https://www.forskningsradet.no/en/financing/what/infrastructure/veikart-for-forskningsinfrastruktur/guidelines/international-cooperation-on-research-infrastructures/?download=true

Norwegian Roadmap for Research Infrastructure 2023

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About the roadmap in 2023

Background

The Ministry of Education and Research has given the Research Council of Norway responsibility for preparing a Norwegian roadmap for investments in research infrastructure. The roadmap for national research infrastructure is updated prior to each call under the INFRASTRUKTUR scheme and is intended to highlight the need for future research infrastructures and infrastructures that have received Research Council funding. Norwegian researchers cooperate extensively with international actors and participate in several European research infrastructures. The roadmap therefore highlights both national infrastructures and international research infrastructures with Norwegian participation.

Function of the roadmap

The roadmap should:

- communicate the Research Council's strategic basis for decision-making in connection with upcoming allocations of funding from the National Financing Initiative for Research Infrastructure (INFRASTRUKTUR)
- highlight nationally important research infrastructures that are crucial for achieving research policy objectives
- clarify Norwegian participation in international research infrastructures and demonstrate the balance and relationship between such participation and national investments
- advise applicants, as well as public and private funders of research infrastructure, to compare future needs with the opportunities that already established infrastructures provide

The structure of the roadmap

The roadmap has three main parts:

Part 1: Research Council funding of research infrastructure – guidelines and recommendations.

This part covers what was previously the Research Council's strategy for research infrastructure, "Verktøy for forskning – Nasjonal strategi for forskningsinfrastruktur 2018-2025". This section presents the guidelines for how the Research Council finances research infrastructure and makes recommendations to the ministries and R&D institutions. This is largely a continuation of previously defined priorities and principles for division of responsibilities between the different stakeholders and allocations from the Research Council. The changes are mainly that we have added details about EOSC (European Open Science Cloud), EuroHPC and consequences given the geopolitical situation.

Part 2: Strategic basis

This section describes the strategic basis for the Research Council's thinking and priorities regarding research infrastructure for various disciplines, thematic areas and technology areas. This section corresponds to the area strategies in the previous roadmaps. The Research Council's investments in research infrastructure are to support research that contributes to realising the objectives described in the Research Council's main strategy and portfolio plans, as well as knowledge development within the priority areas in the Government's long-term plan for research and higher education.

Part 3: Description of research infrastructures under establishment or operation

This section presents most of the research infrastructures that have received funding from the National Financing Initiative for Research Infrastructure, as well as some international infrastructures that receive funding through a political decision outside the open competitive arena. These constitute the current landscape of national research infrastructures funded through INFRASTRUKTUR.

The process for a new roadmap 2023

The institutions that receive infrastructure funding from the Research Council assume a significant responsibility for operating and making available national research infrastructures. It is therefore important for the Research Council to involve the institutions in our thinking about national and international research infrastructure.

An external committee has contributed to the preparation of part 2 of the roadmap. As a follow-up to recommendations from the evaluation of the infrastructure initiative, the committee was asked to describe the national and international infrastructure landscape and needs seen from a national point of view in a 15-year perspective. However, given the major changes we have experienced recently, partly as a result of the geopolitical situation, the Committee concluded that it is more important that the roadmap will be frequently updated to ensure flexibility and the possibility of necessary adjustments at shorter intervals. The geopolitical situation also affects research priorities, and we will therefore continue to update the roadmap ahead of each call to help identify new needs that may arise.

In June 2022, all research organisations that have used the National Financing Initiative for Research Infrastructure (INFRASTRUKTUR) were invited to submit written input to the new roadmap. In November 2022, we arranged seven thematic workshops with invited participants from research institutions, the public sector, the business sector and the Research Council's departments and portfolio boards. Summaries from the workshops and written input have been an important part of the knowledge base for the external committee. Part 2 of the roadmap is based on the Committee's draft, but has been revised somewhat by the Research Council to clarify that the infrastructure initiative will support priorities and objectives in the Research Council's portfolio plans and the Government's Long-term Plan for Research and Higher Education.

Handling input

We are very grateful for all the input we have received. We have tried to consider most of the input that relates to the needs for research infrastructures in the future, although in some areas we provide a somewhat more general presentation of the needs than the input does. This applies, for example, to concrete proposals for specific new infrastructures in which investments should be made. We wish to receive input on specific new infrastructure investments in the form of applications.

Input concerning the design of the infrastructure scheme (e.g. timing of announcements, distribution of roles and responsibilities) has not been significantly taken into account in this roadmap. Such input will be useful for further work on the development of INFRASTRUKTUR, but this round of input concerned area descriptions and infrastructure needs within the various areas as a basis for the preparation of part 2 of the roadmap.

Several suggestions and inputs concern needs that are not funded through INFRASTRUKTUR. This applies, for example, to pilot facilities and test facilities for industry, collection of data through population surveys, as well as long-term support for operations. We recognise the needs, but this scheme does not fund data collection and the state aid rules place restrictions on public financing of infrastructures that are mainly to be used for economic activities. We can support infrastructure/tools for the implementation of data collection/data generation and for further handling of the data collected/generated. We will encourage the infrastructures to collaborate with relevant actors from the business sector and provide guidance to exploit the opportunities provided for by the state aid rules. Regarding long-term support for operations, the Research Council's policy is still that INFRASTRUKTUR only in special cases provides long-term support for operations (see a more detailed description of the section on division of responsibilities in part 1).

Note: this document has been machine translated from Norwegian, which is the official version of the roadmap.

Part 1: Research Council funding of research infrastructure – guidelines and recommendations

Goal

The Research Council of Norway's funding of research infrastructure (INFRASTRUKTUR) forms the basis for the following main objectives:

- The Research Council will focus its efforts on achieving relevant, updated and broadly available research infrastructure

Background

Over the past 10-15 years, there have been major changes in the funding of national research infrastructure. The Government's long-term plan for research and higher education for the period 2015–2024 made it clear that the best researchers and students should have access to world-class research infrastructure, and that funding of infrastructure should be strengthened based on strategic assessments and priorities. Since then, the Government has followed up an ambitious and predictable escalation plan with an increase in the annual allocations to research infrastructure, so that the National Financing Initiative for Research Infrastructure now (2023) has an annual budget of approximately NOK 800 million. The need for and importance of access to research infrastructure are also highlighted in the new long-term plan for 2023–2032.

The National Financing Initiative for Research Infrastructure was established in 2009 as part of the follow-up of the white paper Klima for forskning ("Climate for Research") and the Research Council of Norway's strategy "Verktøy for forskning – Nasjonal strategi for forskningsinfrastruktur". The National Financing Initiative for Research Infrastructure is funded by the Ministry of Education and Research and is intended to contribute to a well-functioning research system that delivers high-quality research, develops knowledge to meet key challenges in society and the business sector, contributes to dynamics and interaction nationally and internationally, and facilitates learning, application and innovation. In addition, funding of high-quality research infrastructure must support increased internationalisation and recruitment.

The National Financing Initiative for Research Infrastructure is intended to give Norwegian research access to infrastructures that are necessary at any given time to:

- conduct research of high international quality
- achieve a high degree of institutional cooperation and division of labour at the national level
- increase international cooperation

- achieve access to the use and reuse of FAIR research data

The international FAIR principles for good facilitation and accessibility of research data

The international FAIR principles have been developed as a set of guidelines to facilitate increased data value and further use of research data. FAIR is an acronym for the words *findable, accessible, interoperable and reusable*. In other words, research data must be of a quality that makes them accessible, retrievable and reusable. Furthermore, data and metadata should be machine-manageable, and consistent vocabulary should be used.

Source: Wilkinson, Mark D. et al. (2016) "The FAIR Guiding Principles for scientific data management and stewardship". Scientific Data.3

See also: https://www.force11.org/group/fairgroup/fairprinciples

Knowledge needs

Research contributes to the development of knowledge to meet key challenges in society and business6. With access to good, up-to-date tools, research groups can meet societal needs for increased sustainability and more innovation and restructuring through high-quality research and efficiency. Updated infrastructure facilitates that researchers from different disciplines utilise the infrastructure and collaborate in interdisciplinary projects. Business competitiveness is increasingly built on expertise and technology developed in close cooperation with internationally leading academic environments with access to modern research facilities. The development of public sector services in Norway also requires high-level research.

Attractiveness and efficiency

The right tools are needed to ensure targeted and effective work. This is also the case in research. Modern and up-to-date research infrastructure contributes to high quality in Norwegian research and facilitates collaboration with the best international research groups, while at the same time inspiring good students to pursue a research career. Up-to-date research infrastructure, combined with good researchers, is also important for the effective implementation of innovation projects in industry and public administration, and may encourage Norwegian and foreign companies to choose to organise their research activities in Norway.

International cooperation on research infrastructures

Participation in international research organisations gives Norwegian researchers access to research infrastructures and the opportunity to participate in innovative and resource-intensive research that would be impossible to achieve with national funding alone. This may be important in order to safeguard and further develop national expertise in subject and technology areas where it is not obvious that Norway should have a leading role with regard to the establishment of research infrastructure. Participation also provides considerable potential for technology transfer and development of Norwegian industry. National research infrastructures also help to make Norwegian research groups attractive partners for international projects (e.g. increased opportunities under Horizon Europe) and for Norwegian and international companies. At the same time, a cost-benefit assessment must be made of membership in major new international research infrastructures and of the need to maintain existing membership.

More information about the international research infrastructures Norway participate is provided in part 3 of the roadmap.

ESFRI's roadmap and Norwegian participation

The European Strategy Forum on Research Infrastructures (ESFRI) was established in 2002 by the research ministers of the EU as an advisory forum for research infrastructure. ESFRI has participants from all member states and from associated countries to the EU Framework Programme for Research and works for pan-European policy development and cooperation on investments and operation of research infrastructures. ESFRI develops a strategic roadmap on Europe's need for new or upgraded research infrastructure in most research areas. ESFRI also prepares landscape analyses in its roadmaps describing the national and international research infrastructures that are established and open to European researchers and industry actors. This thus constitutes an important knowledge base for where there are good opportunities for Norwegian research groups to initiate international cooperation related to existing or future research infrastructures. ESFRI published its latest roadmap in September 2021.

Localized or distributed research infrastructure.

Research infrastructure can either be located in one location or distributed – which means that different countries have complementary sub-infrastructures (called nodes) in a common infrastructure. In the first case, the infrastructure's investment and operating costs are usually relatively high – which is why several countries join forces to finance the infrastructure. Distributed research infrastructure, as defined by ESFRI, is organised as a separate legal entity owned and controlled by the participating countries jointly and with nodes in national ownership. The nodes undertake to make parts of their capacity available to users in the other participating countries. It is important that the national nodes establish a long-term business model that covers operating costs. As a rule, investment and operating costs for the common legal entity will be covered by a membership fee from the participating countries. The vast majority of research infrastructures on the ESFRI Roadmap are distributed.

