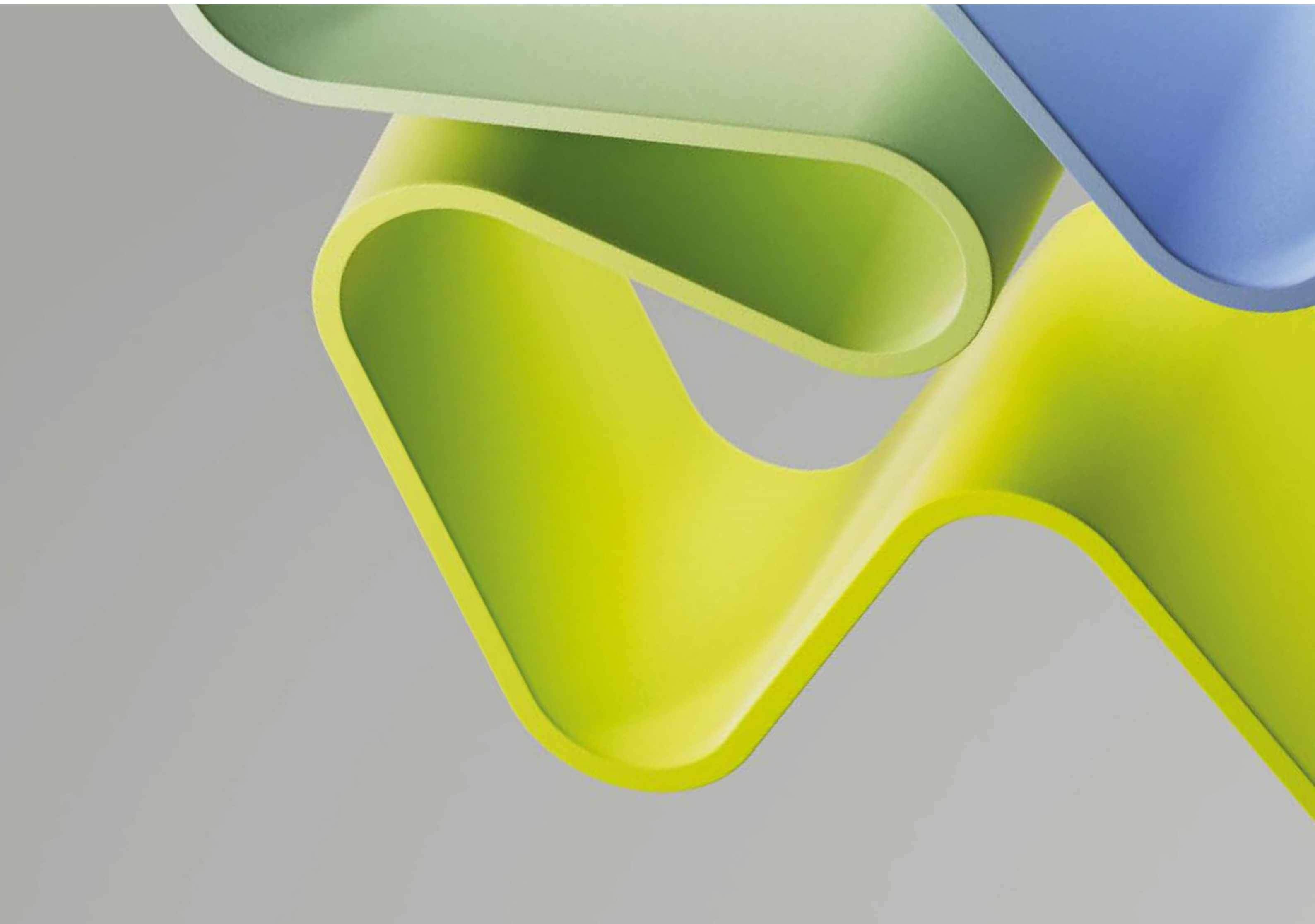
Forskningsrådet

# National report

## Evaluation of Natural Sciences in Norway 2022-2024

March 2024



# Contents

# Preface by the Research Council of Norway

The Research Council of Norway (RCN) has been given the mission by the Ministry of Education and Research to perform subject-specific evaluations. The RCN carried out an evaluation of Norwegian research within natural sciences in 2022-2024.

The primary aim of the evaluation of Natural sciences is to identify and confirm the quality and the relevance of research performed at Norwegian Higher Education Institutions (HEIs) and across the Institute Sector.

The evaluation was carried out by international peers, using an Evaluation protocol developed by RCN (Appendix 1).

The evaluation has been carried out at three levels. In total, 115 research groups were evaluated in 12 expert panels divided by subjects and disciplines within the field of natural sciences (chemistry, physics and geosciences). Thereafter, four evaluation committees were established to evaluate the 28 participating administrative units (faculty/institutes/departments/centre) based on self-assessments, research group reports and additional input such as bibliometric data. These evaluation reports give important input to the individual administrative units, and each institution/administrative unit is responsible for following up the recommendations that apply to their own institution.

The National Committee consisted of six international experts including the chairs of the four evaluation committees. The Committee was requested to prepare a national level report for natural sciences in Norway, based on the assessments and recommendations from the 28 independent evaluation unit reports and additional input. The national report will be used by the Research Council of Norway in developing national funding schemes and in dialogue with the ministries and institutions involved in the development of natural sciences.

This national report pays specific attention to:

- Strengths and weaknesses of the research area in the international context
- The general resource situation regarding funding, personnel, and infrastructure
- PhD training, recruitment, mobility, and diversity
- Research cooperation nationally and internationally
- Societal impact and the role of research in society, including Open Science

This national report offers an overall assessment of the state of the research in natural sciences in Norway.

Lysaker 15 March 2024

# Composition of National Committee for EVALNAT

This report offers an overall assessment of the state of natural sciences research in Norway and presents recommendations for future development. All committee members support the conclusions and recommendations.

Professor **James Kirchner** (chair)
ETH Zurich, Switzerland

Professor **Mat Collins**
University of Exeter, United Kingdom

Professor **Stewart Clarke**
Durham University, United Kingdom

Professor **Ilenia Rosetti**
University of Milano, Italy

Professor **Florencia Canelli**
University of Zurich, Switzerland

Professor **Amelie Hagelauer**
Fraunhofer Research Institution, Germany

Dr Erik Arnold, Senior Partner, Technopolis Group, was the secretary to the committee.

# Summary

This document, authored by an international committee of scientific experts, reports the national-level results of the 2022-24 evaluation of natural sciences research in Norway and makes recommendations for their future development. It builds on 115 panel evaluations of research groups, which in turn contributed to 28 evaluations of the natural sciences in administrative units such as university departments and research institutes.

Here, the natural sciences are defined as chemistry, physics and the geosciences. These are important in their own right because they help us better to understand the natural world. They have also enabled much of Norway's industrial development and will underpin the way Norway tackles challenges such as climate change, the green transition and strategic materials, which offer huge industrial and scientific opportunities, if the research system evolves flexibly to tackle new problems.

While each discipline contains stronger and weaker elements, overall the geosciences appear strong, building on traditional Norwegian scientific strengths. Physics has an acceptable level of quality and performance, though in a rich developed country there is scope to do better. Notwithstanding Norway's strengths in some sub-fields, the state of chemistry overall is unsatisfactory. Improvement across the natural sciences requires investment in strong and growing, high-quality themes and careful decisions about where to consolidate without jeopardising core competences. There is a need for a system-wide approach to strategy and funding, especially in chemistry. Barriers to change (notably in the universities) include rigidities in governance and budgeting, a need to develop more robust research and organisational strategies and improve human resource management, and insufficient incentives for change.

While the natural sciences are broadly well funded and there is a good level of institutional funding in the universities, many organisations depend heavily on external research funding. Recent funding cuts appear to have undermined researchers' trust, creating an obstacle to longer-term planning. Low success rates in the funding of researcher-initiated projects also cause uncertainty.

The number of researchers in Norwegian natural sciences has grown, especially in geosciences and developing fields of physics and chemistry, but a generation of professors is nearing retirement, succession plans are not always clear, and a systematic approach is needed to support PhD students and early-career researchers to become future research leaders. The administrative units are committed to responsible research and innovation and open science. Most have high percentages of open access publications.

National research infrastructure is generally of high quality, underpinning Norwegian researchers' ability to work in international collaborations, and Norway has good access to international infrastructure. There may nonetheless be opportunities to complement national infrastructure strategies with better coordination of infrastructure use. Norwegian natural scientists collaborate well, both nationally and internationally, though participation in international programmes including the EU Framework Programme could usefully increase further. Many research groups maintain close relations with industry but there is less outreach to citizens, who are an increasingly important audience in a time of "alternative facts" and the need to change lifestyles to tackle climate change.

Gender inequality is slowly declining, but women publish less than men. The importance of ethnic and cultural diversity is underestimated and requires more attention.

Our recommendations are systemic:

- Develop a national plan to support evolution (and quality improvement in) Norwegian chemistry
- Reduce uncertainty in overall funding, while maintaining competition in external funding
- Remove barriers to evolution in the organisational structure of the natural sciences in Norway, provide incentives to address new needs, and tackle weaknesses in governance, strategy development and human resource management so Norwegian science and industry are not left behind
- Review and take opportunities to increase gender equality, through measures that encourage women into natural science careers and make their research environment more hospitable
- Launch research and interventions to understand and address women's disadvantages in publication and the degree of diversity in the Norwegian natural sciences research community

# Sammendrag

Denne rapporten, som er utarbeidet av en internasjonal komité av vitenskapelige eksperter, gir en evaluering på nasjonalt nivå av naturvitenskapelig forskning i Norge og kommer med anbefalinger for fagenes fremtidige utvikling. Den bygger på panelevalueringer av 115 forskergrupper, og evaluering av tilhørende 28 administrative enheter ved universiteter/høyskoler og forskningsinstitutter.

I denne evalueringen er naturvitenskap definert som kjemi, fysikk og geofag. Disse fagene er viktige i seg selv fordi de hjelper oss til bedre å forstå våre naturlige omgivelser. De har vært viktige og muliggjort mye av Norges industrielle utvikling og underbygger måten Norge takler utfordringer som klimaendringer, det grønne skiftet og strategiske materialer De gir enorme industrielle og vitenskapelige muligheter, dersom forskningssystemet har en fleksibilitet til å kunne takle nye utfordringer.

Mens hver disiplin inneholder både sterke og svake elementer, fremstår geovitenskapene samlet sett sterke, og bygger på svært gode norske vitenskapelige tradisjoner. Fysikk har et akseptabelt nivå av kvalitet og ytelse, men i et rikt utviklet land er det rom for forbedringer. Til tross for Norges sterke sider på noen delfelt, er tilstanden innenfor kjemi totalt sett lite tilfredsstillende. Forbedring på tvers av naturvitenskapene krever investeringer i sterke og voksende fagområder av høy kvalitet og veloverveide beslutninger om hvor man skal konsolidere seg uten å sette kjernekompetansen i fare. Det er behov for en omfattende systemtilnærming til strategi og finansiering, spesielt innenfor kjemi. Barrierer for endring (spesielt ved universitetene) inkluderer rigide styrings- og budsjetteringsmekanismer, og det er et behov for å utvikle mer robuste forsknings- og organisasjonsstrategier, bedre utnyttelse av menneskelige ressurser, og insentiver for endringer.

Mens naturvitenskapene i hovedsak er godt finansiert og det er et godt nivå på institusjonell finansiering ved universitetene, er mange organisasjoner sterkt avhengig av eksterne forskningsmidler. Nylige finansieringskutt ser ut til å ha undergravd forskernes tillit, og har skapt et hinder for langsiktig planlegging. Lav suksessrate i finansieringen av forskerinitierte prosjekter skaper også usikkerhet.

Antall forskere innenfor norsk naturvitenskap har vokst, spesielt innenfor geovitenskap og utviklingsfelt innenfor fysikk og kjemi, men en generasjon professorer nærmer seg pensjonsalderen, uten at det er klare planer for nyrekruttering. Det er behov for en systematisk tilnærming for å støtte doktorgradsstudenter og tidlig -karriereforskere for å bli fremtidige forskningsledere. De administrative enhetene er forpliktet til ansvarlig forskning og innovasjon med åpen tilgang til forskningsresultater. De fleste forskere har en høy andel av sine publikasjoner med åpen tilgang.

Nasjonal forskningsinfrastruktur er generelt av høy kvalitet, som støtter opp under norske forskeres muligheter for internasjonalt samarbeid, og Norge har god tilgang på internasjonal infrastruktur. Det er likevel behov for å komplettere nasjonal infrastrukturstrategi med bedre samordning av infrastrukturbruk. Norske forskere innenfor naturvitenskap samarbeider godt, både nasjonalt og internasjonalt, men deltakelse i internasjonale programmer inkludert EUs Rammeprogram kan med fordel øke ytterligere. Mange forskergrupper opprettholder nære relasjoner med industrien, men det er mindre utadrettet virksomhet mot innbyggerne, som er et stadig viktigere publikum i en tid med "alternative fakta" og behovet for å endre livsstil for å takle klimaendringene.

Ulikheten mellom kjønnene avtar sakte, men kvinner publiserer mindre enn menn. Betydningen av bredere mangfold (f.eks. etnisk og kulturelt mangfold) er undervurdert og krever mer oppmerksomhet.

Våre anbefalinger er på systemnivå:

- Utvikle en nasjonal plan for å støtte utviklingen av (og kvalitetsforbedring i) norsk kjemi
- Redusere usikkerhetene i forskningsfinansiering, samtidig som konkurransen innenfor ekstern finansiering opprettholdes
- Fjerne strukturelle hindre for utvikling av naturvitenskapen, gi insentiver for å møte nye behov, og håndtere svakheter i styring, strategiutvikling og menneskelig ressursforvaltning, slik at norsk naturvitenskap og industri ikke kommer på etterskudd.
- Vurdere muligheter og legge til rette for å bedre likestillingen, gjennom tiltak som oppmuntrer kvinner til karrierer innenfor naturvitenskap.
- Iverksette forskning og tiltak for å forstå og adressere kvinners ulemper i publisering og graden av mangfold i det norske naturvitenskapelige forskningsmiljøet

Det er det engelske sammendraget som er det gjeldende.

# 1. General observations on Norwegian natural sciences

This evaluation of Norwegian research in the Natural Sciences (EVALNAT) covers chemistry, the geosciences and physics. Participation was voluntary, but most research organisations active in the field asked that their relevant research groups and administrative units should be included. In total, 115 research groups from 28 administrative units (faculties, institutes or departments) participated[1] (see Appendix 2), involving about 3,270 researchers: some 1,650 from the higher education sector and about 1,620 from research institutes.

The evaluation, both at this national level and at the underlying levels of research groups and administrative units, is based on 'informed peer review', informed primarily by the self-assessment reports at the group and unit levels as well as video interviews with several representatives of each unit. As supporting information, statistical data and bibliometric indicators have also been made available to the reviewers as important context for the research assessment (such as funding and publication output). These quantitative metrics were largely consistent with the committees' qualitative judgments derived from the informed peer review process. The assessments made are the responsibility of the evaluation committee.

The scientific fields evaluated here provide an understanding of how the natural world works and how human society interacts with it, as well as providing a basis for industrial and economic development. These scientific efforts have historically supported the development of the Norwegian economy and society. Together with other disciplines such as mechanical engineering, they have underpinned Norway's extractive industries and supported marine, maritime, metals, and process industries through national scientific strengths in areas such as geology, meteorology, and chemistry. They were vital as Norway transitioned into the oil and gas age, and remain important for maintaining Norway's high-skill, high-welfare, high-wage economy while tackling today's challenges such as climate change, decarbonisation, and strategic materials. However, these new needs mean that natural sciences research must evolve, with growth in some areas and consolidation in others. Some changes are already taking place in Norwegian research, but it will be crucial for Norwegian scientific and economic competitiveness that Norway keeps up with international developments and builds on its scientific capabilities to maintain and build leading positions in areas of national importance.

The research covered in this evaluation is central to the overall objectives of the government's Long-Term Plan[2] for research and higher education, namely: increased competitiveness and innovation; environmental, social, and economic sustainability; and high quality and accessibility of research and higher education. It underpins the two thematic priorities the government has brought forward into the current plan – climate, environment and energy, and enabling and industrial technologies. The future health of this research is crucial if Norway is to cope with not only the costs, but especially also the opportunities, presented by the green transition. A key element is to increase the use of research-based knowledge in industry and the wider society. This requires not only increased engagement and absorptive capacity on the part of society, but also openness and engagement by the research community.

Norway spends roughly the same proportion of GDP on R&D (2.24% in 2020) as the EU average (2.18%)[3]. However, Norway's industrial structure is relatively specialised in resource-based and other industries that do little R&D and therefore rely heavily on state-funded research (even if the companies in Norway are more R&D-intensive than their equivalents abroad (OECD, 2008). Most of the EU has a bigger share of science- and manufacturing-based industries than Norway. These tend

[1] A small number of research groups, for example at SINTEF Industry, UiS and NMBU, were assessed by panels in this evaluation because their disciplinary focus was in chemistry geosciences or physics, while the administrative units to which they belonged are evaluated in parallel evaluations. In these cases, the assessments of the groups' work have contributed to the committee's judgements about the three disciplines

[2] Meld. St. 5 (2022-2023), Langtidsplan for forskning og høyere utdanning 2023-2032

[3] Source: 2020 figures from the OECD Main Science and Technology Indicators

to do more R&D in-house and are therefore less reliant on state-funded research than many companies in Norway. Thus, in 2020 the state-funded share of Norway's gross expenditure on R&D was 54%, compared with 33% for the EU. The policy implication is that the amount and quality of state-funded research – especially in the natural sciences – is key to industrial performance in a resource-based economy like Norway's.

Measured by numbers of publications, Norway is strongly specialised in geosciences and biology compared with other countries, and to a slightly lesser extent in health subjects, psychology and social sciences. The share of Norway's publications in physics is low compared with the rest of the world, and that in chemistry and materials science is even lower (Research Council of Norway, 2021).

It follows from this discussion that state-funded natural science research has been and will remain crucial for Norway's economic performance and its ability to maintain a high quality of life, as science and society adapt to the green transition and other challenges posed by shifting geopolitics and rapidly changing technologies. The quantity, quality and flexibility of the national natural science research effort are key elements in meeting those challenges.

# 2. Strengths and weaknesses of Norwegian natural sciences research in an international context

This section first presents the evaluation committee's synthetic view of the natural sciences in Norway and presents SWOT analyses of each of the three major disciplines. It then summarises statistics made available to the committee about scientific production, how Norwegian Natural Sciences research is cited, and the extent to which it has been recognised via ERC grants in 2011-2023. To avoid cluttering the text, most tables and figures have been put into a separate section (Section 8) at the end of this report.

## 2.1 The evaluation committee's perspective

The natural sciences are not only important in their own right but also provide foundations for present and future Norwegian industry. Many Norwegian research groups are internationally recognised for the quality of their work and the infrastructure available to them. There are stronger and weaker groups, but the stronger ones tend to have the most clearly articulated strategies. Many focus on applied work and have strong links to industry, and there are also groups doing good fundamental research.

Climate change and other challenges including environmental conservation, pollution reduction, public health, sustainable resources, renewable energy development, biodiversity, hazard assessment, and future device technologies impose new needs on the natural sciences. The historical pattern of research in Norway in many areas provides a good basis for meeting the new challenges, and there are some important corresponding points of growth and excellence, especially in the geosciences. Some Norwegian research organisations are trying to restructure their activities to meet the new needs, but there are also important administrative and funding barriers to change, and the pace of evolution in the Norwegian research landscape needs to increase, otherwise Norwegian science and industry risk being left behind in international competition.

