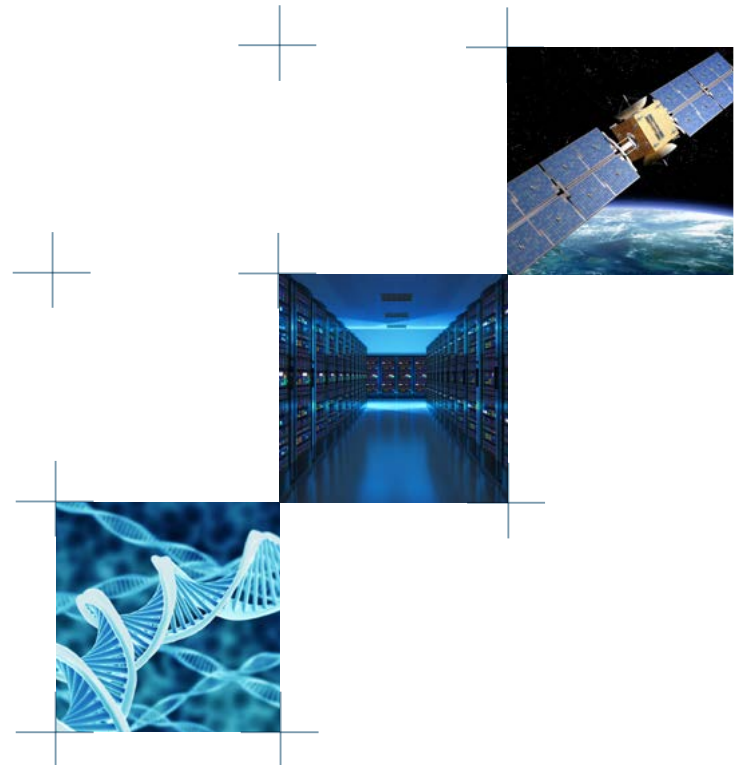




Norwegian Roadmap for Research Infrastructure 2018

National Financing Initiative for Research Infrastructure (INFRASTRUKTUR)



Norwegian Roadmap for Research Infrastructure 2018

National Financing Initiative for Research Infrastructure
(INFRASTRUKTUR)

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Introduction

Preface

The first version of the Norwegian Roadmap for Research Infrastructure was published in 2010. Since then, the roadmap has been revised after each major funding announcement under the National Financing Initiative for Research Infrastructure issued by the Research Council. This is thereby the fourth revision of the roadmap. The updated Norwegian Roadmap for Research Infrastructure 2018 supports the recommendations set out in Tools for Research – The National Strategy for Research Infrastructure of maintaining the investment volume in, and ensuring long-term funding of, research infrastructures in the years to come.

The Norwegian Roadmap for Research Infrastructure 2018 has two main parts:

1. A description of the strategic basis for the Research Council's priorities regarding research infrastructure in specific disciplines, thematic areas and technology areas, called area strategies.
2. A presentation of large-scale research infrastructures of national importance, which have either received funding after the call for proposals in 2016 or previously, or are considered as "worthy of funding" by the Research Council.

The area strategies in part 1 describe the research objectives, existing infrastructure and possible future needs for infrastructure in the respective areas. Prior to this revision, the Research Council invited research institutions to collaborate and prepare input to the area strategies on future needs for new or upgraded infrastructure within high priority areas in Norway. All inputs have been assessed by the Research Council's administration and linked to priorities in existing national strategies.

The research infrastructures presented in part 2 are included on the roadmap based on assessments made after the call for proposals in 2016 or previously, or are considered as "worthy of funding" by the Research Council. In this document these projects are referred to as "roadmap projects".

Many of the roadmap projects presented in part 2 are now entering or have entered operation phase. This means that after a period of about 8 years with the National Financing Initiative for Research Infrastructure an increased share of new investments will now be allocated toward renewal and upgrading of important national research infrastructures. In addition, there is still a considerable need for investments in a range of novel infrastructures as indicated in the area strategies and by the received applications to the National Financing Initiative for Research Infrastructure.

The need for e-infrastructure and open access to research data is a major challenge in all areas of research and is discussed in a separate chapter. In addition, the Norwegian participation in international research infrastructures is presented in a separate chapter.

The roadmap is not meant to be a static document, and it will be revised in the wake of each major funding announcement. Roadmap projects that have received funding in an establishment phase, but no longer receive funding through the National Research Infrastructure, are listed in a separate table. The area strategies will continually be evolving. For this reason the most recent electronic version of the Norwegian roadmap, www.forskingsradet.no/veikart, will be the updated version at any given time.

John-Arne Røttingen
Chief Executive, The Research Council of Norway

Background

The previous government's white paper on research called *Climate for Research* (2008–2009), assigned the Research Council of Norway the responsibility for drawing up a Norwegian roadmap for investments in research infrastructure. The roadmap substantiates and presents the national and international large-scale research infrastructures which the Research Council recommends funded in the near future – within a realistic budget framework. The Research Council selects research infrastructure investments to be included on the roadmap based on stringent criteria in terms of quality as well as strategic relevance.



The function of the roadmap

The roadmap will:

- communicate the strategic basis for the Research Council's priorities relevant to emerging funding announcements under the National Financing Initiative for Research Infrastructure;
- highlight major research infrastructures that are essential for achieving research policy objectives;
- emphasize Norwegian participation in international research infrastructures and demonstrate the balance and proportionality between such participation and national investments;
- provide a guide for public and private funders of research infrastructures by presenting thoroughly reviewed projects that are quality-assured and considered worthy of support, but are in need of full or partial funding.

Selection of projects for inclusion on the roadmap

After each major funding announcement under the National Financing Initiative for Research Infrastructure, the Research Council administration will assess which projects to be highlighted on the roadmap. The assessment will be based on three criteria, which must be fulfilled. Please go to *Tools for Research – Part I: Norway's national strategy for research infrastructure 2012-2017* for a more detailed description of criteria and terminology.

Criterion 1: The infrastructure has a national status and performs national tasks

The National Financing Initiative for Research Infrastructure only allocates funding to projects with certain characteristics of national importance. These are defined as follows:

- Infrastructure that is of widespread national interest;
- Infrastructure that will be limited to only one or a few locations in Norway, as a general rule;
- Infrastructure that lays a foundation for internationally cutting-edge research;
- Infrastructure that will be made accessible to relevant researchers and industries.

Criterion 2: The grant proposal has been assessed as outstanding excellent, both scientifically and strategically

The projects highlighted on the roadmap have been reviewed as “Outstanding excellent” after a thoroughly scientific review by international referees. They have further been considered to be of major strategic importance for Norwegian research by the Research Council.

Criterion 3: The project involves a large-scale, comprehensive research infrastructure

To be considered for inclusion on the roadmap, a project must not only be of great national importance, but must also entail a high investment level compared to other research infrastructures within the respective field.

Decisions at the ministerial level

The Research Council assesses grant applications for research infrastructure involving investment costs starting at NOK 2 million and up to a maximum of NOK 200 million in project funding. After consultation with the Ministry of Research and Education, research infrastructure involving investments that exceed NOK 200 million may be included on the roadmap, provided that the project proposal has been reviewed and assessed by the Research Council as having high scientific merit and strategic value.

Projects on the ESFRI Roadmap

The Norwegian roadmap also includes projects listed on the European Roadmap for Research Infrastructures in which Norway has entered into binding agreements. All such projects have undergone a thorough review by the European Strategy Forum on Research Infrastructures (ESFRI) and are considered by the Research Council to be of major strategic importance for Norwegian research. ESFRI-projects that have received funding from the Research Council have been assessed on the same terms as other projects under the National Financing Initiative for Research Infrastructure. The decision on whether Norway should apply for membership in an ESFRI project is made at the ministerial level.



Research Council assessment of roadmap projects

Projects listed on the Norwegian Roadmap for Research Infrastructure that are considered "worthy of funding", but have not yet been funded must compete for funding with new project proposals on equal terms. This will ensure that priority always is given to the projects of highest merit and strategic value when allocating grant awards. It will also allow adequate consideration to be given to new needs and political priorities that may have emerged during the timespan between funding announcements.

The strategic basis

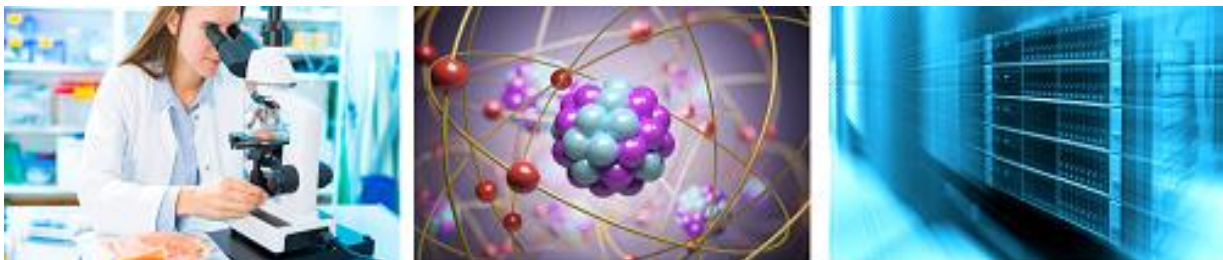
The area strategies describe research objectives, existing infrastructure and possible future needs for research infrastructures in various thematic areas, disciplines and technology areas.

The area strategies form the basis for allocations from the Research Council's budget and planning of future calls for research infrastructure. The division into area strategies reflects the overall priorities in the Government's long-term plan for research and higher education 2015-2024 as well as the Research Council's R & D funding.

Projects on the roadmap

Projects highlighted on the roadmap include projects that have received funding from the National Research Infrastructure Initiative, in addition to projects that have not yet received funding, but have been assessed as excellent and considered to be of major strategic importance for Norwegian research.

The descriptions of the roadmap projects can be found at the Research Council website <https://www.forskningsradet.no/prosjektbanken/>. For several of the projects, the Research Council's contribution constitutes only a part of the total cost of the project.

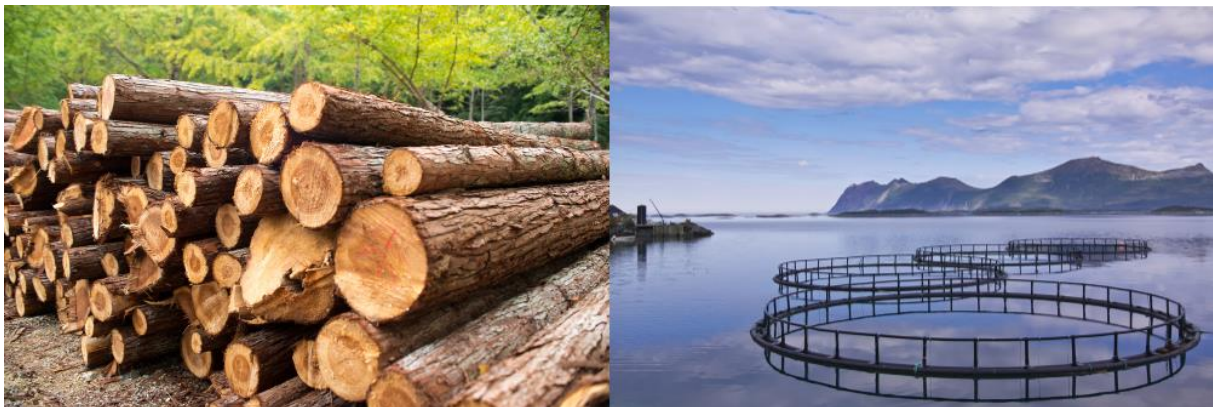


Area strategies

Bioresources

Fisheries, aquaculture, agriculture and forestry

Core activities in the area of bioresources involve food from oceans and land and raw materials from forests (excluding for bioenergy purposes), but also encompass research to facilitate optimal development of other bio-based products, e.g. fish feed and animal feed, biochemicals and biomaterials to replace petroleum-based materials or to fill other needs.



Research objectives

The objective is for all bio-based raw materials to be optimally and sustainably utilised throughout the entire value chain. There is also great potential to be found in new, value-creating forms of utilisation and in links between the bioresource closed-loop systems, within and between sectors. Biotechnology, nanotechnology and other enabling technologies are driving development in this research field. Interdisciplinarity and wider use of computational methods and bioinformatics will increase the relevance and impact of application of these technologies.

There is a need to encourage more research activity that facilitates the use of bioresources from the ocean and land, including waste and residual raw materials from industry and households, in a sustainable closed-loop system/circular approach and in many cases as alternative raw materials.

Norway has strong natural resource-based industries. Exploiting their potential requires developing and implementing infrastructure that promotes research and innovation and paves the way for necessary restructuring. At the same time, the underlying framework is subject to constant change due to new technology and knowledge, the emergence of new industries, growth in existing industries and increasing demands for internationalisation.

The food industry

It is important to generate knowledge that helps the food industry to develop new and innovative processes and products that satisfy requirements relating to sustainability and the circular economy.

The Government's Long-term plan for research and higher education 2015–2024 identifies the need for more knowledge to curb pollution and food waste and to ensure efficient utilisation of resources through the entire value chain, from raw material production to consumption. There is great potential for reducing waste, raising the efficiency of resource utilisation, and increasing food production and other activities related to local food production.

Ensuring food safety and reducing potential negative impacts of food production and consumption will require good monitoring systems and research infrastructure. Other important objectives include developing science-based dietary recommendations and preventing lifestyle diseases.

Fisheries and aquaculture/marine industries

There are high expectations for the expansion of marine-based value creation (fisheries, aquaculture and new marine industries) in Norway. Global demand for food and new feed sources is rising, and the oceans offer many opportunities. Marine natural resources not currently utilised can become a source of new industries if Norway develops more knowledge using modern technological know-how.

Norway is the world's second-largest exporter of seafood measured by value, and the largest producer of Atlantic salmon. It is a stated Government objective for Norway to become the world's leading seafood nation. It is a national goal to increase salmon production and the domestic processing of both farmed and wild fish. Increased processing will open up opportunities to better utilise valuable residual raw materials and lead to reduced export (including ice), providing environmental and climate benefits.

Agriculture and forestry

The Norwegian agriculture sector faces increasingly keen competition from abroad. Norwegian agriculture is at the forefront of important areas such as food safety, animal health and export of excellent breeding materials. Norwegian food production is among the best in the world at using antibiotics and pesticides sparingly. Intensified efforts in research, technology, innovation, restructuring and efficiency measures are vital to promote an agricultural sector equipped for future challenges.

In recent years, a number of large-scale wood-based projects using new products and construction systems have been implemented, and Norwegian projects have achieved international acclaim. In addition to replacing products based on fossil fuels, biorefining of forest biomass can lead to innovation in the form of a variety of new, sustainable consumer products.