Principles for Norwegian ESFRI membership

The Ministry of Education and Research has asked the Research Council of Norway to follow up the Norwegian participation in ESFRI. This includes preparing a basis for decision-making and submitting recommendations on Norwegian membership of relevant infrastructures on ESFRI's roadmap. In cooperation with the Ministry of Education and Research, the Research Council has also established principles for the establishment, continuation and eventual termination of membership, how the institutions and the Research Council should relate to membership funding, and to Norwegian representation in the governing bodies of the infrastructures (see fact box). The Research Council's recommendations are drawn up on the basis of the assessment of applications for INFRASTRUKTUR. This means that Norwegian research groups planning to participate in international cooperation on research infrastructure, including membership of the infrastructures in ESFRI's roadmap, must, as a general rule, apply for INFRASTRUKTUR on an equal footing with other Norwegian projects of national importance. This is to ensure that the projects of the highest quality and relevance to Norwegian research are awarded funding. The Research Council prepares its recommendations on Norwegian participation to relevant sectoral ministries that make the final decision on Norway's membership after each application review process in INFRASTRUKTUR.

It is common practice in most countries for a national authority, usually a ministry or research council, to have a representative in the governing body for the international infrastructure. In most of the international infrastructures in which Norway participate, it is the Ministry of Education and Research (KD) or another ministry that has signed the membership agreement.

Norwegian participation in international research infrastructure

Establishment of membership

- It is normally a ministry that formally applies for Norway to become a member of an international research infrastructure and can later withdraw Norway from the collaboration.
- Research groups must apply to the Research Council for new membership. The application will be included in the ordinary application review process in the same way as other applications to the National Financing Initiative for Research Infrastructure. This will ensure that projects of the highest quality and national relevance are awarded. The Research Council will assess the long-term financial obligations that membership entails and whether the membership will constitute added value for Norwegian research, which means that the grant application should be given priority over other national or international grant applications.
- After assessing the grant application, the Research Council will advise the relevant ministry on whether Norway should become a member.

Membership fees

- For localised infrastructures, operating costs will usually be financed through an annual membership fee. The National Financing Initiative for Research Infrastructure could help finance such membership fees. Any commitment is only given for a period of time, usually five years. Any continued funding must be based on regular applications to the National Financing Initiative for Research Infrastructure or evaluations.
- For distributed research infrastructures where one or more Norwegian nodes exist, the Research Council considers membership fees to be part of the national node(s)'s operating costs.
- The National Financing Initiative for Research Infrastructure funds membership fees in the EOSC Association for Norwegian Institutions and is based on annual applications to the Research Council.

Norwegian representation in governing bodies in projects on the ESFRI Roadmap

- In order to anchor membership in Norwegian research institutions, the institutions should be involved in the management of Norwegian memberships.
- In ESFRI projects in the planning and implementation phase where Norway have decided to become a member or recommended by the Research Council, the Research Council must, as a rule, participate in the governing body. However, the Research Council may, after consultation with the relevant ministries, choose to appoint a resource person from a Norwegian research institution to take the Research Council's place in the governing body.
- In ESFRI projects that have entered a well-functioning operational phase, the Research Council will, in consultation with the relevant ministries, consider replacing its own representation on the governing body with a resource person from one of the participating Norwegian research institutions.

Read more about which infrastructures on the ESFRI roadmap Norway participate in under part 3 of the roadmap.

European Open Science Cloud and Norwegian participation

The European Open Science Cloud (EOSC) is an ambitious initiative for open science, launched by the European Commission. The vision for EOSC is a common digital framework to give researchers in Europe access to an integrated and secure data infrastructure and seamless services to manage, analyse, share, collaborate and reuse research data, across disciplines and borders. This will help to promote open research in practice.

To achieve this vision, it is necessary to ensure that the EOSC is useful and relevant to researchers, adapted to their needs and challenges. It is therefore important that these are represented in the organisation and involved in the implementation of the EOSC. Members of the EOSC-Association (EOSC-A) consist of organisations and the growing membership base includes European research performing and research funding organisations as well as research infrastructures and service providers. ESFRI infrastructures have had and continue to play a particularly important role in the implementation of the EOSC, and cooperation with ESFRI is ensured at several levels of the organisation. The Research Council is a member of EOSC-A and is a mandated organisation, given by the Ministry of Education and Research, as a representative of the interests of the Norwegian research system. EOSC-A also has several Norwegian research institutions as members, and their participation helps them to take an active role in the development of the EOSC and promotes cooperation with other research institutions across national borders. This collaboration is of great importance to ensure that the EOSC is relevant and adapted to the needs of researchers in different countries and within different disciplines.

EuroHPC Joint Undertaking and Norwegian Participation

Norway is a member of the EuroHPC Joint Undertaking (hereinafter EuroHPC JU) since 2019, whose purpose is to develop, acquire, operate and make available European high-performance computing technology and infrastructure for research and innovation across sectors and national borders. The membership gives Norwegian actors the opportunity

to apply for funding through the calls administered by EuroHPC JU. A prerequisite for Norwegian actors being awarded funding under these calls is that Norway is associated with the EU framework programmes that provide funding for the various EuroHPC JU calls. EuroHPC JU manages funds from Horizon Europe, Digital Europe and the Connecting Europe Facility-2. Norway is associated only with the first two framework programmes.

The Research Council represents Norway in the steering group of EuroHPC JU, with one delegate. In addition, a number of Norwegian experts from relevant actors in Norway with expert advice are used when deciding matters of particular interest.

Division of responsibilities in connection with decisions on the establishment of research infrastructure

The white paper "Klima for forskning" ("Climate for research"4) defined a division of responsibilities between the R&D institutions, the Research Council and the ministries with regard to decisions on the establishment of research infrastructure.

R&D institutions

Basic infrastructure at the R&D institutions includes scientific equipment required to ensure academic activities at an acceptable level. Investment in and establishment of such infrastructure should be made by the institutions themselves and financed through the institutions' basic allocations. The R&D institutions are considered to be in the best position to assess the need for this type of equipment and to ensure simple and good allocation procedures.

The Research Council will contribute to the institutions' own investments by ensuring that all allocations to R&D projects from the Research Council that involve the use of "procured" infrastructure can cover a proportionate share of the depreciation of these infrastructures. In addition, the awards can cover operating costs for the project's use of infrastructure. "Project-specific equipment" may also be funded through the Research Council's grants. This is equipment that is necessary for the implementation of the research project, but does not have use beyond the current project.

The Research Council of Norway

The Research Council is to make decisions on investments in infrastructure of national importance (see text box below). Allocations from the Research Council's budget are intended to support the development of nationally prioritised research areas and nationally important industries with a major need for research infrastructure. The division of responsibility entails that the Research Council must help to ensure that the institutions coordinate when several research groups need research infrastructure, but the costs are so high that collaboration is most appropriate. The Research Council assesses infrastructure applications from NOK 2 million and upwards, and may contribute up to NOK 200 million to individual projects.

The establishment of research infrastructure that requires external funding in excess of NOK 200 million is decided at ministerial or government level. However, as part of the process of assessing other grant applications, the Research Council may assess applications for amounts larger than NOK 200 million and submit recommendations to the relevant ministries. Institutions or consortia wishing to establish research infrastructures that entail such high investments are therefore encouraged to contact the Research Council so that any grant applications can be submitted and assessed together with other applications. Any positive recommendation from the Research Council will be based on a very positive assessment of the infrastructure in accordance with the Research Council's criteria. In exceptional cases, following dialogue with the Ministry of Education and Research, the Research Council will be able to support a design phase.

Since the primary purpose of the National Financing Initiative for Research Infrastructure is to renew Norwegian research infrastructure, the Research Council is restrictive in allowing this scheme to contribute to financing the operation of research infrastructure. Instead, and as far as possible, expenses for the operation of research infrastructure must be covered by projects that use the infrastructure. The Research Council therefore requires applicants for funding for the establishment of research infrastructure to also submit plans for how sustainable operation of the infrastructures can be achieved. User payments from R&D projects that use the infrastructure shall preferably be an important part of operational funding. Expenses for the use of research infrastructure are therefore legitimate costs in any application for research funding from the Research Council's various programmes and funding schemes.

In exceptional cases, however, consideration may be given to whether operating costs for new or existing infrastructure of national importance should be supported through the National Financing Initiative for Research Infrastructure. Infrastructures with very high operating costs that there are good reasons why ongoing projects, host institutions or other funders are not fully able to cover may, after a special assessment, receive long-term support for operations. Similar exceptions may be made under other circumstances where funding from the user projects or the infrastructures' owner institution(s) is clearly inappropriate.

Data management infrastructure

Through the National Financing Initiative for Research Infrastructure, the Research Council will contribute to making research data available in secure systems and in such a form that they can form the basis for research cooperation both nationally and internationally, as well as ensure Norwegian participation in international computer networks. In this context, *research data* means "registrations/records/reports in the form of numbers, texts, images and sounds that are generated or arise during research projects.

Funding from the National Financing Initiative for Research Infrastructure may be sought for infrastructure that promotes the management and accessibility of research data, more specifically for the acquisition and establishment of equipment and tools for collecting data for research, technical systems for quality assurance and preparation of data, and technical systems for archiving and making data available for research.

It is not possible to apply for funding for the implementation of data generation/data collection under the National Financing Initiative for Research Infrastructure, as this is financed through the Research Council's research projects and the R&D institutions' own financed activities (and for some datasets of the ministries and their subordinate administrative bodies).

Research infrastructure of national importance:

- **The infrastructure should have a broad, national interest**
  It shall be of great interest to Norway as a nation to establish the infrastructure. The Research Council will take national priorities into account.
- **As a general rule, the infrastructure must only be located in one or a few places in the country**
  The Research Council encourages research institutions with similar interests to establish an appropriate division of responsibilities and to cooperate on grant applications.
- **The infrastructure must lay the foundation for internationally leading research**
  Grants are to support activity in research groups that are already at the forefront of international research, or that have good, realistic opportunities to achieve such a position.
- **The infrastructure must be made available to relevant research groups and industries**
  If there are research groups outside the applicant institution that will need to use the infrastructure, these must be granted access, and a plan for such user access must be described in the application.

Funding from the Research Council for research infrastructure is available for applications within all disciplines and thematic areas. Furthermore, the Research Council must ensure scientific quality and undertake strategic assessments and emphasise national priorities through the allocations. This may mean that different priority areas or subject areas may be given different emphasis in calls for proposals, so that the Research Council can channel investments towards areas where research activity is high and the need for research infrastructure is great, as well as follow up political and strategic guidelines.

Ministries

Decisions on international research cooperation that entail significant and permanent commitments related to investments and membership fees are made at the ministry level. National research facilities involving investments exceeding NOK 200 million will also be managed at ministerial or government level, preferably on the advice of the Research Council. Preferably, these are funds that must come in addition to the permanent item for research infrastructure in the national budget.