While there are high points in all areas, through the lens of bibliometric indicators the major fields considered here – geosciences, physics and chemistry, with materials science spanning the latter two – differ in their overall quality and performance. Each contains a mixture of stronger and weaker elements. Overall, geosciences appear strong, building on traditional Norwegian scientific strengths. Physics is close to the world average level of quality and performance, which is clearly below expectations for a rich developed country, even though Norway is a small one. The state of chemistry overall is unsatisfactory. The key to improvement is not an undifferentiated effort to improve the quality of everything but a process of renewal that emphasises investing in strong and growing, high-quality themes and careful decisions about where to disinvest without jeopardising core competences.

**Chemistry[4]**

In the view of the evaluation committee, while some groups attain high standards, consistent with the bibliometric evidence, some others are substantially weaker. A strategic approach is needed to keep the portfolio of activities relevant and to decide whether and how to remediate or disinvest from the weakest areas.

Theoretical chemistry, renewable energies, metallurgy, electrochemistry, and catalysis are well represented and substantially healthy. Many groups in the chemical and materials engineering departments at NTNU perform well. However, nationally the groups in organic/organic-synthesis/analytical chemistry and some in bio/medical chemistry are, except in a very few cases,

[4] The Pharmaceutical institute at UiO is not evaluated here, but will be included in the medical-health evaluation

well below international standards for organisation, productivity and quality. The Pharmaceutical institute at UiO is not evaluated here, but will be included in the medical-health evaluation

Most groups do a good mixture of applied and fundamental research, enabling them to do research with and for firms, as well as to conduct and publish basic research. Chemists' strong links to companies have generated both research income and societal impact, not only in the strong and growing sub-fields but also among some of the more traditional groups. Surprisingly, while many have strong links with industry, little wider outreach and dissemination to society is done.

It appears that application-orientated groups have the greatest impacts in projects, contracts and publications. However, the theoretical chemistry groups that are present in most institutions also appear quite productive and alive.

Most groups have good access to both national and international infrastructures. This boosts their productivity and attractivity as partners in national and EU research collaborations, since such a rich availability of state-of-the-art equipment is difficult to find elsewhere.

Many groups are adapting their organisation and activities to meet new challenges. UiB (University of Bergen) Chemistry is working on a deep transformation to this end, which appears promising but has yet to bear fruit. UiS (University of Stavanger), situated at the centre of the Norwegian oil & gas industry, is attempting a similar reorientation in its Department of Energy Resources. Others are less explicit about the need to restructure.

Most relevant groups (especially NTNU, SINTEF Industry, UiO – University of Oslo) are trying to maintain activities and collaborations with the oil & gas, metallurgy, and basic chemical industries, which in many cases provide substantial funding. However, a shift is also visible towards new challenges such as CO2 capture, exploiting renewable energy and resources, and wider sustainability, in line with the UN SDGs. The green transition will not be instantaneous, so it makes sense to maintain a mix of 'old' and 'new' chemistry, especially as there is strong demand from external funders and limited funding for wholly PI-initiated research, but overall, a further shift towards new topics will be needed.

There was little evidence about staff mobility, and the numbers of PhD students and their training strategies differ widely among groups. As in other disciplines, the gender balance is problematic, but especially so in Chemical Engineering and among the research institutes.

Table 1 Chemistry SWOT Analysis

| **Strengths** | **Weaknesses** |
|---|---|
| • Very strong groups in catalysis, energy conversion, materials, chemical engineering & process systems engineering, theoretical chemistry<br>• Some peaks of excellence for quality of scientific outcome<br>• Excellent equipment and shared infrastructure<br>• Good participation in European projects and international partnerships, with some groups particularly visible<br>• Substantial funding from private companies (especially for institutes sector)<br>• High impact on companies involved (especially by the institute sector)<br>• Activities meet important UN SDGs | • Weak groups (with some exceptions) in organic chemistry and biochemistry, analytical chemistry, environmental chemistry<br>• Some groups are small or fragmented and poorly organised<br>• Strategy often unclear, limiting performance<br>• Scientific productivity generally well below international norms<br>• In some cases, limited number of PhDs and post-docs<br>• Outreach and communication to the general public is almost never considered |
| **Opportunities** | **Threats** |
| • Excellent infrastructure and equipment foster international partnerships and participation in collaborative projects<br>• Availability of critical raw materials in Norway offers research, exploitation and commercial opportunities<br>• Strong competences in Catalysis, chemical engineering and material science from oil & gas work can easily be reapplied to search challenges in green and energy transitions<br>• Very strong network of companies, used to collaborate with universities and research institutes | • Limited institutional research funding for Institutes limits basic research and can make it harder to participate in EU projects<br>• High share of external funding at research institutes exposes groups to risk<br>• Limited attractiveness for employment in geographically peripheral Universities |

In chemistry, larger research groups and departments can have important advantages over others, in part because they can be broader and more interdisciplinary and can mix fundamental and applied research. Scale also brings advantages in fund-raising, reducing risk by smoothing 'lumpy' income streams, easing investing in expensive equipment and doing more structured teaching at both under- and postgraduate levels. Some of the smaller and scientifically weaker groups have also been able to leverage the generous chemistry infrastructure available in Norway to build EU collaborations. Seizing these opportunities requires good strategies and management, which were not always in place among the groups evaluated.

The evaluation identified both strong and weak sub-fields (Table 1). The lack of strong groups in analytical and organic chemistry can negatively affect the sector itself, but also neighbouring fields such as pharmaceutical, medicinal, and environmental chemistry.

As in other parts of the natural sciences, weaker groups were often small, or small parts of fragmented departments and faculties, where collaboration and interdisciplinary work bringing together complementary skills and assets were hard to achieve, and strategies were unspecific and lacked means to be implemented. Fixing these problems requires not only good scientists but skills in strategy and management, and organisational arrangements that allow resources to be redirected to achieve strategic goals. Institutes, operating under intense market pressure, can be better placed to do this than established universities with traditional management structures.

The larger or better-funded groups have the potential to invest in the latest technologies and equipment, enabling them to stay at the forefront. Financial strength also eases collaboration with industry, with potential for commercialisation. Some of the smaller groups also have good international links, and could use these as well as increased national collaboration to build strength. This would involve better coordination and use of the considerable investments that have been made in nationally-based equipment and infrastructure, and could usefully involve sharing services (such as characterisation labs) that have an infrastructural character. It could also provide opportunities to close some of the thematic gaps identified above.

In Norway, chemistry research is dominated by the higher education sector, especially by UiO and NTNU. The major institute in scope – SINTEF Industry – is intimately linked to NTNU, to such an extent that the boundary between the two is not always clear. This reflects SINTEF's history as, in effect, a technology transfer and industrial extension arm of the former national technical university (NTH, now NTNU). SINTEF hosts large numbers of NTNU PhD students while NTNU maintains strong links with industry via adjunct professors ('Professor 2') from SINTEF and industry. The other free-standing institutes appear to have weaker links to universities. Given the importance for chemistry research of maintaining its presence at both the scientific and the industrial frontiers, there is probably a case for further strengthening such links across the field nationally.

### Geosciences

In the view of the evaluation committee, the geoscience research sector in Norway is extremely diverse, both in the scope of the research topics that are covered and in the mandates of the different organizations. The research quality of many of the units was assessed as excellent relative to international standards in the geosciences. Although a small number of individual research groups were flagged for low performance or lack of strategic vision, several units were also assessed as internationally leading in specific areas, such as offshore wind energy and natural hazards. Many units compete successfully in EU funding schemes and have attracted a significant number of prestigious and highly competitive ERC grants. The discipline has also attracted a substantial number of RCN-funded centres of excellence.

All of the units assessed were making important contributions to Norway on topics of high societal relevance, including preserving environmental quality, navigating the green transition, securing access to strategic minerals, developing renewable energy resources, managing natural hazards, and predicting, mitigating, and adapting to the effects of climate change.

The research institutes were generally assessed as interacting strongly with national stakeholders and contributing substantially to policy formulation, consistent with their more applied focus, while the academic units understandably rated less strongly in these areas. Many of the research institutes are also tasked with developing and maintaining critical databases, models and observational infrastructure, which serve important societal needs and are key inputs to research although they do not by themselves generate highly visible research outputs.

Table 2 Geosciences SWOT Analysis

| Strengths | Weaknesses |
|---|---|
| • Strong research groups, especially in areas of geoscience relevant to understanding and mitigating climate change and other environmental challenges<br>• Norway is internationally recognised as a leader in geosciences, enabling strong international collaboration and attracting high levels of international funding<br>• Numerous and diverse research institutes provide important services to Norwegian society (e.g., in hydrology and natural hazards)<br>• Norwegian geoscience groups not only enjoy good physical infrastructure, including research vessels, but develop and maintain databases critical for monitoring and research<br>• Some research groups (particularly those previously focused on oil and gas) are re-orienting their work to new needs, providing a basis for growth and restructuring in areas of social as well as scientific relevance | • Some organisations are resistant to restructuring and to doing more work in areas of societal need<br>• The large number of free-standing research institutes involved means that university-institute links are weaker than they could be<br>• High reliance on external funding, and a shortage of permanent posts in the universities, make scientific careers in Norway less attractive<br>• Many units are reliant on winning funding from competitive grant schemes and thus invest a lot of time and energy into this, to the detriment of pursuing long-term strategic aims |
| **Opportunities** | **Threats** |
| • The geosciences have been growing in Norway over the period being evaluated, producing more work of societal relevance and making it easier to adapt organisations to new needs<br>• Many areas of research that have historically supported the growth of oil & gas and other important Norwegian industries can also be applied to climate change mitigation and adaptation, and to meeting other societal challenges | • Need to preserve fundamental research and core research competences while evolving to meet new needs<br>• High capital and running costs of the needed infrastructure – especially ships but also aircraft, satellites, and high-performance computing – offer potential targets for funding cuts, which would make it difficult or impossible to conduct research that is critical to tackling climate change and other societal challenges |

Many of the units are in the process of making a difficult but necessary transition from traditional geosciences toward more contemporary environmental concerns. For some units, this also entails a transformation from applied research, which was often well funded by the oil and gas industry, toward more basic research. Some of the expertise that was highly relevant to oil and gas exploration in the past can, looking forward, be redirected toward fields like carbon capture and storage. However, given the time scales of research careers, and the time required to build expertise in new areas, such shifts in focus will necessarily be gradual.

Most of the units have forward-looking strategies, although many are less specific about how their strategic vision can and will be implemented. A key strategic challenge is how to preserve core competencies while exploiting emerging opportunities, all in the context of stagnant or declining base funding. Several of the units rely for their success on national research infrastructures, such as research vessels and high-performance computing facilities.

All of the research institutes except NGU have proportions of external competitive funding that are extremely high by international standards, ranging up to 80, 85, or even 90 percent. The very small fractions of base funding – even for operations and infrastructure – have important consequences for these organizations. High rates of external funding impose significant proposal-writing burdens on the permanent staff, who should ideally be leading the research and providing the strategic direction rather than constantly hunting for money. Reliance on external funding also makes these groups vulnerable to changes in the Norwegian funding system. Scientific expertise and advanced infrastructure can take decades to develop and are put at risk when an organisation's research agenda is vulnerable to the shifting priorities of external funding sources.

Public funding for research is perceived by many units as having become significantly less reliable in recent years, which lowers morale and makes strategic planning difficult. The scarcity of permanent positions in many units, combined with an increasingly difficult funding picture, creates poor prospects for junior researchers, threatening the long-term future of the Norwegian research enterprise.

Historically, women have been under-represented across the much of the geosciences (both in Norway and elsewhere). This is reflected in a relative scarcity of women in senior roles in most units, although there are exceptions such as NVE. Talented women are in the pipeline at the PhD and postdoc levels, but it will take many years for demographic change at the more senior ranks.

### Physics

In the view of the evaluation committee, areas such as particle, high energy and some areas of condensed matter physics are very strong and performing above the international average. These are mainly based in the larger Universities. For example, UiO is strong in particle physics, astrophysics, and condensed matter physics; NTNU is strong in applied physics. Smaller groups based outside the three big universities tend to having less impact

The large units, especially at UiO, UiB and NTNU, have excellent equipment, access to infrastructure and the potential for delivering high-quality education at both first degree and postgraduate levels. Groups doing fundamental research tend to have insufficient interest in applications and societal impact. Others work in more application-relevant areas, often on interdisciplinary projects, and with better means to transfer knowledge and technology. They emphasise practical applications, with research yielding tangible outcomes such as enhanced solar cell efficiency, expedited cancer diagnostics, and advancements in low-carbon energy solutions.

Some physics groups are extending their work into new areas – including but not only sustainability-related ones – helping to create a dynamic that could allow Norwegian physics research to evolve in line with changing scientific and societal needs. Some groups devote effort to connecting their research with societal needs and transferring knowledge. However, others miss opportunities by failing to take account of society.

Table 3 Physics SWOT Analysis

| **Strengths** | **Weaknesses** |
|---|---|
| • Areas such as particle, high energy and some areas of condensed matter physics are very strong<br>• Some peaks of excellence for quality of science<br>• Strong links with international infrastructures, especially CERN and ESA<br>• Good participation in European projects and international partnerships<br>• Some groups are reorientating their work towards new scientific and societal challenges, restructuring into fields such as quantum, sustainability and climate, materials science and biophysics, which provide bases for growth and development<br>• Larger groups and departments are well placed to deliver strong teaching at all levels<br>• High impact on society, for example via more efficient solar cells, faster cancer diagnostics, low-carbon energy solutions | • Some groups are small or fragmented and poorly organised, so they miss opportunities to use scale and scope to reduce their vulnerability, have difficulty in spanning both fundamental and applied aspects of research themes, and the emergence of new research fields becomes a treat rather than an opportunity<br>• Strategy often unclear, limiting performance<br>• Lack of interest by some groups in societal needs and ways to connect them to the research effort<br>• Low proposal success rates and high ‘bureaucratic’ costs associated with obtaining research funding |

| **Opportunities** | **Threats** |
|---|---|
| • Excellent infrastructure and equipment combined with good access to international research organisations provide opportunities to increase both national and international collaboration<br>• Opportunities to increase both national and international collaboration, which would be enhanced by better group strategy and a clearer national strategy on physics infrastructure<br>• A more strategic approach at both levels, including more focus on interdisciplinary research, is needed to restructure and modernise the overall physics portfolio<br>• Better strategies and management would increase both the quality and relevance of research, focusing effort on important scientific objectives and attention on the needs of problem-owners in society and ways to work with them to generate socio-economic impact<br>• Clearer research strategies, better mentorship and quality control of proposals should imply a need to write fewer, better proposals to obtain external funding | • Existing organisational structures can impede restructuring and development, especially at the older universities<br>• Scattered or inadequate buildings are in some places obstacles to growth and development<br>• Difficulty of attracting students and junior academics in physics, especially in more peripheral areas<br>• The high proportion of external funding may become a longer-term risk |

Key weaknesses faced by Norwegian physics include the small size and vulnerability of some research groups, lack of internal collaboration, poor gender balance, shortages in infrastructure management, and high dependence on external funding. Lack of resources hinders the development of some smaller research groups and limits their ability to compete on a national or international level.  Such groups often rely heavily on one or a few professors, making them vulnerable to the loss or retirement of faculty members or a funding decrease. Especially in the older universities, such groups can be found in Departments with a wide scope of research and teaching activities and where the university is unwilling or unable to enable change by prioritizing some groups' activities over others. This is consistent with a more widespread inability to set and implement strategies, especially where they imply resource allocation or reallocation.

Despite the potential for interdisciplinary collaboration, the presence of specialised research groups sometimes leads to siloed research efforts. Some groups stated that they struggle with securing external funding, especially for larger projects such as EU initiatives, and that this poses a longer-term threat, limiting their access to the time and equipment and needed to continue their research. Departments also expressed concerns about the sustainability of building and maintaining experimental infrastructure corresponding to the Departments' needs. These perceptions suggest a need to improve strategic planning of research infrastructure and human resources, including both succession planning and research training and mobility.

Some larger departments need help with logistical challenges, such as being spread across multiple buildings or locations, which can hinder communication and collaboration while smaller departments need to increase national collaboration to obtain critical mass.

Norwegian physics nonetheless has important opportunities to strengthen its scientific performance and societal relevance. Its strong equipment and infrastructure base strengthens its hand in joining and working within research collaborations. Improving strategy development and research management capacity is needed not only to do better within the *status quo* but also help Norwegian physics evolve in line with changing scientific and societal needs, improving quality and relevance. Capacity building is therefore needed not only in routine PI-level strategy and planning but also at the level of Departmental research strategy and its links to education (including PhD training), building big enough 'platforms' to support high-quality PhD training while supporting researcher mobility as well as human resource strategy and management. There is also a governance dimension, especially in the universities, reducing the internal barriers to change so as to allow Norwegian physics to restructure at a rate equal to or faster than that elsewhere, otherwise Norway will be left behind, as appears already to be the case in quantum physics, some areas of theoretical physics and smaller groups in materials science, for example.

Failure to keep up with the pace of change poses a threat to science. A conspicuous Norwegian example from another part of science was the failure to address genomics at scale in the late 1990s, which necessitated launching the large FUGE catch-up funding programme. As in the other disciplines considered here, the high proportion of external funding in physics is seen as a threat, even if a substantial proportion emerges from international collaborations like CERN that are intended to continue over the long term. Another shared problem is the difficulty of recruiting students and post-docs, especially outside the central regions of Norway. It appears especially hard to recruit first-degree physics students, apparently students regard physics as especially difficult and because of the great interest in sustainability and related issues within the generation now applying to university.

Several of the physics subfields considered here are in absolute terms fundamental, while the Norwegian institutes largely deal with applied research and development, so Norwegian institutes are not very active in the areas of physics pursued by the universities.

**Natural sciences overall**

The societal impacts of the Natural Sciences have been crucial to Norway's industrial and economic development in the past and will continue to be so as attention increasingly turns towards sustainability and the societal challenges.

Many organisations are responding to the need to reorient towards sustainability transitions by reorganising some groups and departments, reconfiguring established capabilities and building new ones. The new opportunities often involve increased interdisciplinarity. This provides many opportunities. Too often, however, these are being pursued at research-group level rather than being orchestrated at a higher and more strategic level in organisations. This means that opportunities to build scale within individual organisations and by cooperating with others are being missed, and insufficient attention is being paid to developing strategies for the parts of organisations ‘left behind’.

Research groups are generally well provided with resources and infrastructures, which help them maintain international visibility and networks.

The roles of the universities and the research institutes are complementary. As the general level of scientific literacy goes up across society and innovation increasingly depends on science and technology, the links and overlaps between the university and institute sectors become even more important and should be further strengthened, especially beyond the NTNU-SINTEF nexus.

In many cases, however, research groups are too small and organisations too fragmented to develop effective strategies and efficiently to build the scale needed. More generally, strategies tend to be descriptive or to focus on overall objectives rather than being specific about what to do. Quite a number of university research groups are led by ageing professors, whose imminent retirement is often not being met by adequate succession planning in the universities.

Many groups are excellent at connecting their work with societal and industrial needs. However, a significant minority do not consider societal impact in a serious way. Despite the applied focus of much research and long-standing links to certain industries, the committee finds that the element of the universities’ third mission that relates to knowledge dissemination and exchange is underperformed, especially in disciplinarily focused departments in the universities.

Research groups almost universally perceive that they are over-dependent on external, competitive funding, where success rates are generally seen as low.

Recruitment of students and early-career researchers is becoming more difficult, in part because students and researchers increasingly want to pursue sustainability rather than traditional disciplines and are turning away from traditional fields such as oil & gas.