Existing research infrastructure

Developing methods for sound, sustainable utilisation of bioresources requires research in many scientific disciplines and technology areas that need different types of research infrastructure. There are a number of national infrastructures featuring various instrumentation, and several of the laboratories provide access to users from academia as well as industry.

Pilot Plant Facilities for Food Processing at Campus Ås is an infrastructure for research targeted towards the entire production chain – from raw materials to finished, packaged food products – to promote efficient production of safe food. The infrastructure includes a pathogen facility used to test the survival and growth of pathogenic bacteria in food and production environments.

Norway participates in the European Marine Biological Research Centre (EMBRC-ERIC). The infrastructure supports studies on how marine organisms react to various changes in the marine environment. The Norwegian node of EMBRC-ERIC is specially targeted towards studies of organisms that are of relevance to fisheries and aquaculture.

The Aquafeed Technology Centre (ATC) will provide research infrastructure for developing new and improved utilisation of feed ingredients for fish farming and other industries, based on available marine, vegetable, animal and single-celled resources. The infrastructure will be completed in 2019.

Two national research infrastructures for utilising marine raw ingredients are Mobile Sealab and the Norwegian Center for Plankton Technology. Mobile Sealab comprises a small, complete factory

facility for the recovery of oil, protein-rich fractions, and other nutrients from residual raw materials produced by the fisheries industry. The Norwegian Center for Plankton Technology is a national infrastructure for development of new cultivation methods and new technology for harvesting, cultivating and processing lower trophic-level organisms in the ocean.

The Norwegian Biorefinery Laboratory (NorBioLab) is a national research infrastructure for development of processes to convert Norwegian land-based and marine biomass to new, environment-friendly biochemicals, biomaterials and bioenergy products. The infrastructure can be used to carry out research on many different bioresources, such as lignocellulose, marine resources and waste.

The European Life Science Infrastructure for Biological Information (ELIXIR) coordinates data resources for the life sciences. ELIXIR.NO is the Norwegian node of ELIXIR, coordinating development of Norwegian bioinformatics and providing services for the research community and industry.

Need for new infrastructure, upgrades and/or coordination

In the years ahead there will be a need for upgrades and replacement of existing equipment and for entirely new infrastructures.

Needs will include infrastructure for monitoring and management, sustainable processing and refinement of natural resources, research on new species for harvesting, cultivation and farming, and research targeted towards development of new products based on biological raw materials.

Given the increasing volumes of data, not least molecular data generated by modern biotechnology, it will be important to develop systems that enable data from different sources to be made accessible, compared and analysed. To take advantage of the inherent potential of computational methods in the future, it will be critical to have adequate analytical and computing capacity to accommodate vast volumes of data.

There is also a need for coordination to facilitate better utilisation of technologies and infrastructures across relevant fields, e.g. biotechnology, nanotechnology, energy, health, climate, the environment, oceans and e-infrastructure.

Interface with other areas

Development of research infrastructure in the areas of fisheries, aquaculture, agriculture and forestry must be viewed in context with infrastructure in other areas, such as biotechnology, nanotechnology, energy, health, climate, the environment, oceans and e-infrastructure.

Biotechnology

Biotechnology encompasses all studies involving modification of the composition or structure of organisms and parts of organisms in order to gain knowledge and develop products, processes and services. Biotechnology requires up-to-date, costly equipment to stay on the cutting edge of research, promote quality across the full range of Norwegian research activities, and support knowledge-driven innovation.



Research objectives

According to the Government's Long-term plan for research and higher education 2015–2024, biotechnology is an enabling technology that, together with other disciplines and technologies, will help to promote innovation and address social challenges. The plan states that there is large, untapped potential for biotechnological innovation.

A national strategy for biotechnology was drawn up for the period 2011–2020 which states a clear expectation that biotechnology as a field is to help to create sound solutions for the public and private sectors. As one of the enabling technologies, biotechnology offers great economic potential in marine industries, health care, agriculture and process industries. Biotechnology is viewed as essential to the development of the bioeconomy, which in the coming years will comprise a significant part of the global economy, in keeping with the increased focus on sustainable utilisation of bioresources. Thus the bioeconomy should be a chief consideration in future investments and activities in the biotechnology field.

Transdisciplinary and cross-sectoral areas such as biostatistics, bioinformatics/systems biology and synthetic biology are identified as important areas at the research front where the public agencies within the research and innovation system have a special responsibility for building capacity. This is manifested through e.g. the national collaborative platform National Centre for Digital Life as well as interdisciplinary efforts at the R&D institutions. Research infrastructure plays a vital role in enabling research activity using computational methods and modelling. Biotechnological methods and research infrastructure must also accommodate the scales relevant to biology – both in reach, from biomolecular and individual cells to entire organisms and ecosystems, and in time, from microseconds to years.

The Research Council supports biotechnological research via a variety of funding schemes, with the Research Programme on Biotechnology for Innovation (BIOTEK2021) as the key individual programme for following up the national strategy. The BIOTEK2021 programme works to promote socially responsible innovation and industrial development from biotechnological research, through e.g. expanded transdisciplinary collaboration across subject fields, technologies and institutions.

Existing research infrastructure

The available infrastructure for biotechnological research groups is largely based on technology platforms that were established under the National Programme for Research in Functional Genomics (FUGE) and further developed through funding from the *National Financing Initiative for Research Infrastructure*. This includes infrastructures related to human biobanks, bioinformatics/systems biology, gene sequencing, NMR analysis and biorefining, as well as super-resolution light microscopy, structural biology and chemical biology (see the list of roadmap projects at the end of this document). The infrastructures for four of these fields (bioinformatics, biobanks, light microscopy and chemical biology) are associated with joint European cooperation on infrastructure under ESFRI. Additional infrastructure and core facilities have been developed in a number of important areas through investments on the part of R&D institutions.

Need for new infrastructure, upgrades and/or coordination

To achieve the objectives of the national strategy for biotechnology, investments in infrastructure must ensure that advanced technology is accessible and benefits Norwegian researchers in academia and industry by enhancing the quality of research. Greater technological expertise must be developed to achieve optimal use of infrastructure for new scientific research questions and innovation.

The rapid pace of technological advancement taking place in many areas is due to combinations of and convergence between technologies. Such technological convergence is considered critical for addressing the major societal challenges where biotechnology can provide a valuable contribution. Analysis is trending towards the level of individual cells and molecules, and imaging technologies are being developed across the board.

Data-driven and computational methods will become more and more common in biotechnology research and innovation in the coming years. There is thus a large and growing need for competence-based services that can process and utilise the large volumes of molecular data generated in modern biotechnology. In light of this, there will also be a demand for services for making data accessible and establishing evidence bases on organisms that are important for Norway and that can support data-driven innovation.

Achieving new biotechnological innovations requires that investments in existing and new infrastructure also accommodate the needs of the business sector. Future needs and priorities for research infrastructure in this field will be viewed in the context of national strategic initiatives, and will take the following factors into account:

- Need for upgrades, further development and coordination of already-established infrastructures;
- Support for infrastructure that enhances quality and capacity in Norwegian biotechnological R&D, including development of cutting-edge technology in high-throughput screening, 3D cultivation/processing, fermentation technology, downstream processing and separation technology, structural biology, the “omic” technologies, bioinformatics/systems biology and synthetic biology;
- Support for infrastructure that ensures data management across technologies in keeping with the FAIR principles (Findable, Accessible, Interoperable, Reusable);
- Support for infrastructure that facilitates biotechnological research which has a broad basis for applications; extends across multiple sectors; and facilitates collaboration between universities,

research institutes, hospital trusts and the business sector and a wide range of relevant societal stakeholders;

- Support for infrastructure to promote the strategic initiative “Digital Life – Convergence for Innovation” and other biotechnology initiatives at the Research Council of Norway;
- Efforts to foster effective cooperation and task-sharing on research infrastructure, nationally and internationally. In particular, assessment of the value of participation in joint European infrastructures in the field (including ESFRI projects) and Norway’s role in these, specialising in and focusing on areas where Norwegian researchers can take a leading role in selected technologies.

Interface with other areas

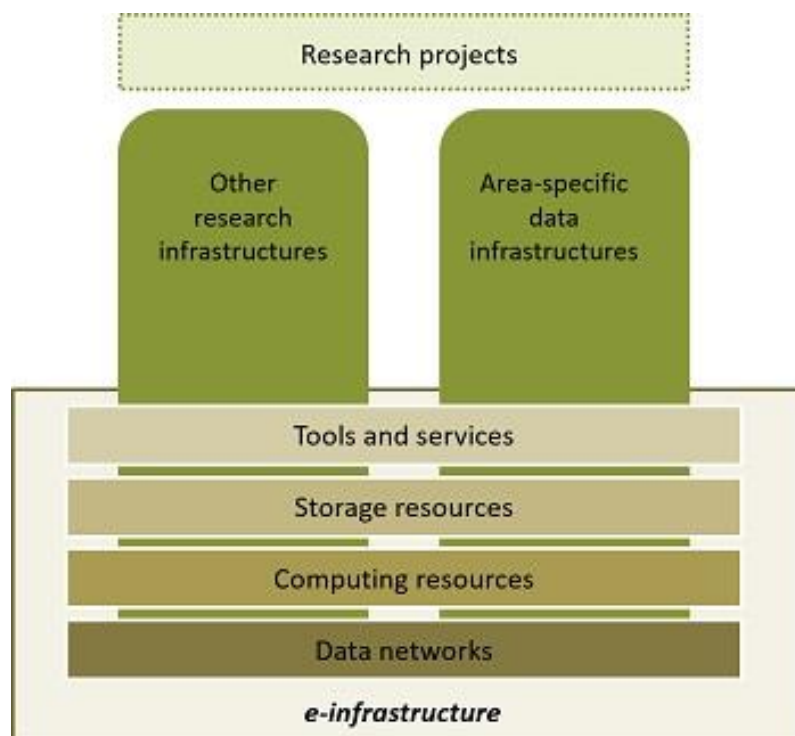
Biotechnology is an enabling technology for fields such as medicine and health care, marine industries, climate and environment, and bioresources. Greater focus on interdisciplinary cooperation and technological convergence also enhances the interface with nanotechnology, ICT and the humanities and social sciences.

E-infrastructure

Electronic infrastructure (e-infrastructure) encompasses tools and services for most subject areas, but it is particularly important for research activity requiring extensive computer-processing capacity or generating large amounts of data. E-infrastructure also encompasses digital registries and databases. Climate research, biology, bioinformatics, medicine, chemistry, physics, materials science, energy research and linguistics are a few of the various subject areas that all make use of e-infrastructure.



E-infrastructure for research consists of ICT-based infrastructures that enable advanced, collaboration-oriented research. E-infrastructure for research encompasses equipment, operations and related services for high-performance computing, data storage, software systems and high-capacity networks, as well as tools for efficient workflow and software for simulations and data analysis. The term “e-infrastructure” also refers to digital registries and databases as well as the tools and services for ensuring security and accessibility.



E-infrastructure provides fundamental services for research

Research objectives

E-infrastructure encompasses fundamental services used in most subject areas and lays a foundation for numerous other research infrastructures. E-infrastructure is especially important for research that requires high-performance computing or where simulation and analysis activities generate massive amounts of data, as is the case with climate research, biology, bioinformatics, medicine, chemistry, physics, materials science, energy research and linguistics. E-infrastructure must also be able to handle sensitive data securely.

The objectives for e-infrastructure are divided into three parts:

- deliver services for research projects and other research infrastructures;
- provide secure storage and accessibility of data in line with the international FAIR Principles;¹
- deliver area-specific infrastructure.

The magnitude of the resources invested in procuring and analysing data makes it necessary to ensure that the data are protected, that their value is enhanced through cataloguing and generation of metadata and that they are made accessible to other users in keeping with the FAIR principles. Thus, access to, and the effective use of, e-infrastructure in all subject areas is a cornerstone of data-intensive research.

Better access to research data will enhance the quality of research in that results can be validated and verified in a more effective manner and data sets can be used in new ways and in combination with other data sets. Open access to research data helps to prevent unnecessary duplication of results or efforts and paves the way for more wide-ranging interdisciplinary research. Open access to research data is a national and international priority area. In 2017, the Ministry of Education and Research launched a national strategy on access to and sharing of research data.

In 2017, the Research Council revised its policy on open access to research data in the aim of making research data more accessible to relevant users, on equal terms, and at the lowest possible cost while adhering to the international FAIR principles for added value from data. R&D institutions are to assess whether projects receiving Research Council funding need to draw up a data management plan as a means of providing a framework for the secure management of research data not just during the life of a project, but also for future reuse. The policy guidelines apply to all data generated under projects that receive funding from the Research Council with a few exceptions. Different e-infrastructures have developed digital tools that research projects can use to generate data management plans.

Existing research infrastructure

Norwegian research institutions have the benefit of cost-effective, coordinated e-infrastructure for research and higher education in many subject areas. UNINETT AS develops and operates the Norwegian high-performance network for research and education, connecting over 200 Norwegian institutions and over 300 000 users and linking them to international research networks. UNINETT AS is a non-commercial enterprise owned by the Ministry of Education and Research. Affiliation with the research network is the basis for most other services provided by UNINETT AS.

UNINETT Sigma2 AS, a subsidiary of UNINETT AS, is responsible for the procurement, operation and further development of the generic national e-infrastructure for high-performance computing and data storage in Norway. In the period from 2016 to 2019, the four national high-performance computing facilities acquired in 2012 are being phased out and replaced by two new computational

¹ The international FAIR Principles have been formulated as a set of guidelines for the reuse of research data. The acronym FAIR stands for findable, accessible, interoperable and reusable. Research data and metadata must be of a quality that makes them accessible, findable and reusable, and they must be machine-readable.

facilities (E-INFRA at UNINETT Sigma2 AS). Prior to 2015, computational processing resources and data storage solutions for Norwegian research were supplied independently by facilities in separate physical locations. The growing volume of data and steady increase in the number of research projects based on data analysis have given rise to a need to integrate the two facilities to a greater degree so that data analysis can be carried out at the site where the data are stored. For this reason, ongoing investments in new equipment also encompass restructuring efforts to create a more data-centric e-infrastructure: the new National e-Infrastructure for Research Data (NIRD). NIRD, formerly known as NorStore, is now directly connected to the computing facilities, which makes it possible to deliver services for data analysis and visualisation more efficiently. NIRD provides storage resources that are upgraded annually, data security through dual-site storage, support for multiple storage protocols and migration to third-party cloud service providers.

Through close cooperation with Norway's four oldest universities, Sigma2 offers several related high-performance computing and data storage services to Norwegian universities and university colleges as well as to other publicly funded research organisations. Sigma2 also heads and coordinates Norway's participation in international collaborations on e-infrastructure, such as the Nordic e-Infrastructure Collaboration (NeIC), the Partnership for Advanced Computing in Europe (PRACE) and the European Data Infrastructure (EUDAT).