The value of national coordination

Several types of research infrastructure, such as very expensive scientific equipment, databases and high-performance computing resources, may be uneconomical and difficult for a single research institution to fund. At the same time, it is important that these investments are utilised effectively by a large number of users. It is therefore often appropriate and necessary for several research institutions to collaborate on building, developing and utilising such infrastructures.

To ensure that such infrastructures are utilised well at the national level and that investments are coordinated appropriately so that researchers' needs are met, the Research Council can play an important role in coordinating and supporting such collaborations.

Analysis and strategic prioritisation of large individual investments

Coordinating the allocation of relatively large funding for research infrastructure of national importance makes it possible to take steps where a few large, nationally important research infrastructures are placed ahead of others in a given allocation process. Similar measures are normally not possible within the Research Council's other instruments and programmes, partly because of limited funding, and partly because particularly large infrastructure investments are easily given low priority in favour of other research projects.

Analyses of the application influx provide the Research Council with an overview of the infrastructure needs that exist, while the national coordination provides a better overview of which investments are actually being made. This puts the Research Council in a better position to set strategic priorities, and to be able to align infrastructure calls towards specific disciplines and thematic areas as needed.

Cooperation and division of labour

The Research Council stipulates requirements for collaboration and division of labour between different research institutions and/or between research institutions and actors from industry, public administration or health trusts in order to be eligible to receive funding. To a large extent, the infrastructures' research applications are also aimed at actors outside the R&D institutions. This creates a culture and practical routines for accessibility beyond the host institutions' own researchers. The Research Council sets similar requirements for cooperation and division of labour between Norwegian institutions when funding Norwegian participation in the development of joint international infrastructures.

Coordinated generic e-infrastructure in Norway

Research from many disciplines is now more data-driven than before. The development of new sensor technology, digitalisation of research data and advanced data analysis tools mean that an increasing number of research fields need large analysis capacity, network transfer, storage and access to large amounts of research data. E-infrastructure for research includes equipment, operations and related services for high-performance computing, data storage, software systems and high-speed networks as well as tools for

efficient and secure information management and software for simulation and analysis of data. The term e-infrastructure is also used for digital registers and databases, as well as tools and services to secure and make these accessible.

Norway has coordinated generic e-infrastructure for research and higher education through Sikt and Sigma2 AS (Sigma2). Sikt develops and operates the Norwegian high-speed network for research and education, which connects Norwegian institutions, researchers and students and links them to international research networks. Sigma2 is responsible for procuring, operating and further developing the generic national e-infrastructure for high-performance computing and data storage. Long-term service agreements with the universities of Bergen, Oslo, Tromsø and Trondheim, and basic funding from the Research Council through the National Financing Initiative for Research Infrastructure, constitute a significant part of the funding to Sigma2. This ensures a more cost-effective development of e-infrastructure solutions than requiring institutions to build their own solutions only.

Investments in generic e-infrastructure should be considered in the light of the needs of other national research infrastructures. By coordinating investments in these infrastructures, Norway can adapt the level of investment to real needs and focus efforts on the areas that will benefit most from the investments. This also provides the opportunity to bridge the gap between infrastructures and disciplines to support multidisciplinary research. The Research Council will therefore work to ensure long-term, adequate funding of e-infrastructure that meets the needs it is intended to cover, within the current budget framework.

Recommendations

Recommendations to the ministries:

The large number of applications submitted to the National Financing Initiative for Research Infrastructure, and the excellent assessments that many of these applications have received, show that there is a great need and potential for national research infrastructure in Norway. In some areas, there is a need to establish new infrastructure, and there will be a continuous need to upgrade existing infrastructure to ensure that Norwegian research groups have the equipment required to achieve sufficient quality and efficiency.

It is important that Norway maintain the investment volume in national research infrastructure over the next few years. Some of the investments are expected to be used to cover operations. A long-term approach to funding is crucial for maintaining strategic room for maneuvering to the benefit of Norwegian research over time.

Sharing and reuse of FAIR research data requires special research infrastructure and expertise. The long-term plan uses the recommendations of the Data Infrastructure Committee9 as a basis for further work on data infrastructure. The committee recommends a high, but realistic level of ambition where, by 2030, all subject areas should be offered expertise, guidance and curation of research data, either in the form of national solutions or wholly or partly through participation in European or international infrastructure cooperation. As of 2023, the annual allocation from the Ministry of Education and Research is close to NOK 800 million. Based on its long-term ambition to maintain this annual level of funding, the Research Council has proposed an increase in its input to the update of the Government's Long-term Plan for Research and Higher Education to cover increased expenses for tools for handling research data.

Recommendations to R&D institutions:

Have clear plans for how the role as host will be managed

Hosting a national research infrastructure entails a great responsibility and, in many cases, financial consequences. Host institutions should have clear, long-term plans for how they will manage, operate and make available the infrastructures they establish. The institutions should ensure that qualified personnel have special responsibility for day-to-day operations and that the infrastructure is available to all relevant users, including users outside their own institution.

The establishment and operation of data infrastructures entails a national responsibility for access to and secure storage of research data, and an obligation to develop and facilitate the infrastructure for the relevant user groups. Furthermore, it is important to ensure that data can be safeguarded and handled in a long-term perspective. This requires that the institutions consider how they can commit financially and that business models are established for long-term and sustainable operations where relevant user groups and/or user institutions contribute to the funding. To ensure sustainability and anchoring in the research community, it is often important to establish relevant institutional cooperation nationally and/or internationally. Data infrastructures that are established or further developed should strive to build on existing solutions, technology and networks whenever possible.

Good management of the role as host role includes user dialogue and mobilisation of users/the research community to use and utilise the infrastructures. In order to ensure good and sustainable operation of the infrastructures, it is important that the services developed respond to the needs of users.

Highlight infrastructure costs

Research institutions are encouraged to have financial systems that highlight all costs associated with research infrastructure, including operating costs and depreciation of procured infrastructure. As far as possible, these costs should be allocated to the R&D projects that use the infrastructure and be highlighted in the project budget. Thus, those who fund research activities, including the Research Council, can cover infrastructure costs incurred under the projects. Expenses for the use of research infrastructure are legitimate costs in applications for research funding from the Research Council. Research institutions are encouraged to take advantage of this opportunity.

Prioritise research infrastructure within the basic allocation

The institutions must continue to focus on the need for new investments, upgrades and operation of research infrastructure in their budgets.

Clear guidelines and competence in data sharing and reuse

Research institutions are encouraged to have clear guidelines and good routines for sharing and reusing data that are in line with national and international guidelines. In addition, the institutions should have solid expertise in sharing and reusing data, both through good support services, but also close to researchers in the research communities. Clear guidelines, good routines and solid expertise in sharing and reusing research data contribute to increased quality, ethical integrity and transparency in research, and promote cooperation and innovation.

The Research Council will:

Further develop national research infrastructures

Through the National Financing Initiative for Research Infrastructure, the Research Council has established a tool to further develop the Norwegian research infrastructure landscape. Quality assessments and a comprehensive strategic assessment will clarify which investments will benefit Norwegian research. The Research Council is working to ensure that this funding scheme works well with other Research Council instruments and funding schemes to ensure that the strategic perspective is safeguarded in the best possible way. The Research Council will also provide research policy advice on investments in research infrastructure.

Follow up Norway's participation in international cooperation on research infrastructure and data management

Norway participates in European cooperation on research infrastructure to give Norwegian research access to infrastructures that Norway alone cannot fund. At the same time, European cooperation could contribute to increased use of our national research infrastructures. The decisions will be directed towards international cooperation that supports the priorities of the Long-Term Plan. Norway's participation in the distributed ESFRI infrastructures is of greatest strategic importance where we already have research infrastructures that can be coordinated and further developed in cooperation with other European countries.

Stimulate optimal use of infrastructures

The centralised allocation process at the Research Council provides an overview of the research infrastructures that exist at any given time. The requirement to make national research infrastructure available will also improve utilisation of the infrastructures.

Increase innovation capacity in the private and public sectors

The Norwegian business sector consists largely of small and medium-sized enterprises. The Research Council wants research efforts in these companies to be increased – and for more results to be useful. The Research Council wants an innovative business sector that increases research efforts together with the public sector and sees the sector as an important partner and market for the development of innovative solutions. The Research Council wishes to encourage companies and public entities to collaborate more with Norwegian and international researchers in order to better utilise research results for innovation and development. Updated research infrastructure is a crucial factor in achieving this goal, and the Research Council's infrastructure investments are intended to support such cooperation.

Contribute to access to research data

Access to high-quality research data can contribute to increased innovation and knowledge-based management. The Research Council will contribute to increased access to and reuse of research data for industry and the public sector, as well as for research itself, through requirements and guidelines for R&D projects, and through funding of data infrastructures of national importance. The Research Council also has an important advisory role when it comes to sharing and reusing research data and data infrastructures for this.

Contribute to good management, operation and accessibility in line with international principles

Through the call text, application processing and follow-up of the projects, the Research Council will attach importance to the organisation and operation of the infrastructures. The infrastructures shall be established in accordance with international principles for, among other things, user access, proper processing and access to data and results.

Contribute to raising awareness of the consequences the geopolitical situation may have for access to and operation of research infrastructures and responsible sharing of data

Changes in the geopolitical situation have a significant impact on research and research collaboration. The ideals of openness and accessibility face challenges because security policy considerations can limit the sharing of data and make infrastructure available to users. The Research Council has an important advisory role in raising awareness of good safety practices and protection of infrastructure and research results against unauthorised access and misuse, when funding national research infrastructures.

Obviously, there must be limits to the sharing of personal data, but there are also other types of data we must be careful about sharing. The possibilities for data collection are increasing in line with technological developments, including remote sensing from space, sensor technology and autonomous vehicles. The data volumes are large, the accuracy is increasing, and a significant part of the research effort is naturally shifted to the analysis of collected data. The data is a goldmine for those who are good at exploration. It will sometimes happen that sensitive information is hidden in the data as a kind of bycatch, perhaps also information of a non-civilian nature.

There will be a number of cases where it is necessary to restrict access to research data, particularly raw data. This may also apply to access to the research infrastructure that generates the data. Greater attention to these challenges is necessary, and the practice of the ideals of openness and accessibility must be adapted to the specific assessments. The changes in the geopolitical situation require increased attention to these issues.

Part 2: Strategic basis

Basis for priorities

This part of the roadmap describes research objectives, existing infrastructures, and possible future needs for research infrastructure within different thematic areas, subject

areas, and technology areas. These descriptions are an important part of the decision basis for allocations to research infrastructure from the Research Council's budget and planning of future calls for research infrastructure.

It is desirable that Part 2, together with Part 3, can contribute to an overview of the existing landscape of research infrastructures and future needs to achieve better coordination of infrastructures across disciplines and technology areas. The establishment of new research infrastructures must be assessed in relation to the opportunities provided by existing infrastructures.

Classification

In the division of subject thematic and technology areas, we have based our work on the division in the ESFRI roadmap, but have made some adjustments to address specific national needs. In addition, three overarching objectives are described.