Issues in the following list are discussed in more detail in subsequent chapters.

- Norway has a ‘dual support’ research funding system that combines institutional and external funding. Funding growth appears to have flattened off, posing risks to both new research needed to address the societal challenges and to their more traditional underpinnings. The high proportion of external funding in the mix poses additional challenges.
- Research infrastructure is generally of high quality, and Norway has good access to international infrastructures for the natural sciences. This level of support is one factor underpinning Norwegian researchers’ ability to work in international collaborations.
- The numbers of research personnel have been growing. Recruiting the best depends on being able to attract both nationals and non-nationals, with research becoming increasingly dependent on hiring non-Norwegians. Recruitment is especially difficult in physics and in the far North
- Gender equality is slowly improving, but there is still a long way to go, given that many natural science fields have historically been male-dominated and turnover in career research positions is slow.
- Overall, the units exhibit a strong commitment to open science, and most have already achieved high percentages of open-access publication.
- The Norwegian natural sciences have substantial positive impacts on the economy, policy and society more broadly, though additional contributions are possible.

## 2.2 Supporting bibliometric and statistical evidence

This section provides some key points from the supporting evidence provided to the evaluation committee.

Bibliometric studies indicate that Norwegian research is highly cited and internationally visible in geosciences, physics has some strong points but also areas that are internationally lagging, while several sub-fields in chemistry are weaker than would be expected. Scientifically oriented research institutes are both interdisciplinary and highly cited[5]. ERC grants tend to go mainly to the three older and larger universities.

### Scientific production

The main producers of natural sciences publications are the universities (72%) and the research institutes (26%). The dominant organisations are NTNU (22%) and UiO (17.8%) (Table 8, Section 8). While the total number of Norwegian natural sciences publications in the Web of Science has grown from just over 3,000 to just over 5,000 between 2011 and 2021, the growing number of authors per paper means that, based on the fractional counting method used in Norway[6], the number of author shares totalled some 2,600 in 2011 and 3,700 in 2021. This increase of 42% in author shares, compared with the 24% increase in researchers at the evaluated units over the slightly shorter period 2013-2021 for which we have data (Table 9, Section 8), suggests that researcher productivity (in terms of author shares per researcher) has increased substantially.

NTNU is the largest producer of chemistry research publications in Norway, producing 39% of Norway's author shares in chemistry, and materials science/engineering publications indexed in the Web of Science for 2021. SINTEF produced a further 12%, so the NTNU/SINTEF dyad published about half of Norway's chemistry. The other big producer was UiO (15%) while the rest of the university sector produced 21% and the other institutes a further 10% (Karlstrøm & Aksnes, 2023). 'Big' fundamental physics and the corresponding links to CERN and ESA are concentrated at UiB and UiO. NTNU and SINTEF tend to be more applied and also work at the interface between physics and chemistry.

Norwegian physics is concentrated at UiO, which produced 35% of Norway's physics publication author shares in publications indexed in the Web of Science for 2021 – roughly the same as the combined share of UiB (17%) and NTNU (15%). Other organisations' shares are individually very small (Karlstrøm & Aksnes, 2023). 'Big' fundamental physics and the corresponding links to CERN and ESA focus at UiB and UiO. NTNU and SINTEF tend to be more applied and also work at the cross-over between physics and chemistry.

Norwegian geosciences publication is less concentrated than chemistry or physics. UiO is the biggest producer with 15% of the total output in 2021, followed by UiB (13%) and NTNU (11%). The other universities produced 22%, so the university sector, as a whole, produced 61% of the author shares. NORCE was the biggest producer among the institutes (4%), with the rest of them producing the remaining 35% of the author shares.

### Citation performance

NIFU provided publication and citation indicators in background reports to the EVALNAT evaluation. These employ two widely-used and complementary indicators in its background reports for EVALNAT: namely, mean normalised citation scores (MNCS); and the degree to which national research is represented in the 10% of most highly cited papers in their respective fields worldwide. Both rely on citations as indicators of the esteem in which scientists hold each other's work and compensate for the fact that different disciplines have different publication and citation patterns. Calculating MNCS involves relating the number of citations individual papers receive to the world average for the discipline and the year in which they are published, allocating a score of 100 for the world average. That makes it possible to combine sub-disciplines and disciplines together and compare the average citation performance of researchers within a specific country, organisation, etc. to the world average.

MNCS provide a shorthand for scientific quality, but do not distinguish between populations of researchers whose scores cluster tightly around the average and populations that contain very highly cited and less-cited papers. Most commonly, organisations are interested in the proportion of their publications that appear among the Top-10% of most highly cited papers in their field.[7] If 10% do so,

[5] It should be noted, however, that these tend to be relatively small. It is easier for smaller and highly focused groups to be well cited than for larger departments spanning a range of sub-fields

[6] See Karlstrøm & Aksnes (2023c)

[7] Of course, the analyst can also use the same technique based on other percentages

the organisation is 'averagely' present among the most highly cited publications (whereas a high MNCS does not necessarily mean that the organisation publishes among the **most** highly cited papers in its field).

Between 2018 and 2021, Norwegian natural sciences publications had an overall MNCS of 115, compared with 120 for all Norwegian publications and the world average of 100. In the same period, Norwegian geosciences as a whole had an MNCS of 127, physics 103, and chemistry and materials science and engineering 87. Much wider variation is visible among sub-fields when these disciplines are disaggregated (Karlstrøm & Aksnes, 2023c).

At the aggregate level of the Norwegian Natural Sciences, MNCS scores have declined slightly between 2011 and 2021. Norwegian authors got 11-13% of their papers into the top-10% of most highly cited papers in the Web of Science (the most demanding of the bibliographic databases used by bibliometricians) between 2012 and 2016, but since then the proportion has settled down to roughly 10% (Figure 3, Section 8).[8]

**Citation performance over a decade[9]**

Norwegian MNCS citation indicators have declined slightly during the decade 2012-2021 in all three fields considered. Chemistry and geosciences were strong in the first couple of years, then stabilised at a lower level, with chemistry slightly below and geosciences slightly above the world average. Physics shows a similar pattern, but the decline happened in 2017, and by 2020 there were signs of a recovery.

Table 10, Section 8 shows MNCS indicators for Norwegian research in the most impactful sub-fields in each of the three disciplines considered here. The picture across the natural sciences as a whole is of (mostly applied) sub-disciplines in areas of Norwegian strength continuing to do well, as do 'big physics' sub-fields, while some more traditional disciplinary fields lag. Some of the strong fields are in areas that are crucial to needed transitions in the Norwegian economy, but it is less clear that there is strength in wholly new areas whose economic importance is likely to grow. The lagging position of quantum science and technology is of particular concern, given the importance of at least having a degree of absorptive capacity in this area.

The MNCS for the Norwegian chemistry as a whole have been below the world average since 2015. In 2018-2020, applied materials science-related sub-fields and other applied chemistry areas such as wood and textiles had MNCS above the world average, while more traditional and theoretical fields lay below the average.

Geosciences MNCS have been above the world average for the whole decade. In 2018-2020, meteorology and atmospheric sciences (172) as well as geology (156) stand out as well above the world average while oceanography, remote sensing, multidisciplinary geoscience, environmental sciences and physical Geography sit in the MNCS range 120-127.
Physics MNCS varied between 116 and 126 during 2012-2016, then fell to about the world average before starting to increase again in 2020. In 2018-2020, particle and field physics (158), astronomy and astrophysics (153), nuclear physics (143) and acoustics (126) were the leading fields, with others at – or in several cases well below – the average world level. Traditional sub-fields such as condensed matter, applied, atomic, molecular and chemical physics were the lowest performing (70-79). Quantum science and technology was also very low (83).

Table 11 and Table 12 in Section 8 respectively show bibliometric indicators at the level of administrative units in the HE and institute sectors.

There are two clearly different groups of Universities. The older traditional universities – UiO and UiB – show a mixture of administrative units both above and below the 'average' values of 10% of the unit's publications being represented in the 10% of most highly cited papers in their field and an MNCS score of 100. Consistent with the discipline-level scores, UiO and UiB Geoscience departments score highest; UiO Theoretical Astrophysics is also strong; other UiO departments'

[8] This may not only be due to a real decline in citations. The huge volume and growth of Chinese publications combined with their increasing numbers of citations (especially within the Chinese research community) mean that – arithmetically – the rest of the world's publications have become relatively less cited

[9] This section is based on Karlstrøm & Aksnes (2023c)

scores are at or below the average level. Among the remaining University departments, UiT's (University of Tromsø) Physics and Geosciences departments have average-level scores; the remaining departments are below average levels.

Among the institutes, CICERO Climate, the Nansen Centre, NILU Atmospheric and Climate and NILU Environmental Chemistry stand out, and there are solid scores for the Geological Survey, NORCE Climate and Environment. the Water Resources directorate, and the Geotechnical and Meteorological Institutes. NORSAR and NORSUS are problematic. SINTEF Industry scores fairly low, but it needs to remembered that this is an RTO whose primary aim is not research excellence but to support industrial innovation.

Another way to understand scientific quality is to look at the number of ERC grants received. Table 4 shows the number of natural sciences ERC grants awarded to people at Norwegian research institutions in 2011-2023 (Column 3). Column 4 shows the number of those grants that are within the fields addressed in EVALNAT. Twenty-one of the mainstream ERC grants were in Earth System Sciences while four of the Synergy (collaborative) grants related to Arctic climate and ice sheets, so almost 60% of the grants were in the geosciences.

Table 4 Natural Sciences ERC Grants to Norwegian Recipients 2011-2023

| **Panel** | **Description** | **ERC grants awarded for Norwegian natural sciences** | **ERC grants in fields in scope to EVALNAT** |
|---|---|---|---|
| PE1 | Mathematics | 5 | |
| PE2 | Fundamental Constituents of Matter | 2 | 2 |
| PE3 | Condensed matter physics | 2 | 2 |
| PE4 | Physical and Analytical Chemical sciences | 5 | 5 |
| PE5 | Synthetic Chemistry and Materials | 0 | 0 |
| PE6 | Computer Science and Informatics | 4 | |
| PE7 | Systems and Communications Engineering | 4 | |
| PE8 | Products and Process Engineering | 8 | |
| PE9 | Universe Sciences | 4 | 5 |
| PE10 | Earth System Science | 21 | 21 |
| PE11 | Materials Engineering | 0 | |
| SyG | Synergy | 8 | 8 |
| Totals | | 63 | 43 |

Source: RCN, ERC

Forty of the 43 grants in scope to EVALNAT went to universities and three to institutes, as follows:

- UiO (21), UiB (10), NTNU (5), UiT (3), NMBU (1)
- NORCE (2), NILU (1)

# 3. The general resource situation

This section discusses research funding in Norway, distinguishing between institutional and external funding, drawing out implications for the Natural Sciences individually and collectively.

In the year 2000, at the same time as the EU, Norway adopted the Barcelona Goal of spending 3% of GDP on R&D by 2010. Over two decades later, both Norway and the EU are still a fair way from reaching this goal (Figure 1).

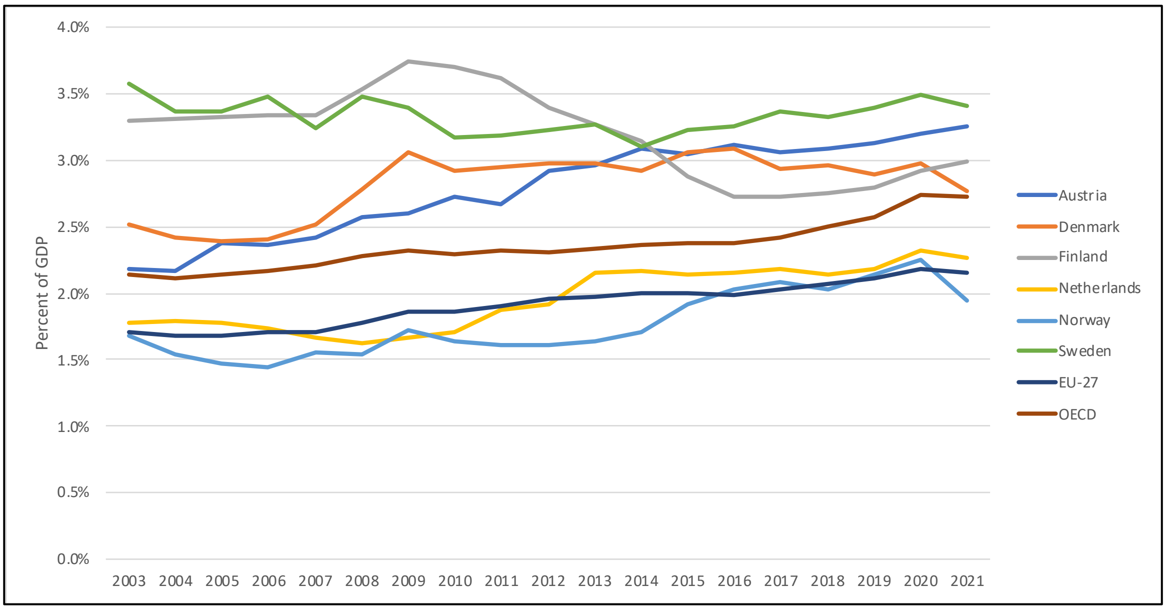



Figure 1 GERD as a percentage of GDP for Norway and comparator countries, 2003-2021

Source: OECD Main Science and Technology Indicators, accessed 20 February 2024

Sub-goals of the Barcelona Goal are that government should spend 1% of GDP on R&D, while the business should spend 2%. In 2020 (2021 being an exceptional year), Norway spent 2.24% of GDP on GERD (Gross domestic Expenditure on Research and Development), with business contributing 1.22%, while the EU as a whole spent 2.18% on GERD, of which business contributed 1.43%. Figure 1 confirms that Norway's GERD spending is low compared with the 'barometer' countries with which it usually compares itself. The Norwegian government contribution exceeds the Barcelona goal, but Norwegian business R&D spending remains substantially below it[10].

## 3.1 Funding

### Institutional funding

The administrative units evaluated come from both the university and the institute sectors (comprising free-standing research institutes that are not parts of universities), which have very different funding models. Comparisons between university and Institute performance need to take these fundamental differences into account.

Norwegian higher education institutions received some 69% of their research expenditure in the form of institutional funding (block grants) in 2021, and a further 15% from RCN (Aksnes & Fossum, 2023). This means that, while universities in some other countries have an even higher proportion of

[10] The reasons for the disparity are largely structural. Norwegian industry is largely specialised in branches that are not R&D-intensive. Although within these branches Norwegian industry tends to do more R&D than its equivalents in other countries, this has not been enough to overcome the structural effect (OECD, 2008)

institutional funding, Institutional funding at Norwegian universities is well above the level in highly competitive systems such as the UK and Finland, and the research groups' perceptions that they are highly dependent on external project funding need to be seen in this light. Norwegian universities fund some PhD and post-doc positions as well as the wages of PIs out of institutional funding, with the rest coming from external sources. While institutional funds are traditionally deployed by faculties to create a stable set of capabilities that lets them reliably deliver research and teaching, the need for restructuring discussed in Section 2 also implies that the universities need to have the flexibility and resources to reallocate institutional resources as needed.

In contrast to the universities, the research institutes have very little institutional funding – those considered here received between 6% and 20% of their income this way in 2022.

- SINTEF is the main national Research and Technology Organisation (RTO) whose mission is to support industrial innovation and gets about 12% institutional funding – typically a little less than its Scandinavian counterparts (GTS, Denmark and RISE, Sweden) – and considerably less than the 'continental' RTOs VTT (Finland), Fraunhofer (Germany) and TNO (Netherlands), which traditionally get 30-40%. Despite their focus on external funding all these RTOs are large, successful and stable
- NORCE Environment, NERSC and CICERO depend heavily on national research grants, though NERSC also has substantial international income and CICERO benefits financially from its internal fund
- NGI, NORSAR, NILU and NORSUS depend heavily on national contract research (as to a lesser extent do NILU and NORSUS)[11]
- NGU, MET and NVE are in practice parts of government that produce public goods such as geological maps and weather forecasts, but which also do research (in the case of MET, a very substantial amount of research, in line with its equivalents abroad). Their funding models are not comparable to those of the other institutes reviewed as part of this evaluation.

Like their international counterparts, the Norwegian research institutes are mostly rather stable in size over time. They generally do more applied research than the universities and adjust their production to the needs of the markets in which they operate. Norwegian labour protection law means their staff are not exposed to the kind of insecure, short-term employment markets which post-docs have to endure internationally. In many cases, the institutes' continuity of income is shaped by long-standing relationships in small public and private sector markets, and the need for government to procure particular research services over long periods.

A negative consequence of the low levels of institutional funding for Norwegian institutes combined with high labour costs in Norway is that it can be uneconomic for them to participate in EU Framework Programme projects and they can be unattractive partners abroad because they need higher day rates than others. RCN therefore runs the Retur-EU scheme that compensates for this by providing a top-up to institutes' institutional funding to help them participate in the Framework Programme.

### External funding

The state in Norway is the primary patron of research. Like other late-industrialising countries, Norway has few private research funding foundations. While business is a substantial customer of the applied industrial research institutes (RTOs – here SINTEF Industry and NORCE), the results are primarily intended for private exploitation, though there are important spillovers.

Table 5 shows RCN's project funding of the major disciplines in real (2015) terms. The largest grouping is Technology (38%), followed by Mathematics and Natural Sciences, which rose by 59% in real terms in 2011-2022.

[11] Source: RCN Institute Annual Reports, (Norges Forskningsråd, 2023a; Norges Forskningsråd, 2023b)

Table 5 RCN Real-Terms Project Funding, Major Disciplines, 2011-2021 (Millions of 2015 NOK)

| Disciplines | Cumulated real (2015) MNOK | Shares | Growth |
|---|---|---|---|
| Humanities | 2,776 | 4% | 39% |
| Agriculture and fisheries science | 5,282 | 7% | -30% |
| Mathematics and natural sciences | 17,492 | 23% | 59% |
| Medicine and health | 9,671 | 13% | 47% |
| Social sciences | 11,307 | 15% | 71% |
| Technology | 29,117 | 38% | 41% |
| Other | 1,363 | 2% | -40% |

Source: RCN

Within the natural sciences, RCN project funding in 2021 went 51% to universities, 25% to the institute sector, 9% to abroad, 9% to business and the rest to the public sector and 'others'.

RCN funding for physics has been stable over the decade 2011-2021 (Figure 4, Section 8). There has been a surge of investment in the geosciences but also in chemistry. The interdisciplinary Mathematics and Natural Sciences category (which is not considered separately in this evaluation) is bigger than the others, but less stable.

Table 6 RCN Real-Terms Project Funding for Natural Sciences by Discipline and Funding Instrument, 2011-2021 (Millions of 2015 NOK)

| | Chemistry | Geo-sciences | Physics | Cross-disciplinary | Total | Percent |
|---|---|---|---|---|---|---|
| **Bottom-up funding** | 355 | 438 | 368 | 284 | 1,445 | 15% |
| **Research Excellence Centres** | 246 | 370 | 285 | 0 | 901 | 9% |
| **Innovation Excellence Centres** | 63 | 6 | 0 | 0 | 69 | 1% |
| **Equipment** | 54 | 321 | 737 | 1,250 | 2,363 | 25% |
| **Infrastructure** | 0 | 0 | 420 | 0 | 420 | 4% |
| **Basic Research Programmes** | 48 | 65 | 449 | 69 | 630 | 7% |
| **Thematic programmes** | 411 | 1,166 | 191 | 2,047 | 3,815 | 40% |
| **Total** | 1,178 | 2,366 | 2,449 | 3,651 | 9,644 | 100% |
| **Percent** | 12% | 25% | 25% | 38% | 100% | |

Source: RCN data

RCN funds fundamental and PI-initiated projects in a variety of ways (Table 6). The bottom-up funding shown is traditional funding for PI-initiated research – mainly in the FRIPRO programme. The Research Excellence Centres (SFF) are also PI-initiated, as are the Innovation Excellence Centres (SFI), which in the Natural Sciences are only found in chemistry. Equipment funding is considerable. Infrastructure appears low because multilateral funding arrangements such as CERN, ESA, COST and the EU Framework Programme are funded at government (ministry) level, because they are governed by inter-government treaties, and therefore and do not appear in RCN's budget . There are also specific basic research programmes, which complement the bottom-up funding, ensuring that there is activity within specific disciplines.