In certain areas where management of sensitive personal data is involved, solutions are needed to meet requirements concerning secure data while also providing researchers access to the data for the purpose of analysis. Solutions of this type are provided by Services for Sensitive Data (TSD), among others, which is operated and developed in cooperation with Sigma2 at the University of Oslo. Funding from the National Financing Initiative for Research Infrastructure has been allocated for investments in new equipment to safeguard sensitive personal data at the Services for sensitive data (TSD).

The Norwegian Centre for Research Data (NSD) archives and prepares data for dissemination to research groups, both nationally and internationally, and develops technological solutions to provide open access to research data within the research sector. NSD serves as Data Protection Officer for the nation's universities, most Norwegian university colleges and numerous health trusts and research institutes. In 2003, NSD was established as a limited company owned by the Ministry of Education and Research. NSD has received funding from the National Financing Initiative for Research Infrastructure for the Norwegian Open Research Data Infrastructure (NORDi), a solutions provider for research data storage and access.

Another generic data infrastructure of note is UiT Open Research Data, an open research data archive established at UiT The Arctic University of Norway. This infrastructure is available to UiT researchers and other institutions as well as individual researchers. In addition, BIBSYS BIRD is a generic tool for storing, documenting, sharing and publishing research data, developed by BIBSYS (now part of the new agency for higher education and research services) in cooperation with BI Norwegian Business School.

There are a number of other subject area-specific data infrastructures that provide services targeting specific needs among different communities of users. These subject-specific data infrastructures are adapted for data that are to be made accessible within the various subject areas. In order to achieve the highest possible reuse of previously collected data it is imperative to have good infrastructures that make it easy to locate relevant data and link together different data sets. More information about subject-specific data infrastructures is provided in the various area strategies.

Need for new infrastructure, upgrades and/or coordination

Steadily improving measurement and sensor technologies, more extensive measurements, increased focus on data-driven research and more advanced data analysis tools all add to the need for high-performance computing, data storage and accessibility to massive amounts of research data. This

does not just apply to traditionally data-intensive subject areas; an increasingly wider range of research fields are generating or using very large amounts of data.

Computing facilities need to be replaced approximately every four years because equipment wears down and becomes too expensive to operate. Sigma2 is currently working on replacing and upgrading both the computing and data storage facilities used in Norwegian research. Based on projections using historical data on demand and requests from new user groups, Sigma2 calculates the amount of computing capacity the new facilities should have in order to meet the needs of Norwegian researchers.

The demand for management of sensitive data is expected to increase substantially in the future, in line with increased demand for high-performance computing and data storage.

Interface with other areas

The Research Council encourages cooperation between actors in establishing services for data management in order to capitalise as much as possible on prior investments. Such cooperation may take the form of project collaboration or direct use of existing services. Collaborations of this type are not limited to national efforts. In some areas the best approach will be to cooperate on international data infrastructures, as exemplified by the many ESFRI projects on data management.

The Research Council will normally not contribute funding for investment in, and operation of, computing resources for data-intensive computing unless the investment has been coordinated with, or comes entirely from, Sigma2. Research groups with a need for computing resources are advised to contact Sigma2 at the outset in order to clarify whether their needs can be met through existing or planned Sigma2 investments. For applications for new national research infrastructure requiring storage or computing resources, the Research Council expects the Project Owner to establish a dialogue with Sigma2 on how these needs can be met and to incorporate the costs into the budget for the infrastructure being sought.

The humanities

The humanities include many different subjects which have in common the attempt to interpret, explain and understand human beings, human expression and the human cultural environment.



Humanities research plays an important role in society through knowledge development, education, public opinion formation, public administration and policy design. Such research may also be relevant to business development, especially in the cultural sector, travel and tourism, language technology and service industries. Digital tools and technology are increasingly integral to research processes in the humanities, while the research itself is increasingly focused on the digital transformation and its consequences.

Research objectives

The white paper Humanities in Norway (Meld. St. 25 (2016–2017)) comprehensively reviews humanities research in Norway. The Government expresses a clear expectation that humanities research must be applied more widely in activities to address complex challenges in society and that efforts to further improve the quality of research must be continued. The report clarifies the role of the humanities in the long-term priorities set out in the Government's Long-term plan for research and higher education 2015–2024 (Meld. St. 7 (2014–2015)).

The Research Council of Norway's main strategy, Research for Innovation and Sustainability 2015-2020, points out the necessity of a broad understanding of the cultural prerequisites for social development and notes that targeted initiatives in the humanities and social sciences would strengthen this area. The EU Framework Programme for Innovation and Research, Horizon 2020, underscores the importance of incorporating social sciences and humanities research in order to maximise society's return on investments made in research and technology development.

For humanities research to contribute in the ways prescribed, it will require infrastructures that can support high-quality research. Investments in digital infrastructure useful in humanities research will help more groups to move to the forefront of international research and attract international partners.

Existing research infrastructure

Within the humanities, a number of scientific collections have been digitised and are accessible for research purposes, including parts of the Norwegian Language Collections and the Museum Project. These resources are available but lack a unified profile and up-to-date interface.

The arts and cultural history museums have databases which provide overviews of their collections (catalogues) and other digitised source material. Several museum databases have been linked and made accessible via DigitaltMuseum.no, but the amount of the collections that have been digitised varies among the museums. The web portals of Norwegian university museums, at unimus.no, provide access to several of the museums' collections, including an extensive database of archaeological objects. The contents of the National Archives of Norway are largely analogue, but all digitised state archive materials and some digital private archives are accessible in the Digital Archives.

Linguistics groups at Norwegian universities have extensive experience establishing and developing textual corpora, language databases and technological solutions and tools used for both research and language technology development. Several linguistics infrastructures are funded through the National Financing Initiative for Research Infrastructure. These include the Infrastructure for the Exploration of Syntax and Semantics (INESS), the Medieval Norwegian Text Corpus (MENOTEC) and Language Infrastructure made Accessible (LIA). The Norwegian Language Bank, a national infrastructure for language technology and research at the National Library, was launched in 2010. The aim of the National Library's ongoing digitisation project is to digitise the entire collection of the National Library; it will become an important tool for research in many humanities subjects.

CLARINO, the Norwegian node in the ESFRI CLARIN project (Common Language Resources and Technology Infrastructure), has received funding through the National Financing Initiative for Research Infrastructure. The project has established a common infrastructure for Norwegian language and text databases. CLARINO is linked to international databases and provides search and analysis services that make research more efficient and open the door to new research questions. Several of the Norwegian linguistic research databases have already been integrated into CLARINO. Language researchers are the primary users of CLARINO, but it holds potential relevance for other subject areas, such as the social sciences, psychology and media and information science.

Other infrastructures for humanities research that have been awarded funds through the National Financing Initiative for Research Infrastructure include a historical population registry (HISTREG), technical equipment for the study of the Four Ms (music, mind, motion and machines), and a digital corpus and digital dictionary for the study of Latin as used in Norway in the Middle Ages (MIDLAT). In 2018 an infrastructure called Archaeological Digital Excavation Documentation (ADED) is being established for archaeological excavation data in a collaboration between the university museums.

Need for new infrastructure, upgrades and/or coordination

Information technology holds great potential to be an effective and powerful tool for humanities researchers. Digitisation opens new opportunities for mining text and data from a wide range of source materials. Access to digital tools in combination with new ways of working and evolving methodologies enlarges the cooperative interfaces with other disciplines.

The biggest infrastructure challenges in the humanities are in digitisation, standardisation, systematisation, linkage and accessibility of data in open archives and databases. Many of the established humanities databases cannot be linked together in their current form. As a result, research involving data compilation from different databases and scientific collections can be both time-consuming and resource-intensive. It has long been an objective of humanities research groups to standardise and link databases.

Much historical material remains stored in the archives and scientific collections of research institutions, libraries and museums. In its present form some of this material, including documents, objects, photographs and audio and video files, is decaying. Preserving the material for posterity will require a major digitisation and systemisation effort. It is important that academic and scientific groups assemble informational material and take the initiative to set up infrastructures to digitise, systematise and annotate this data and make it accessible. Looking forward, there will be a need for

new and updated infrastructure projects in connection with digital language collections and data services.

In some research areas, access to costly high-tech equipment is crucial to be able to carry out high-quality research. Such areas include archaeology, where advanced instruments are needed to analyse finds, and linguistics, where cognitive research laboratories will make it possible to carry out neurological and psychological tests of language users. Research groups have identified a need to upgrade existing digital infrastructure in music technology to make the most of innovative interdisciplinary research in this area.

The digitisation of humanities research greatly enhances the potential for innovative methods and interdisciplinary cooperation. The ability to fully exploit this potential in future will require competence building and better coordination of this activity. Norwegian institutions and research communities should aim to collaborate more on developing good project applications to establish infrastructure in key subject areas, and they should use the projects as platforms for building expertise in digital research and infrastructure operations. The Research Council will utilise its various funding instruments to encourage cooperation between relevant research groups in Norway in a manner that achieves good national distribution of both costs and expertise.

In addition to establishing and further developing national initiatives, Norwegian research groups need to assume a larger role in relevant international research infrastructure efforts. This is something which humanities researchers themselves have expressed a desire to do. Greater international involvement will improve awareness of the needs and opportunities present in Norwegian humanities research.

Interface with other areas

Sophisticated facilities used for analysis in the natural sciences should also be employed by humanities research groups when appropriate. Humanities researchers have identified a need for new infrastructures facilitating technological and scientific analysis in the area of cultural heritage.

The humanities will become more and more dependent on expanding storage and computing capacity. E-infrastructure investments of sufficient scale will be needed to achieve the objectives that have been set for humanities research. Coordinating the development of database systems across disciplines is another relevant undertaking, in part because it permits more efficient use of expertise, standards and systems.

ICT

The digital transformation, where information and communication technologies (ICT) are a key driver across subject fields and sectors, is having a profound effect on society. ICT encompasses technologies for collecting, storing, processing, presenting and transferring data and information.



ICT has applications within virtually all industries, is used in all technology areas and is linked to most societal challenges. Research infrastructures within the area of ICT will therefore often be connected to other subject areas, but there is also a need for high-performance infrastructure in basic ICT research.

Research objectives

The objectives of the Research Council's IKTPLUSS initiative for ICT and digital innovation are to build dynamic research groups in priority areas, to produce a significant number of projects displaying bold thinking and link the portfolio to national needs for ICT research and innovation in selected areas of society.

Priority thematic areas:

- **Ubiquitous data and services:** Big data, artificial intelligence, robotics and the Internet of things are areas that will bring about major changes to society, create new opportunities and give rise to difficult dilemmas and issues of global and national significance.
- **A safe and secure information society:** Efforts will be steered towards specific areas of society and sectors with vulnerable infrastructures of major importance for society as well as towards building and further developing robust scientific groups in the area of ICT security.
- **Radical, groundbreaking projects** with a high potential for generating breakthroughs and future value creation in the form of new research and commercial or societal value creation.

The objectives also underscore that investments are to contribute to meeting societal challenges in national priority areas. Information security and digital vulnerabilities, the public sector and health form the core of the Research Council's IKTPLUSS initiative. The UN's Sustainable Development Goals are also relevant for efforts in the field of ICT.

Meld. St. 27 (2015–2016) Digital agenda for Norge — IKT for en enklere hverdag og økt produktivitet, white paper on a digital agenda for Norway and ICT for a simpler everyday life and increased productivity from the Ministry of Government Administration and Reform and Meld. St. 27 (2016–2017) A greener, smarter and more innovative industry, white paper from the Ministry of Trade, Industry and Fisheries, as well as the national strategy for ICT research and development set out ambitions and guidelines that are relevant for the Research Council's ICT investments. In addition,

the Government's Long-term plan for research and higher education 2015–2024 points out that ICT is essential for promoting growth and value creation in Norway.

Existing research infrastructure

Advances in the area of ICT require a wide range of research infrastructures, from development of software systems, powerful servers and networking technologies to laboratories for the development of sensors and circuit technologies. At the same time, many research infrastructures for other subjects and thematic areas, e.g. in biotechnology (life sciences), climate, energy and health, will be important drivers of ICT research.

Listed below are several infrastructures of vital importance for Norwegian ICT research:

- UNINETT - Sigma2 AS provides the research community with a generic, national e-infrastructure for high-performance computing and data storage. Sigma2 also coordinates Norway's participation in European research infrastructures such as the Partnership for Advanced Computing in Europe (PRACE) and the European Collaborative Data Infrastructure (EUDAT)/European Open Science Cloud (EOSC) while also participating in the Nordic e-Infrastructure Collaboration (NeIC).
- NorNet – Norwegian Infrastructure for Network Experimentation provides a large-scale, real-world Internet testbed where enhanced performance and a robust network are key research challenges.
- ReRaNP – Reconfigurable Radio Network Platform provides opportunities for validating and demonstrating new methods and systems of radio communication. Higher speeds, the development and establishment of true massive multiple-input-multiple-output (massive MIMO) systems and advanced wireless sensor networks are key research challenges.
- The Norwegian Smartgrid Centre's laboratory and demonstration platform makes it possible for researchers, energy companies and suppliers to develop and test everything from electricity transmission from the central grid and electricity distribution network to smart homes and electric vehicles.
- LIA – Language Infrastructure made Accessible is to provide linguistic data for development and research on speech and language technology for the Samí and Norwegian languages.

A number of research infrastructures targeting other subject areas are also relevant for ICT research and innovation, e.g. Virtual Arena – OpenLab Drilling; ELIXIR Norway – a distributed infrastructure for the next generation of life science; Biobank Norway 2 – a national research infrastructure for clinical- and population-based biobanks; NorMIT – Norwegian Centre for Minimally Invasive Image-guided Therapy and Medical Technologies; e-infrastructure for Video Research and Music and Motion Lab.

Need for new infrastructure, upgrades and/or coordination

The need for national and international data storage centres and high-performance computing resources will increase significantly in coming years and will call for the development of new services for easy, secure access to data and high-performance computing resources. More and more research fields generate and/or use large data volumes while technological developments are also yielding greater amounts of data on their own. It is therefore important that the development and renewal of generic infrastructures keep pace with emerging needs.

Developing the supercomputers and data storage centres of tomorrow is a research field in itself and Norwegian researchers will need access to Norwegian and European state-of-the-art research infrastructures to be of interest when future supercomputers are built using European technology.

A more detailed description of the needs for research infrastructures associated with the three thematic areas is provided below:

Ubiquitous data and services: Research infrastructures providing access to vast amounts of data for research and development for artificial intelligence; testing new technologies and platforms for the future internet, including the Internet of things; smart environments and interaction between individuals; physical and digital systems (cyber-physical systems) are a few examples of infrastructures that can be instrumental in meeting research challenges. This is also important for innovation in the public and private sectors.