Overarching objectives:

- Sharing and reuse of research data
- International cooperation on research infrastructures
- Sustainability

The areas and associated subareas:

- Technology and science
  - Information- and communication technology
  - Material-, process technology and basic natural sciences
  - Energy and energy systems of the future
  - Earth science, oceans, climate and environment
- Life science and health
  - Bioresources
  - Biotechnology
  - Health and medicine
- Humanities and social sciences
  - Humanities
  - Social sciences

Because infrastructure needs in different areas differ considerably in terms of types/categories of infrastructure, investment and operating costs, and the number and types of users, the descriptions will vary somewhat in length and level of detail. There will be some overlap between some of the sub-areas, and the classification shall not represent obstacles to cooperation on research infrastructure across disciplines and technology areas. An interdisciplinary approach is a prerequisite for solving many of the societal challenges and for succeeding in the development and utilisation of new technology and industries. Over the past few years, it has become evident that in order to address climate change, environmental sustainability, energy transition, migration management, health challenges and disease prevention, data on social behaviour and cultural practices (past and present) are indispensable along with the recognition of the importance of ethical, legal and societal issues.

In addition to the area descriptions in the roadmap, the Government's long-term plan for research and higher education3 (the Long-term plan) and the Research Council's portfolio plans are important parts of the decision basis. This is illustrated in Figure 1.

Area	Sub-area	Overarching objectives		
		Sharing and reuse of research data	International cooperation on research infrastructures	Sustainability
Technology and science	Information- and communication technology			
	Material-, process technology and basic natural science			
	Energy and energy systems of the future			
	Earth science, oceans, climate and the environment			
Life science and health	Bioresources			
	Biotechnology			
	Health and medicine			
Humanities and social science	Humanities			
	Social science			
Long-term plan for research and higher education (2023-2032)				
Research Council's portfolios				

Figure 1 - Relationship between the roadmap's areas/sub-areas and the Research Council's other portfolios, the Long-term plan and overall objectiveLong-term plan for research and higher education 2023-2032 (Long-term plan)

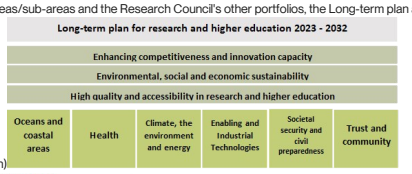

Figure 2 – Overview of the overall objectives and Thematic priorities of the Long-Term Plan

The long-term plan has been, and will continue to be, an important part of the decision basis for the Research Council's allocations to research infrastructure. The Long-Term Plan proposes three overarching objectives that apply to all subject areas, including six thematic priorities. The six thematic priorities are selected areas where the Government considers it particularly important that Norway invest strategically in research and higher education in the years ahead.

The long-term plan encompasses a wide range of topics, disciplines and technology areas, and also provides some guidelines for areas that are to be given special attention. The need for investments in research infrastructure in all the priority areas has been clearly addressed, and in particular the need for infrastructure for handling data.

The Research Council's portfolios

It is a principle for INFRASTRUKTUR to invest in research infrastructure within topics and disciplines where research is funded. This underpins the objective that investment in research infrastructure shall be anchored in the needs of research today and in the future, and that the infrastructure will have a user group that ensures further utilisation and operation of the facilities.

The Research Council's portfolios have their own portfolio plans that describe any knowledge needs and priorities. When evaluating applications for INFRASTRUKTUR, the administration will look at one or more of these to ensure that new infrastructures or further development and upgrading of existing infrastructures are based on research needs that can be funded through the Research Council's other policy instruments.

Overarching objectives

Sharing and reuse of research data

Digitalisation and technology development contribute to society and research becoming increasingly data-driven.

An expressed national goal in the white paper Data as a resource is to create value and create more new jobs, with data as a resource. It is an ambition to achieve more data sharing between the public and private sectors to enable new insights and innovation. It is also a political objective, both nationally and internationally, that data produced through publicly funded research shall be managed in accordance with the FAIR principles ("Findable, Accessible, Interoperable, Reusable"), as far as possible. This means sharing data in a way that safeguards ethical, privacy and security considerations, while making the data available to other researchers in a simple and accessible way – as open as possible, as closed as necessary. Achieving this requires a high degree of competence in the interface between law and ethics, technology and cyber security, secure data management and management, in research communities and at institutions. The events of recent years have shown that this competence is also particularly important in various crises, also within the public sector as a whole.

Europe is in the process of establishing the European Open Science Cloud (EOSC), which will be a coordinated network of FAIR data and related research services (see Part 1). The Long-term plan emphasises that Norwegian data infrastructures, services and research data must comply with the internationally established FAIR principles and be compatible with the international ones, and must be able to take into account future data growth and the need for compilation of data sources, both nationally and internationally.

To enable safe and reliable sharing and reuse of research data, a secure and efficient data infrastructure is essential. The report from the Data Infrastructure Committee9 makes several recommendations related to the level of ambition for data infrastructures in Norway. These are set out in the Long-term plan and form the basis for the Government's further work on data infrastructure. Overall, both the Data Infrastructure Committee's report and the Long-term plan point to the importance of having a holistic approach to the development of data infrastructure, and there is a need to allocate sufficient resources to achieve this.

In the report with recommendations from the Data Infrastructure Committee, data infrastructure includes:

- Basic, generic e-infrastructure that is a prerequisite for data-driven research. This includes physical infrastructure and software for analyzing and processing big data.
- Tools and services related to active use, sharing and reuse of data.

- Services for long-term retention and long-term data management. Infrastructure that offers long-term management can be general, interdisciplinary or subject-specific.
- Both generic and domain-specific/region-specific data infrastructures.

Sustainability

Environmental, social and economic sustainability is one of the overarching objectives of the Long-term plan. The Research Council's strategy for sustainability mentions some areas of particular relevance to the UN goals where Norway have advantages and opportunities, and where research and innovation are particularly important for addressing sustainability challenges.

Circular economy is highlighted among the areas that contribute to business development that supports sustainability and green competitiveness. One of the goals is to facilitate research and technology development for circular resource management. This supports sustainable production, which entails reducing resource use, environmental degradation and greenhouse gas emissions, and will thus benefit both the environment and the economy.

Developing holistic solutions for realising the green transition requires research and involvement from different disciplines. Research based in the natural sciences, technology, economics, humanities and social sciences must be seen in context, and the digital research infrastructure must facilitate access to data across disciplines.

The SDGs also apply to the infrastructures themselves – in establishment, further development and operation. The INFRASTRUCTURE scheme is intended to encourage applications that aim to limit the environmental footprint of research infrastructures.

International cooperation

The need for updated research infrastructure characterises Europe's research policy at both national and pan-European level. Participation in European cooperation on research infrastructure is important both to attract top international researchers and to ensure that Norwegian professionals have access to the best research infrastructures available in Europe.

Norway is involved in more than thirty European collaborations on research infrastructure and pays annual dues to be able to use these. This is important for Norwegian research, but at the same time there must be an ongoing cost-benefit assessment of membership in major new international infrastructures and of the need to maintain existing membership. It is also important that investments in national infrastructure are seen in conjunction with and assessed in relation to the opportunities offered by Norwegian researchers through participation in and utilisation of international infrastructures.

Technology and Science

Information and communication technology

Digitalisation is a comprehensive process of change involving the transition from traditional information processing methods to digital technologies and tools. Information and communication technology (ICT) is a key driver for this, across disciplines and sectors. ICT is a generic term for technologies that make it possible to collect, store, process, share, communicate, visualize, use and collaborate on data and information in electronic form.

Generic data- and e-infrastructure

In order to support increasingly data-driven research, the need for robust and generic data and e-infrastructure and good services for data management is increasing. Research data is a valuable resource that must be stored, analysed, archived, shared, made available and preserved long-term in a secure and efficient manner.

Data and services everywhere

Many disciplines need generic data and e-infrastructures for e.g. high-performance computing, data storage, archiving and long-term preservation of data and associated services such as authentication and authorization, tools for efficient workflow and software for simulation and analysis of data. This includes digital registers and databases for storing large amounts of data, so-called 'big data', and computational resources for complex calculations, so-called High Performance Computing (HPC). HPC is an important tool for meeting major scientific and societal challenges, including marine research, climate research and health research. Data infrastructures are particularly important for research that requires complex calculations and generates large amounts of data through simulation and analysis.

Technology development in high-performance computing and big data is happening at a rapid pace, and new user groups with different and specific needs are constantly emerging. It is therefore of great importance that the infrastructure being developed is able to meet these needs and support research effectively. It is also important to have interacting data infrastructures, and to establish infrastructures along the entire digital value chain.

A safe information society

Sensitive data that cannot or should not be shared openly, for legal, ethical or security reasons, must also be collectable, managed, analysed and archived in a secure and good manner. For this, one needs data infrastructure, services and tools that ensure that data collection and management takes place in accordance with applicable legislation and ethical guidelines and prevents unauthorized access and misuse.

Groundbreaking ICT research and development

The new Long-term plan for research and higher education describes ICT as a transformative driving force that provides the basis for new business models and applications in all areas of society. ICT spans a wide field of technology areas including computer science, informatics, information systems, artificial intelligence and machine learning, network and software technology, sensor technology and the Internet of Things, human-computer interaction, network and security, cryptography and cyber security. Research and research-based innovation in artificial intelligence and quantum technology are particularly highlighted in the Long-term plan, but there are also a number of other disciplines within ICT research that are relevant in an infrastructure context. The various disciplines may need capacity for generic infrastructures for high-performance computing, storage, etc., but there may also be a need for infrastructures related to the specialist areas.

ICT is not just a field in itself. ICT is the technical basis for a comprehensive innovation system, linked to most societal challenges. The internet and digital technologies are transforming not only industries, but also work processes and tasks and the dynamics of organizations and labor markets. The digitalisation wave is a driver for Industry 4.0 perspectives, the green shift, restructuring in the private and public sectors and value creation in important areas for society. Norway has good prerequisites for succeeding through the digital transformation. However, this requires that we succeed in competence building, research activities and priorities, strategic investments in national infrastructures, innovations and solutions in the ICT field.

The infrastructure landscape today and in the future

Generic data- and e-infrastructure

For a complete picture of data- and e-infrastructures, it is necessary to also look to the other sub-areas of the roadmap. The INFRASTRUKTUR-portfolio contains a large number of relevant projects that have been developed for the needs of one or more disciplines and technology areas. Part 3 provides an overview of the cross-cutting research infrastructures that can be used in a number of disciplines and areas.

Within all sub-areas of the roadmap, there is a need for continued investment in national high-performance computing capacity. Sigma2 is a generic data infrastructure with great significance for a number of disciplines, within high-performance computing and data storage. Managing and sharing sensitive data and enabling analyses on it is a challenge and a need in many fields of research, including health and social sciences. In order for researchers to do this, one needs a secure and reliable data infrastructure with services that comply with relevant legislation and research ethics guidelines.