A large part of RCN's funding goes through thematic programmes, which are allowed to contain a mix of PI-initiated and thematically defined projects ranging from basic research to innovation. The main thematic programmes to which natural sciences projects contributed in 2021 were MAROFF (Maritime activities and offshore operations), NANO2021, ENERGIX, POLARPROG, KLIMAFORSK (Climate research). PETROMAKS-2 (Petroleum research), BIA (Innovation support to company networks), and MILJØFORSK (Environmental research).also shows that basic research programmes are used mostly in physics. Dedicated equipment funding is important in physics and geosciences, but most (including much of that on which chemistry depends) is funded in the cross-disciplinary category. Table 6 also shows that basic research programmes are used mostly in physics. Dedicated equipment funding is important in physics and geosciences, but most (including much of that on which chemistry depends) is funded in the cross-disciplinary category.

The success rate in bottom-up project funding is very low – sometimes as low as 5%, while thematic programmes have higher success rates, often of the order of 30%. This low bottom-up success rate may be exacerbated by a lack of proposal quality control by the universities, so that many rejected proposals are repeatedly recycled to no effect. Internationally, thematically-focused calls tend to have higher success rates than bottom-up ones because they can only be addressed by sub-sets of the research population. Some researchers complained in their submissions to this evaluation about a lack of thematic funding opportunities, for example in chemistry and parts of geosciences.

**Implications for research**

While almost all the administrative units evaluated are significantly exposed to external funding contract markets, these tend to provide opportunities and constraints for doing research, rather than posing existential threats to researchers and academics with permanent contracts. Most units evaluated would prefer to have more institutional funding. Many have become more anxious about the continuity of funding since a recent conflict between the Minister of Higher Education and Research and the RCN Board, and reductions in the amount of money available through RCN calls for proposals since 2022.

The share of external funding in administrative units' research income varies considerably, in part depending on the funding model of the individual unit, in part depending on their strategy and the extent to which they aim to leverage institutional funding and other assets (such as infrastructure) into external funding, and in part based on other pressures.

Chemistry departments at UiB, UiO and NTNU obtained less external funding than the evaluation committee would have expected, in part because of the need to provide large amounts of teaching, and were missing opportunities to increase their income from both the EU Framework Programme and industry. While some parts of the geosciences had generous industry funding, there were opportunities in other parts to increase industrial income. Sub-atomic physics at UiO and UiB benefitted from the national contributions to CERN, and at UiB also to ESA. Norway's high GDP per capita means that its contributions per capita to international organisations are also high. In cases such as CERN and ESA there is an element of *juste retour*. This creates substantial opportunities for Norwegian researchers and can embed their positions in their universities.

Natural sciences research tends to need more external funding than many other areas because it requires a lot of equipment and technical support. Large infrastructure – equipment and facilities so expensive that they cannot be funded from a single project – is also important, and Norway is fortunate in having extensive, high-quality infrastructure at the national level as well as good access to international infrastructures, for example at CERN and ESA. Good infrastructure is attractive not only to Norwegian natural scientists but also to potential collaboration partners abroad, making it easier for Norwegian researchers to join international projects such as those in the EU Framework Programme. Established access to international infrastructure can be a platform from which to attract a lot of national funding (as for example UiB and UiO physicists do) but can also be a barrier to entry or exit, impeding change, especially in parts of physics.

The importance of natural sciences to industry in what is still substantially a resource-based economy not only means that Norwegian research is more likely to be applied than in more science-based economies such as Sweden, but also means that active industrial involvement is necessary. This is very important for example in geosciences at UiB and NGI (as well as some of the other institutes involved). The same logic applies to chemistry (as well as applied physics), but it is notable that chemistry departments at UiB, NTNU and UiO all report difficulty in obtaining industry funding. NTNU suffers from the same problem, even though its work in chemistry tends to be more applied than in the three other universities mentioned.

Increasing the 'return' to Norway from the EU Framework Programme has been and remains a concern in Norwegian STI policy. In this evaluation, administrative unit evaluation committees observed that UiB and NGI were particularly concerned to increase their Framework programme income, but the issue is more general.

## 3.2 Personnel

SSB statistics show that there were about 3,270 researchers in 2021 in the natural science administrative units evaluated, up 24% from 2,630 in 2013. Geosciences in the universities grew by 57% during the period – much faster than the natural sciences in the HE sector as a whole, which grew by 31%, compared with 18% for the institute sector.

There are fewer personnel data about the institutes and they are not classified by field, but the fast-growing institutes in 2013-2021 were CICERO, NORCE (Climate and Environment), NORSUS, NGI and MET – most of them involved with geosciences and atmospheric sciences. The share of institute researchers with a PhD rose from 58% in 2013 to 68% in 2021 as part of a long-term trend.

Table 9, Section 8 shows the number of researchers (including PhD students) at the administrative units evaluated in 2013, 2017 and 2021, the percentage change between 2011 and 2021, and the proportion of women researchers in 2021.

Overall, the number of Natural Science researchers has grown by 36% – somewhat slower than the roughly 60% increase in RCN's natural sciences funding over the same period – with significantly higher than average growth rates evident in groups (including UNIS) doing earth sciences, climate, sustainability and environmental research.

In the university groups considered in this evaluation, professors' average age in 2021 was 55, associate professors 45, researchers and post-docs 36, and PhD students 29 (consistent with a continental rather than an Anglo-American pattern). The mean age of institute researchers was 44.

The institutes had few researchers over 62 (the minimum retirement age). However, in the HEIs 28% of the professors were 62 or older. Five university departments may be at risk from having a high proportion of professors beyond this age. Three are at UiB: Earth Sciences, where 40% of the 25 professors are 62 or above, Chemistry (40% of 15), and Physics and Technology (30% of 15). The others are Chemistry at UiO (38% of 21) and the NTNU Department of Geosciences and Petroleum (50% of 24). (Rørstad & Wendt, 2023) In contrast, only 7% of researchers in the institutes were aged 62 or more. The highest proportion is at NORSAR, with 11%

## 3.3 Research infrastructure

Most of the administrative units evaluated were crucially dependent on shared infrastructure as well as having a high level of local advanced equipment and instrumentation. Overall, preserving the accessibility and affordability of infrastructure is at least as important as preserving the infrastructure itself.

Infrastructure access plays a key role in international collaborations, so its provision is a critical ingredient in maintaining and improving Norway's membership of international research networks and communities, in addition to directly supporting Norwegian research. Several of the major pieces of infrastructure, such as the RV Kronprins Haakon as well as other research vessels and the national high-performance computing facility Sigma 2 are used across disciplines. Computing facilities appear to be especially important, as research continues to become more modelling-intensive across disciplines, and the widening use of digital twins further drives up demand.

The infrastructure described for the chemistry sector was assessed as excellent. It includes centralised facilities, for which some of the largest research groups and units are responsible or are co-organisers, as well as state-of-the at instrumentation held by the units or by single research groups. The main facilities needed are present, with a quality at the highest international levels. Most groups appear satisfied with the level of infrastructure, though access to facilities should be maintained in the future, ensuring proper maintenance and possibility of access. Any reduction in base funding would limit the availability of these resources for researchers, reducing their competitive advantage and the support they can offer to Norwegian industry and society. The variety and quality of these infrastructures also offers important opportunities for Norwegian researchers to join international partnerships.

There are also excellent levels of infrastructure across physics departments and institutes in Norway, but this is mainly concentrated amongst the larger departments that are the most successful in fund raising. UiB and UiO are both heavy users of CERN and space-related infrastructures. There should be a concerted effort to enhance resources and facilities across the board. An approach would be to strengthen collaborative networks among institutions, enabling sharing of equipment and expertise to maximize utilisation and efficiency. Additionally, strategic investment in upgrading existing facilities and procuring state-of-the-art equipment can modernise research capabilities and enable further innovation. A key corollary is the need to fund operating, maintenance and periodic upgrading costs. Government funding initiatives tailored to support infrastructure development in universities and institutions can also play a crucial role in advancing Norwegian science. Promoting partnerships with industry can provide access to advanced technologies and resources while fostering mutually beneficial collaborations, also increasing impact. By finding methods for more equitable access to high-quality infrastructure and promoting collaboration, Norway can strengthen its position as a hub for physics research and innovation.

The geosciences are heavy users of large infrastructure, of which some of the most expensive (especially ship time) is national in character. Norway's strong position in geosciences and the expansion of the field driven by climate change and other sustainability concerns, as well as the desire to explore and exploit the deep sea, make the provision and maintenance of relevant national infrastructure especially important for Norway. At the same time, the geosciences make heavy use of international infrastructures since the driving issues concern all countries but especially those with an interest in the polar regions.

While infrastructure provision and quality are high across much of the Natural Sciences, there seems to be an increasingly urgent need for more HPC facilities. There are also opportunities to offer better access to some of the smaller research groups and to share resources more efficiently. This is especially important in a country with a small population, as many infrastructural investments are indivisible and therefore have to be shared[12].

[12] RV Kronprins Haakon cost about NOK1.4 billion in 2013, compared with the latest equivalent UK vessel the RV Sir David Attenborough, which cost about NOK 2.6 billion in 2020 but serves a country with 13 times the population of Norway.

# 4. PhD training, Recruitment, Mobility and Diversity

The information in the self-assessments about PhD training, career development, recruitment and diversity is patchy, at both research group and administrative unit levels. This limits what the committee can say.

## 4.1 PhD training

In the University sector in 2021, 28% of the Natural Science scientific employees were PhD students, while 28% were researchers and postdocs (non-permanent staff) and 30% were permanent staff: associates (10%) and professors (20%). This proportion of PhD students is relatively low compared to international standards. The ratio of PhD students to professors is 2.1:1 in Norway, compared with the international norm of 2-3 students to 1 professor. The statistical bureau estimates that 63% of PhDs currently being awarded go to foreign nationals (SSB report).

Parts of UiB, UiO and NTNU referred to the use of obligatory career plans for post-docs and/or PhD students. Again it was not evident how consistently this requirement is fulfilled.

The research institutes have their own career development policies. Where these were discussed, they were seen as positive, but they probably resemble good business practice more than academic practice.

## 4.2 Recruitment

Several research groups pointed out that their small size, and sometimes also the age of their professors, left them vulnerable to the loss or retirement of key personnel (see Section 3.2). This problem was more prevalent in traditional sub-fields – notably in chemistry – than in newer and expanding fields. In some cases it was also said that there was no money available to replace retiring professors. This may reflect universities' desire to restructure rather than an absolute shortage of professors or money. In many cases, little consideration was given to succession planning.

Many of the administrative units referred to the difficulty of recruiting students in physics and chemistry at the masters level, as well a post-docs and PhD students – especially in the north of Norway, and particularly in relation to foreign candidates.

## 4.3 Mobility

By and large, the universities had mobility policies or schemes in place, though information was patchy and there were few numeric data, so it was not always clear whether researchers' knowledge that opportunities existed was often translated into action. UiO Chemistry actively used its international fellowships and RCN's Young Research Talent to increase the number of high-quality international and national students. It also mentioned the faculty's high-quality research mentorship and the availability of proposal-writing training and support. UiT Chemistry and Geoscience also explicitly mentioned the availability of mobility funding, though UiT Chemistry also pointed out that that it was reluctant to support mobility because of its negative effects on teaching capacity.

More generally, RCN encourages PhD students to spend some time abroad, to obtain wider experience and establish personal international networks, though it is not clear that this desire is consistently connected to the money needed to make it possible.

# 4.4 Gender equality and diversity

Practices vary among administrative units, but most had some kind of policy for both gender equality and diversity. Statistics are collected on gender, but apparently not on diversity. Only one of the 28 administrative unit reports referred to LGBTQ+ people.

While gender equality remains a problem in most administrative units, many reported that PhD students are more likely than permanent staff to be women. In 2021, 39% of Natural Sciences PhD students were women compared with 33% of staff overall and 21% of professors (SSB report). In the institute sector, the proportion of female researchers overall grew from 34%in 2013 to 39% in 2021.

The higher education sector units evaluated show the usual pattern of gender imbalance, with women making up 39% of PhD students, 33% of post-docs and people on researcher grades, 35% of assistant professors, 21% of full professors and 33% of researchers overall. The gender balance is slightly less skewed in the institute sector (39% women) than the higher education sector (33%) women.

In most of the university administrative units evaluated, women produce fewer author shares than men (Table 13, Section 8), though there are exceptions such as the Departments of Chemistry at NTNU and UiT[13], and Geosciences at UiT. It is not clear whether the imbalance is caused by differences in gender roles reducing women's research output compared with men's, by behavioural differences in negotiating authorships or seniority. One of the administrative units hypothesised that the disparity could be caused by the higher proportion of women in early-career-stage jobs, where people generally publish less than their seniors. It was also noted that women are invited to join research collaborations less often than men. Unfortunately, we do not have equivalent data to Table 13 for the institutes, but the issue may be a little less acute, given the higher proportion of women there.

Our impression is that, unsurprisingly, the long-established administrative units working in applied areas with a strong tradition of recruiting men have the greatest difficulties dealing in improving gender balance. SINTEF Industry pointed out that it received very few job applications from women, reflecting such a history.

Some administrative units nonetheless provide examples of good practice. UiO Theoretical Astrophysics had a 7-point plan for hiring women, and ran regular seminars on gender and cultural diversity. UiT Chemistry had at times selectively recruited women to PhD and junior academic positions. NGI appears to operate at international best practice.

In some cases, organisations appeared to have appropriate policies at top level, but it was not always clear that these were well implemented at the level of Departments of Research Groups. For example, administrative units at UiB were not always convincing about the implementation or effectiveness of equality and diversity policies. UiB Physics and Technology said that while there was some internal committee activity, the proportion of female post-docs has declined since 2016/17, when the University stopped paying post-docs for teaching.

Generally, administrative units said they have rules in place to protect against discrimination, though there was little evidence of any comprehensive Equality, Diversity and Inclusiveness frameworks. Only one mentioned having specific targets for this. Some organisations are proud of their internationalism but take no account of their (lack of) ethnic diversity. Clearly, gender inequality needs to be addressed more effectively, while diversity needs to be taken more seriously.

# 4.4 Patterns in the three disciplines

In chemistry, the number of PhDs is exceptionally variable amongst groups, with a lack of uniformity in training across the units. Some institutions outside the main cities suffer recruitment challenges. These challenges may impede their ability to attract and retain highly qualified individuals and also exacerbate existing inequalities in academic representation and productivity. The limited information

[13] This is also the case at the Department of Chemistry at UiB, but there the difference between the women and the men is so small as to be meaningless

given by the groups may be an oversight in parts, but it may also reflect a lack of PhD training strategies.

The landscape of physics PhD training in Norway presents both strengths and challenges. On the positive side, PhD programmes typically offer rigorous training and mentorship, providing students with opportunities to engage in cutting-edge research and develop critical thinking skills. Some departments are very engaged with wider impact and have collaborations with industry giving more advantages within PhD training. Initiatives like the Research Council of Norway's funding schemes support mobility among research institutions and international collaboration, enriching the academic experience and broadening perspectives. However, recruitment practices sometimes struggle to ensure diversity, with efforts needed to actively promote inclusivity and equity in the selection process. Additionally, while mobility is encouraged, bureaucratic hurdles and limited funding for international students can hinder participation. Streamlining administrative processes to facilitate mobility and attract talent from around the world would be helpful.

Within the geosciences, PhD training seems particularly poor in the Institute sector. Only one or two PhD students seemed to be based at the institutes at any one time. In principle, the Institutes should have lots of interesting data and research questions that PhD students could tackle, though the institutes' more problem-oriented work may need to be tackled on shorter time-frames than are needed for a PhD. However, given the mutual benefits of having PhD students working in the institutes as well as the universities, some specific industry/Institute PhD scheme – perhaps building on the existing industry PhD (*Nærings PhD*) – might help improve the links between institute research and the often more fundamental work done in the universities.

# 5. Research cooperation nationally and internationally

## 5.1 Administrative units' cooperation within and between different sectors

Norway's university and research institute systems were established separately but have co-evolved. The first innovation agency – NTNF, which funded natural sciences research and innovation and owned a chain of applied industrially-orientated research institutes – was established in 1946, at which time the higher education sector comprised UiO and the Norwegian Institute of Technology (NTH, the technological university in Trondheim, which was merged with other units to form NTNU in 1996). The Norwegian Research Council NAVF was established only in 1949.

NAVF set up a Central Institute for Industrial Research (SI) in 1949 as an RTO which helped link UiO research with industry. The following year, NTH established SINTEF for the same purpose on its campus in Trondheim, initially very much under the control of NTH professors. SINTEF eventually took over SI in 1993. UiB was established in 1949, and built close links to both established and newer institutes around Bergen, many of which have recently merged into NORCE. UiT opened in 1972, and while it has strong links to the UNIS university centre on Svalbard, it does not have its own distinct institute cluster.

This history underpins the pattern of co-publication in natural sciences shown in Figure 2. The diameters of the nodes are proportional to the number of co-publications it had in the period. The lines indicate co-publication, and their widths are proportional to the number of co-publications there were between the organisations at the ends of the lines. UiO is much bigger than the other organisations and forms a natural centre for the collaboration network. NTNU and UiB are tightly connected to their local institutes. UiO's links to SINTEF are partly based on SINTEF's presence on campus based on former SI institutes.

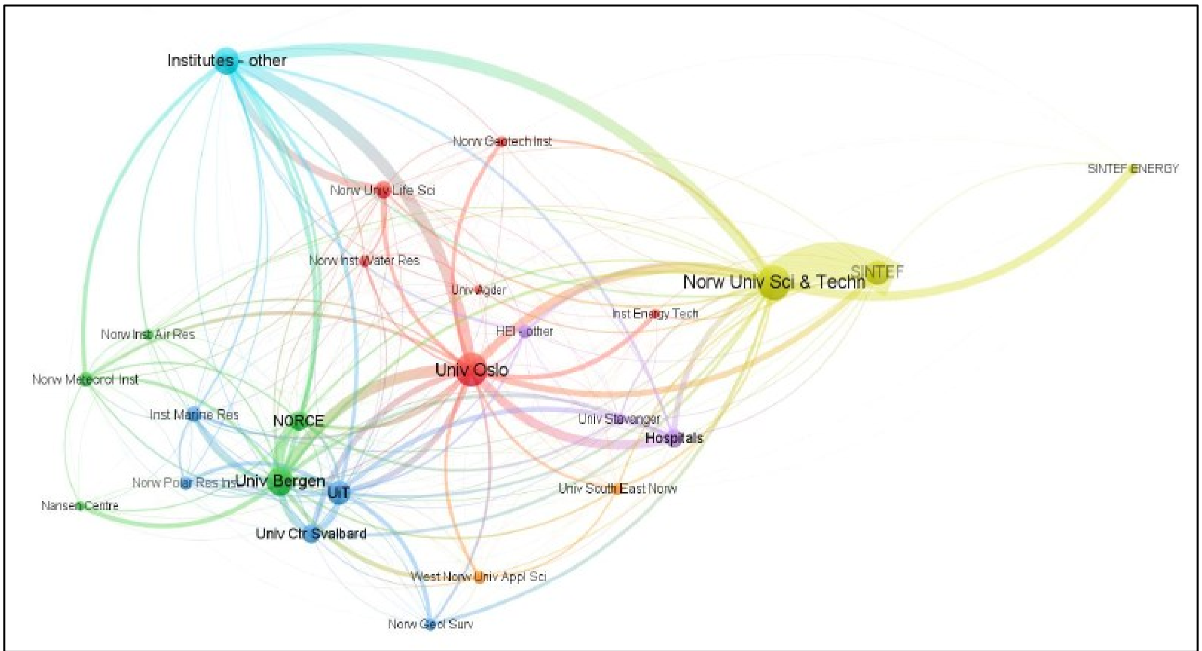



Figure 2 Co-publication among Norwegian organisations in Natural Sciences, 2019-2021

Source: Karlstrøm & Aksnes, (2023c)

Adjunct Professor (Professor II) positions form a key link between the institutes and the universities. These positions are mainly used by the medical and natural sciences. Just over 200 (12%) of Professor II positions in 2019 were held by people employed in research institutes. Given Norway's lack of medical research institutes, these would have been mainly in the natural sciences (Norges Forskningsråd, 2019).