A safe and secure information society: Research infrastructures for understanding and developing technologies and solutions that help to reduce digital vulnerabilities in critical infrastructures and in society at large will be of great importance. There is a need for infrastructures for interpreting data (visualisation and image processing) and for managing data systems (human-machine interaction).

In the area of **Radical, groundbreaking projects**, needs that have yet to be identified will emerge, e.g. in the interface between the areas of biotechnology, nanotechnology and data technology. For instance, research infrastructures for the computers of the future may lead to radical breakthroughs for supercomputers, high-speed computational processing and data traffic.

In 2017, the Research Council revised its policy on open access to research data, emphasising the importance of making research data accessible for future use in keeping with the international FAIR principles (findable, accessible, interoperable, reusable). This will increase the need for storing large amounts of data and for the implementation of a service layer ensuring access to data while safeguarding the protection of personal privacy, legal and security concerns and commercial rights. For a number of actors data are considered competition-sensitive information, for example in seismology, finance, medical data (images) or internet traffic. To the extent that data are to be used in research projects it is important to have clear agreements on how the data and the results are to be managed.

Interface with other areas

It is of benefit to ICT research that the general capacity of e-infrastructure (services based on computing solutions, high-speed networks and storage facilities) expands in parallel with technological developments and the growing volume of data generated by research.

Data-driven learning and artificial intelligence represent a research field that brings together ICT researchers and researchers from other subjects and disciplines, for example precision medicine, economics and finance, societal security and media and consumer research. Research and development within artificial intelligence requires research infrastructures with substantial storage and processing capacity that can meet demands for protection of personal privacy, security and ownership of data and results.

Research infrastructures draw on ICT research in areas such as biotechnology, medicine and health and environment-friendly energy. These infrastructures also play a role in driving ICT research forward.

The development of new production technologies and materials for sensor elements and actuators integrated into smart sensor systems is crucial for optimal ICT solutions. Therefore, the infrastructure for nanotechnology and new materials also contributes the quality of research in ICT.

Climate and the environment

Climate and environmental change has had and will continue to have substantial impacts that pose major challenges for nations, societies and people, but that also create new opportunities. An extensive body of knowledge is necessary for solving these challenges and exploiting these opportunities. These changes are particularly great in Norwegian ocean areas and polar regions, and the knowledge we possess about the ocean and polar regions is also essential to our ability to understand and deal with climate and environmental challenges both in Norway and worldwide. Norway has particular responsibility for ensuring sound management and sustainable economic development that are based on national natural advantages and internationally leading knowledge environments in climate, environmental and polar research and in marine research and resource management.



Research objectives

Climate

Climate change represents one of the greatest international societal challenges the world faces. To implement targeted, cost-effective measures across all sectors of society, Norway and the international community need research-based knowledge about climate change and its local, regional and global impacts. Greater insight is needed into how climate change will affect ecosystems and different industries, including the primary industries. This will require a better understanding of what a low-emission society will look like, what it will take to bring us there, and the social challenges inherent in this process. Norwegian climate research is to contribute to this and support the targets set out in the Paris Agreement. Climate research activities under the Research Council are long-term in nature and in keeping with the Government's Long-term plan for research and higher education 2015–2024.

The environment

Environmental research will generate more knowledge about key environmental challenges and provide the public administration, trade and industry, and society at large with a better foundation on which to take decisions to promote a green transition. The loss of biodiversity, the spread of hazardous substances, pollutants and invasive species, and changes in water quality are pressing global challenges. To safeguard biodiversity and stop the deterioration of ecosystem services, it is essential that research activities are targeted towards the composition, function and dynamics of biodiversity. Knowledge about changes in the quality of the environment, causes of these changes, and measures and instruments for preventing or alleviating environmental damage will require more multi- and interdisciplinary environmental research as well as international collaboration. The Research Council's environmental research activities are based on several government white papers

and research strategies, not least the Government's Long-term plan for research and higher education 2015–2024 and the national environmental R&D strategy, Miljø21 (2014).

The oceans

Clean oceans and coastal areas with abundant resources are a prerequisite for long-term, sustainable value creation based on marine resources. There is a constant need for more knowledge about the structure and functioning of marine ecosystems and how they are affected by climate change, ocean acidification, plastics and other pollutants in the oceans, and other anthropogenic drivers of change. Norwegian research is to promote sustainable value creation based on marine resources, better management of ecosystems and resources in maritime areas, clean oceans and safe, healthy seafood. Marine research activities under the Research Council are in keeping with the Government's Long-term plan for research and higher education 2015–2024, the Norwegian Government's ocean strategy New Growth, Proud History as well as the national R&D strategies HAV21 and Miljø21.

The polar regions

An overall objective of the Research Council's policy document on Norwegian Polar Research (2014–2023) is for Norway to be a leading polar research nation and for polar research to reflect Norway's special responsibility for generating knowledge for policy implementation, responsible resource management and industrial activity in the polar regions. The white paper on Svalbard (Meld. St. 32 (2015–2016)) emphasises that Norwegian polar research is to build upon areas where Norway has high-quality research groups with scientific strengths, accessible infrastructure and natural advantages. The Norwegian Government's Arctic strategy also identifies key challenges for Norwegian marine and polar research and priority areas in environmental, resource or industrial policy. In Svalbard in particular, close collaboration between the business sector and the research community will be necessary for making the most of the archipelago's natural advantages, ensuring sustainability and safeguarding the environment.

Existing research infrastructure

Research on climate and the environment is dependent on *in-situ* measurements of climatic components, pollution and biological conditions based on the use of weather stations, research vessels, ocean buoys, autonomous vessels/vehicles and advanced logistics. Norway has well developed land-based research platforms, new icebreaker research vessels and various fixed and mobile marine observation systems. In addition there are good logistics in place for collection of environmental, climatic and biological data in the polar regions and waters near Norway.

Norway also has research infrastructure with year-round stations in Antarctica (Troll) and Svalbard. Ny-Ålesund has a unique position as the leading Arctic environmental research station, with year-round research stations and laboratories for terrestrial, atmospheric and marine research. Longyearbyen also has advanced infrastructure, particularly for research on the middle and upper atmosphere.

For reliable analysis of samples there are several laboratories using quality-assured analytical and calibration tools for conducting environmental chemical analysis (e.g. of hazardous substances, air/water quality), biological analysis (e.g. DNA analysis) and physical analysis (e.g. of sediments and isotopes).

Linked ecosystem and circulation models are vital tools for climate and environmental research. Norway has particularly advanced Earth system models used by the Intergovernmental Panel on Climate Change (IPCC), among others, which encompass all parts of the climate system (ocean, atmosphere, land, biogeochemistry and biology). These are important for calculating various outcomes of future climate with increasingly high resolutions in time and space.

Research on climate and the environment often requires large storage and computing capacity. There are a number of databases for different climate and environmental data, and Norwegian research groups contribute substantially to many internationally coordinated databases as well as manage many valuable long time-series. Norway contributes to the use of satellites under Copernicus, the EU Earth observation programme.

Need for new infrastructure, upgrades and/or coordination

Norway has a special responsibility to continue conducting long-term observations of unique, long time-series for climate and environmental monitoring. This requires ongoing maintenance, upgrading and renewal of the observation systems. Establishment of integrated observation systems, new technology and Earth observations, particularly in Norwegian ocean and coastal areas, can provide a basis for designing operational services of benefit to society as well as research of high quality and importance. Research infrastructure that enables scientists to establish new, unique datasets can, together with other unique research platforms, open up opportunities to be at the forefront of strategically important areas. Examples of such infrastructure are research satellites, seabed observatories, research vessels and autonomous underwater vehicles. Tying together research and innovation is especially important for exploring and utilising the ocean space in Norwegian and polar ocean areas, from the surface down to great depths.

Environmental research requires continual development of and investment in new analytical tools, laboratories and measurement technology for e.g. detecting new hazardous substances and pollutants (such as microplastics and nanoparticles) and for understanding their biological effects. Biological taxonomic research, for instance, is important for developing new DNA techniques, improving systems for storing and safeguarding biological samples, and establishing a modern biobank for biological samples from Norwegian nature. Increased use of molecular biological methods can be achieved by enhancing cooperation with existing infrastructures for data analysis and management and within bioinformatics.

It is necessary to develop, upgrade and validate major, linked Earth system models to maintain Norwegian advantages in polar and marine research on climate and the environment. Model components and observation systems that support the Norwegian Earth System Model (NorESM) are particularly important. In this regard, international cooperation to develop international research infrastructures and observation systems will be crucial. Improved utilisation of Svalbard as a research platform will promote this through better coordinated, joint access to various research services. International coordination of the observation systems under the Svalbard Integrated Arctic Earth Observing System (SIOS) could be a joint contribution to an Arctic integrated observation system.

Research on climate and the environment often requires large computing capacity for quickly performing complex calculations. This research field therefore has a great need for investment in e-infrastructure (see the e-infrastructure area strategy). There is a need for increased utilisation, accessibility and harmonisation of data in open, quality-assured national and international databases. For example, integration and harmonisation of existing climate and environmental databases, establishment of services for biodiversity data, and better facilitation of social science-related climate and environmental data could support research of benefit to society. Establishment of databases and biological databanks for marine model organisms and key commercial species are vital for maintaining Norway's leading international position in research on and management of marine resources.

Dealing with global climate and environmental problems will require extensive international cooperation on research and research infrastructure. Several joint European infrastructures for research on climate and the environment are identified on the ESFRI Roadmap for Research Infrastructure. Norwegian research groups should actively contribute to developing these in areas where Norway has leading groups and relevant research infrastructure.

Interface with other areas

Infrastructure for climate and environmental research helps to generate knowledge of relevance for a great many areas of society. The observation systems, for example, support research on use of biological resources (sustainable food production) and non-biological resources. Environmental and climate data are relevant within other disciplines such as environment-friendly energy and health research. The volume of data being collected is growing exponentially, and coordination of databases and the use of vast amounts of data from different disciplines and fields can also open up opportunities for breakthroughs in research and establishing new services. Coordinating database systems across research areas will facilitate more efficient utilisation of expertise, standards and systems, but this is also contingent upon adequate investment in e-infrastructure.

Maritime technology

Maritime technology comprises technologies important to the development of all ocean industries, which are the maritime industry, aquaculture, fisheries, offshore oil and gas production, offshore renewable energy and new ocean industries. The area includes innovative use of new markets, technologies and business models by companies that own, operate, build and supply equipment and services to all types of vessels and installations designed for the utilisation of ocean space.



Research objectives

Maritime technology, which is of major importance to all ocean industries, is particularly important for Norway as a country with deep ties to the ocean. It is Norway's objective to remain a leading ocean nation and to ensure that its ocean industries provide the most innovative, sustainable and environment-friendly systems for the future.

Research in the field is designated a priority area in the Government's Long-term plan for research and higher education 2015–2024, and is intended to help increase value creation in the maritime industry and other ocean industries. Increased competitiveness, improved restructuring capacity and better interaction and knowledge transfer between the R&D community and industry are the objectives, all to be achieved within sustainable frameworks. The interplay of theory, experimentation and numerical calculation has been important in maritime research, and is becoming increasingly essential for understanding new linkages and relationships.

To achieve these objectives, research is needed that gives rise to new competence and innovations in the thematic priority areas:

- Opportunities in the ocean industries;
- Autonomous and remote-controlled vessels;
Digital transformation of the maritime industry;
- Promoting greener maritime activities;
- Safety and security at sea;
- The Arctic and northern areas.

The Innovation Programme on Maritime Activities and Offshore Operations (MAROFF) is the Research Council's main instrument for the maritime industry and its research partners, and is to provide support to research and development that helps to increase value creation.

Existing research infrastructure

The experimentation infrastructure at the Marine Technology Centre in Trondheim is of major importance to maritime technology development in all ocean industries. It includes five large laboratories whose operations complement one another to allow development under controlled conditions of all types of vessels, designs, structures and procedures to be used at sea. Simulations with full control over wind, waves and ocean currents provide unique testing conditions for models of floating or fixed objects at sea, whether they are ships, aquaculture installations or oil platforms. The maritime technology laboratories are located at Tyholt in Trondheim. Through the *National Financing Initiative for Research Infrastructure*, the Research Council has contributed funding for the first three phases of an upgrade of these laboratories.

Need for new infrastructure, upgrades and/or coordination

Norway has a number of strong marine and maritime technology research groups. Upgraded and new infrastructure will be important to maintaining a strong international position in this area.

Infrastructure needs in maritime technology development concern laboratories for hydrodynamics, marine construction, strength-testing and machinery as well as increased laboratory flexibility and automation. The national research laboratories at the Marine Technology Centre in Trondheim remain in need of upgrading and maintenance, and were given special emphasis in the Government's Long-term plan for research and higher education 2015–2024.

Norwegian economic restructuring and technological development give rise to the new research objectives mentioned above. An intensified research effort will be required to exploit new opportunities in the ocean industries, autonomous and remote-controlled vessels and other forms of maritime digitalisation. To that end, research infrastructure such as instrumentation and testing facilities for a full-scale marine laboratory will be needed. There are plans to establish a field laboratory for research and development of autonomous vessels, including both underwater and surface vessels. Such infrastructure will play an especially important role in digitalisation and automation research and to make ocean transport and maritime operations fully autonomous. It will also be of major significance to the aquaculture and fisheries industries and for monitoring and providing warnings related to the marine environment. Infrastructure for this purpose will therefore be a key to increased competitiveness in the maritime and other ocean industries and to the sustainable and efficient exploitation of marine resources in future.

Interface with other areas

Maritime technology is of great importance to all the ocean industries, which in addition to the maritime industry include the petroleum industry, fisheries and aquaculture, renewable energy from the sea and other new ocean industries. Maritime technology is also essential to the development of platforms for measuring and observing the marine environment. Such platforms can make ocean monitoring more effective so that costs can be reduced and the scope and coverage area of observations can be increased.

Medicine and health

Medicine and health encompass a wide range of basic, clinical and public medical and odontological subjects in addition to other subjects in the health sciences and health-related psychology. The research contributes to advances in health monitoring, health promotion, disease prevention, diagnostics, treatment and rehabilitation.



Research objectives

Better health and health care services and reduced social inequalities in health are among the primary objectives set out in Meld. St. 18 (2012–2013) Long-term perspectives – knowledge provides opportunity, white paper from the Ministry of Education and Research. In the Government’s Long-term plan for research and higher education 2015–2024, the objectives are set out in more detail in the priority area “Public sector renewal, better and more effective welfare, health and care services”.

Better public health, breakthrough research and national economic and business development are the objectives of the National Research and Innovation Strategy on Health and Care for the 21st Century (2014), also known as the Health&Care21 strategy, and the Government’s Action Plan for implementing that strategy (2016). Main priorities include knowledge mobilisation for municipalities, health and care services as a focus area of industrial policy, better utilisation of health data and a strong commitment to internationalisation of research. The need for easier and more secure access to health data was also highlighted in the report of the Government’s health data committee (2016–2017).