It is important that Norway take part in international cooperation to ensure that Norwegian research groups and infrastructures operate and are established in accordance with international standards and principles for good data management, -administration and curation. In this regard, Norway should continue to play an active role in the cooperation on EOSC, EuroHPC JU and ESFRI landmarks such as the Partnership for Advanced Computing in Europe (PRACE).

Infrastructure for groundbreaking ICT research and development

Research and development in ICT requires a wide range of research infrastructures along the entire digital value chain, from data collection to analysis and user interfaces. This includes, among other things, experimental infrastructures for communication networks, sensor and circuit technology, analysis tools and high-performance computing platforms, and solutions to improve the user experience in various technological systems.

The eX3 research infrastructures offer an experimental heterogeneous high-performance computing facility for experimentation with exascale computing and NorNet offers a large-scale, real-world Internet testbed, where increased performance and robustness in the network is a key research challenge. ReRaNP provides opportunities to validate and demonstrate new methods and systems for radio communication. Increased speed, development and realization of truly massive MIMO systems and advanced wireless sensor networks are key research challenges. NAIC will establish the most powerful infrastructure for artificial intelligence in Norway and find the best technology solutions for this.

For most new technologies, basic and applied research on ICT is a necessary part, and in the future it will be important to have infrastructures that enable ICT research that is strategically important for Norway.

There are good opportunities for increased international cooperation in several areas within ICT. For example, quantum computing (QC) is a field where cross-border collaboration can provide significant added value.

Material-, process technology and basic natural sciences

The Long-term plan emphasises the importance of long-term basic research for building new knowledge we need to handle challenges and crises. Basic natural sciences are wide-ranging, but here we have described some particularly equipment-demanding subject areas. Basic research is also important for the development of new advanced technology. Research on new advanced and industrial technologies contributes to new applications and new production methods that will be crucial for the implementation of the green transition.

Space-, particle- and nuclear physics

Basic research in space- and astrophysics/astronomy, particle physics and nuclear physics helps to increase understanding of various fundamental phenomena that contribute to building knowledge and competence and developing technology that is also important in many other areas.

Space research contributes important knowledge, among other things, to understanding climate systems, ocean currents and the movements of the earth's crust. Norway's participation in the European Space Agency (ESA) and the EU Space Programme facilitates strong research communities and international cooperation within the breadth of space-related research and technology development. Norway has long traditions when it comes to space exploration, including northern lights- and solar research. In order to maintain Norwegian research communities, for example in the fields of Earth observation, operational meteorology and ice, climate and environmental applications, access to advanced research infrastructure is necessary, both nationally and through international cooperation.

CERN is one of the world's largest and most respected centres for research. Here, the smallest building blocks of the universe are revealed using particle collisions at extremely

high energies. Norway has been a member since its inception in the 1950s and participates in several of the experiments. Participation in this work is important for the scientific development of Norwegian research communities in the field of particle physics. The infrastructure itself is located in Geneva, but much of the work on developing new detectors takes place in Norway.

In both space-related research and particle physics, very large amounts of data are generated, which necessitates data infrastructures that can handle it. However, it also contributes to expertise in handling and using large amounts of data, which is in demand in several areas.

Norway has long traditions also within nuclear research. The need for knowledge and expertise in basic nuclear physics and nuclear chemistry is made clear in the Long-term plan. Although Norway do not have electricity production based on nuclear power today, there are several countries nearby that have nuclear power plants and plans for new ones. It is necessary that Norway's expertise in nuclear safety and preparedness is maintained and further developed. Norway also has significant activity in radiopharmaceuticals.

Nanotechnology and advanced materials

The Long-term plan emphasises the importance of research in nanotechnology and materials technology, and the importance of investments in research infrastructures in these areas.

Nanotechnology encompasses the study of phenomena occurring at the nanoscale and how we can control and manipulate these phenomena. Technology can thus contribute to innovations in most areas of society. This also applies to microtechnology and advanced materials. Nano-, micro- and materials technology are technologies used to develop and manufacture advanced materials and systems with specific and controllable properties. This contributes to increased competitiveness within topics such as energy and the environment, oceans, food and health, with the goal of avoiding creating undesirable effects on health, the environment and society.

Within this field, there is often a close link between public R&D environments and companies. For example, new advanced materials are important in the development of various types of sensors, solar cell technology and new batteries. Advanced biomaterials are important in the development of new medical products and more sustainable packaging.

Production and process technology

There is a need for advanced production processes and process technology, which can contribute to reduced resource use and a low carbon footprint. The Long-term plan refers to vulnerable value chains that highlight the need for advanced production processes that can also contribute to reduced emissions and increased reuse. Reference is also made to the need for basic research in disciplines necessary for the development of enabling and industrial technologies for more sustainable production.

The Government's roadmap The green industrial initiative points out that there can be much to be gained for business and industry by increasing research efforts, strengthening links between different sectors and improving the interaction between research and innovation. For the latter, the importance of knowledge sharing between actors within research and industry is pointed out. The business sector in Norway uses advanced production processes, but there is a potential to exploit the opportunities inherent in new technologies and data to an even greater extent.

The infrastructure landscape today and in the future

Many national and international research infrastructures have been established within technology and basic natural sciences with funding from INFRASTRUKTUR. These are listed in Part 3.

Within space research, particle physics and materials research, Norway participate in major international infrastructure collaborations. This includes EISCAT_3D, CERN, European Synchrotron Radiation Facility (ESRF) and European Spallation Source (ESS). ESS is still under construction in Lund, Sweden, and is scheduled for completion in 2027/2028. National and international infrastructure for calculating large amounts of data (Sigma2-NRIS and Norwegian participation in Euro HPC and NeIC-Tier-1) is very important, because research in these areas generates large amounts of data. Norway also participates in the Swiss-Norwegian Beamline (SNBL), which serves as an important home laboratory for the use of synchrotrons and provides an increased benefit from membership of the ESRF.

Within space research, there are also several important infrastructures that have been developed and made available to Norwegian researchers with support from sources other than the INFRASTRUCTURE scheme. An example of the latter is satellite data from ESA and the EU's space programmes, where Norwegian participation helps to ensure relevance to Norwegian needs. The launch base, which is currently under construction on Andøya, is another example.

Through INFRASTRUKTUR, investments have been made in several national infrastructures, including cleanroom facilities for nano- and microtechnology and various national infrastructures for materials characterization, as well as cyclotron laboratory for nuclear research. In order to exploit the European Spallation Source (ESS), expertise in neutron research is needed, and we have invested in NcNeutron as a national infrastructure for this. NcNeutron was moved to the Paul Scherrer Institute (PSI) in Switzerland after the JEEP II reactor at the Institute for Energy Technology (IFE) was shut down in 2019, but is still available to Norwegian research communities.

Within production and process technology, several national research infrastructures have also been established, for example within commodity and metal production.

In the years ahead, there will be a need to maintain and further develop existing research infrastructures, both national and international. Modern, advanced equipment for material characterization will be important, and will also have high relevance for a number of other disciplines and technology areas.

Norwegian researchers currently have access to several international research infrastructures adapted for basic scientific research. Access to these should be maintained and further developed. Among other things, new upgrades of CERN are planned. There will also be a great need for infrastructures for the use and utilisation of data, for example for the development of new production methods and computing resources for large amounts of data.

Energy and the energy systems of the future

The Long-term plan emphasises the need for research that contributes to the green transition and low emissions, and further develops the energy industry to be profitable also in the future. Energy efficiency is an important part of the transition to a sustainable low-emission society. Energi21 and OG21 are the national strategies for research, development, demonstration and commercialisation of energy and petroleum technology, respectively.

Energy research encompasses a number of different disciplines and technologies such as geophysics, nano- and materials technology and digital technology. The emergence of new energy industries requires an interdisciplinary approach with contributions from, for example, climate and environmental research, the social sciences and the humanities.

New industries such as offshore wind, hydrogen and carbon capture and storage and seabed minerals can build on further development of expertise and technology from the established energy industries.

Hydrogen, carbon capture, utilization and storage

A number of research needs remain along the entire value chain of hydrogen and hydrogen carriers. This research entails a need for adapted research infrastructure, as pointed out by, among other things, the Energi21 strategy. The OG21 strategy also points out that hydrogen as part of the decarbonisation of petroleum value chains can also contribute to securing the future market for natural gas.

Carbon capture, utilisation and storage (CCUS) is central to the green transition, and is highlighted in, among other things, the EU's green growth strategy. Especially within carbon capture and storage (CCS), there is great potential for international cooperation. The OG21 strategy16 points out, among other things, the importance of making natural gas greener, and CCS is central in this context.

Environmentally friendly energy

Research on renewable energy and low emissions is intended to support long-term, sustainable development of the energy system, contribute to the transition to a zero-emission society and promote a competitive Norwegian business sector.

The Energi21 strategy points out that the European power system of the future will increasingly consist of intermittent and renewable power production. To ensure flexibility in the integration of intermittent and distributed energy sources in the power system, there is a need for further research into hydropower and the consequences of variable operation of hydropower plants, as well as research infrastructures where conditions relevant to the future power grid can be tested. According to Energi21, digitalisation will provide a more precise decision basis and a more solid basis for good analyses of investments and choice of operational strategies.

There is a major investment in offshore wind power at home and abroad. The white paper Energy for work – long-term value creation from Norwegian energy resources refers to different knowledge needs associated with bottom-fixed wind turbines compared to floating turbines. In general, for ocean-based power production, based e.g. on petroleum, wind, sun, wave and tidal, there is also a need for knowledge to ensure coexistence with other ocean-based industries and social acceptance, as well as to understand the consequences for the environment and climate.

In Europe, there is a strong focus on sustainable battery production and an increased degree of self-sufficiency. There is a need for a broad approach in the energy transition, and for increased capacity build-up both solar and battery technology are important. The International Energy Agency (IEA) has developed a scenario for reaching the 1.5°C target and thus net zero emissions in the energy sector in 2050. This requires the development of new and advanced battery technologies. In the IEA scenario, solar energy accounts for about one-fifth of the global power supply, and this requires continued investment in research and technology development in solar cell technology.

The Long-term plan also identifies bioenergy as an important factor in an effective and just transition to a sustainable low-emission society, for a society with increased circularity and a sustainable bioeconomy. Energi21 also points out that bioenergy will play an important role in the transformation of a number of sectors.

Research on environment-friendly energy is also central to the transformation of the transport sector, which includes maritime and land-based transport and aviation by contributing to knowledge, expertise and innovation for future sustainable zero- or low-emission transport solutions. In addition to the transition to zero-emission solutions, it will be important to make all transport more energy efficient.

There is also a great need for energy conversion in buildings and industry, both for more energy-efficient solutions and for solutions based on zero-emission energy carriers. In the construction sector, this is particularly about reduced heat loss from buildings and reduced energy consumption for ventilation and lighting. In the manufacturing sector, there is a particular focus on switching to more energy-efficient processes and replacing fossil energy raw materials. This applies both to processes that require heat and to processes that require energy raw materials as a reducing agent.