## 5.2 Administrative units' research cooperation nationally and internationally

Figure 2 indicates that in chemistry, co-publication focuses on the NTNU-SINTEF axis, with a smaller but still substantial link between these two places and UiO. Geosciences have distinct but overlapping networks centred on UiO, UiB, and to a lesser degree NTNU. The physics collaboration network has distinct but overlapping networks centred on UiO and UiB, with a further fragmented but rather separate network centred on NTNU and including SINTEF.

The pattern of international collaboration appears healthy. The natural sciences have a higher proportion of papers co-authored with foreign collaborators than any other major discipline in Norway (Aksnes & Fossum, 2023).

Some 71% of Norwegian natural sciences publications in 2019-2021 had international co-authors. Norwegian natural scientists collaborate particularly with colleagues in the USA, Germany and the UK, which have large and well-performing natural sciences communities. They also collaborate with colleagues from smaller countries such as Denmark, The Netherlands and Switzerland, that tend to produce a high proportion of highly cited papers (Table 14, Section 8).

Some 71% of natural sciences papers published by the higher education sector in 2019-21 had international co-authors, compared with 65% for the institute sector, reflecting the more applied and local focus of institute research. Both figures are high, signalling that Norwegian research is internationally well embedded. NTNU and UiS have levels of international co-authorship well below those of UiO, UiB and UiT (Table 15, Section 8).

Among the institutes, those working with geoscience and climate have very high levels of international co-authorship, reflecting the international nature of many of the problems they address and the fact that Norway has built comparatively strong positions in these sciences. The industrially focused institutes (especially SINTEF) and those that have more of the character of government labs and focus on Norwegian problems (such as NVE and NGI) have lower levels of international co-authorship, though MET is comfortably above the average for the institutes (Table 16, Section 8).

# 6. Societal impact and the role of research in society, including open science

## 6.1 General description of impact cases

Impact statements have been used in earlier field evaluations, such as that for the humanities (HUMEVAL) but they are new to the Natural Science community. A minority of the researchers involved did not prioritise responding to the request for information about impacts.

Overall, the impact cases submitted to the evaluation usefully illustrate some of the societal benefits of research.  Few quantitative data are available because these impacts are not actively monitored, and researchers naturally lose sight (or are unaware) of many of the more distant impacts of their work, so such cases almost certainly understate the impacts of research.

Impacts are evident in the activities of most chemistry research groups and administrative units. Chemistry research in Norway has strong foundations in the process industries, fertilisers, metals/metallurgy and oil and gas. These departments' active and long-lasting collaborations with industry underpin their strong impact. Many of the research groups are taking on research challenges for the green and energy transitions, meeting many of the UN SDGs and this can be expected to lead to cleaner technologies. In this, the role of institutes (e.g. SINTEF Industry) and of application oriented universities (e.g. NTNU, UiO) is very important. Few devote much effort to outreach to the unspecialised public, beyond some outreach efforts to schools. Given the importance and relevance to the society of many of the topics studied, the research community should engage more in public scientific and policy debates, and in combatting the increasing flow of disinformation relating to climate change and sustainability.

A considerable portion of Norwegian physics is orientated towards applications. Norway's physics researchers have aided economic growth and also pioneered new technologies, and much of its future impact lies in sustainable development, leveraging its natural resources, particularly in energy and maritime industries. The close relationship between NTNU and SINTEF help connect research to use and hence societal impact. More interdisciplinary research would be helpful in connecting knowledge with solving societal problems. Additionally, forming strong partnerships with industry, government agencies, and institutions can aid the translation of research findings into solutions that benefit society. It would have been especially interesting to have some impact cases based on the 'big science' being done in physics.

Geosciences involved a different balance of activities, compared with physics and chemistry, developing and applying an understanding of how large and complex natural systems work, documenting and monitoring them and studying resource exploitation. Much of the knowledge produced is public goods and/or is used in developing policy. The institute system is more heavily involved than in physics and chemistry, so research-industry and research-society interactions are especially important. There were some really good examples of impact case studies, although some institutes appear to have put more effort into presenting impact cases than others.

## 6.2 Review of selected EVALNAT impact cases

A small selection of the impact cases submitted to the evaluation is provided here and illustrates the breadth of the research as well its often significant impact. The cases include development and transfer of more sustainable technologies to industry, rapid uptake of results from fundamental research and their use in responding to the Covid crisis, the production of public goods for the benefit of both the general public and industry, involvement of the public in citizen science, predicting and mitigating disasters such as landslides, helping tackle decarbonisation of the energy system and making the operation of space-based electronic systems safer and more reliable.

**Chemistry**

**Administrative Unit:** NTNU - Chemical Engineering: Industrial Catalysis Science and Innovation (iCSI) centre (an SFI centre)

**Case:** SFI iCSI

During 2015-16, the centre started research to deepen understanding of catalysis in the production of PVC, nitric acid and formaldehyde – bulk chemicals for which there are large markets and many industrial uses, and of which members of the industrial consortium are major producers. iCSI developed new methods and protocols which were used by the industrial partners by the industrial partners to increase yields, reduce energy consumption, develop new process technologies and reduce the risk of environmental pollution. The 4 PhD and 18 masters graduates associated with the projects up to 2023 now work in the chemicals industry or universities and are using their education significantly to reduce the climatic and environmental impacts of chemical processes, and form part of much bigger cohort of graduates and postgraduates from the Centre taking similar skills with them to industry.

**Administrative Unit:** UiO Department of Chemistry, Catalysis Section

**Case:** UiO-66 metal organic frameworks

In work starting around 2005, researchers in the Catalysis Section discovered and developed the UiO-66 series of metal organic framework materials, which are very stable, have massive surface area, and whose porosity can be tuned for different applications, for example in catalysis and gas storage. A long-standing collaboration with characterisation specialists at the University of Turin was crucial for the work. It took several years to learn how reliably to synthesise metal-organic compounds on the frameworks, leading to a series of patents starting in 2011 and the creation of the ProfMOF company in 2015, which by 2022 was trading profitably with three employees and a turnover of NOK 4.2m, providing research and intellectual property to major manufacturers. The research has enabled applications such as adsorption and separation, gas phase heterogeneous catalysis, photo- and electrocatalysis, sensors, healthcare and drug delivery. The researchers believe there has been very large industrial as well as scientific impact, and that several hundred PhDs are currently being researched in the area.

**Administrative Unit:** NTNU, Department of Chemical Engineering

**Case:** Development and production of Covid-19 test kits

Owing to shortages of reagents for Covid-19 tests early in the recent pandemic, NTNU's Departments of Chemical Engineering, and Clinical and Molecular Medicine developed a new test method based on magnetic nanoparticles, which was developed, validated, patented, and put into use in Norwegian hospitals in less than two months during the Spring of 2020. The project built on long-standing interdisciplinary cooperation in fundamental research between the two NTNU Departments and TU-Delft, and included setting up pilot-scale and then industrial-scale reactor to make the nanoparticles, eventually supporting production of a million tests per week. The project received wide national publicity, serving (like the mRNA vaccines) as a useful demonstration that basic research results can sometimes quickly be turned into practical solutions. NTNU was able to set up a new Particle Engineering Centre in 2021, linking particle research to applications. The inventors set up a medical diagnostics company Lybe Scientific – in Trondheim which currently has 8 employees and turns over NOK 15m.

**Geoscience**

**Administrative Unit:** Norwegian Meteorological Institute (MET)

**Case:** Yr.no weather app

Like other meteorological institutes, MET runs a continuous programme of research and model-building as well as collecting data to provide weather forecasts – mostly free of charge, as public goods. Currently, MET and the Swedish meteorological and Hydrological Institute cooperate on using a version of Méteo-France's short-term weather prediction model that they have modified to meet Scandinavian conditions. They collect additional weather data from Internet-connected domestic weather stations in domestic 'smart home' installations and use these and other citizen science data to refine the weather forecasts. Together with the Norwegian Broadcasting Corporation (NRK), MET has built a free weather forecast app (Yr.no) that combines forecast information from international sources to provide weather information about the world with specific Scandinavian information on things like snow depths, bathing water temperatures and whether mountain passes are open. Yr is now the most highly trusted weather app in Norway, and was being accessed by 11 million unique users per week during 2022.

**Administrative Unit:** Geological Survey of Norway (NGU)

**Case:** InSAR.no

In 2005, NGU and the Norwegian Space Agency started to develop the first capability to process interferometric synthetic aperture (InSAR) satellite data in Norway. This made it possible to track very small movements on the ground, and identify places with a high risk of landslides. A new generation of satellites from 2014, made it possible to make a comprehensive map of ground deformations across Norway starting in 2018, which has since been integrated with the European Land Monitoring Service. Areas identified as having high landslide risk have since been equipped with terrestrial monitoring equipment. InSAR data are now used more widely by the Norwegian road, rail and water authorities, monitoring the stability of infrastructure and making it possible to take preventive action. InSAR data are also used in areas such as monitoring ice sheets, changes in the permafrost layer, monitoring movements in the earth's crust in the study of plate tectonics and assessing volcanic and earthquake activity. NGU makes the InSAR data freely available, so they are not only important for building and maintaining safe and efficient infrastructure but are also important public goods for wider use.

**Physics**

**Administrative Unit:** UiB Department of Physics and Technology

**Case:** Achieving energy security with reduced carbon footprint

The research group works on the way liquids and gases flow through porous materials, in order to understand how to increase oil and gas yields from natural reservoirs as well as to understand opportunities for carbon capture, use and storage and other approaches to reducing carbon emissions. The group has to tackle the difficult problem of scaling up results from the bench top to real-world reservoirs. This is an example of repurposing research and skills to help achieve the energy transition, and the teaching activities of the Department produce a substantial flow of graduates to the energy industries. Two examples of impacts from the research are

- Freeing methane from gas hydrates (water- and methane-containing solids often found in conjunction with natural gas) by exposing them to carbon dioxide. One molecule of carbon dioxide is captured for each methane molecule released, so using the methane is effectively carbon-neutral
- Using carbon dioxide foam for lower-carbon oil production. Carbon dioxide in foam more effectively forces it out of the reservoir and better captures the carbon dioxide. While burning the oil still produces carbon dioxide, this method of extraction is less carbon-intensive than using carbon dioxide gas and captures more carbon

Both results have been demonstrated in the field, and projects have involved energy producers, EU Framework Programme researchers and in the first example also the US Department of Energy

**Administrative Unit:** UiO Department of Physics, research sections for plasma and space physics and electronics

**Case:** Space weather products for the Arctic regions

Space weather, in the sense of changing environmental conditions in near-Earth space, interacts with the Earth's magnetic field and affects the performance of electronic systems. Irregularities in the density of plasma in the ionosphere near the poles can be especially problematic. UiB has been part of an international research effort to understand and forecast space weather and reduce its effects on global navigation satellite systems. UiB set up the 4DSpace Strategic Research Initiative for understanding the ionospheric irregularities in 2014 and has developed instrumentation, codes, data analysis and models to help forecast space weather. Using instruments located in the Arctic and Antarctic, they have also explored effects on the ground. Two patents have been taken, and results from 4DSpace are being used in developing space weather forecasting models and are being implemented in ESA's Space Weather / Space Situation Awareness initiative. The early impacts of the work are in the research community and in increased safety and reliability of space systems, and they are expected to have wider impact on users of global navigation satellite systems and users of electronic systems operating in the Arctic regions.

**Administrative Unit:** University of Oslo, Department of Physics

**Case:** Bringing the discovery of the Higgs boson to classrooms and lay audiences worldwide

High energy physics researchers have played leading roles in the ATLAS collaboration at the LHC, which, in 2012, alongside the CMS collaboration, announced the first observation of the Higgs boson. This discovery garnered global media attention in July 2012. Groups at the University of Oslo contributed significantly to helping the lay audience understand and appreciate this monumental breakthrough in elementary physics. They achieved this through direct participation in news programs, writing news articles, engaging on social media and blogs, and live-streaming the official announcement at the local institute. Furthermore, researchers and students in high energy physics swiftly augmented educational materials utilized annually in the International Masterclasses in Particle Physics (IMC) by incorporating data from the Higgs boson discovery. Since then, tens of thousands of high school pupils and teachers worldwide have had the unique experience of rediscovering the Higgs boson using the same data and methods employed in the discovery.

## 6.3 Open science

Most if not all the organisations participating in the EVALNAT evaluation have policies relating to open data and software. Many are described as conforming to good or best practice, with at least the larger organisations having facilities for storing open data. In the absence of statistics, however, the degree and quality of compliance with open data policies are hard to establish.

Software is broadly shared through repositories such as GitHub. There are databases such as viten.no for holding educational materials, but these do not seem to be so widely used.

The natural sciences – especially the geosciences – already have an established tradition of building and maintaining databases of evidence, which are used and re-used by the research and policymaking communities. Holding, curating and updating such databases has clear scientific and societal value and supports the scientific reputations of those who maintain them. The value of one-off data sets is probably more variable, and while it is felt that funders like to see them being held, it is less clear what to do with them in practice. For example, UiB Chemistry noted that, while the university has data storage policies in line with the FAIR principles, the institute itself did not curate the data it stored.

The degree of open publication has increased rapidly in recent years, in Norway as elsewhere. Table 7 summarises the extent and type of open access publication by universities and research institutes. It is based on information input to the national CRIS (CRISTIN), which requires that authors be from recognised Norwegian research-performing organisations and that works should be externally peer reviewed. Roughly speaking, this means that publications are from academic journals, peer reviewed books and conferences or peer-reviewed monographs, but excludes institutions' own working papers, other publication series, and reports. The Table shows that roughly three-quarters of publications are Open Access, with only modest differences between the two sectors, although at the administrative unit level there is substantial variation within each category.

The administrative units universally have policies that favour Open Access publication, though units at UiO and UiB sometimes report that university policy only asks that researchers "do their best" or are "strongly encouraged" to do so. RCN does not fund article processing changes (APCs). Rather, organisations need to pay them from their institutional funding. Thus, the research-performing organisations themselves pay the costs of Open Access publication. UiO's budget for this is reported to run out during the financial year.

Table 7 Open access publication by Administrative Units evaluated

| | Archived ('green') Open Access | 'Gold' Open Access | Not Open Access |
|---|---|---|---|
| Universities | 48% | 32% | 20% |
| Research institutes | 40% | 37% | 23% |
| Total | 44% | 35% | 22% |

Source: (Karlstrøm & Aksnes, 2023a) (Karlstrøm & Aksnes, 2023b; Research Council of Norway, 2023)

# 7. Recommendations

The natural sciences have been key to economic and social development in Norway to date, and will remain so as policy attention shifts towards sustainability and resilience, public health, the changed geopolitical environment and needs for new strategic materials and technologies. These trends affect all countries and are urgent, so there is intense scientific and industrial competition to address them and to avoid being left behind in the new and growing areas. In doing so, the quantity, quality and flexibility of Norwegian natural science will be key to maintaining and improving national positions. Given the structure of industry in Norway, the extent of public funding of the natural sciences is one of the determinants of success.

While there are high points in all areas, the major fields considered here – geosciences, physics and chemistry, with materials science spanning the latter two – differ in their overall quality and performance. Each contains a mixture of stronger and weaker elements. Overall, geosciences appear strong, building on traditional Norwegian scientific strengths. Physics is closer to the world average level of quality and performance, which is clearly insufficient in a rich developed country, though again there are both high and low points. Notwithstanding Norway's strengths in some sub-fields, the state of chemistry overall is unsatisfactory. The key to improvement across the natural sciences is not an undifferentiated effort to improve the quality of everything but a process of renewal that emphasises investing in strong and growing, high-quality themes and careful decisions about where to disinvest without jeopardising core competences. There is a particular need for a system-wide approach to strategy and funding in chemistry.

Barriers to change are not so much in the science as in rigidities in governance and budgeting (especially in the universities), a need to develop better ways to manage human resources and develop robust research and organisational strategies, and a lack of incentives for change.

While the natural sciences are broadly well funded and there is a good level of institutional funding in the higher education sector, many organisations nonetheless have a high dependency on external research funding, especially in the institute sector. This funding pattern can be efficient as long as the funding system and budgets are reasonably stable and researchers can count on them remaining so. Unfortunately, recent funding changes appear to have undermined trust within the research community and this is an obstacle to longer-term planning. Low success rates in bottom-up programmes funding PI-initiated research cause uncertainty and need to be addressed.

The numbers of researchers in Norwegian natural sciences have been growing, reflecting increased real funding, especially in geosciences and developing fields of physics and chemistry. At the same time, a generation of older professors are nearing the end of their careers, and succession plans are not always clear. A large part of the growth in researchers is enabled by hiring foreigners, so it is especially important to maintain the attractiveness of employment in Norwegian research. Both faculty and student recruitment are said to be difficult in the North of Norway, and there is a more widespread difficulty in recruiting students to physics and chemistry.

Research infrastructure is generally of high quality, and Norway has good access to international infrastructures for the Natural Sciences. This level of support is one factor underpinning Norwegian researchers' ability to work in international collaborations. However, there are opportunities to improve strategy for infrastructure development and use through better coordination among universities and institutes involved. There also needs to continue to be sufficient funding to maintain and develop existing infrastructures through their useful lives.

Gender equality is slowly improving, but there is still a long way to go, especially in areas (for example in parts of geosciences) where historical recruitment has been particularly male-dominated. While the importance of gender equality is widely appreciated, that of wider diversity (such as ethnic and cultural diversity) is much less recognized and requires more attention.

The administrative units evaluated are committed to responsible research and innovation and open science. Most have already achieved high percentages of open access publication.

Norwegian natural scientists collaborate well, both nationally and internationally, though there is still scope for greater participation in international programmes including the EU Framework Programme. The roles of the universities and the research institutes are complementary. As the general level of scientific literacy goes up across society, innovation increasingly depends on science and technology, and industry depends on acquiring and developing new knowledge form a changing set of fields, the links and overlaps between the university and institute sectors become even more important than before and should be strengthened.

As indicated, the natural sciences are of great economic and social importance for Norway, and will continue to be so as the country addresses new challenges in a changing world. Many research groups are acutely aware of this and maintain close relations with industry. There is somewhat less attention to greater outreach to citizens and society, which are increasingly important audiences in a time of ‘alternative facts’ and when significant transitions are needed to tackle sustainability, with implications for the daily lives of all citizens.

Addressing the challenges faced by the Norwegian natural sciences mostly requires systemic action involving the research-performing organisations, RCN and the Ministry of Education and Research, hence our recommendations largely go to all three.