Medical and health sciences research requires advanced research infrastructure and qualified personnel with interdisciplinary skills to help to expand the global knowledge pool and address major societal challenges.

Health and care services are an area of business development policy in which greater interaction between the public and private sectors offers many new opportunities. To promote innovation in preventive health care and patient treatment, investments in existing and new infrastructure must also address health care industry needs.

Existing research infrastructure

The Research Council has contributed to the establishment of a number of national infrastructures that are important for health research and innovation. These include technology platforms related to bioinformatics/systems biology, gene sequencing and nuclear magnetic resonance (NMR) analysis; to imaging technologies, proteomics and structure determination; and to health registries and biobanks.

Norway has unique data in a number of health registries, population-based health surveys with associated biobanks and disease-specific research biobanks. The national infrastructure Biobank Norway and Health Registries for Research will make these resources more accessible for research. Biobank Norway is a national node in the Biobanking and Biomolecular Resources Research Infrastructure (BBMRI-ERIC), which works to increase researcher access to biomolecular resources, health data and biological materials distributed among member states in an effective, secure and ethically and legally sound manner. Services for Sensitive Data (TSD) provides solutions that meet regulatory requirements on processing and storing sensitive research data while also providing researchers with access to analyse the data.

Norway participates in the European Life-Science Infrastructure for Biological Information (ELIXIR), a bioinformatics and systems biology infrastructure which provides analytical tools, computer resources and expertise. Among its collaborators are sequencing infrastructures, such as the National Consortium for Sequencing and Personalised Medicine (NCS-PM), and biobanks.

Advanced imaging technologies and high-resolution microscopes make up the core of the Norwegian Brain Initiative (NORBRAIN), a national infrastructure for research on the brain and disorders of the brain and nervous system. Two national infrastructures – the Norwegian Advanced Light Microscopy Imaging Network (NALMIN) and the Norwegian Molecular Imaging Infrastructure (NORMOLIM) – are dedicated to advanced light microscopy and molecular imaging technologies, respectively. Both aim to become nodes in the ESFRI project Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences (EuBI-ERIC) and together they provide a wide range of imaging technologies that are highly relevant to life sciences research. NOR-OPENSREEN, a national platform for chemical biology with additional relevance to molecular medicine and health research, is the Norwegian node of the ESFRI project European Infrastructure of Open Screening Platforms for Chemical Biology (EU-OPENSREEN-ERIC). Norway also participates as a node in the ESFRI project European Infrastructure for Translational Medicine (EATRIS-ERIC), which provides technology and expertise needed to bridge the gap between basic research and clinical research.

A key national infrastructure for all types of clinical research is the Norwegian Clinical Research Infrastructures Network (NorCRIN), which establishes a framework for and facilitates high-quality clinical studies and seeks to increase the number of Norwegian patients included in trials and industry-initiated clinical studies. NorCRIN is the Norwegian node in the ESFRI project European Clinical Research Infrastructure Network (ECRIN-ERIC). Norway is also involved globally in the Clinical Research Initiative for Global Health (CRIGH). A new infrastructure for clinical studies in the primary health services called the Primary Care Research Network (PCRN) will provide researchers with effective access to patients and data from the primary health services and help to ensure that clinical studies are carried out effectively and within the established time frame. In medical technology, the Norwegian Centre for Minimally Invasive Image Guided Therapy and Medical Technologies (NorMIT) provides a wide assortment of modern operating theatres with advanced medical technology equipment.

Research infrastructures and core facilities have also been developed in other important areas via internal investments on the part of the R&D institutions.

Need for new infrastructure, upgrades and/or coordination

In the years to come there will be a need for new investments and upgrades as well as reinvestment in existing medical and health infrastructures. Cases in point include advanced imaging equipment and enabling technologies (biotechnology, nanotechnology, ICT) for developing future patient treatment programmes.

Given the rapid pace of technological advancement and the rising expectations as to what the health services are to provide, the development of infrastructure for personalised (precision) medicine is becoming increasingly important. The goal is early diagnosis and targeted preventive care and

treatment of disease based on information about hereditary, lifestyle and environmental factors. For Norwegian research to make its mark internationally and contribute to the development of advanced new therapies and personalised medical care, it is essential that Norway invests in infrastructure enabling research on organs, tissues, cells, proteins, genomes and other biomolecules. Infrastructure is also needed for data on the genomes, diffusion characteristics and transmission pathways of pathogenic microorganisms in order to facilitate research on antimicrobial resistance in a One Health perspective.

Research activity that generates large amounts of data often requires computational approaches such as modelling, simulation, and machine learning that enable the data to be exploited further. There is accordingly a great need for powerful ICT tools with high-performance computing capacity.

Norwegian personal data and human biological material are under the stewardship of many different institutions. An integrated system is needed to broaden the overview and improve quality assurance in academic and industrial research as well as to compile, store, make accessible and analyse sensitive personal data more effectively and securely. An integrated research data system must be able to link health data with socioeconomic personal data and personal data from all public health-related sectors, and especially welfare, education and transport. Protection of personal privacy and ethical principles, including the importance of user dialogue, must be built into the system, and all data must be reusable in accordance with the FAIR principles (findable, accessible, interoperable, reusable). The newly created Health Data Programme will help to make valuable Norwegian health data sources, such as health registries and health survey results, more readily available for research. This is important for many research fields in the area of medicine and health, including research on antimicrobial resistance, mental health, oral health and illnesses related to harmful environmental factors.

High quality clinical research is a prerequisite for developing new knowledge and applying it in clinical practice. Clinical infrastructures must be designed so that the needs addressed include those of clinical odontological research. With intensified focus on personalised medicine and access to the best forms of treatment comes greater demand and expectation among patients, families and the health authorities for participation in clinical studies. More expertise and capacity are needed to facilitate early-phase studies in which new knowledge can be put to use. International cooperation and opportunities for interaction between hospitals, research and innovation circles and private industry are of particular importance.

Interface with other areas

There is an increasing need for collaboration between research infrastructures, both within the area of medicine and health and across disciplinary lines. Of particular relevance is coordination with the areas of biotechnology, nanotechnology and advanced materials as well as with e-infrastructures, especially in pursuit of objectives concerning better utilisation of health data in research and personalised medicine. Here, a well-integrated system for handling sensitive data is called for. Linking social sciences data effectively to health data is also necessary. The Research Council encourages expanded cooperation and utilisation of infrastructures in all relevant fields of expertise and technology.

Environment-friendly energy

Research on environment-friendly energy encompasses the areas of renewable energy, energy use, energy systems, carbon capture and storage (CCS) and energy policy.



Research objectives

Research activities in environment-friendly energy are to promote the long-term, sustainable restructuring of the energy system, the central elements of which are increased availability of renewable energy, enhanced energy efficiency and flexibility, and closer integration with Europe. For carbon capture and storage (CCS), key objectives are reducing costs and realising the storage potential in the North Sea. Research efforts are to help to reduce Norwegian and global greenhouse gas emissions, as well as strengthen Norwegian industry and enhance its international competitiveness. The Energi21 strategy document is Norway's national strategy for research, development, demonstration and commercialisation of new climate-friendly energy technology.

High-quality research infrastructure is crucial for the energy sphere. A combination of laboratory work, model development and simulation are needed to ensure reliable, sound results. Laboratory-scale testing is valuable for realising new and improved solutions in order to reduce the risk of errors and deficiencies when industry implements the solutions.

The Research Council's targeted efforts in this area are carried out under the Large-scale Programme for Energy Research (ENERGIX), the Norwegian RD&D CCS Programme (CLIMIT) and the Centres for Environment-friendly Energy Research (FME). The respective work programmes for the ENERGIX and CLIMIT programmes describe objectives and priority areas for research activities. Energy-related research is also funded via other Research Council initiatives/programmes, including the Research Programme on Nanotechnology, Microtechnology and Advanced Materials (NANO2021).

Existing research infrastructure

Environment-friendly energy covers a broad range, and existing infrastructure is extensive. The FME centres help to ensure good coordination and utilisation of research infrastructure and close ties to industry.

Norway is well-equipped with regard to infrastructure for wind power and marine energy production. In addition to general infrastructure, there is a fair amount of specialised equipment such as wind measuring instrumentation (Equipment For Offshore Wind-Energy Infrastructure (EFOWI) and Offshore Boundary Layer Observatory (OBLO)) and a full-scale floating wind turbine (Hywind). This equipment is subject to ongoing development. OBLO, for instance, is being upgraded with WindScanner software to provide enhanced location-specific measurements.

In the area of hydropower, the Norwegian University of Science and Technology (NTNU) has two key facilities, the Vassdragslaboratoriet (hydropower laboratory) and the Waterpower Laboratory. The turbine producer Rainpower has a laboratory in Trondheim for turbine testing and development. Through the FME Centre for Environmental Design of Renewable Energy (CEDREN), good infrastructure for measuring the environmental impacts of wind power and hydropower has been established.

The FME centres for solar energy have facilitated the establishment of effective collaboration and distribution of tasks between research stakeholders in this field. Solar energy infrastructure is satisfactory and the Norwegian Laboratory for Silicon-based Solar Cell Technology (NSST) has proven to be an important addition.

Infrastructure for biofuels and other biorefining has been modernised in recent years through close collaboration between the R&D actors. The infrastructure has been coordinated and upgraded via the Norwegian Biorefinery Laboratory (NorBioLab) and completely new infrastructure has also been developed. NorBioLab produces important research on pre-treatment and upgrading to biogas, bioethanol, biodiesel and other biorefining.

Norway has two national infrastructures in the area of electric power transmission and distribution. In addition, established laboratories at research institutions are important. The new National Smart Grid Laboratory is largely completed. While it is targeted towards distribution and markets, it will also address energy use in buildings. ELPOWERLAB, which was allocated funding in 2016 and is under construction, is being specially designed for testing various electric grid components.

With regard to energy use in buildings, comprehensive infrastructure has been developed in connection with the FME Research Centre on Zero Emission Buildings (ZEB), and this will also play an important role in the new FME Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN) and the SFI centre Klima 2050. The ZEB Flexible Lab is a full-scale commercial building for testing individual components and materials in practice, and is expected to be completed in 2020.

The HighEFFLab is targeted towards energy efficiency in industry and received funding in 2016. Currently under construction, the laboratory will accommodate testing of theories, components and systems on a larger scale before their implementation.

Infrastructure for developing enhanced technology for fuel cells and electrolyzers is being established through the Norwegian Fuel Cell and Hydrogen Centre. This infrastructure supports R&D on technology for producing hydrogen from renewable energy sources and for applications of hydrogen in the transport sector and more.

Research infrastructure for CCS is largely integrated into the ESFRI project European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL), headquartered at NTNU. ECCSEL is a European project that integrates R&D infrastructure from several countries. In addition to ECCSEL, there are a number of large pilot projects, the main ones being the Technology Centre Mongstad (TCM), Aker Solutions' carbon capture test unit, SINTEF's pilot plant for carbon capture, and field laboratories for storage in Svelvik and Longyearbyen.

Need for new infrastructure, upgrades and/or coordination

In the years ahead there will be a need for upgrades and replacement of existing equipment and for entirely new infrastructures.

With regard to hydropower, Norway has infrastructure that is relevant and adequate but parts of it are very old. There is a need for upgrades and new investment in several areas.

The use of solar cells in Norway is expanding and an industry for developing and operating solar parks is emerging. Solar cell use by end-users is addressed under two FME centres: the Research Center for Sustainable Solar Cell Technology (SuSolTech) and ZEN. There is a need to develop

research infrastructure for monitoring solar irradiation and performance, and for testing and development of solar panels.

In the area of bioenergy, technological breakthroughs require updated laboratories, and further investment is needed in both advanced analytical equipment and equipment for biological, biochemical and thermochemical conversion and combustion technology.

Given the rapid development of the energy system, it will be necessary to upgrade and expand the National Smart Grid Laboratory at NTNU, particularly with respect to ICT infrastructure and software for monitoring and management.

There is a need to further expand research infrastructure within the entire field of electrification of the transport sector (batteries, fuel cells, hydrogen and direct electrification). In the area of batteries, there is a need not only for generic research infrastructure but also for specialised equipment for testing and characterisation of commercial batteries and battery systems, and for development of new battery materials and concepts. There are also equipment needs related to materials recycling from scrapped batteries and the development of next-generation battery cells.

For developing next-generation carbon capture technologies, it is important to upgrade existing equipment and develop new infrastructure for carbon capture from industrial sources. The needs for CO₂ storage are related to further development of storage pilot projects and establishing a pilot for CO₂ storage combined with enhanced petroleum recovery. The development of Norwegian CCS infrastructure should be organised through ECCSEL.

Hydrogen production from natural gas, in combination with CCS, will open up new business opportunities for Norway. There is a need for research infrastructure for studying materials for transporting hydrogen. The export of hydrogen from Norway will promote large-scale use of hydrogen in power production and industry. Infrastructure related to this type of hydrogen use will be important.

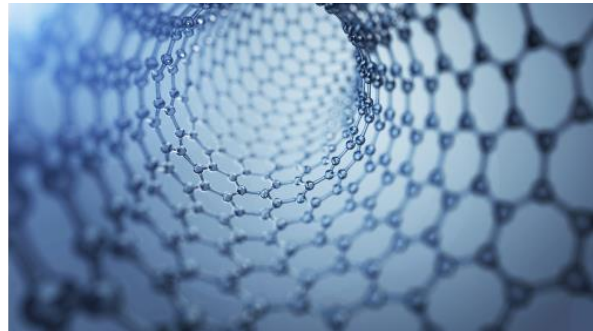
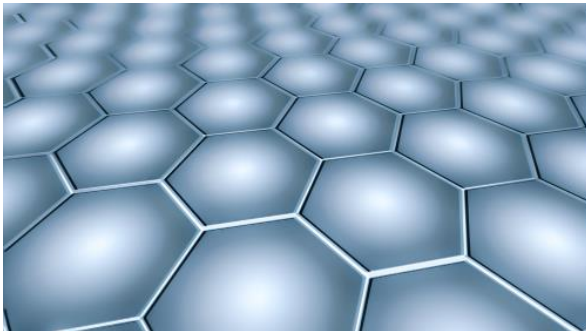
For social science-related research, it will be important to establish open, joint databases and frameworks. Joint data infrastructure will lead to more broad-based scientific approaches and more applicable analyses. Examples include a joint framework for linking models across different modelling traditions and sectors, curation of databases on energy technologies and energy/climate policy measures in different countries, and curation of databases and time-series for the global carbon budget.