Petroleum

Petroleum research and technology development is important to ensure continued value creation from the sector, to develop the sector in a sustainable direction and to help ensure that expertise and solutions from the sector can be used in new industries. To achieve this, new technology will be developed and adopted that provides more cost- and energy-efficient extraction of petroleum, better knowledge about the subsurface and lower greenhouse gas emissions.

Several petroleum fields on the Norwegian Continental Shelf are in a mature phase. There is therefore a continued need for cost- and energy-efficient methods of production, as well as safe, cost- and energy-efficient methods for permanent plugging and abandonment of wells (P&A). Moreover, there is also a continued need for research and technology development related to oil spill preparedness, which will also be of great value for the maritime sector.

Within the petroleum sector, there is also a need for continued utilisation and further development of infrastructure to meet existing and future needs. There is a strong focus on energy efficiency and emission reductions. Here, autonomy, automation, robotics and artificial intelligence can play an important role together with workflow and interaction across disciplines, in addition to more efficient processes and energy recovery.

The infrastructure landscape today and in the future

Investments have been made in a number of national infrastructures within the above-mentioned research fields. Research centres that have been launched also help to ensure good coordination and utilisation of research infrastructure and to good links with industry.

The research infrastructures that have received funding from INFRASTRUKTUR are listed in part 3. This includes infrastructures within wind power, solar cell technology, bioenergy, energy systems, energy use in buildings and industry, drilling and well technology and multiphase flow. Investments have also been made in research infrastructures that support research and development of technology to produce hydrogen from renewable energy, the use of hydrogen in the transport sector, and for transport and storage of hydrogen.

Research infrastructure for CO2 handling is largely integrated into the ESFRI project ECCSEL, which is led by NTNU. ECCSEL is a European project that brings together R&D infrastructures from several countries. The infrastructure has received funding from the Research Council on several occasions. In addition to ECCSEL, there are several major piloting facilities. The most important are the technology centre at Mongstad (TCM), Aker Solutions test unit for CO2-catch, SINTEF's pilot for CO2-catch and field laboratories for storage in Svelvik and Longyearbyen.

Looking to Europe, there are also several infrastructures among ESFRI Landmarks that may be relevant for parts of the Norwegian energy sector, e.g. in ocean-based power generation or solar energy. However, the European research infrastructure landscape is deficient for several parts of the energy field, including petroleum.

In addition to specialised infrastructures, equipment in several other areas is important for energy research. This applies in particular to nano- and materials technology, which are used in large parts of the energy research field, and which are central to solar energy research and research on battery and fuel cells. Infrastructures in the area of bioresources are also used in bioenergy research, and within ocean-based power production infrastructures within maritime technology (towing tank and ocean basin) are of great importance. Climate and environmental infrastructures, as well as generic infrastructures for high-performance computing and other computer infrastructure are also very important for the breadth of the energy field.

In the years ahead, there will be a need for both upgrading and renewal of existing infrastructures. There is also a need for completely new research infrastructures. Generally for new infrastructures in the energy area, digitalisation, security, circular value chains and reuse are becoming increasingly important. These are factors that must be given great weight.

The sustainable energy systems of the future require the development of new and advanced technologies, for example within energy storage. There is a need for access to research infrastructures that include necessary test facilities and facilitate research on the reuse and recycling of materials.

In order to realise the value chains for hydrogen (blue and green) and hydrogen carriers, there is a need for a targeted and coordinated effort to ensure that research infrastructures exist along the entire value chain. There is a need for research activities based on real volumes and the complexity of the value chain. It is important to look at the development of infrastructure in Norway in the context of the establishment of research infrastructure in the EU.

Within ocean-based power production, a number of needs for increased efforts have been promoted. There will be a need for the development of marine technical, electrotechnical and material technology laboratories. Test centres for floating structures may be relevant to offshore petroleum, offshore wind (including mooring methods) and floating solar power (FPV). There is also a need to develop technology for shipping and assembly of floating offshore wind, and for maintenance and repairs. There is also a need for sensors and more measurement data to be able to design even better models that are used, among other things, to optimize wind and solar power facilities.

There is a growing need for high-performance computing, data storage and sharing, as well as data security and digital technologies.

Earth science, oceans, climate and environment

The area of geoscience, oceans, climate and environment comprises research and technology development that will contribute to increased knowledge about the earth system, climate and environmental change, geohazards such as earthquakes, landslides, volcanic eruptions and tsunamis, including the risks and harmful effects to society. Projects within this sub-area shall also contribute to safe, environmentally friendly and sustainable exploration, extraction and utilisation of georesources, such as metal raw materials, energy and industrial minerals, construction raw materials and groundwater. The area also includes research and technology development that contributes to more sustainable solutions and adaptation to climate change. Of particular importance to Norway is the management of oceans, coastal and polar areas.

The Long-term plan describes a number of objectives and priorities relevant to geoscience, oceans, climate and the environment.

Climate and environment

Climate and environmental research includes research on terrestrial and marine environments, all components of the coupled climate system, research in the social sciences and humanities related to climate challenges and societal, business and geopolitical issues.

Norway has research groups that for decades have contributed to UN climate reports and participated in the World Climate Research Programme. Climate research will provide the necessary new knowledge about the climate system, the evolution of climate in the past, present and future, as well as the effects of climate change on nature and society – as a basis for adaptation measures. In an emergency preparedness and climate perspective, it will be of added value to link natural and social science models to see the impact of different scenarios or the effect of different measures. In addition, climate research will contribute to new knowledge about policy instruments and policies for emission reductions.

Studies of the carbon cycle and biogeochemical processes provide important knowledge about the coupling between the ocean, land (biosphere) and atmosphere and how these interact and affect the Earth's climate. Knowledge about the carbon cycle is key to seeing whether Norway and Europe are achieving their emission targets. It is important that the time series established in this area are continued.

Environmental research covers both terrestrial and marine environments. The research shall increase knowledge about key environmental challenges and provide the public administration, business and industry and society at large with a better basis for making decisions for a green transition. Loss of biodiversity and the spread of pollutants and alien species, as well as deterioration of water quality, are key global challenges. Moreover, the various threats and causal relationships are often closely intertwined. The greatest threats to biodiversity are land-use change, exploitation, climate change, pollution and the spread of alien species. Monitoring biodiversity, ecosystem change and environmental pollution requires an interdisciplinary approach and cooperation with/contributions from other areas, especially health and bioresources, but also social sciences and energy.

Norwegian research groups have contributed significantly to the global knowledge summaries under the IPBES within biodiversity, ecosystems and ecosystem services. Research efforts in the field of biodiversity include a societal perspective, i.e. research on society as the cause of the nature crisis, but also potential solutions to the crisis with research-based action alternatives for policy development.

A number of hazardous substances are now banned in industry and production, and stricter requirements for industry have reduced pollution through point emissions. At the same time, more and more chemical compounds are being used in society, many of which have negative or unknown effects on ecosystems. Diffuse emissions of hazardous substances are considered to be the most important source of proliferation today, and greater research efforts in this area are required to map the origin, spread and isolated and interacting effects of established and new pollutants

Several basic biosciences are based on research on ecosystem services and nature recycling. Rapid advances in genetic sequencing and ICT, including big data analysis of genetic sequences and mass digitization, can be adapted to provide more automated systems regarding genomics, species, and ecosystem analysis7.

Environmental data are important for achieving national climate and environmental goals. It is important to have good coordination of the collection and analysis of different types of environmental data, and a breadth of infrastructures that together cover the aquatic, terrestrial and atmospheric. The focus on autonomous vehicles, both at sea and in the air, has been important for Norwegian research communities. This is important for the collection of high-resolution data in time and space and for reducing the environmental footprint associated with data collection.

The sea and coastal areas

Clean and resource-rich marine and coastal areas are a prerequisite for long-term sustainable marine value creation. More and more knowledge is needed about the structure and function of marine ecosystems, and how they are affected as a result of climate change, ocean acidification, pollution and plastics in the oceans, and other anthropogenic factors. Norwegian research must promote sustainable value creation based on marine resources, and improve management of ecosystems and resources in Norway's sea areas.

Our goal is for Norway to continue to be a world-leading maritime nation, and for Norwegian ocean industries to deliver the most innovative, sustainable and environmentally friendly solutions for the future. Maritime technology is of great importance for safe and sustainable value creation in all ocean industries. The Long-term plan promotes a goal of climate and environmentally friendly maritime transport, and reference is made to the recommendations from the Maritim21 strategy. It states, among other things, that in order to succeed in taking a leading position in the green shift, it must be facilitated for the maritime industry and research communities to be early adopters with regard to research, development, demonstration and commercialisation of technologies and sustainable solutions. Priority strategy areas are Maritime 4.0, which involves digitalisation of the maritime industry, low- and zero-emission technologies and solutions, as well as green and safe maritime transport.

Within marine research, there is a need for continuous coastal and ocean monitoring. This will have great significance for ocean-based industries and for environmental and climate research. There is also a constant need for test facilities for ocean technologies, including subsea technology that may be important for marine minerals and seismic.

Polar

According to the Research Council of Norway's policy for Norwegian polar research, an overarching goal for Norwegian polar research is that Norway shall be a leading polar research nation and that polar research shall safeguard Norway's special responsibility for developing knowledge as a basis for policy, administration and business activity in the Arctic and Antarctic. An overriding consideration for Norway is to maintain the Arctic as a peaceful and stable region based on international cooperation and respect for principles of international law, and to strengthen Svalbard as a research platform.

Norway's ocean interests in the north and south have been emphasised from a political perspective, and exploitation of its resources must be sustainable and safeguard natural values. In the polar regions, we need more knowledge about the effects of hazardous substances, ocean acidification and reduced ice cover in combination with increasing human activity.

There is a need for better earth system models and increased national modelling capacity to link weather and climate. Good access to data is needed, such as ocean observations in Antarctica and long time series, especially from the Arctic. Autonomous and/or mobile observation systems can play an important role here. There is also a need to link different observation systems to ensure multiple uses across disciplines and technology areas.

The infrastructure landscape today and in the future

A lot of infrastructure has been invested in this area – both through the INFRASTRUKTUR scheme and other sources of funding. Infrastructures that have received funding from INFRASTRUKTUR are listed in Part 3.

Norway has well-developed land-based research platforms, ice-breaking research vessels and various fixed and mobile marine observation systems. Norway also has research infrastructure at the year-round stations in Antarctica (Troll) and on Svalbard, and there are good logistics for collecting environmental, climate and biological data in polar areas and our adjacent sea areas.

To ensure good analyses of samples, there are several laboratories for environmental chemical (e.g. contaminants, air and water quality), biological (e.g. DNA analyses) and physical/chemical analyses (e.g. sediments and isotopes) using quality-assured analysis and calibration tools.

