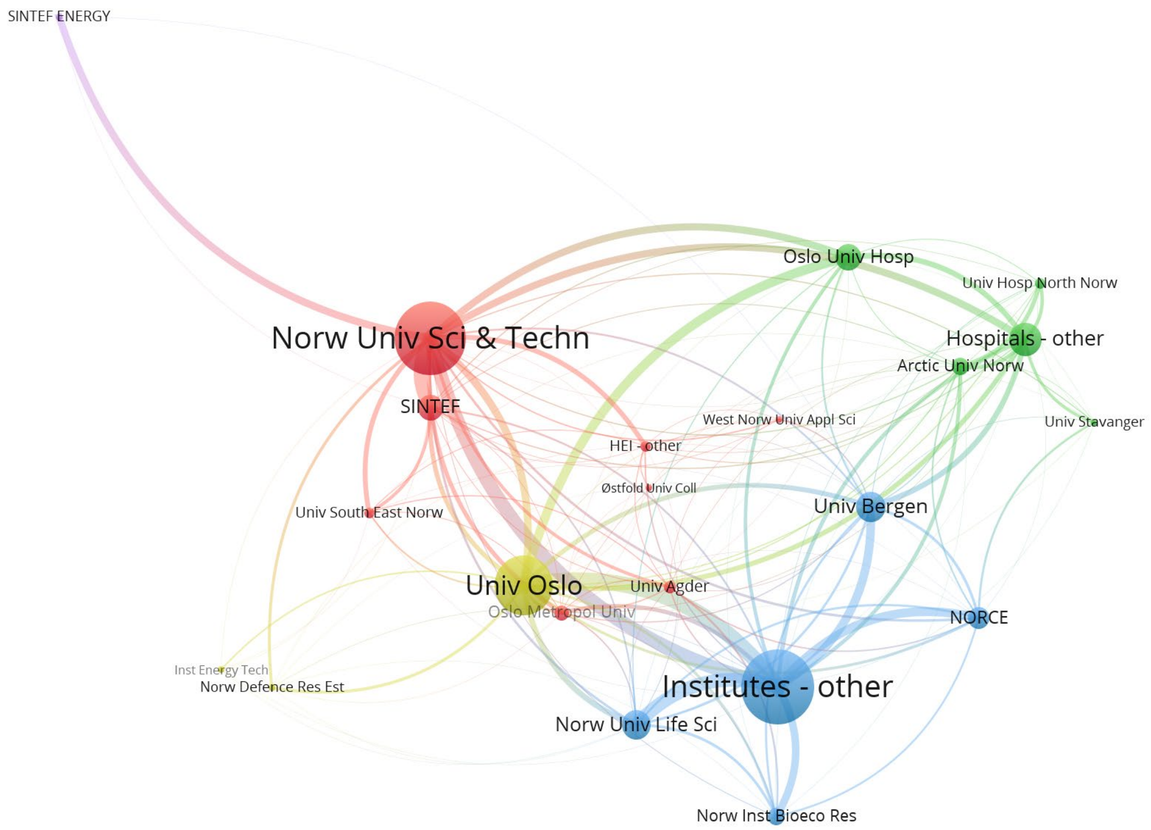

Figure 7.6. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021

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