Interface with other areas

The field of energy research encompasses a wide array of disciplines and technologies. Equipment in a number of other areas plays an important role in energy research alongside specialised infrastructures. In particular, this includes nanotechnology and materials technology, which are applied throughout much of the field of energy research and are essential in research on solar energy as well as on batteries and fuel cells. Equipment in the area of bioresources is used for bioenergy research, and the equipment for maritime technology (towing tanks and ocean tanks) is of great benefit for marine energy research. Equipment for climate and environmental research is important for scientists studying environmental effects of renewable energy.

Nanotechnology and advanced materials

Nanotechnology encompasses studies of nanoscale phenomena and ways of controlling and manipulating these phenomena. The technology can thus contribute to innovation in most areas of society. The Research Council of Norway's definition of this technology area extends beyond nanoscience and nanotechnology to include microtechnology and advanced materials.



Research objectives

Research activities in nanotechnology, microtechnology and advanced materials are a priority area of the Government's Long-term plan for research and higher education 2015–2024, under the rubric of enabling technologies. The national R&D strategy on nanotechnology stipulates that these activities are to boost Norwegian industrial development and be of benefit to society. Nanotechnology, microtechnology and advanced materials are to enhance competitiveness in thematic areas such as energy, the environment, oceans, food and health without leading to undesirable effects on health, the environment and society.

Research infrastructure is crucial to research in this field. The needs range widely from cleanroom laboratories to variety of advanced equipment for producing, characterising and integrating materials and systems.

The Research Council's targeted effort in this area is the large-scale Programme on Nanotechnology, Microtechnology and Advanced Materials (NANO2021). The NANO2021 work programme sets out the objectives and priority areas for research in this field. Several other programmes also provide funding for research in which these technologies play some role, including energy research in the Large-scale Programme for Energy Research (ENERGIX), broad participation from the business sector in the Programme for User-driven Research-based Innovation (BIA) and basic research in the FRIPRO scheme for independent projects.

Existing research infrastructure

Nationally there are a number of laboratories whose instrumentation and areas of application are to some extent specialised. Some of the laboratories operate in a complementary fashion and provide access to users from both academia and industry.

The Norwegian Micro- and Nanofabrication Facility (NorFab) is a national infrastructure with cleanrooms and instrumentation for nano- and microtechnology processing and characterisation. NorFab has three nodes: the Norwegian University of Science and Technology (NTNU) NanoLab in Trondheim, the microtechnology and nanotechnology laboratories SINTEF MiNaLab/University of Oslo MiNaLab in Oslo and the University College of Southeast Norway's microsystems technology laboratory (MST-Lab) in Horten. These nodes have entered into binding collaboration and cover a wide variety of nanotechnology, microtechnology and advanced materials applications while making

state-of-the-art laboratories accessible to users from universities, university colleges and research institutes, as well as from business and industry.

The University of Bergen has a local cleanroom and laboratory for nanostructuring where instrumentation is in place for a variety of applications, including nanoscale biological systems. At SINTEF there are also laboratories for nano-characterisation, materials characterisation and surface characterisation, including a national platform for surface characterisation (such as X-ray photoelectron spectroscopy and secondary ion mass spectrometry) and nuclear magnetic resonance.

The Norwegian Centre for Transmission Electron Microscopy (NORTEM) is a national centre operated cooperatively by SINTEF, the Norwegian University of Science and Technology and the University of Oslo. It has two nodes (Trondheim and Oslo) with a high-resolution transmission electron microscope (TEM) on each site in addition to other microscopes. The techniques available at each node complement those employed at the other nodes.

The Norwegian Centre for X-ray Diffraction, Scattering and Imaging (RECX) is a national platform located at the University of Oslo and the Norwegian University of Science and Technology. This platform helps elevate Norwegian expertise in advanced radiological techniques and the use of synchrotron and neutron scattering facilities.

Some laboratories which are highly relevant to nanotechnology, microtechnology and advanced materials are also well known for practical applications. One is the Norwegian Laboratory for Silicon-based Solar Cell Technology (NSST), which covers the entire value chain from basic research to final production of solar cells. The FME centres for solar energy have facilitated the establishment of effective collaboration and division of tasks between research stakeholders in this field. A newly established national infrastructure for characterising structures and chemical properties of minerals, metals and advanced nanomaterials – the Norwegian Laboratory for Mineral and Materials Characterisation (MiMaC) – could become very important to the minerals and metals industry in Norway.

Establishing and operating some infrastructures requires international cooperation. Synchrotron and neutron scattering facilities are cases in point. The Norwegian Centre for Neutron Research (NcNeutron) utilises the JEEP II research reactor at the Institute for Energy Technology (IFE) at Kjeller and is a national resource for basic research in physics and neutron radiation. NcNeutron collaborates with the European Spallation Source (ESS), an ESFRI project, and helps build expertise in Norway's neutron research community while improving ESS utilisation. The Swiss-Norwegian Beamlines (SNBL) at the European Synchrotron Radiation Facility (ESRF) in Grenoble is a synchrotron facility for advanced nanotechnology and materials research. Norway's ESRF membership gives it access to the beamline.

Need for new infrastructure, upgrades and/or coordination

There is a need for long-term, continual upgrading and renewal of existing research infrastructure in addition to new investments.

Infrastructure investments are a crucial aspect of enabling Norwegian research groups to participate and succeed in international research cooperation while providing Norwegian industry with the kinds of laboratory facilities it needs. Resource constraints limit the number of large-scale state-of-the-art nanotechnology laboratories in Norway. NorFab and NORTEM are examples of costly infrastructure made possible because key institutions committed themselves to long-term cooperation on start-up activities and operations.

At present, Norway lacks similar commitments for centres capable of addressing the complete value chain from basic production of specific materials to the making of prototypes. Materials groups for which interest has been registered include thin films and piezo materials. Strong scientific groups have also been established in the area of thermoelectric materials, with applications mostly involving

conversion of surplus heat to electricity in the process industry and smelting plants. There are plans to establish an infrastructure – Thermoelectrics Norway (TENOR) – with equipment and laboratories to provide a foundation for new, world-class research activity and to cover the full expanse of a large value chain.

There is also a need for microtechnology and nanotechnology infrastructure focusing on electronic construction methods, including packet technology and systems integration. In recent decades this has become an important field of research in microtechnology and nanotechnology, and the infrastructure is important in supporting industry-oriented development in the field.

The Norwegian Nanocellulose Laboratory will be a relatively small but important upgrade of an existing laboratory specialising in nanocellulose at the RISE-PFI paper and fibre research institute. In recent years there has been a substantial amount of research in the field, which continues today, with many applications of importance to the Norwegian bioeconomy.

National use of, and access to, international infrastructure

The bulk of Norwegian synchrotron users satisfy their synchrotron radiation access needs through the European Synchrotron Radiation Facility (ESRF) and the Swiss-Norwegian Beamlines (SNBL), but some groups and areas of research require access to synchrotron and X-ray free-electron laser (XFEL) facilities which are complementary to and, to some extent, competitive with what is available at the ESRF. Norwegian research groups therefore have interests in the new MAX IV synchrotron facility in Sweden.

Norway is participating in the construction of the world's largest neutron microscope, the European Spallation Source (ESS), in Lund, Sweden. Neutron scattering is a technique that complements synchrotron radiation. The first neutrons are expected to be produced in 2022 and full operation is planned from 2025. The establishment of NcNeutron and updating of JEEP II instrumentation will provide new opportunities for cooperation with the ESS and strengthen the expertise of Norwegian research groups in the use of neutron radiation. For NcNeutron to function as an important national research infrastructure in neutron-based methods and as important instrumentation for use in ESS competency building, access to advanced testing environments for in-situ experiments will be required.

Interface with other areas

Nanotechnology, microtechnology and advanced materials cover a broad spectrum of applications within such fields as environment-friendly energy, climate and the environment, bioresources and life sciences and health. Other infrastructures with a narrower focus – such as battery technology, fuel cells, low-emission buildings and advanced production processes – can therefore play a significant role in this area of technology as well.

Petroleum technology

The status of petroleum research activities, including scientific opportunities and challenges, reflects an objective to manage Norwegian petroleum resources in a sustainable, environment-friendly and safe manner by employing new technologies that make petroleum production more cost- and energy-efficient and reduce greenhouse gas emissions.



Research objectives

The Government's Long-term plan for research and higher education 2015–2024 emphasises investment in petroleum sector research, development and demonstration that will help to increase value creation and ensure safe, cost-effective and sustainable utilisation of petroleum resources. Research activity inside the portfolio for the petroleum area targets knowledge, expertise and technology that can lead to new Norwegian oil and gas discoveries, developments and production. Petroleum production must be carried out in a way that maximises recovery of the petroleum present in each deposit or in several deposits combined. Petroleum research is intended to enhance value creation for society by ensuring that petroleum resources are utilised optimally within an environmentally sound framework and by strengthening the Norwegian supply industry's competitiveness in the global market.

The Oil and Gas for the 21st Century (OG21) strategy organisation is an important policy adviser for the Research Council of Norway's petroleum programmes. The OG21 strategy document highlights four thematic areas: 1) Energy efficiency and environment; 2) Exploration and increased recovery; 3) Drilling, completions and intervention; and 4) Production, processing and transport.

Existing research infrastructure

In 2016 Rystad Energy conducted an analysis for OG21 and the DEMO 2000 programme (DEMO2000) to identify national and international opportunities to demonstrate new technologies relevant to the oil and gas industry in Norway. The results show that there are many test centres, both private and public, but that researchers face unresolved challenges in learning about and gaining access to the facilities, especially the private ones. In the case of subsea technology infrastructure, the report points out that the available test facilities are almost all private. Their availability, moreover, is of course more limited than would be the case for public facilities. Rystad Energy's report highlights the importance of the Ullrigg and Multiphase Lab infrastructures, which receive Research Council support.

OpenLab Drilling (formerly Virtual Arena) is currently under development, and parts of it have been put into service by university and industrial users in Norway and abroad. This infrastructure is based on calculation models for well pressure and drill string forces during drilling operations. At OpenLab, simulations can be done via a web interface, in a physical simulator at the International Research

Institute (IRIS) and at Ullrigg. The creation of OpenLab Drilling is timely with regard to the digital transformation under way.

Norwegian multiphase technology has had an enormous impact on the Norwegian oil industry and hence on Norway's economic development. Funding allocated to the Multiphase Lab (IMF) project has been important to maintaining international competitiveness. The project's main objective is to establish unique new laboratory infrastructures for advanced experimental studies which are relevant to the oil and gas industry and focused on multi-phase pipeline flow and flow assurance.

Infrastructure providing knowledge about the marine environment is important for petroleum activities on the Norwegian continental shelf. The Lofoten-Vesterålen Cabled Observatory will give researchers and other users access to marine data in an important geographical area and provide a sensor platform for new and existing technology. It will play a significant role in the further development of ocean monitoring in Norwegian waters.

A Norwegian Coastal Administration test facility in Horten is one of several that ensure the continued development of oil spill preparedness on the Norwegian continental shelf. Each year in the North Sea, new technology is validated during the Oil on Water exercise.

Need for new infrastructure, upgrades and/or coordination

Future infrastructure needs involve laboratories and data capacity for research as well as pilot and demonstration facilities where new technology can be validated and demonstrated. The following examples of infrastructure needs are drawn from the OG21 strategy and suggestions provided by the research community:

Permanent plugging and abandonment of wells

Although the Norwegian continental shelf is thought to have several decades of production remaining, decommissioning plans are needed. In addition to finding new technological solutions to reduce industry and state expenses, Norway will have an opportunity to develop a new industry that can operate internationally. A more complete infrastructure would accelerate the development of competencies and technology by lowering the threshold for carrying out full-scale experiments.

Digitalisation

Digitalisation is widely needed in the petroleum industry and is expected to bring about major savings for the industry and reduce the impact on nature and the environment. A need has therefore emerged to research and develop technologies that exploit increased volumes of data from many different suppliers. The need is present in technology disciplines throughout the petroleum industry value chain, including data collection, data processing, data quality, data integration, decision-making support and data security for enabling automation, autonomous and ICT technologies.

Improved geological knowledge to lower costs and expand reserves and resources

Among the relevant research infrastructures that improve insight into reservoirs and basins are experimental ones that accommodate advanced laboratory-based imaging techniques, facilities for developing better geophysical exploration methods and infrastructures to exploit digitalisation, machine learning and large amounts of data. These will make it possible to increase the Norwegian continental shelf's reserve and resource base and to provide for more precise exploration. The infrastructures must be tied directly to the development of production systems which are as sustainable and as environment-friendly as possible.

Environment and safety

The environment and safety are areas distinguished by broad-ranging and interdisciplinary research groups. These fields are important for the petroleum sector, and their transfer potential to other sectors is large. A report from Konkraft (2018) showed that actors on the shelf see few conflicts over

sharing of health, safety and environment (HSE) data, so there is great potential to establish standards and protocols for storage, exchange and use of data. Access to research infrastructure dedicated to safety and the environment can help to reduce the risk of major accidents on the Norwegian continental shelf and increase knowledge about important aspects of the environment. Such research requires common national platforms, registries and databases.

Interface with other areas

Norway has long experience in the field of service life extension and materials selection for offshore installations. Service life extension and product design of industrial input factors are very important in a circular economy, where the goal is to optimise sustainable natural resource utilisation by keeping offshore installations and infrastructure in operation as long as possible and facilitating recycling and reuse when service life is over. An investment in laboratories where advanced lifecycle testing can be carried out will be of use in sectors well beyond offshore petroleum, including offshore wind, marine and maritime industries, processing plants, bridges and port facilities.

Hydrogen technology and hydrogen production from natural gas will be part of the energy system of the future. Norway is well positioned to capitalise on this emerging global market due especially to its significant natural gas production and the Government's plans for full-scale CO₂ capture and storage in Norway. There are therefore good opportunities for integration of petroleum technology and environment-friendly energy.

Social sciences and welfare

The social sciences provide knowledge and understanding of areas important to society's development. The knowledge base must be updated to reflect changes in the economy, changes in population structure and demographics, increased digitalisation and the restructuring of working life and business. To ensure good living conditions for everyone in all stages of life, it is important to invest in the infrastructures that sustain research, public administration and policy.



Research objectives

The Government's Long-term plan for research and higher education 2015–2024 highlights public sector renewal and better and more effective welfare, health and care services as key focus areas. Research on welfare, economics, wealth distribution, working life, education and migration, both national and global, are a necessary part of the knowledge used in determining policy and strengthening the welfare society. Such research may help us to better understand societal trends and address national and global challenges with targeted, effective measures. Adequate, secure access to high-quality data that is systematised and curated for research purposes is essential to ensuring that a given research task is feasible and can produce relevant knowledge that breaks new ground. Such data may consist of qualitative and quantitative data collected in research projects or of data gleaned from various registries not necessarily dedicated to research.