Norway has particularly advanced earth system models used by the Intergovernmental Panel on Climate Change (IPCC) that connect all parts of the Earth system. Development of the model requires large data storage and computing capacity and access to high-performance computing facilities. Norwegian research groups are important contributors to many internationally coordinated databases and manage many valuable and long time series.

Through INFRASTRUKTUR, the Research Council of Norway has provided funding for several phases of the upgrade work of the Marine Technology Centre in Trondheim. This infrastructure has been very important for maritime technology development relevant to all ocean-based industries. The upgrade work will be useful now that construction of the new ocean technology laboratory is under way, which is financed directly through a grant from the Storting (the Norwegian Parliament). The Ocean Technology Laboratory is referred to in the Long-term plan as the Ocean Space Centre, and includes a number of laboratories and pools. This also includes a fjord laboratory spread over three different locations.

There is a high degree of international cooperation in the areas of geoscience, oceans, climate and the environment, including cooperation on research infrastructure and sharing and reuse of research data. In the time ahead, it will be necessary to upgrade and further develop existing infrastructure and continue international cooperation on infrastructure.

Norway has a responsibility to establish and maintain historical archives and long-term observations of relevance to climate and environment on Norwegian land, sea and polar areas. This entails continuation of unique, long time series, renewal of the observation systems, maintenance and availability of data, in addition to equipment for collecting and analysing new data.

There is a need for technology development that enables increased use of autonomous and mobile observation systems, electronic sensors and instrumentation and simulation tools etc., that include the use of artificial intelligence and digital twins.

There will be a need for new analytical tools, laboratories and measurement technology – among other things to be able to detect new pollutants and contaminants and understand their biological effects. In biological and ecological research, it is important to adopt new DNA techniques, improve systems for storing and securing information in natural history collections, conduct in-situ ecological experiments and establish archives/databases for biological material and environmental samples.

Well-integrated observation systems that utilise new technology, remote sensing and earth observations from ships, satellites, aircraft and drones, in Norwegian coastal and marine areas and linked to geohazards on land are important. These allow for dynamic data acquisition and adaptive spatial resolution, and research of high quality and importance. There are publicly available and highly detailed data sources in this area. Nevertheless, there is a need for a breadth of infrastructures that together cover and coordinate data for aquatic, terrestrial and atmospheric observations, and that enable short- and long-term climate modelling.

There is a need to link observation systems (based on e.g. land-ocean observations, molecular biological monitoring, as well as chemical and physical measurements) to ensure multiple use and data sharing across disciplines and technology areas. There is a great international need for development and harmonisation of existing observation systems in the Arctic and Antarctic. Improved coordination and joint access to various research services and international coordination of regional and global observation systems in Svalbard and in surrounding waters will be important Norwegian contributions to a pan-Arctic integrated observation system.

Climate research is dependent on large computing capacity to be able to perform complex calculations in a short time, and there is therefore a need for access to infrastructure for large calculations (high-performance computing and supercomputers).

There is a need for infrastructure for data management, analysis and modelling for research on various issues. This includes research on biodiversity and all parts of the ecosystem, carbon cycles and ocean acidification, marine resources, etc., as well as digitalisation and virtual access to natural history collections. There is a need for better cooperation with existing infrastructures for analysis and management of data in other sub-areas, e.g. bioinformatics and modelling of ecosystems in a climate perspective. For the development of smart, sustainable and carbon-neutral cities, open platforms and databases for climate and energy modelling and urban effects are important.

Life Science and Health

Bioresources

The core areas of bioresources are the production and processing of bioresources from land, sea and raw materials from forests. This includes research that will facilitate the best possible development of bio-based products. Sustainable food production is central, but it also includes all bio-based products such as animal and fish feed, biochemicals and biomaterials that can replace oil-based materials and/or fill other needs, as well as new bio-based products.

The goal is that all bio-based raw materials are fully utilised in a sustainable way throughout the entire cycle. In addition, there are great opportunities in new, value-creating forms of exploitation and in connections between bioresource cycles, within and between sectors. Biotechnology, nanotechnology and other enabling technologies characterize and drive the development of the research field. Interdisciplinarity and increased use of computational methods and bioinformatics will make the application of these technologies more relevant and effective.

Sustainable use of bioresources requires knowledge and infrastructure for research on organisms, populations, genetic variation, biodiversity and ecology. This sub-area should be seen alongside 'Geoscience, oceans, climate and environment' in terms of biodiversity and ecosystems.

The Research Council's priorities for bioresources are anchored in the Long-term plan, which emphasises the importance of circular solutions and safe use of bioresources across industries, sectors and subject areas. Important basis for priorities is also the national strategy for the bioeconomy, as well as the Bioeconomy – joint action plan for research and innovation. Norway has strong industries based on natural resources and relatively significant unexploited bioresources. In order to develop this industry in Norway, it will be important to invest in new, innovative and circular solutions for a more advanced processing in order to utilize resources more efficiently.

In the future, it will be important to exploit resources other than those used today - new raw materials, feed ingredients, and this applies to both "blue" and "green" bioresources. At the same time, bio-clusters and industrial symbioses (companies/enterprises within a geographically delimited area that cooperate on the use of resources) shall be facilitated. The Government has launched a national social mission with the goal that all feed for farmed fish and livestock shall come from sustainable sources and contribute to reducing greenhouse gas emissions in food systems.

Food and food production

Food production and food security are closely linked to important societal challenges such as pandemics, war, health, climate and the environment, societal security, social inequality and regional development. Both in Norway and Europe, there is a focus on safe and sustainable food production, and the need for new knowledge and technology for the further development of future-oriented climate and environmentally friendly production of food – both from land and sea.

There is also a need for more knowledge about the accumulation of pollutants and other contaminants in organisms and food chains, their exposure and the harmful effects they may have on health and the environment.

In the food and beverage industry, it is important to acquire knowledge that contributes to new and innovative processes and products that satisfy requirements for sustainability, circular economy and public health. It is important to have quality in research throughout the value chain - from raw material production to human consumption.

Biotechnology and process technology for sustainable food production will contribute to new ways of producing food and enable better utilisation of residual raw materials. Digital platform technologies (e.g. 5G, robotics, machine learning and artificial intelligence) have the potential to improve sustainable food production – crop production and production. The development and implementation of new technologies, together with common standards for the use of data, can lead to better integrated production in the food industry.

Fisheries and aquaculture/marine industries

There are high expectations for the development of marine value creation (fisheries, aquaculture and new marine industries) in Norway. Globally, we see an increasing need for food and new sources of feed, and the opportunities in the oceans are many. Marine natural resources that are not currently exploited can become the source of new industries if we build more knowledge and expertise with modern technology. Increased activity at sea will also require new monitoring and emergency response systems. Better utilisation of ocean data is important both in the management of marine resources and in the development of ocean industries.

The Government's goal is for Norway to be the world's foremost seafood nation. Research must be conducted on stocks and resources in the ocean, in order to provide new knowledge (and new forms of operation) to ensure sustainable fisheries and fish welfare. Increased processing of fish domestically will both provide opportunities to utilise valuable residual raw materials better and lead to less exports (including ice) and thus provide an environmental and climate benefit.

It is important to focus on research regarding coexistence between ocean industries and sound management of ecosystems and resources in marine and coastal areas. This is also prioritised at European level through the EU Mission: Restore our Ocean and Waters, and is mentioned as important in The EU Blue Economy report 2022.

Some of the challenges in developing sustainable ocean industries in Norway are safeguarding existing industries (e.g. fisheries, aquaculture, transport, tourism and petroleum) at the same time as establishing new industries (e.g. offshore wind, offshore aquaculture, CO2 storage, mineral extraction, harvesting in new areas and cultivation of new species). This requires the development of an interdisciplinary approach with contributions from several areas including energy, climate and environment, social sciences and humanities.

Agriculture and forestry

Norwegian agriculture is a leader in important areas such as food safety, good plant and animal health and the use and export of excellent breeding stock. A stronger focus on research, new technology, digitalisation, restructuring and rationalisation are important measures for a forward-looking climate and environmentally friendly agricultural sector. This is in line with the European commitment to sustainable agriculture and food production systems.

Climate change will affect primary production in both agriculture and forestry. The transition to sustainable and future-oriented agriculture requires knowledge about reducing greenhouse gas emissions and at the same time increasing uptake and carbon sequestration in soil and forests. Good soil and plant health is important to take into account in a changing climate. Norway has its own soil health programme and ESFRI Roadmap highlights the need for research on improving plant health and ecosystem function through an agro-ecologically integrated approach. This approach aims to ensure sustainable ecosystem services while addressing the effective management of harmful alien species. Within forests and forestry, it is important to shed light on how forests and other terrestrial ecosystems can contribute to emission reductions, by exploiting the potential for increased CO2 uptake and storage of carbon, and how we can use the raw materials from Norwegian forests in the most climate-friendly way possible (relevant for materials research/packaging). Biorefining with biomass from forests as raw materials can, in addition to replacing fossil products, contribute to innovation and the development of new, sustainable products.

In both construction and building materials, there is a potential for wood and other bio-based materials to replace climate-damaging materials and products. In order to make greater use of both wood and other bio-based building materials, there will be a need for both research and a suitable research infrastructure.

The infrastructure landscape today and in the future

Within this sub-area, there are several research infrastructures that play an important role in the transition to a green bioeconomy, based on Norwegian bioresources, piloting and scaling up to industry. In addition, there are several infrastructures for utilisation of marine raw materials, processing of organisms from lower trophic levels in the sea and development of feed ingredients. These have a goal of contributing to the development of new biomarine industries that meet the climate and environmental challenges of the future in a sustainable manner. Several of the research infrastructures within climate and environment, biotechnology, energy and process, nano- and materials technology will also be relevant.

Norway participates in European infrastructure cooperation (ESFRI infrastructures) for research on marine organisms and coordination of computing resources for the life sciences. European infrastructures in materials technology will also be relevant.

Infrastructures belonging to this area are listed in Part 3.

In the years ahead, there will be a need to upgrade existing research infrastructure and link existing platforms to increase the co-use of instruments/facilities for better resource utilisation. In addition, Norwegian research groups are encouraged to increase their involvement in relevant international initiatives for research infrastructure and further develop Nordic cooperation. In this area, it is also important to have links between business/industry and research, publicly and privately financed infrastructure.

The development of research infrastructure in this area must be seen in the context of infrastructure in other areas, such as biotechnology, nanotechnology, energy, materials technology, building construction, health and medicine, climate and environment, and e-infrastructure.

Among other things, there will be a need for infrastructure that strengthens research and education for the green shift, infrastructure for monitoring and management (sensors, drones), for sustainable processing and processing of natural resources, for research on new cultivation systems, soil health and carbon storage, plant breeding, aquaculture, and for research aimed at the development of new products based on bioraw materials.

New technology in the form of advanced sensors, automation, digitalization and robotization, etc. can help develop food production, fisheries, agriculture and forestry in a more sustainable direction.

With an ever-increasing amount of data, it is important to develop systems so that data from different sources can be made available, compared and analyzed.