Norway is not alone in needing to rethink its approach to chemistry. However, despite having some high points, there is a clear need to **address new needs and improve quality in chemistry** in Norway. As with the more general need to facilitate the evolution of natural sciences in order to meet new needs, this is a system-wide issue that needs a system-wide solution.

- The **Ministry** should therefore support the development and implementation of a national plan to restructure and support quality improvement in chemistry, with the involvement of **RCN** and relevant **universities and institutes**

This evaluation also finds that there is a need to **reduce uncertainty in overall funding, while maintaining competition**.

- **Ministry and RCN**: develop and secure commitment to medium-term plans for research funding in the natural sciences. This involves, on the one hand, securing political understanding and commitment to the driving role of science for Norwegian industry and society, and, on the other, restoring trust through making medium-term commitments through the Long-Term Plan or other key policy decisions
- **Research organisations and RCN**: improve proposal success rates by improving quality control of outgoing proposals and imposing rules making it more difficult to submit weak proposals repeatedly

There is a clear need for some **evolution in the structure of the Norwegian natural sciences, addressing new needs and consolidating some more established areas** without losing core competences. This should in part be driven by entrepreneurial researchers pursuing scientific opportunities and societal challenges and in part by systemic considerations such as the need to support changing teaching requirements. The need for change is urgent, yet there are important organisational, governance and funding impediments to change, primarily in the higher education sector. There is a risk that if this is left wholly to the universities they will only be able to optimise locally, resulting in system-level sub-optimisation. Action is therefore needed at all three levels

- Universities: improve strategy-making capabilities and revise internal governance to enable changes in structure and budgeting
- RCN: develop support programmes to promote restructuring strategies, perhaps on the lines of the Finnish ‘profiling’ programme, or ‘starter grants’ for new groupings
- Ministry: develop guidelines and incentives to support making university structures and governance more flexible and able to handle thematic changes; support the development of more strategic capacity and better human resource management in the universities

There is a need to review the opportunities to i**ncrease gender equality**, despite the structural problems imposed by the demography of the more unequal disciplines. There has been progress over the years, but in some places the natural processes of retirement and recruitment are unlikely to resolve the problem within the foreseeable future.

- **Ministry and RCN**: take opportunities to increase gender equality, through measures that encourage women into natural science careers and make the research environment more hospitable to them

Finally, this evaluation points to two important puzzles, namely: why women systematically publish less than men; and the extent and importance of lack of diversity. A first step towards improvement is to **collect and understand data**. Gender data are collected, but the publications puzzle is not understood. Diversity data (beyond gender) appear not to be collected

- The **Ministry** should therefore launch research and data collection efforts to illuminate these issues and then develop appropriate policy responses, in consultation with the research-performing organisations and RCN

# 8. Additional figures, tables and bibliography

### Figures

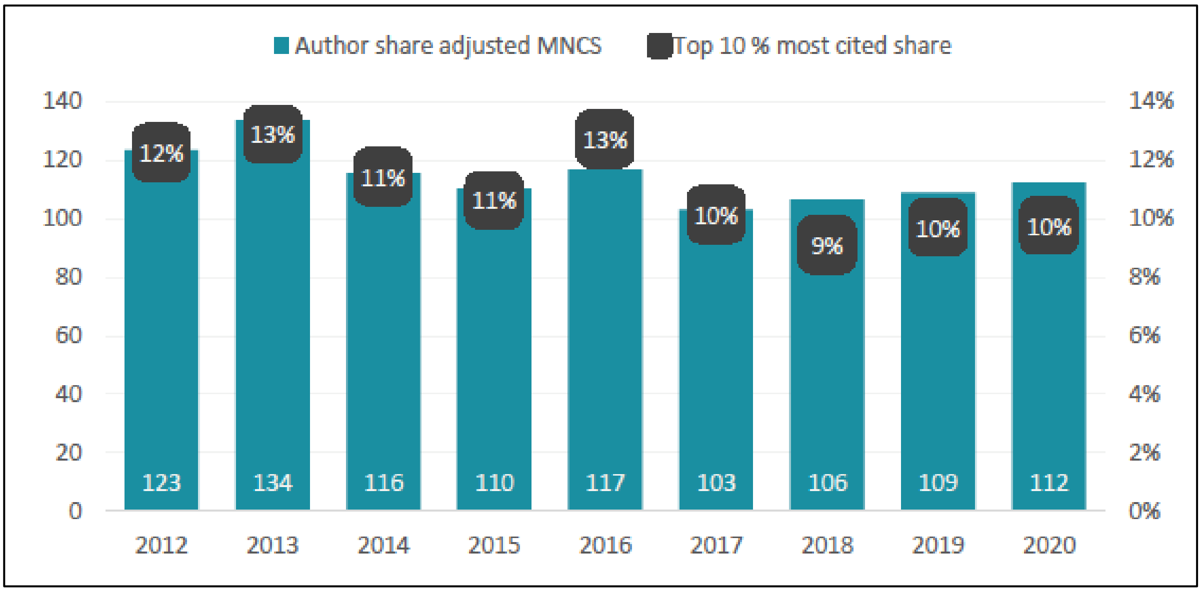



Figure 3 Citation Performance of Norwegian Natural Sciences, 2012-2020
Source: Karlstrøm & Aksnes (2023a)

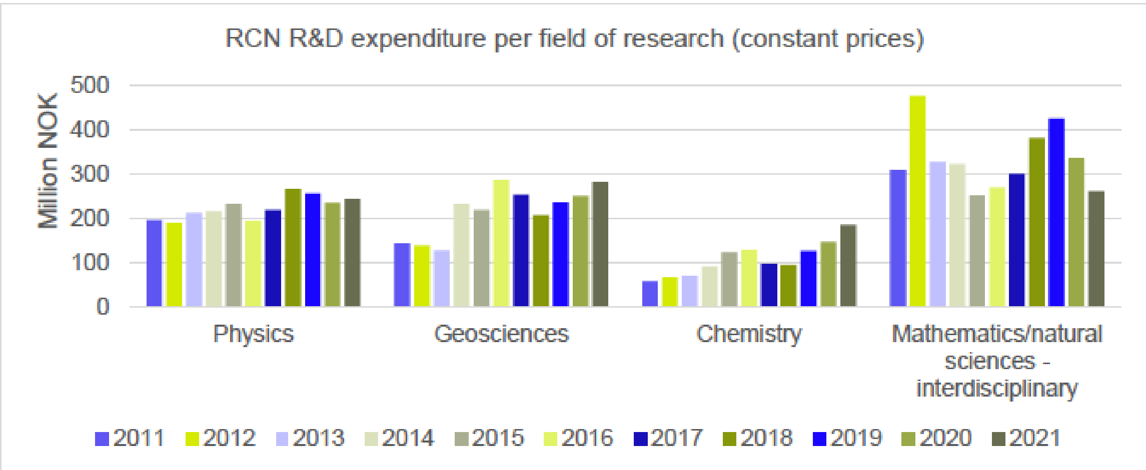



Figure 4 RCN R&D expenditure per field of research (constant 2015 prices)
Source: (Research Council of Norway, 2023)

## Tables

Table 8 Most-publishing institutions in the Norwegian 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 | NTNU | 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 % |

Source: Karlstrøm & Aksnes (2023a)

Table 9 FTE Research Personnel at units evaluated

| Institution | Department | Field of R&D in 2021 | Researchers 2013 | Researchers 2017 | Researchers 2021 | % Change 2013-21 | % Women 2021 |
|---|---|---|---|---|---|---|---|
| NTNU | Department of Chemical Engineering | Chemistry | 94 | 101 | 108 | 15% | 30% |
| NTNU | Department of Chemistry | Chemistry | 52 | 52 | 53 | 2% | 30% |
| NTNU | Department of Geoscience and Petroleum | Earth sciences | 54 | 110 | 88 | 63% | 22% |
| NTNU | Department of Materials Science and Engineering | Chemistry | 80 | 145 | 115 | 44% | 37% |
| NTNU | Department of Physics | Physics | 113 | 120 | 126 | 12% | 31% |
| UiT | Department of Chemistry | Chemistry | 67 | 69 | 74 | 10% | 35% |
| UiT | Department of Earth sciences | Earth sciences | 36 | 65 | 71 | 97% | 46% |
| UiT | Department of Physics and Technology | Physics | 41 | 64 | 106 | 159% | 29% |
| UNIS, Svalbard | UNIS The university centre in Svalbard | Earth sciences/ Physics/ Biosciences/ Technology | 53 | 53 | 60 | 13% | 47% |
| UiB | Department of Chemistry | Chemistry | 48 | 59 | 58 | 21% | 31% |
| UiB | Department of Earth Science | Earth sciences | 89 | 124 | 112 | 26% | 29% |
| UiB | Department of Physics and Technology | Physics | 87 | 84 | 111 | 28% | 24% |
| UiB | Geophysical Institute | Earth sciences | 52 | 74 | 92 | 77% | 42% |
| UiO | Department of Chemistry | Chemistry | 103 | 74 | 85 | -17% | 32% |
| UiO | Department of Earth sciences | Earth sciences | 119 | 168 | 162 | 36% | 43% |
| UiO | Department of Physics | Physics | 140 | 143 | 128 | -9% | 34% |
| UiO | Institute of Theoretical Astrophysics | Physics | 37 | 38 | 64 | 73% | 25% |
| UiS | Department of Energy Resources | Earth sciences | - | - | 39 | - | 18% |
| **Total Universities** | **Sum/average of the units** | | **1,265** | **1,543** | **1,652** | **31%** | **33%** |
| CICERO | Centre for International Climate Research | | 40 | 41 | 59 | 48% | 56% |
| NGU | Geological Survey of Norway | | 140 | 133 | 123 | -12% | 39% |
| NERSC | Nansen Environmental and Remote Sensing Centre | | 44 | 52 | 42 | -5% | 17% |
| NORCE | Climate and Environment division | | 85 | 105 | 146 | 72% | 40% |
| NORSAR | Norwegian Seismic Array | | 27 | 26 | 27 | 0% | 30% |
| NORSUS | Norwegian Institute for Sustainability Research | | 19 | 21 | 25 | 32% | 68% |
| NGI | Norwegian Geotechnical Institute | | 151 | 173 | 208 | 38% | 31% |
| NILU | Norwegian Institute for Air Research | | 91 | 89 | 89 | -2% | 51% |
| SINTEF | Digital* | | 235 | 216 | 311 | 32% | 25% |
| SINTEF | Industry | | 383 | 337 | 395 | 3% | 32% |
| MET | Norwegian Meteorological Institute | | 111 | 134 | 154 | 39% | 36% |
| NVE | Norwegian Water Resources and Energy Directorate | | 35 | 39 | 32 | -9% | 47% |
| **Total Institutes** | **Sum/average of the units** | | **1,361** | **1,366** | **1,611** | **18%** | **39%** |
| ***Total units*** | ***Sum/average of the units*** | | ***2,626*** | ***2,909*** | ***3,263*** | ***24%*** | ***36%*** |

Source: Rørstad & Wendt (2023)

Table 10 Mean normalized citation scores (MNCS) of the most impactful Web of Science subfields for the three disciplines, 2018-2020

| Chemistry | MNCS | | Geosciences | MNCS | | Physics | MNCS |
|---|---|---|---|---|---|---|---|
| Materials Science, Textiles | 159 | | Meteorology & Atmospheric Sciences | 172 | | Physics, Particles & Fields | 158 |
| Materials Science, Paper & Wood | 133 | | Geology | 156 | | Astronomy & Astrophysics | 153 |
| Materials Science, Composites | 115 | | Oceanography | 127 | | Physics, Nuclear | 143 |
| Chemistry, Applied | 115 | | Remote Sensing | 126 | | Acoustic | 126 |
| Materials science, Characterisation | 114 | | Geosciences, Multidisciplinary | 124 | | Physics, Multidisciplinary | 106 |
| Electrochemistry | 108 | | Environmental Sciences | 123 | | Mechanics | 105 |
| Polymer Science | 105 | | Geography, Physical | 120 | | Physics, Fluids & Plasmas | 102 |
| Chemistry, Inorganic & Nuclear | 96 | | Palaeontology | 108 | | Spectroscopy | 91 |
| Materials Science, Biomaterials | 91 | | Geochemistry & Geophysics | 107 | | Physics, Mathematical | 88 |
| Materials Science, Multidisciplinary | 89 | | Mineralogy | 79 | | Quantum Science & Technology | 83 |
| Chemistry, Physical | 84 | | | | | Nuclear Science & Technology | 79 |
| Nanoscience & Nanotechnology | 84 | | | | | Physics, Atomic, Molecular & Chemical | 74 |
| Chemistry, Analytical | 81 | | | | | Physics, Applied | 71 |
| Materials Science, Ceramics | 81 | | | | | Physics, Condensed Matter | 70 |
| Chemistry, Multidisciplinary | 77 | | | | | | |

Source: Karlstrøm & Aksnes (2023a)

Table 11 Citation impact indicators, higher education administrative units, 2012-2020 average

| University | Department | Share of 10 % most cited publications | Mean normalised citation score |
|---|---|---|---|
| NTNU | Department of Chemical Engineering | 7 % | 95 |
| NTNU | Department of Chemistry | 4 % | 85 |
| NTNU | Department of Geoscience and Petroleum | 3 % | 72 |
| NTNU | Department of Materials Science and Engineering | 7 % | 96 |
| NTNU | Department of Physics | 4 % | 78 |
| UiT | Department of Chemistry | 3 % | 76 |
| UiT | Department of Geosciences | 9 % | 108 |
| UiT | Department of Physics and Technology | 10 % | 108 |
| UNIS | - | 7 % | 101 |
| UiB | Department of Chemistry | 10 % | 90 |
| UiB | Department of Earth Science | 15 % | 132 |
| UiB | Department of Physics and Technology | 7 % | 90 |
| UiB | Department of Physics and Technology * | 4 % | 77 |
| UiB | Geophysical Institute | 12 % | 136 |
| UiO | Department of Chemistry | 5 % | 69 |
| UiO | Department of Geosciences | 15 % | 133 |
| UiO | Department of Physics | 8 % | 98 |
| UiO | Department of Physics* | 6 % | 82 |
| UiO | Department of Theoretical Astrophysics | 12 % | 127 |
| UiS | Department of Energy Resources | 6 % | 81 |

* Mega-authored publications (with more than 50 authors) removed

Source: Karlstrøm & Aksnes (2023c)

Table 12 Citation impact indicators, Institute administrative units, 2012-2020 averages

| Institute | Department | Share of 10 % most cited publications | Mean normalised citation score |
|---|---|---|---|
| CICERO Centre for Climate Research | | 26 % | 259 |
| Geological Survey of Norway* | | 11 % | 105 |
| Nansen Centre | | 18% | 148 |
| NILU – _Norwegian Institute for Air Research | Atmospheric and Climate Research | 19 % | 180 |
| NILU – _Norwegian Institute for Air Research | Environmental Chemistry Department | 17 % | 143 |
| NORCE Norwegian Research Centre | Climate and Environment | 13 % | 126 |
| NORSAR Foundation | | 3 % | 77 |
| NORSUS Norwegian Institute for Sustainability Research | | 4 % | 101 |
| Norwegian Directorate for Water Resources and Energy | | 12 % | 130 |
| Norwegian Geotechnical Institute | | 13 % | 137 |
| Norwegian Meteorological Institute | | 12 % | 169 |
| SINTEF | Industry | 7 % | 90 |

* 2019 & 2020 average
Sources: (Karlstrøm & Aksnes, 2023b)

Table 13 University author shares of publications per FTE work-year by gender

| Institution | Department | Number of author shares per FTE 2021 | | Average number of author shares per FTE 2019-2021 | |
|---|---|---|---|---|---|
| | | Women | Men | Women | Men |
| NTNU | Chemical Engineering | 1.50 | 2.00 | 1.56 | 1.73 |
| NTNU | Chemistry | 1.91 | 1.46 | 1.67 | 1.27 |
| NTNU | Geoscience and Petroleum | 0.84 | 1.96 | 1.03 | 1.51 |
| NTNU | Materials Science and Engineering | 1.15 | 1.57 | 1.17 | 1.50 |
| NTNU | Physics | 1.06 | 1.33 | 0.84 | 1.28 |
| UiT | Chemistry | 0.75 | 0.74 | 0.91 | 0.76 |
| UiT | Geosciences | 0.76 | 0.59 | 0.69 | 0.55 |
| UiT | Physics and Technology | 0.81 | 0.99 | 0.86 | 0.99 |
| UiB | Chemistry | 0.55 | 0.46 | 0.63 | 0.61 |
| UiB | Earth Science | 0.78 | 0.59 | 0.69 | 0.73 |
| UiB | Physics and Technology | 1.27 | 1.09 | 1.23 | 1.33 |
| UiB | Geophysical Institute | 0.47 | 0.68 | 0.52 | 0.68 |
| UiO | Chemistry | 1.05 | 1.04 | 1.19 | 1.31 |
| UiO | Geosciences | 0.52 | 0.94 | 0.68 | 1.05 |
| UiO | Physics | 1.20 | 1.23 | 1.26 | 1.39 |
| UiO | Theoretical Astrophysics | 0.64 | 0.85 | 0.68 | 0.99 |
| IiS | Energy Resources | 1.25 | 1.63 | 1.35 | 1.52 |
| Average all departments | | 0.97 | 1.13 | 1.00 | 1.13 |

Source: Evaluation of natural sciences in Norway : Bibliometric statistics and analyses for included administrative units in universities Karlstrøm & Aksnes, (2023c). Equivalent data are not available for the research institute sector

Table 14 Number of internationally collaborative papers published by Norwegian natural scientists 2019-2022, by country of co-authors' institutions

| Country | No of publications | % of Norwegian authors publishing with country | | Country | No of publications | % of Norwegian authors publishing with country |
|---|---|---|---|---|---|---|
| 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 % |

Note: The Table shows the absolute numbers of joint publications between Norway and partner countries, and the percentage of Norwegian authors publishing with people in each country in 2019-2022

Source: WoS, from Karlstrøm & Aksnes (2023a)

Table 15 Shares of university publications with national and international collaborators

| **Institution** | **Department** | **National collaboration** | | **International collaboration** | |
|---|---|---|---|---|---|
| | | 2021 | Average 2019-2021 | 2021 | Average 2019-2021 |
| NTNU | Chemical Engineering | 18 % | 20 % | 57 % | 53 % |
| NTNU | Chemistry | 34 % | 31 % | 52 % | 60 % |
| NTNU | Geoscience and Petroleum | 25 % | 30 % | 55 % | 47 % |
| NTNU | Materials Science and Engineering | 36 % | 37 % | 52 % | 56 % |
| NTNU | Physics | 35 % | 30 % | 68 % | 68 % |
| UiT | Chemistry | 15 % | 21 % | 71 % | 68 % |
| UiT | Geosciences | 47 % | 51 % | 81 % | 82 % |
| UiT | Physics and Technology | 27 % | 27 % | 73 % | 75 % |
| UNIS | | 79 % | 79 % | 81 % | 79 % |
| UiB | Chemistry | 33 % | 34 % | 63 % | 65 % |
| UiB | Earth Science | 41 % | 38 % | 79 % | 80 % |
| UiB | Physics and Technology | 60 % | 63 % | 88 % | 86 % |
| UiB | Geophysical Institute | 53 % | 53 % | 77 % | 79 % |
| UiO | Chemistry | 30 % | 30 % | 73 % | 71 % |
| UiO | Geosciences | 32 % | 30 % | 80 % | 80 % |
| UiO | Physics | 52 % | 51 % | 82 % | 84 % |
| UiO | Theoretical Astrophysics | 1 % | 2 % | 94 % | 92 % |
| UiS | Energy Resources | 19 % | 25 % | 52 % | 46 % |
| Average university sector | | 35 % | 36 % | 71 % | 71 % |
| Average university and institute sectors | | 45 % | 45 % | 67 % | 68 % |

Source Karlstrøm & Aksnes (2023c)

Table 16 Shares of Institute publications with national and international collaborators

| Institute | Department | National collaboration | | International collaboration | |
|---|---|---|---|---|---|
| | | 2021 | Average 2019-2021 | 2021 | Average 2019-2021 |
| CICERO | | 46 % | 53 % | 72 % | 74% |
| NGU | | 67 % | 56 % | 77 % | 76 % |
| Nansen Centre | | 32 % | 44 % | 90 % | 87 % |
| NILU | Atmospheric and Climate Research | 38 % | 45 % | 94 % | 95 % |
| NILU | Environmental Chemistry | 72 % | 65 % | 67 % | 80 % |
| NORCE | NORCE Climate and Environment | 52 % | 53 % | 79 % | 80 % |
| NORSUS | | 57 % | 53 % | 29 % | 40 % |
| NVE | | n.a. | n.a. | 63 % | 59 % |
| NGI | | 45 % | 40 % | 58 % | 60 % |
| MET | Research and Development | 60 % | 59 % | 67 % | 70 % |
| SINTEF | SINTEF Industry | 62 % | 68 % | 53 % | 51 % |
| Average institute sector* | | 58 % | 55 % | 63 % | 65 % |
| Average university and institute sectors | | 45 % | 45 % | 67 % | 68 % |

Source: Karlstrøm & Aksnes (2023b) * Includes SINTEF Digital, which is not in scope to this evaluation

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# 9 Description of the evaluation process of natural sciences 2022-2024

**Evaluation process and methods**

The evaluation of natural sciences was conducted in 2023-2023. It was carried out by international peers, using an Evaluation protocol developed by RCN (Appendix 1), Evaluation of natural sciences in Norway 2022-2023). The evaluation protocol was approved by the portfolio board of Natural sciences and technology April 2022.