In the social sciences several infrastructures facilitate the collection, quality assurance and sharing of different types of data. Major tasks remain, however, in developing those infrastructures and promoting standardisation and reuse of the data stored there. It is also important to establish new infrastructures and exploit opportunities to generate data in new and original ways, such as by creating a framework for using new technology, social media and vast amounts of data.

To strengthen the ability of Norwegian social researchers to take part in international research projects and research collaboration, Norway must join in comparative surveys and research infrastructure initiatives that are part of the ESFRI Roadmap.

Existing research infrastructure

The Norwegian Centre for Research Data (NSD) and Statistics Norway (SSB) are the most important infrastructure institutions for Norwegian social sciences research. The NSD is a coordinating body for data management in Norway that plays an important strategic role in facilitating secure storage and open access to research data generated in Norwegian research activities. The NSD is one of the world's largest research data archives, and stores, manages and curates survey data for research on social science and welfare policy topics. These include large-scale national surveys on living conditions and time use, etc., as well as a number of other Norwegian and international surveys,

such as the European Social Survey (ESS), the International Social Survey Programme (ISSP) and the World Values Survey (WVS).

Statistics Norway is responsible for collecting and coordinating public statistics in Norway, and it cooperates with the NSD. Statistics Norway manages large amounts of personal, institutional and regional data on its own behalf, for the Government and ministries and for other data owners. Data managed by Statistics Norway are of great interest to social scientists. Processed statistics based on the data are an important research infrastructure. Statistics Norway provides such statistics via StatBank Norway. Eurostat, the OECD and UN organisations also have large statistics banks from which researchers can freely extract valuable statistics. The health registries and other databases managed by bodies such as the Norwegian Institute of Public Health (FHI) are also useful for wide-scale research on welfare issues.

Through the National Financing Initiative for Research Infrastructure, the Research Council of Norway has made several infrastructure investments at the NSD and Statistics Norway. The NSD has received funds to upgrade its services related to deposit, curation and accessibility of research data through the Norwegian Open Research Data Infrastructure (NORDi) project. The NSD and Statistics Norway have also received funds for the Remote Access Infrastructure for Register Data (RAIRD) project with an eye to granting Norwegian and international researchers more effective, simpler and better access to sensitive personal data from multiple registries simultaneously.

Researchers enjoy data access across national boundaries through the European Social Survey (ESS) and the Council of European Social Science Data Archives (CESSDA), which are both ESFRI projects. The NSD cooperates closely with CESSDA and is a national ESS partner with funding from the Research Council.

Funding under the National Financing Initiative for Research Infrastructure has also been provided for a number of subject-specific social sciences infrastructures. Examples include:

- the ACCESS Life Course database, which facilitates data from a Norwegian study of life course, ageing and generation (NorLAG);
- the Historical Population Register (HPR), which links historical data about individuals, families and generations;
- E-infrastructure for Video Research (eVIR), which is developing a national video database for secure video data storage;
- the Advanced Conflict Data Catalogue (ACDC), which has developed standards and an integrated data model for studies of regional and international conflicts.

Need for new infrastructure, upgrades and/or coordination

Norwegian welfare data acquired from surveys and registries are in a class of their own. The stored knowledge pertaining to Norwegian welfare, wealth distribution and economic policies is in demand by researchers in other countries. However, society's digital transformation is altering the basis of this research, and new infrastructure is needed to generate data that reflects the digitalised society and exploits the opportunities it provides. In Norway, digitalisation has come exceptionally far, especially as regards the spread of internet access. As a result, there are new digital research opportunities in the social sciences and across disciplines that should be exploited by establishing new infrastructures, such as the capability for internet panels.

An improved body of data is needed in Norway for documenting the causes and ramifications of social inequality in health, education and welfare. Advanced social sciences research often requires detailed access to data, and it is important to ensure both access to and the ability to link together sensitive personal data in national registries.

Access to high-quality interdisciplinary data is essential for social research. There is a need to establish access to industrial data and commercial data, but this may require the use and development of ICT technology for data encryption and anonymisation, among other things.

Maintaining and developing existing infrastructures, including through access to more and larger continually updated data sets, is crucial to the ability of Norwegian social sciences researchers to perform at the forefront of international research and contribute to the global knowledge pool related to important societal challenges. Sharing and reuse of research data, both nationally and internationally, are key factors in the Research Council's investments in, and recommendations for, social science infrastructures.

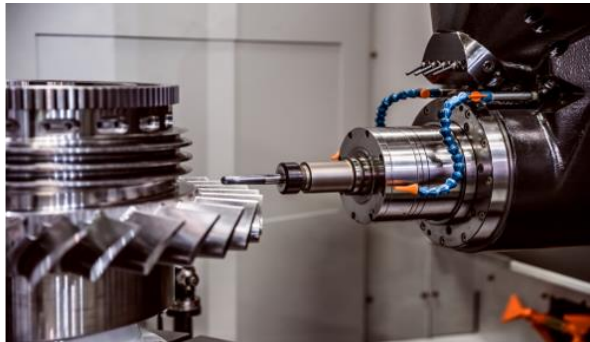
Advanced scientific equipment is needed for some social sciences and welfare research. Research on education and the professions requires laboratories with a focus on professional life, while behavioural research calls for equipment and technology for storage and analysis of multimedia materials.

Interface with other areas

Social research in general and research on welfare, working life and education in particular have points of contact with other research areas, including public health and health services research. Infrastructure support measures in these areas will have benefits for social research. It is important to utilise existing infrastructures that can manage data across subject areas.

Other infrastructure needs in the natural sciences and technology

Most research infrastructure needs in the natural sciences and technology are discussed in the area strategies addressing national priority areas. This area strategy centres on research infrastructures not covered in those thematic area strategies.



Research objectives

In its Long-term plan for research and higher education 2015–2024, the Government states that its overall objectives are to strengthen competitiveness and innovation capacity, seek solutions to major societal challenges (research infrastructure needs for this objective are discussed in several thematic area strategies) and to develop world-class academic environments. Research in the natural sciences and technology plays an important role in achieving these objectives. Basic research is an end in itself but can also be a prelude to innovations that are difficult to foresee. According to Meld. St. 27 (2016–2017) A greener, smarter and more innovative industry, white paper by the Ministry of Trade, Industry and Fisheries, new materials are being used and processes are being changed, automated and digitalised as a step in maintaining an internationally leading Norwegian export industry. To maintain its competitiveness, Norway increasingly will have to compete on the strength of its knowledge. Research, innovation and technological development will be essential.

Existing research infrastructure

Very well-equipped laboratories have been built at universities and research institutes, especially in physics, chemistry, biology and geosciences. The various subject areas require different types of research infrastructure. Common to all is the need to replace equipment periodically with newer and more advanced equipment. The National Financing Initiative for Research Infrastructure has helped to establish a number of national infrastructure collaborations for science and technology research where the research groups enjoy high international acclaim. International collaboration is particularly important for costly, large-scale scientific installations that cannot be financed and operated by one country alone. Norwegian participation gives researchers in Norway access to world-class equipment and data as well as the opportunity to collaborate with leading international researchers.

The European Organisation for Nuclear Research (CERN), where the universe's tiniest components are revealed in high-energy particle collisions, is one of the world's largest and most respected research centres. Norway is a member and participates in multiple experiments. CERN has established a European particle physics strategy which is an integral part of the ESFRI roadmap.

In the field of space research, investments have been made in ground-based instrumentation – at such organisations as the European Incoherent SCATter Scientific Association (EISCAT), the Kjell Henriksen Observatory, the Andøya Space Center and the Svalbard Rocket Range (SvalRak) – that provide support to another ESFRI project, the Svalbard Integrated Arctic Earth Observing System (SIOS). Norwegian research groups are also actively involved in realising the new EISCAT_3D radar system and the Grand Challenge Initiative Cusp. In astronomy, Norway is a member of the Nordic

Optical Telescope Scientific Association and participates in the European Association for Solar Telescopes. Norwegian researchers also have access to observations from the European Space Agency's (ESA's) research satellites.

In addition to laboratory facilities and Earth observation data from satellites, geoscience research requires access to aircraft, vessels and fixed stations as well as internationally coordinated expeditions and observation programmes. As the national contribution to ESFRI's European Plate Observing System (EPOS) project, EPOS Norway has brought together Norwegian research infrastructures to engage in studies of geophysics.

In physics, chemistry, biology and geology, among other subjects, it is important to have good access to synchrotron, electron and neutron sources. Norway is participating in construction of the large new European Spallation Source (ESS) research facility in Lund, Sweden. Powerful neutron beams generated there will be used to study structures inside materials and biological samples. The MAX IV synchrotron source will complement the use of the neutron beams.

Industrial goods production is becoming more and more complex, with increasingly stringent specifications for new materials and composites as well as quality and production processes. Establishing a research infrastructure for industrial goods production will help to strengthen basic research in the field and to create competitive, sustainable industries in Norway.

Need for new infrastructure, upgrades and/or coordination

There is a need to develop new research infrastructure, but there is also a continuous need to upgrade existing research infrastructure with newer and more advanced equipment. Sometimes, an established research infrastructure can continue providing high-quality results if its older equipment is supplemented with devices to create new technology and new opportunities.

More storage and computing capacity is needed if researchers in the natural sciences and technology are to store, organise and exploit collected data as effectively as possible. A sufficient level of e-infrastructure investment is therefore essential. Coordinating database systems across a variety of disciplines and simplifying access to physical collections are also important.

Research infrastructures that help us to generate unique new datasets can make it possible, in conjunction with other unique research platforms, to perform at the cutting edge of science in a range of fields.

Operating research infrastructures in a sustainable manner takes coordination, task-sharing and national collaboration. Small but scientifically strong research groups should coordinate more with adjacent disciplines to make the research infrastructures more relevant and significant in a national context. National infrastructures must work together as an integrated system to fully take advantage of the investments made. As infrastructure components fall into place, they must be linked and made accessible nationally and internationally.

Norwegian companies are engaged in an international technology race. Digitalisation affects the entire value chain, and new products, markets and business models are under development. When advanced technologies from different disciplines are combined, it becomes possible to manufacture products in completely new ways. National infrastructures that can assist industries with this shift are needed for the enabling technologies (biotechnology, nanotechnology, ICT and advanced production processes).

Interface with other areas

The natural sciences and technology area comprises many disciplines and extends across the other area strategies which address national priority areas.

Norway's participation in international research infrastructures

International cooperation gives Norwegian scientists access to research infrastructures and opens opportunities to participate in innovative and costly research that would otherwise be impossible to achieve with national means alone. Membership in international cooperation on infrastructures for research also represents a significant potential for technology transfer and may in the longer term have an impact on business and technology.

Norwegian scientists have participated actively in international research organisations for many decades. Cooperation in these organisations is based on international agreements where member fees for each individual country are determined by a contractual calculation key using the gross domestic product or an equivalent as the main factor. Table 1 shows Norway's membership of international research organisations which are funded by government ministries.

Table 1. Norway's participation in international research organisations funded by government ministries.

Projects	Full name	Status
CERN	European Organization for Nuclear Research	Member since 1954
EMBL/EMBC	European Molecular Biology Laboratory European Molecular Biology Conference	Member since 1985
ESRF	European Synchrotron Radiation Facility	Member since 1989
IARC	International Agency for Research on Cancer	Member since 1987
ESA	European Space Agency	Member since 1987
OECD Halden	Halden Reactor project	Established in 1958

The European Strategy Forum on Research Infrastructures (ESFRI) was formed in 2002 by the research ministers of the EU member countries and associated countries, working together to develop a joint vision and a common strategy for research infrastructures. ESFRI has participants from all 28 member countries and the 11 associated countries to the EU Research and Innovation Framework Programme. ESFRI's mandate is to develop a strategic roadmap (ESFRI Roadmap) reflecting the needs for new or upgraded pan-European research infrastructure in Europe within all scientific disciplines, and follow up the implementation of these infrastructures.

The ESFRI roadmap has encouraged many countries to develop national roadmaps for research infrastructures and to specify more concretely their national priorities for new investments. The

ESFRI Roadmap was first published in 2006 and updated in 2008, 2010 and 2016. Even when Europe was suffering from economic crisis in 2008–2016, research infrastructures were given high priority both nationally and internationally. This is not least due to the fact that European collaboration on research infrastructures is viewed as being of common interest, with a crucial role to play in research to resolve major societal challenges relating to health, climate, the environment, oceans, food and energy. Common projects make it possible to realise infrastructure that is too costly for a single country to manage alone.

A research infrastructure can either be located at a single site or distributed across countries that have complementary nodes within a common infrastructure. An infrastructure located at a single site typically has relatively high investment and operating costs, which is why several countries work together on funding that infrastructure. It is usually the case that membership fees more or less cover the investment and operating costs in full. For the distributed infrastructures, however, the membership fees normally cover only the operating costs for an office or legal entity that organises joint services. A majority of the research infrastructures on the ESFRI Roadmap are distributed.

The legal agreements for establishing and operating CERN, ESRF, EMBL and similar international research infrastructures were highly complex and involved several years of negotiations. The EU Commission, in cooperation with ESFRI, has therefore prepared the ERIC framework to facilitate the establishment and operation of joint research infrastructures across borders.

Norwegian research communities planning to participate in international infrastructures, including membership in infrastructures on the ESFRI Roadmap, must apply for funding under the National Financing Initiative for Research Infrastructure (INFRASTRUKTUR). The applications will be assessed on equal footing with other Norwegian projects of national importance. Participation in international research infrastructures must be seen in the context of investment in research infrastructure located in Norway. This will ensure that only those projects with the highest quality and relevance to Norwegian research priorities will be granted funding. The Research Council of Norway prepares recommendations for Norwegian participation for the relevant sectoral ministries, which take the final decisions on Norway's membership after each application round under the INFRASTRUKTUR initiative.

So far Norway has entered into binding participation in 16 of the pan-European infrastructures, including three with Norway as the host country (CESSDA ERIC, ECCSEL ERIC and SIOS Svalbard AS). After the application review process for the fifth call for proposals under the INFRASTRUKTUR initiative, in 2016, the Research Council awarded funding for and recommended Norwegian membership in two more research infrastructures on the ESFRI Roadmap.

All Norwegian memberships established after 2010 have been for infrastructures on the ESFRI Roadmap. Norwegian scientists and researchers also participate in other international cooperation initiatives on research infrastructure. These are financed either by the research institutions, through research programmes and other instruments in the Research Council, or by other public funding initiatives.

In most countries it is common practice for a national authority, typically a ministry or research council, to have a representative on the governing body of the joint international infrastructure. In most of these cases for Norway, it is the Ministry of Education and Research or another ministry that has signed the membership agreement who fill this role.

Table 2. Norwegian participation in infrastructures on the ESFRI Roadmap. The list comprises research infrastructure as defined in the strategy document Tools for Research. The Research Council contributes funding and/or administers Norway’s membership of these infrastructures, and it is Norway, not a Norwegian R&D institution, that is a member of the respective international infrastructure.

Name	Full name	Status	Project designation
Social sciences and the humanities			
CLARIN ERIC*	Common Language Resources and Technology Infrastructure	ESFRI Roadmap, NL host nation	(1)
ESSurvey ERIC*	European Social Survey	ESFRI Roadmap, UK host nation	(1)
CESSDA ERIC*	Council of European Social Science Data Archives	ESFRI Roadmap, NO host nation	(1)
Natural sciences and technology			
EISCAT_3D	European Next Generation Incoherent Scatter radar European Incoherent Scatter Scientific Association	ESFRI Roadmap, SE host nation. Member in EISCAT since 1975	(1)
Energy			
ECCSEL ERIC*	European Carbon Dioxide Capture and Storage Laboratory Infrastructure	ESFRI Roadmap, NO host nation	(1)
WindScanner	European WindScanner Facility	ESFRI Roadmap, DK host nation	(3)
Climate and the environment			
Euro Argo ERIC*	European contribution to the Argo programme	ESFRI Roadmap, FR host nation	(1)
ICOS ERIC*	Integrated Carbon Observation System	ESFRI Roadmap FI/FR host nations	(1)

Name	Full name	Status	Project designation
ACTRIS	European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases	ESFRI Roadmap, FI coordinator	(3)
EPOS ERIC*	European Plate Observing System	ESFRI Roadmap, IT host nation	(2)
SIOS Svalbard AS	Svalbard Integrated Arctic Earth Observing System	ESFRI Roadmap, NO host nation	(1)
LifeWatch ERIC*	E-infrastructure for Biodiversity and Ecosystem Research	ESFRI Roadmap, ES host nation	(3)
Biology and medicine (Life sciences)			
ELIXIR (EMBL)	European infrastructure for biological information, supporting life science research and its translation to medicine, agriculture, bioindustries and society	ESFRI Roadmap, UK host nation	(1)
BBMRI ERIC*	Biobanking and Biomolecular Resources Research Infrastructure	ESFRI Roadmap, AU host nation	(1)
EATRIS ERIC*	European Advanced Translational Research Infrastructure in Medicine	ESFRI Roadmap, NL host nation	(1)
EU-OPENSREEN ERIC*	European Infrastructure of Open Screening Platforms for Chemical Biology	ESFRI Roadmap, DE host nation	(1)
ECRIN ERIC*	European Clinical Research Infrastructures Network	ESFRI Roadmap, FR host nation	(1)
Euro-BioImaging ERIC*	Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences	ESFRI Roadmap FI/IT/DE host nations	(2)
ISBE	Infrastructure for Systems Biology Europe	ESFRI Roadmap, NL host nation	(3)

Name	Full name	Status	Project designation
EMBRC ERIC*	European Marine Biological Resource Centre	ESFRI Roadmap, FR host nation	(1)
AnaEE	Infrastructure for Analysis and Experimentation on Ecosystems	ESFRI Roadmap, FR host nation	(3)
Analysis			
European Spallation Source ERIC*	European Spallation Source	ESFRI Roadmap SE/DK host nation	(1)
ESRF - EBS	European Synchrotron Radiation Facility - Extremely Brilliant Source	ESFRI Roadmap FR host nation	(1)

* ESFRI project that is or will apply to become a European Research Infrastructure Consortium (ERIC). This is an optional legal framework designed as a regulation in the EU. The framework can be used by member states and associated countries to regulate countries' cooperation in the establishment and operation of pan-European research infrastructures. The ERIC regulation is incorporated into the EEA Agreement and the Norwegian ERIC law was passed in the Storting on 10 November 2015.

(1) ESFRI projects in which Norway has entered into binding agreements. These projects are specifically highlighted in the Norwegian Roadmap for Research Infrastructure.

(2) The Research Council has allocated funds after an ordinary application review process under INFRASTRUKTUR calls and has or will recommend to the Ministry of Education and Research and relevant sectoral ministries that Norway should participate in the ESFRI project. The national infrastructure has been specifically highlighted in the Norwegian Roadmap for Research Infrastructure.

(3) ESFRI projects where Norway has not yet decided whether or not it will take part in establishment activities. Norwegian research groups participate/participated in the preparatory phase, but the Research Council has either not received an application to the INFRASTRUKTUR initiative about Norway's participation or the application assessment provided no basis for that project to be specifically highlighted in the Norwegian Roadmap for Research Infrastructure.

Research Council policy for membership of international RI

The policy sets out principles for the establishment, extension and (potential) withdrawal of membership, the respective roles of the institutions and the Research Council in relation to financing of the membership, and Norwegian representation in the infrastructure's governing body.

The policy is briefly summarised below.

Establishment of membership

Research groups are to apply to the Research Council regarding initiation of a new membership. After assessing the application, the Research Council will advise the relevant ministry on whether Norway should become a member.

It is the ministry (usually the Ministry of Education and Research) that formally applies for Norwegian membership of an international research infrastructure, and which subsequently may withdraw Norway from the cooperation.

Membership fees for distributed research infrastructures

The Research Council considers membership fees to be part of a node's operating costs.

The Research Council's recommendation to relevant ministries regarding membership is given for a time-limited period, usually five years.

Membership fees for single-site research infrastructures

Norwegian research institutions are to apply to the INFRASTRUKTUR initiative for funding for Norwegian membership of a single-site infrastructure. Any funding pledge from the INFRASTRUKTUR initiative is given for a time-limited period, usually five years. For extension of the membership, institutions must submit a new application to the INFRASTRUKTUR initiative.

Norwegian representation in governing bodies

To ensure that memberships are adequately supported in Norwegian research institutions, the institutions should be involved in the management of the Norwegian memberships.

Where Norway has decided on – or the Research Council has recommended – membership in ESFRI projects still in the planning and implementation phase, the Research Council will as a rule have a role in the project's governing body. The Council may, however, in consultation with the Ministry of Education and Research or other relevant ministry, choose to appoint a resource person from a Norwegian research institution to take the Council's place in the governing body.

In ESFRI projects that have entered a well-functioning operational phase, the Research Council, in consultation with the Ministry of Education and Research or other relevant ministry, will consider replacing its own representation in the governing body with a resource person from one of the participating Norwegian research institutions.

Roadmap projects

The table below give an overview of the projects highlighted in the Norwegian Roadmap for Research Infrastructure 2018. The projects are divided according to which area strategy they have the greatest affinity. Relevance for other areas is indicated in its own column.

Projects	Status	Also relevant for the following areas
Bioresources		
ATC - National Aquafeed Technology Centre	Under establishment/in operation	
EMBRC – The Norwegian Node of the European Marine Biological Resource Centre	ESFRI-project in implementation phase	Climate and environment
NorBioLab - Norwegian Biorefinery Laboratory	Under establishment/in operation	Environment-friendly energy
PLANKTONLAB - Norwegian Center for Plankton Technology	Under establishment/in operation	
NBioC - Norwegian BioCentre - Norwegian Centre for Bioprocessing & Fermentation	Under establishment/in operation	Biotechnology
Biotechnology		
ELIXIR.NO - A Norwegian ELIXIR Node	ESFRI-infrastructure in operation	Several area incl. Medicine and Health and Bioresources
NALMIN - Norwegian Advanced Light Microscopy Imaging Network	ESFRI-project in implementation phase	Medicine and Health
NAPI - Network of Advanced Proteomics Infrastructure	Worthy of funding	Medicine and Health Bioresources
NCS-PM - National Consortium for Sequencing and Personalized Medicine	Under establishment/in operation	Medicine and Health Bioresources
NNP - The Norwegian NMR Platform	Under establishment/in operation	Several area incl. Medicine and Health and Bioresources
NOR-OPENSREEN - The Norwegian EU-OPENSREEN node	ESFRI-project in implementation phase	Medicine and Health Bioresources
NORCRYST - Norwegian Macromolecular Crystallography Consortium	Under establishment/in operation	Bioresources

e-infrastructure		
E-INFRA ved UNINETT Sigma 2 - a national e-Infrastructure for science	Under establishment/in operation	All areas
Humanities		
ADED - Archaeological Digital Excavation Documentation	Under establishment/in operation	
CLARINO - Common Language Resources and Technology Infrastructure	ESFRI-infrastructure in operation	
LIA - Language Infrastructure made Accessible	Under establishment/in operation	
ICT		
eX3 - Experimental Infrastructure for Exploration of Exascale Computing	Under establishment/in operation	e-infrastructure
Climate and Environment		
Arctic ABC - Arctic Ocean ecosystems	Under establishment/in operation	
COAT - Climate-Ecological Observatory for Arctic Tundra	Under establishment/in operation	
EMBRC Norway - The Norwegian Node of the European Marine Biological Resource Centre	ESFRI-project in implementation phase	Bioresources
ICOS - Norway Integrated Carbon Observation System	ESFRI-infrastructure in operation	
INES - Infrastructure for Norwegian Earth System modelling	Under establishment/in operation	
LoVe - Lofoten-Vesterålen cabled observatory	Under establishment/in operation	Bioresources Petroleum Technology
NMDC - Norwegian Marine Data Centre	Under establishment/in operation	Bioresources

NorArgo - A Norwegian Argo Infrastructure- a part of the European and global Argo Infrastructure	ESFRI-infrastructure in operation	
NorBOL - Norwegian Barcode of Life Network	Under establishment/in operation	Bioresources
NorDataNet - Norwegian Scientific Data Network	Under establishment/in operation	
NORMAR - Norwegian Marine Robotics Facility	Under establishment/in operation	Several area incl. Bioresources
NorSOOP - Norwegian Ships Of Opportunity Program for marine and atmospheric research	Under establishment/in operation	
SIOS - Svalbard Integrated Arctic Earth Observing System	ESFRI-project in implementation phase	
Maritime technology		
MARINTEK - The Marine Technology Laboratories- Required Upgrading and Developments	Under establishment/in operation	
Ocean Space Field Laboratory Trondheimsfjorden	Worthy of funding	Bioresources Climate and Environment
Medicine and Health		
Biobank Norway - A national infrastructure for biobanks and biobank related activity in Norway	ESFRI-infrastructure in operation	Biotechnology
EATRIS - A Norwegian node for the European Advanced Translational Research Infrastructure in Medicine	ESFRI-infrastructure in operation	Biotechnology
HELSEREGISTRE - Health Registries for Research	Under establishment/in operation	Social sciences and welfare
NORBRAIN - Norwegian brain initiative: a large-scale infrastructure for 21st century neuroscience	Under establishment/in operation	Biotechnology
NorCRIN - Norwegian Clinical Research Infrastructure Network	ESFRI-infrastructure in operation	

NorMIT - Norwegian centre for minimally invasive image guided therapy and medical technologies	Under establishment/in operation	
NORMOLIM - Norwegian Molecular Imaging Infrastructure	ESFRI-project in implementation phase	Biotechnology
PCRN - The Norwegian Primary Care Research Network	Under establishment/in operation	
Environment-friendly energy		
ECCSEL ERIC - European Carbon Dioxide Capture and Storage Laboratory Infrastructure	ESFRI-project in implementation phase	Climate and Environment
ELPOWERLAB - Future distribution and transmission electrical grid components lab	Under establishment/in operation	
HighEFFLab - National Laboratories for an Energy Efficient Industry	Under establishment/in operation	
NABLA - Norwegian Advanced Battery Laboratory Infrastructure	Worthy of funding	Nanotechnology and advanced materials
Norwegian Fuel Cell and Hydrogen Centre	Under establishment/in operation	
NSST - Norwegian laboratory for silicon-based solar cell technology	Under establishment/in operation	Nanotechnology and advanced materials
OBLO - NOWERI Norwegian Offshore Wind Energy Research Infrastructure	Under establishment/in operation	
SmartGrid - National Smart Grid Laboratory & Demonstration Platform	Under establishment/in operation	
ZEB Lab - Norwegian Zero Emission Building Laboratory	Under establishment/in operation	
Nanotechnology and advanced materials		
ESRF Upgrade - European Synchrotron Radiation Facility	ESFRI-infrastructure in operation	Biotechnology
ESS-Lund - European Spallation Source	ESFRI-project in implementation phase	Biotechnology

MiMaC - Norwegian Laboratory for Mineral and Materials Characterisation	Under establishment/in operation	
NcNeutron - Norwegian Center for Neutron Research	Under establishment/in operation	
NORCELLab - The Norwegian Nanocellulose Laboratory	Worthy of funding	Bioresources
NorFab - Norwegian Micro- and Nanofabrication Facilities	Under establishment/in operation	
NORTEM - The Norwegian Centre for Transmission Electron Microscopy	Under establishment/in operation	
NSST - Norwegian laboratory for silicon-based solar cell technology	Under establishment/in operation	Environment-friendly energy
TENOR - Thermoelectric Norway	Worthy of funding	
Petroleum Technology		
Multiphase Lab (IMF) - National Research Infrastructure for Multiphase Flow	Under establishment/in operation	
OpenLab Drilling	Under establishment/in operation	
Remote Gas Research Laboratory	Worthy of funding	
ULLRIGG - Upgrade of Ullrigg	Under establishment/in operation	
Social sciences and welfare		
ACCESS - Life Course Database: Upgrade and Expansion	Under establishment/in operation	
CESSDA ERIC - Council of European Social Science Data Archives	ESFRI-infrastructure in operation	
ESS-Survey - Norwegian Membership and Participation in the European Social Survey	ESFRI-infrastructure in operation	
eVIR - einfrastructure for Video Research	Under establishment/in operation	

HISTREG - National Historical Population Register for Norway 1800-2020 (HPR)	Under establishment/in operation	Humanities
NORDi - Norwegian Open Research Data Infrastructure	Under establishment/in operation	Humanities
RAIRD - Remote Access Infrastructure for Register Data	Under establishment/in operation	
PSI - Peace Science Infrastructure	Worthy of funding	
Other infrastructure need in the natural sciences and technology		
EISCAT_3D - European Next Generation Incoherent Scatter radar	ESFRI-project in implementation phase	
Enabling LHC Physics at Extreme Collision Rates	ESFRI-infrastructure in operation	
EPOS - European Plate Observing System - Norway	ESFRI-project in implementation phase	
ESRF Upgrade - European Synchrotron Radiation Facility	ESFRI-infrastructure in operation	Nanotechnology and advanced materials Biotechnology
ESS-Lund - European Spallation Source	ESFRI-project in implementation phase	Nanotechnology and advanced materials Biotechnology
ManuLab - Norwegian Manufacturing Research Laboratory	Under establishment/in operation	Nanotechnology and advanced materials
NATIONAL GEOTEST SITES	Under establishment/in operation	

Descriptions of the roadmap projects can be found at the Research Council's website <https://www.forskingsradet.no/prosjektbanken/>



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