Institutions that were relevant for the evaluation of natural sciences were invited to participate. The evaluation included 28 administrative units (such as faculty, department, institution) which were submitted for evaluation by the host institution. The administrative units submitted their research groups, 115 in total. The institutions have been allowed to submit and adapt the evaluation mandate (Terms of Reference) to their own strategic goals. This is to ensure that the results of the evaluation will be useful for the institutions' strategic development. The administrative units together with the research group(s) selected appropriate benchmarks for each of the research groups.

The evaluation reports will give important input to the individual administrative units and each institution/administrative unit is responsible for following up the recommendations that apply to their own institution.

The national report will be used by the Research Council of Norway in developing national funding schemes and in dialogue with relevant ministries involved in the development of natural sciences.

**Organisation of the evaluation**

The research has been evaluated at three levels:

*National committee*
The National Evaluation Committee consisted of six international experts including the four chairs of the evaluation committees to cover chemistry, physics and geosciences. The National Evaluation Committee was requested to produce a report based on the assessments and recommendations from the 28 independent administrative unit reports, and the national-level assessments produced by the expert panels and additional documents provided by RCN.

*Evaluation committees*
The administrative units were assessed by evaluation committees according to sectoral affiliation and/or other relevant similarities between the units. The evaluation committees have expertise in the main disciplines of the natural sciences and various aspects of the organisation and management of research and higher education. The committees consisted of 5-7 international members per evaluation committee.

*Expert panels*
The administrative units enrolled their research groups to be assessed by expert panels organised by research subjects or themes. The expert panels assessed research groups across institutions and sectors and provided one evaluation report for each research group. The expert panels consisted of 4-7 international experts per panel.

*External evaluation secretariat*
The Research Council has established an external secretariat for the evaluation. The external evaluation secretariat is responsible for the implementation of the evaluation.

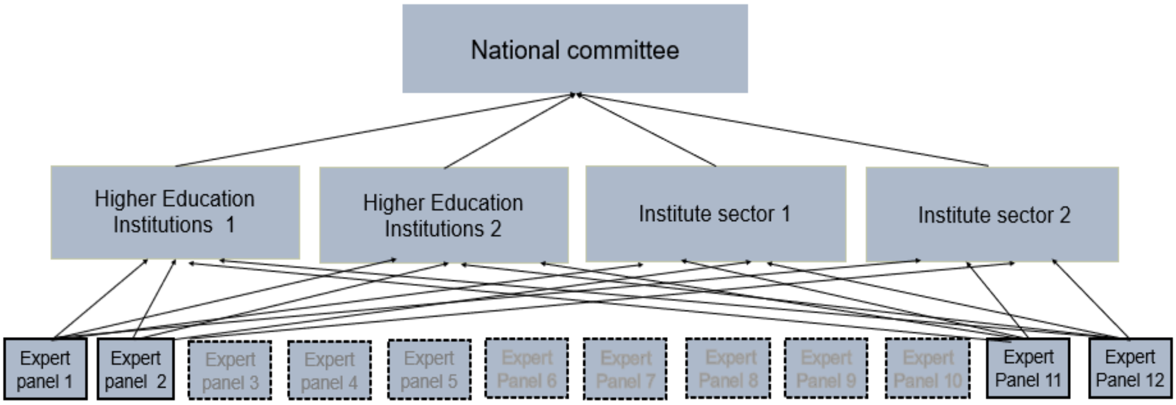


Figure 1. Organisation of the evaluation of natural sciences in three levels; expert panels, evaluation committees and national committee.

**Data available**

The documentary inputs to the evaluation were:

- Evaluation Protocol Evaluation of natural sciences in Norway 2022-2023
- Administrative Unit´s Terms of Reference
- Administrative Unit's self-assessment report
- Administrative Unit's impact cases
- Administrative Unit's research groups evaluation reports
- Panel reports from the Expert panels
- Bibliometric data (*NIFU Nordic Institute for Studies of innovation, research and education*)
- Personnel data (*Statistics Norway (SSB)*)
- Funding data – The Research Council´s contribution to natural sciences research (*RCN*)
- Extract from the Survey for academic staff and the Student Survey (*Norwegian Agency for Quality Assurance in Education (NOKUT)*)

**Evaluation Criteria**

The administrative units were evaluated on all five evaluation criteria cf. the evaluation protocol:

2.1 Strategy, resources and organisation
2.2 Research production, quality, and integrity
2.3 Diversity and equality
2.4 Relevance to institutional and sectoral purposes
2.5 Relevance to society

The research groups were evaluated on the evaluation criteria 2.1 Strategy, resources, and organisation and 2.2 Research production, quality and integrity. The research groups were allocated five scores based on the three dimensions: Organisational dimension, two scores for Quality dimension and two scores for Societal impact dimension.

**Limitations**

This national report of the evaluation of the natural sciences in Norway 2022-2024 is based on an extensive process of peer review at three levels: research group; the administrative unit (faculty/institute/centre/institution); and the national level.

In most cases, the research groups and administrative units involved had clearly invested a great deal of time and thought in preparing their self-assessments. In some cases it would have been useful if the research groups had given more attention to their societal impact, because this aspect is important not only at the policymaking and political levels but also to the wider public.

In the ideal case, evaluations like this one would be done through site visits. Unfortunately, that would not only be unreasonably expensive but also make it impossible to find experts able to devote the large amounts of time it would require. The process used here appears to be a useful compromise that has worked well.

Opportunities for improvement (without increasing costs) include:

- More precise instructions for parts of the self-evaluations especially those relating to PhD training, recruitment and mobility
- Greater specificity in the scoring scales used at the research group level and better calibration in their use
- In the bibliometrics, analysing scientific production and citations together, so that it is possible to see whether the publications in subfields that are very productive (or very unproductive) are also highly cited, and vice versa

The evaluation architecture is based on collective reporting by research groups. One effect of that is to obscure the presence and relative importance of ‘star’ researchers and less productive researchers. This has both advantages and disadvantages, which might usefully be discussed in the research policy system.

# Appendix (RCN)

- Evaluation protocol, including terms of reference
- List of participating administrative units and research

# Evaluation protocol including Terms of Reference

The Research Council of Norway

# Evaluation of natural sciences in Norway 2022-2023

Protocol version 1.0

*By decision of the Portfolio board for Natural Sciences and Technology 5 April 2022*

# 1 Introduction

Research assessments based on this protocol serve different aims and have different target groups. The primary aim of the evaluation of natural sciences is to reveal and confirm the quality and the relevance of research performed at Norwegian Higher Education Institutions (HEIs), and by the institute sector and regional health authorities and health trusts. These institutions will hereafter be collectively referred to as Research Performing Organisations (RPOs). The assessments should serve a formative purpose by contributing to the development of research quality and relevance at these institutions and at the national level.

## 1.1 Evaluation units

The assessment will comprise a number of administrative units submitted for evaluation by the host institution. By assessing these administrative units in light of the goals and strategies set for them by their host institution, it will be possible to learn more about how public funding is used at the institution(s) to facilitate high-quality research and how this research contributes to society. The administrative units will be assessed by evaluation committees according to sectoral affiliation and/or other relevant similarities between the units.

The administrative units will be invited to submit data on their research groups to be assessed by expert panels organised by research subject or theme. See Chapter 3 for details on organisation.

| | |
|---|---|
| *Administrative unit* | An administrative unit is any part of an RPO that is recognised as a formal (administrative) unit of that RPO, with a designated budget, strategic goals and dedicated management. It may, for instance, be a university faculty or department, a department of an independent research institute or a hospital. |
| *Research group* | Designates groups of researchers within the administrative units that fulfil the minimum requirements set out in section 1.2. Research groups are identified and submitted for evaluation by the administrative unit, which may decide to consider itself a single research group. |

## 1.2 Minimum requirements for research groups

1) The research group must be sufficiently large in size, i.e. at least five persons in full-time positions with research obligations. This merely indicates the minimum number, and larger units are preferable. In exceptional cases, the minimum number may include PhD students, postdoctoral fellows and/or non-tenured researchers. *In all cases, a research group must include at least three full-time tenured staff*. Adjunct professors, technical staff and other relevant personnel may be listed as group members but may not be included in the minimum number.
2) The research group subject to assessment must have been established for at least three years. Groups of more recent date may be accepted if they have come into existence as a consequence of major organisational changes within their host institution.
3) The research group should be known as such both within and outside the institution (e.g. have a separate website). It should be able to document common activities and results in the form of co-publications, research databases and infrastructure, software, or shared responsibilities for delivering education, health services or research-based solutions to designated markets.
4) In its self-assessment, the administrative unit should propose a suitable benchmark for the research group. The benchmark will be considered by the expert panels as a reference in

their assessment of the performance of the group. The benchmark can be grounded in both academic and extra-academic standards and targets, depending on the purpose of the group and its host institution.

## 1.3 The evaluation in a nutshell

The assessment concerns:

- research that the administrative unit and its research groups have conducted in the previous 10 years
- the research strategy that the administrative units under evaluation intend to pursue going forward
- the capacity and quality of research in natural sciences at the national level

The Research Council of Norway (RCN) will:

- provide a template for the Terms of Reference[14] for the assessment of RPOs and a national-level assessment in natural sciences
- appoint members to evaluation committees and expert panels
- provide secretarial services
- commission reports on research personnel and publications based on data in national registries
- take responsibility for following up assessments and recommendations at the national level.

RPOs conducting research in natural sciences are expected to take part in the evaluation. The board of each RPO under evaluation is responsible for tailoring the assessment to its own strategies and specific needs and for following them up within their own institution. Each participating RPO will carry out the following steps:

1) Identify the administrative unit(s) to be included as the main unit(s) of assessment
2) Specify the Terms of Reference by including information on specific tasks and/or strategic goals of relevance to the administrative unit(s)
3) The administrative unit will, in turn, be invited to register a set of research groups that fulfil the minimum criteria specified above (see section 1.2). The administrative unit may decide to consider itself a single research group.
4) For each research group, the administrative unit should select an appropriate benchmark in consultation with the group in question. This benchmark can be a reference to an academic level of performance or to the group's contributions to other institutional or sectoral purposes (see section 2.4). The benchmark will be used as a reference in the assessment of the unit by the expert panel.
5) The administrative units subject to assessment must provide information about each of their research groups, and about the administrative unit as a whole, by preparing self-assessments and by providing additional documentation in support of the self-assessment.

## 1.4 Target groups

- Administrative units represented by institutional management and boards
- Research groups represented by researchers and research group leaders
- Research funders
- Government

[14] The terms of reference (ToR) document defines all aspects of how the evaluation committees and expert panels will conduct the natural sciences evaluation. It defines the objectives and the scope of the evaluation, outlines the responsibilities of the involved parties, and provides a description of the resources available to carry out the evaluation.

The evaluation will result in recommendations to the institutions, the RCN and the ministries. The results of the evaluation will also be disseminated for the benefit of potential students, users of research and society at large.

This protocol is intended for all participants in the evaluation. It provides the information required to organise and carry out the research assessments. Questions about the interpretation or implementation of the protocol should be addressed to the RCN.

# 2 Assessment criteria

The administrative units are to be assessed on the basis of five assessment criteria. The five criteria are applied in accordance with international standards. Finally, the evaluation committee passes judgement on the administrative units as a whole in qualitative terms. In this overall assessment, the committee should relate the assessment of the specific tasks to the strategic goals that the administrative unit has set for itself in the Terms of Reference.

When assessing administrative units, the committees will build on a separate assessment by expert panels of the research groups within the administrative units. See Chapter 3 ‘Evaluation process and organisation’ for a description of the division of tasks.

## 2.1 Strategy, resources and organisation

The evaluation committee assesses the framework conditions for research in terms of funding, personnel, recruitment and research infrastructure in relation to the strategic aims set for the administrative unit. The administrative unit should address at least the following five specific aspects in its self-assessment: 1) funding sources, 2) national and international cooperation, 3) cross-sector and interdisciplinary cooperation, 4) research careers and mobility, and 5) Open Science. These five aspects relate to how the unit organises and actually performs its research, its composition in terms of leadership and personnel, and how the unit is run on a day-to-day basis.

To contribute to understanding what the administrative unit can or should change to improve its ability to perform, the evaluation committee is invited to focus on factors that may affect performance.

Further, the evaluation committee assesses the extent to which the administrative unit’s goals for the future remain scientifically and societally relevant. It is also assessed whether its aims and strategy, as well as the foresight of its leadership and its overall management, are optimal in relation to attaining these goals. Finally, it is assessed whether the plans and resources are adequate to implement this strategy.

## 2.2 Research production, quality and integrity

The evaluation committee assesses the profile and quality of the administrative unit’s research and the contribution the research makes to the body of scholarly knowledge and the knowledge base for other relevant sectors of society. The committee also assesses the scale of the unit’s research results (scholarly publications, research infrastructure developed by the unit, and other contributions to the field) and its contribution to Open Science (early knowledge and sharing of data and other relevant digital objects, as well as science communication and collaboration with societal partners, where appropriate).

The evaluation committee considers the administrative unit’s policy for research integrity and how violations of such integrity are prevented. It is interested in how the unit deals with research data, data management, confidentiality (GDPR) and integrity, and the extent to which independent and critical pursuit of research is made possible within the unit. Research integrity relates to both the scientific integrity of conducted research and the professional integrity of researchers.

## 2.3 Diversity and equality

The evaluation committee considers the diversity of the administrative unit, including gender equality. The presence of differences can be a powerful incentive for creativity and talent development in a diverse administrative unit. Diversity is not an end in itself in that regard, but a tool for bringing together different perspectives and opinions.

The evaluation committee considers the strategy and practices of the administrative unit to prevent discrimination on the grounds of gender, age, disability, ethnicity, religion, sexual orientation or other personal characteristics.

## 2.4 Relevance to institutional and sectoral purposes

The evaluation committee compares the relevance of the administrative unit's activities and results to the specific aspects detailed in the Terms of Reference for each institution and to the relevant sectoral goals (see below).

Higher Education Institutions

There are 36 Higher Education Institutions in Norway that receive public funding from the Ministry for Education and Research. Twenty-one of the 36 institutions are owned by the ministry, whereas the last 15 are privately owned. The HEIs are regulated under the Act relating to universities and university colleges of 1 August 2005.

The purposes of Norwegian HEIs are defined as follows in the Act relating to universities and university colleges[15]

- provide higher education at a high international level;
- conduct research and academic and artistic development work at a high international level;
- disseminate knowledge of the institution's activities and promote an understanding of the principle of academic freedom and application of scientific and artistic methods and results in the teaching of students, in the institution's own general activity as well as in public administration, in cultural life and in business and industry.

In line with these purposes, the Ministry for Research and Education has defined four overall goals for HEIs that receive public funding. These goals have been applied since 2015:

1) High quality in research and education
2) Research and education for welfare, value creation and innovation
3) Access to education (esp. capacity in health and teacher education)
4) Efficiency, diversity and solidity of the higher education sector and research system

The committee is invited to assess to what extent the research activities and results of each administrative unit have contributed to sectoral purposes as defined above. In particular, the committee is invited to take the share of resources spent on education at the administrative units into account and to assess the relevance and contributions of research to education, focusing on the master's and PhD levels. This assessment should be distinguished from an assessment of the quality of education in itself, and it is limited to the role of research in fostering high-quality education.

Research institutes (the institute sector)

Norway's large institute sector reflects a practical orientation of state R&D funding that has long historical roots. The Government's strategy for the institute sector[16] applies to the 33 independent

[15] https://lovdata.no/dokument/NLE/lov/2005-04-01-15?q=universities

[16] Strategy for a holistic institute policy (Kunnskapsdepartementet 2020)

research institutes that receive public basic funding through the RCN, in addition to 12 institutes outside the public basic funding system.

The institute sector plays an important and specific role in attaining the overall goal of the national research system, i.e. to increase competitiveness and innovation power to address major societal challenges. The research institutes' contributions to achieving these objectives should therefore form the basis for the evaluation. The main purpose of the sector is to conduct independent applied research for present and future use in the private and public sector. However, some institutes primarily focus on developing a research platform for public policy decisions, others on fulfilling their public responsibilities.

The institutes should:

- maintain a sound academic level, documented through scientific publications in recognised journals
- obtain competitive national and/or international research funding grants
- conduct contract research for private and/or public clients
- demonstrate robustness by having a reasonable number of researchers allocated to each research field

The committee is invited to assess the extent to which the research activities and results of each administrative unit contribute to sectoral purposes and overall goals as defined above. In particular, the committee is invited to assess the level of collaboration between the administrative unit(s) and partners in their own or other sectors.

<u>The hospital sector</u>
There are four regional health authorities (RHFs) in Norway. They are responsible for the specialist health service in their respective regions. The RHFs are regulated through the Health Enterprises Act of 15 June 2001 and are bound by requirements that apply to specialist and other health services, the Health Personnel Act and the Patient Rights Act. Under each of the regional health authorities, there are several health trusts (HFs), which can consist of one or more hospitals. A health trust (HF) is wholly owned by an RHF.

Research is one of the four main tasks of hospital trusts.[17] The three other mains tasks are to ensure good treatment, education and training of patients and relatives. Research is important if the health service is to keep abreast of stay up-to-date with medical developments and carry out critical assessments of established and new diagnostic methods, treatment options and technology, and work on quality development and patient safety while caring for and guiding patients.

The committee is invited to assess the extent to which the research activities and results of each administrative unit have contributed to sectoral purposes as described above. The assessment does not include an evaluation of the health services performed by the services.

## 2.5 Relevance to society

The committee assesses the quality, scale and relevance of contributions targeting specific economic, social or cultural target groups, of advisory reports on policy, of contributions to public debates, and so on. The documentation provided as the basis for the assessment of societal relevance should make it possible to assess relevance to various sectors of society (i.e. business, the public sector, non-governmental organisations and civil society).

When relevant, the administrative units will be asked to link their contributions to national and international goals set for research, including the Norwegian Long-term Plan for Research and Higher Education and the UN Sustainable Development Goals. Sector-specific objectives, e.g. those described in the Development Agreements for the HEIs and other national guidelines for the different sectors, will be assessed as part of criterion 2.4.

[17] Cf. the Specialist Health Services Act § 3-8 and the Health Enterprises Act §§ 1 and 2

The committee is also invited to assess the societal impact of research based on case studies submitted by the administrative units and/or other relevant data presented to the committee. Academic impact will be assessed as part of criterion 2.2.

# 3 Evaluation process and organisation

The RCN will organise the assessment process as follows:

- Commission a professional secretariat to support the assessment process in the committees and panels, as well as the production of self-assessments within each RPO
- Commission reports on research personnel and publications within natural sciences based on data in national registries
- Appoint one or more evaluation committees for the assessment of administrative units.
- Divide the administrative units between the appointed evaluation committees according to sectoral affiliation and/or other relevant similarities between the units.
- Appoint a number of expert panels for the assessment of research groups submitted by the administrative units.
- Divide research groups between expert panels according to similarity of research subjects or themes.
- Task the chairs of the evaluation committees with producing a national-level report building on the assessments of administrative units and a national-level assessments produced by the expert panels.

Committee members and members of the expert panels will be international, have sufficient competence and be able, as a body, to pass judgement based on all relevant assessment criteria. The RCN will facilitate the connection between the assessment levels of panels and committees by appointing committee members as panel chairs.

## 3.1 Division of tasks between the committee and panel levels

***The expert panels*** will assess research groups across institutions and sectors, focusing on the first two criteria specified in Chapter 2: 'Strategy, resources and organisation' and 'Research production and quality' The assessments from the expert panels will also be used as part of the evidence base for a report on Norwegian research within [natural sciences (see section 3.3).

***The evaluation committees*** will assess the administrative units based on all the criteria specified in Chapter 2. The assessment of research groups delivered by the expert panels will be a part of the evidence base for the committees' assessments of administrative units. See figure 1 below.

The evaluation committee has sole responsibility for the assessments and any recommendations in the report. The evaluation committee reaches a judgement on the research based on the administrative units and research groups' self-assessments provided by the RPOs, any additional documents provided by the RCN, and interviews with representatives of the administrative units. The additional documents will include a standardised analysis of research personnel and publications provided by the RCN.

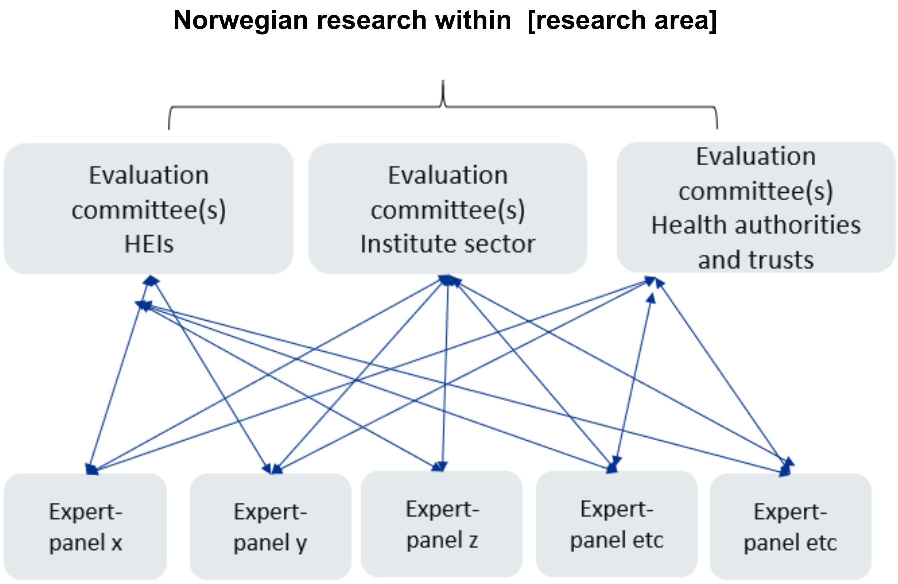


Figure 1. Evaluation committees and expert panels

The evaluation committee takes international trends and developments in science and society into account when forming its judgement. When judging the quality and relevance of the research, the committees shall bear in mind the specific tasks and/or strategic goals that the administrative unit has set for itself including sectoral purposes (see section 2.4 above).

## 3.2 Accuracy of factual information

The administrative unit under evaluation should be consulted to check the factual information before the final report is delivered to the RCN and the board of the institution hosting the administrative unit.

## 3.3 National level report

Finally, the RCN will ask the chairs of the evaluation committees to produce a national-level report that builds on the assessments of administrative units and the national-level assessments produced by the expert panels. The committee chairs will present their assessment of Norwegian research in natural sciences at the national level in a separate report that pays specific attention to:

- Strengths and weaknesses of the research area in the international context
- The general resource situation regarding funding, personnel and infrastructure
- PhD training, recruitment, mobility and diversity
- Research cooperation nationally and internationally
- Societal impact and the role of research in society, including Open Science

This national-level assessment should be presented to the RCN.

# Appendix A: Terms of References (ToR)

[Text in red to be filled in by the Research-performing organisations (RPOs)]

The board of [RPO] mandates the evaluation committee appointed by the Research Council of Norway (RCN) to assess [administrative unit] based on the following Terms of Reference.

**Assessment**
You are asked to assess the organisation, quality and diversity of research conducted by [administrative unit] as well as its relevance to institutional and sectoral purposes, and to society at large. You should do so by judging the unit's performance based on the following five assessment criteria (a. to e.). Be sure to take current international trends and developments in science and society into account in your analysis.

a) Strategy, resources and organisation
b) Research production, quality and integrity
c) Diversity and equality
d) Relevance to institutional and sectoral purposes
e) Relevance to society

For a description of these criteria, see Chapter 2 of the natural sciences evaluation protocol. Please provide a written assessment for each of the five criteria. Please also provide recommendations for improvement. We ask you to pay special attention to the following [n] aspects in your assessment:

1. …
2. …
3. …
4. …
…

[To be completed by the board: specific aspects that the evaluation committee should focus on – they may be related to a) strategic issues, or b) an administrative unit's specific tasks.]

In addition, we would like your report to provide a qualitative assessment of [administrative unit] as a whole in relation to its strategic targets. The committee assesses the strategy that the administrative unit intends to pursue in the years ahead and the extent to which it will be capable of meeting its targets for research and society during this period based on available resources and competence. The committee is also invited to make recommendations concerning these two subjects.

**Documentation**
The necessary documentation will be made available by the natural sciences secretariat at Technopolis Group

The documents will include the following:

- a report on research personnel and publications within natural sciences commissioned by RCN
- a self-assessment based on a template provided by the natural sciences secretariat
- [to be completed by the board]

**Interviews with representatives from the evaluated units**
Interviews with the [administrative unit] will be organised by the evaluation secretariat. Such interviews can be organised as a site visit, in another specified location in Norway or as a video conference.

**Statement on impartiality and confidence**
The assessment should be carried out in accordance with the *Regulations on Impartiality and Confidence in the Research Council of Norway*. A statement on the impartiality of the committee members has been recorded by the RCN as a part of the appointment process. The impartiality and confidence of committee and panel members should be confirmed when evaluation data from [the administrative unit] are made available to the committee and the panels, and before any assessments are made based on these data. The RCN should be notified if questions concerning impartiality and confidence are raised by committee members during the evaluation process.

**Assessment report**
We ask you to report your findings in an assessment report drawn up in accordance with a format specified by the natural sciences secretariat. The committee may suggest adjustments to this format at its first meeting.  A draft report should be sent to the [administrative unit] and RCN by [date]. The [administrative unit] should be allowed to check the report for factual inaccuracies; if such inaccuracies are found, they should be reported to the natural sciences secretariat no later than two weeks after receipt of the draft report. After the committee has made the amendments judged necessary, a corrected version of the assessment report should be sent to the board of [the RPO] and the RCN no later than two weeks after all feedback on inaccuracies has been received from [administrative unit].

# Appendix B: Data sources

The lists below shows the most relevant data providers and types of data to be included in the evaluation. Data are categorised in two broad categories according to the data source: National registers and self-assessments prepared by the RFOs. The RCN will commission an analysis of data in national registers (R&D-expenditure, personnel, publications etc.) to be used as support for the committees' assessment of administrative units. The analysis will include a set of indicators related to research personnel and publications.

- **National directorates and data providers**
- Norwegian Directorate for Higher Education and Skills (HK-dir)
- Norwegian Agency for Quality Assurance in Education (NOKUT)
- Norwegian Agency for Shared Services in Education and Research (SIKT)
- Research Council of Norway (RCN)
- Statistics Norway (SSB)

**National registers**

1) R&D-expenditure
    a. SSB: R&D statistics
    b. SSB: Key figures for research institutes
    c. HK-dir: Database for Statistics on Higher Education (DBH)
    d. RCN: Project funding database (DVH)
    e. EU-funding: eCorda
2) Research personnel
    a. SSB: The Register of Research personnel
    b. SSB: The Doctoral Degree Register
    c. RCN: Key figures for research institutes
    d. HK-dir: Database for Statistics on Higher Education (DBH)
    e. https://www.ssb.no/en/teknologi-og-innovasjon/forskning-og-innovasjon-i-naeringslivet/artikler/statistics-for-use-in-the-evaluation-of-natural-sciences-in-norway
3) Research publications
    a. SIKT: Cristin - Current research information system in Norway
    b. SIKT: Norwegian Infrastructure for Bibliometrics
       (full bibliometric data incl. citations and co-authors)
       https://hdl.handle.net/11250/3121955

4) Education
    a. HK-dir/DBH: Students and study points
    b. NOKUT: Study barometer
    c. NOKUT: National Teacher Survey
5) Sector-oriented research
    a. RCN: Key figures for research institutes
6) Patient treatments and health care services
    a. Research & Innovation expenditure in the health trusts
    b. Measurement of research and innovation activity in the health trusts
    c. Collaboration between health trusts and HEIs
    d. Funding of research and innovation in the health trusts
    e. Classification of medical and health research using HRCS (HO21 monitor)

**Self-assessments**

1) Administrative units
    a. *Self-assessment covering all assessment criteria*
    b. Administrative data on funding sources
    c. Administrative data on personnel

d. Administrative data on the division of staff resources between research and other activities (teaching, dissemination etc.)
e. Administrative data on research infrastructure and other support structures
f. SWOT analysis
g. Any supplementary data needed to assess performance related to the strategic goals and specific tasks of the unit

2) Research groups
    a. *Self-assessment covering the first two assessment criteria (see Table 1)*
    b. Administrative data on funding sources
    c. Administrative data on personnel
    d. Administrative data on contribution to sectoral purposes: teaching, commissioned work, clinical work [will be assessed at committee level]
    e. Publication profiles
    f. Example publications and other research results (databases, software etc.) The examples should be accompanied by an explanation of the groups' specific contributions to the result
    g. Any supplementary data needed to assess performance related to the benchmark defined by the administrative unit

The table below shows how different types of evaluation data may be relevant to different evaluation criteria. Please note that the self-assessment produced by the administrative units in the form of a written account of management, activities, results etc. should cover all criteria. A template for the self-assessment of research groups and administrative units will be commissioned by the RCN from the natural sciences secretariat for the evaluation.

Table 1. Types of evaluation data per criterion

| **Evaluation units** / **Criteria** | **Research groups** | **Administrative units** |
|---|---|---|
| **Strategy, resources and organisation** | Self-assessment<br>Administrative data | Self-assessment<br>National registers<br>Administrative data<br>SWOT analysis |
| **Research production and quality** | Self-assessment<br>Example publications (and other research results) | Self-assessment<br>National registers |
| **Diversity, equality and integrity** | | Self-assessment<br>National registers<br>Administrative data |
| **Relevance to institutional and sectoral purposes** | | Self-assessment<br>Administrative data |
| **Relevance to society** | | Self-assessment<br>National registers<br>Impact cases |

| ***Overall assessment*** | *Data related to:<br>Benchmark defined by administrative unit* | *Data related to:<br>Strategic goals and specific tasks of the admin. unit* |
|---|---|---|

# List of participating administrative units and research

| Institution | Administrative unit | Research Group |
| --- | --- | --- |
| University of Oslo | Department of Physics | Condensed Matter Physics |
| | | Electronics Research Section |
| | | Section for Biophysics and Medical Physics |
| | | Structure Physics |
| | | Plasma and Space Physics |
| | | Theoretical Physics |
| | | Nuclear and Energy Physics |
| | | High Energy Physics |
| | | Semiconductor Physics |
| | | Physics Education Research |
| University of Oslo | Department of Theoretical Astrophysics | Cosmology and Extragalactic Astrophysics |
| | | Rosseland Centre for Solar Physics |
| University of Oslo | Department of Geosciences | Centre for Earth Evolution and Dynamics (CEED) |
| | | Njord - Physics of Geological Processes |
| | | Geology & Geophysics (B): Basin Studies |
| | | Environmental geology and geochemistry |
| | | Geography and Hydrology |
| | | Meteorology and Oceanography |
| University of Oslo | Department of Chemistry | Electrochemistry |
| | | Inorganic Materials Chemistry (NAFUMA) |
| | | Theoretical Chemistry |
| | | Atmospheric Chemistry |
| | | Chemical Life Sciences |
| | | Organic Chemistry |
| | | Catalysis |
| University of Bergen | Department of Geophysics | Biogeochemistry |
| | | Renewable Energy |
| | | Meteorology |
| | | Climate Dynamics |
| | | Physical Oceanography |
| University of Bergen | Department of Earth Sciences | Geochemistry and Geobiology |
| | | Quaternary Geology and Paleoclimate |
| | | Geophysics Group |
| | | Geodynamics and Basin Studies |
| University of Bergen | Department of Physics and Technology | Subatomic Physics |
| | | Theoretical Physics |
| | | Nanophysics |
| | | Space Physics |
| | | Ocean Technology |

| | | |
|---|---|---|
| University of Bergen | Department of Chemistry | Sustainable Energy Carriers, Chemicals and Materials |
| | | Chemistry in Bioresources and Pharmaceutical Chemistry |
| | | Chemistry in Medical Technology |
| | | In Silico Molecular Exploration and Design |
| Norwegian University of Science and Technology | Department of Physics | Atmospheric and Laser Physics |
| | | Astrophysics and Particle Physics |
| | | Computational Physics |
| | | Material Physics |
| | | Porous Media Physics |
| | | Centre for Quantum Spintronics (QuSpin) |
| | | Soft and Complex Matter Lab |
| | | Biophysics and Medical Technology |
| | | Science Education Research |
| Norwegian University of Science and Technology | Department of Chemistry | Theoretical Chemistry |
| | | Environmental Chemistry |
| | | Organic Chemistry |
| Norwegian University of Science and Technology | Department of Chemical Engineering | Catalysis |
| | | Process Systems Engineering |
| | | Reactor Technology and Environmental Engineering |
| | | Ugelstad Lab |
| Norwegian University of Science and Technology | Department of Materials Technology | Resources, Energy &Environment |
| | | Physical Metallurgy |
| | | Functional Materials and Materials Chemistry |
| | | Electrochemistry |
| University of Tromsø - The Arctic University of Norway | Department of Physics and Technology | Complex Systems Modelling |
| | | Renewable Energy (REG) |
| | | Space Physics |
| | | Ultrasound, Microwaves, and Optics |
| | | Earth Observation |
| University of Tromsø - The Arctic University of Norway | Department of Geosciences | Sedimentary Systems, Paleoclimates and Environments |
| | | Solid Earth, Mineral Resources and Geohazards |
| | | Geophysics, Glaciology and Oceanography |
| University of Tromsø - The Arctic University of Norway | Department of Chemistry | Theoretical Chemistry |
| | | Biological Chemistry |
| | | Chemical Synthesis and Analysis |
| University of Stavanger | Department of Energy Resources | Energy Resources |
| The University Centre in Svalbard (UNIS) | The University Centre in Svalbard (UNIS) | Cryosphere Group - Arctic Geology |
| | | Air-Cryosphere-Sea Interaction Group |
| | | Space Physics |
| | | Sedimentology, surface processes, paleoclimate, structural geology and geophysics |
| | | Marine Biology (MarBio)* |

| | | |
|---|---|---|
| | | Terrestrial Biology (TerrBio)* |
| The Norwegian Geotechnical Institute (NGI) | The Norwegian Geotechnical Institute (NGI) | Advanced Geo Modelling |
| | | Offshore Geohazards |
| | | Sustainable Soil and Waste Management |
| | | Environmental Chemistry and Toxicology |
| | | Tsunamis |
| | | Climate adaption and hydrodynamics |
| The Geological Survey of Norway (NGU) | The Geological Survey of Norway (NGU) | Section for Solid Earth Geology |
| | | Mineral Resources |
| | | Marin geology |
| | | Section for Geophysics |
| | | Geohazard and Earth observation |
| | | Quaternary geology (QuatGeo) |
| NORSAR Foundation | NORSAR | NORSAR |
| NORCE Norwegian Research Centre AS | NORCE Climate and Environment | Regional climate and climate services |
| | | Earth Systems |
| | | Ocean Observations |
| | | Molecular Ecology Research Group (MERG)* |
| | | Laboratory for freshwater Ecology and Inland fisheries (LFI)* |
| | | Marine Ecology – MarEco* |
| | | Gene Technology, Environment and Society (GEMS)* |
| | | Industrial Biotechnology (IB)* |
| | | Integrative Fish Biology group (IFB)* |
| | | Marine Biotechnology* |
| Norwegian Meteorological Institute | Norwegian Meteorological Institute | Ocean-coast-remote sensing |
| | | Model and Climate analysis & Climate and Air-quality |
| | | Centre for Weather Forecasting |
| Norwegian Institute for Air Research (NILU) | Atmospheric and Climate Research Department | Atmospheric and Climate Research Department |
| | Environmental Chemistry Department | Environmental Chemistry Department |
| Centre for International Climate Research (CICERO) | Centre for International Climate Research (CICERO) | Research Department 1 |
| Norwegian Directorate for Water Resources and Energy | Hydrologic department | Hydrologic department |
| Nansen Environmental and Remote Sensing Centre (NERSC) | Nansen Environmental and Remote Sensing Centre (NERSC) | Sea Ice and Remote Sensing (SIRS) |
| | | Operational Oceanography |
| | | Climate models and -observations systems |
| Norwegian Institute for Sustainability Research (NORSUS) | Norwegian Institute for Sustainability Research (NORSUS) | Norwegian Institute for Sustainability Research (NORSUS) |

*Research Groups evaluated in an expert panel in the Evaluation of Biosciences (EVALBIOVIT)

**Additional information**

Three research groups from SINTEF Digital and six research groups from SINTEF Industry have been evaluated in panels in EVALNAT but will be forwarded to the Evaluation of Mathematics, ICT and Technology (EVALMIT) together with a larger number of research groups belonging to these two administrative units. In addition, seven research groups have been evaluated in EVALNAT and will be forwarded to EVALMIT and six research groups have been forwarded to EVALBIOVIT

This is a corrected version of the PDF report Evaluation of natural sciences in Norway National Report ( ISBN 978-82-12-04032-8 ).

The corrections from the previous report is the following:

- Page 1, UiS is added to the footnote
- Page 17, "all" is replaced with most of them
- Page 23., NORSUS is removed from the parenthesis

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