Biotechnology

According to the Long-term plan, biotechnology is an enabling technology that, in collaboration with other disciplines and technologies, will contribute to a sustainable society through green restructuring. The plan points to the central role of infrastructure investment in its success. This sub-area should be seen in the context of 'Bioresources', 'Health and medicine' and 'Earth science, oceans, climate and environment', since several of the challenges and research needs mentioned there depend on biotechnological expertise and methodology.

Biotechnology is a relatively mature technology with applications in marine industries, health, agriculture and process industry. Nationally, there is room for better utilisation of biotechnology in the health trusts, as well as strengthening basic research in marine industries, agriculture and the food industry.

Biotechnology is considered to be essential for the development of the bioeconomy, which in a few years will constitute a significant part of the global economy, in line with an increased focus on sustainable utilization of biological resources. They have the potential to prepare primary production both on land and at sea, and contribute to research to meet major societal challenges, such as climate change.

Research infrastructures are central to future research needs in: food security and food production; plant health, soil health and animal health; forestry and materials research; sustainable feed production; biomass processing; blue-green bioeconomy initiative; aquaculture industries; aquaculture. When it comes to future sustainable and circular utilisation of Norwegian biomass, efficiency improvements (digitalisation, robotisation) in the use of limited bioresources are important. In the development of the bioeconomy, biotechnological infrastructure, expertise and methodology are central. Being able to develop cost-effective processing of different types of biomasses is crucial.

Bioprospecting has the potential to develop new products in food, feed, health and energy. Research infrastructure related to bioprospecting can contribute to the utilization of by-products and new preservation methods, testing for bioactive substances for medical purposes (cancer, diabetes, antimicrobial activity), bioingredients and for industrial purposes.

The National Strategy for Personalised Medicine points out that biotechnological methods provide opportunities for better public health through strengthened and more personalised prevention, diagnosis and treatment. Research infrastructure will play an important role in the further development of biotechnological research, as well as utilisation and interaction between health registries and biobanks. Biotechnology is also central to biopharmaceutical production, drug development and the development of diagnostic tools. Norwegian actors should exploit the potential for innovation through international cooperation in pharmaceuticals and health-related biotechnology to strengthen industrial and commercial competence.

The infrastructure landscape today and in the future

Available infrastructure for biotechnological research communities is largely based on technology platforms that were established through the FUGE initiative (National commitment to functional genomics research in Norway) and further developed through funding from INFRASTRUKTUR. This includes infrastructures related to human biobanks, bioinformatics/systems biology, gene sequencing, protein analyses, imaging technologies, NMR analyses and biorefining, in addition to super-resolution light microscopy, structural biology and high-throughput analysis of chemical substances. Three of these (within bioinformatics, light microscopy and analysis) are linked to pan-European infrastructure cooperation under ESFRI (Part 3). The research infrastructures for this sub-area are shown in Part 3.

Further investments in the field should prioritise generic infrastructures that support research in various areas (agriculture, marine, health, industrial processes), as well as infrastructures with many users.

Future investments in research infrastructure in the field should give priority to upgrading and further developing well-functioning infrastructures that have already been established, as well as ensuring good utilisation of these. At the same time, it is important that new infrastructures of high strategic importance can be financed.

Data-driven and computational methods will to a greater extent influence biotechnological research and innovation in the years to come. Machine learning and artificial intelligence are becoming increasingly important in research and development in the life sciences and biotechnology. It is therefore important to maintain the necessary capacity for services to be able to handle and utilise large amounts of data produced in modern biotechnology. It is important to support infrastructure that supports national initiatives in the field, such as Digital Life Norway (DLN) has a coordinating role for infrastructures in the field.

In the interfaces with medicine, there is a need for infrastructures that support initiatives in personalised medicine and health industry. The establishment of such infrastructure will support medical needs and Norwegian industry in drug development and biopharmaceutical production.

Health and medicine

Health and medicine encompasses the broad spectrum of basic, clinical and community-related medical and dental sciences in addition to pharmacy and health-related psychology. The research contributes to new knowledge within the entire spectrum from health surveillance, health-promoting measures and prevention via diagnostics, treatment and rehabilitation of disease to organisation and streamlining of the health and care services.

Better health and health services and reducing social inequalities in health is a main goal of health and research policy. In the Long-term plan, the objectives are elaborated on in the thematic priority "Health", which is highlighted as a particularly important area in our time due to the handling of the coronavirus pandemic, and the importance of basic research and innovation in the health area.

The objectives of the national research and innovation strategy HelseOmsorg21 are good public health, groundbreaking research, and more business development. Main priorities include: knowledge promotion for the municipalities, health and care as an industrial policy initiative, better utilisation of health data and increased internationalisation of research.

Future research in medicine and health will be affected by increased generation of large amounts of data. Therefore, it becomes important to have infrastructure for data storage, management and analysis of large amounts of data. The handling of sensitive personal data is a particular need in the health sector. In the European healthcare landscape, the focus is on standardisation, integration with national infrastructures, implementation of GDPR and cloud services to manage data storage and analysis (ESFRI Roadmap7).

In order to meet future (public) health challenges, it is important to collaborate across the health sector and between actors, interdisciplinary and cross-sectoral research, as well as competence and career development. To solve the R&D challenges within health and medicine, we depend on access to basic research infrastructures also in the field of other disciplines, such as materials science and nanotechnology. In light of future societal needs and public health challenges it is important to invest in research in the field of preventive health and future therapies – development and use of new technologies to enable effective treatment of diseases (ESFRI roadmap7).

Interdisciplinary research in a One Health perspective – the interaction between public health, animal health, plant health, food production and the environment – is central to illuminating and combating several future health challenges, both nationally and internationally. This approach will help to: fight infections/pandemics and antibiotic resistance (JPIAMR), to shed light on the environmental impact of ageing and to develop sustainable health services.

A strategic priority area in medicine and health, both internationally and nationally, is personalised medicine (precision medicine), both in prevention, diagnostics and treatment of diseases. All 'omics' technologies are important for the further development of personalised medicine. Here, artificial intelligence can also contribute as an important tool for further development of the field through focus on imaging technologies, but also the integration of data to strengthen the clinical use of precision medicine in Norway.

The Government's Hurdal platform highlights the need to exploit the health industry's potential for value creation, exports and employment. Norway has research environments that reach well in an EU context. It is important to ensure that infrastructure is in place to ensure increased employment and value creation in the Norwegian health industry in the future.

The infrastructure landscape today and in the future

This area includes infrastructures for clinical trials in the primary and specialist health services, health registries and biobanks, as well as technology platforms related to bioinformatics/systems biology, gene sequencing and various 'omics' techniques, NMR analyses and other imaging technologies and structural determinations. Norway is part of major European initiatives in the fields of imaging technologies, clinical research and biobanks.

There is an increasing need for cooperation across research infrastructures, both in health and medicine and with infrastructures in other areas, such as biotechnology, nanotechnology and advanced materials. At the same time, there is a great need for powerful ICT tools with high-performance computing capacity and for interaction between existing e-infrastructure for health data. This is important for competence building, and within health data it is particularly important to have national cooperation for better utilization of sensitive personal data, especially for large 'omics' data for personalized medicine. It is very important that all infrastructures for sensitive personal data have privacy by design and that trust and ethical aspects are handled to the highest standards. Specifically, national coordination of consent management and dialogue with participants in surveys and

studies is also important. Cooperation with European research infrastructures will also be important in the future, at the same time as Norwegian infrastructures must be adapted to international standards and facilitate international cooperation in connection with both new purchases and upgrades of national infrastructure. In an international perspective, the European Health Data Space may entail a need for data management that should also be addressed at national level.

There is also a need for infrastructure for data on pathogenic microorganisms' genomes, spread and infection routes for research on antibiotic resistance in a one-health perspective. Here it is important to share data across sectors, which can provide valuable knowledge related to e.g. consumption habits and climate change. This is also important from a societal security perspective, where an interdisciplinary approach to social science and humanities perspectives is required. Preparedness for and management of crises are described in the priority 'societal security and emergency preparedness' (the Long-term plan), and are related to e.g. the management of pandemics and antimicrobial resistance (AMR).

High-quality clinical research is a prerequisite for new knowledge to be developed and implemented in clinical practice. In Norway, there is a need for infrastructure that covers the entire spectrum from basic up to clinical research.

With rapid technological development and high expectations for what the health service should offer, the development of infrastructure for personalised medicine (precision medicine) is becoming increasingly important. In order for Norwegian research to assert itself internationally and contribute to the development of new advanced therapies and personalised medicine, it is essential that Norway invest in infrastructure that enables systemic medical research on the genomes, biomolecules, cells, tissues and organs of patients and patient groups. This requires close integration of life science data-driven and clinical research and infrastructure adapted for precision medicine within the breadth of medical sciences.

Humanities and Social Sciences

Humanities

The humanities encompass many different disciplines, e.g. history, philosophy, linguistics, arts, cultural sciences and comparative literature, which have in common that they seek to interpret, explain and understand human beings, human expressions and people's cultural environment. Research in the humanities plays an important role in society through the formation of knowledge, education, artistic insight and competence, the formation of public opinion, administration and policy development. It helps to ensure a broad knowledge base in the face of societal challenges.

Together with the social sciences, the humanities will provide the necessary insight into the cultural and social aspects of many of the societal challenges of our time, such as climate and environmental challenges, social and economic inequality, integration, migration and conflict, and the technological shift we are in the midst of. There is a need for greater efforts within humanities in such strategic areas as made clear in the Long-term plan through the launch of a national social mission: "Include more children and young people in education, work and society" and in the white paper Humanities in Norway. Among the thematic priorities in the Long-term plan, 'Societal security and emergency preparedness' and 'Trust and community' stand out as two priorities where the humanities and social sciences are particularly important.

The humanities contribute with research on ethical, security or other consequences of digital developments. Digital tools and technologies are thus becoming increasingly integrated into research processes in the humanities, at the same time as digitalisation and its consequences are increasingly topics for research. This applies not least to artificial intelligence (AI), which has an important place in the humanities in the development of technology for language, sound and image. The rapid and far-reaching development of AI in all areas of society will entail new research needs and challenges, such as the emergence of a number of ethical and legal challenges, e.g. in terms of democracy, trust, freedom of expression and the public sphere, and in the arts and culture field.

Jurisprudential issues related to privacy or copyright concern many research infrastructures within the humanities. Some examples that can be mentioned are the need for handling, quality assurance and sharing of collected video and image data in accordance with privacy requirements or video, image and audio data in accordance with copyright requirements and possible challenges in reuse. It is therefore important to have competence related to the FAIR principles in order to make such data FAIR.

The infrastructure landscape today and in the future

The infrastructures within the humanities are described in Part 3, and make available the extensive collections found in the university and university college and ABM sectors (archives, libraries and museums), and which enable interdisciplinary collaboration. A number of infrastructures adapted for linguistics have also been established, such as INESS (Infrastructure for the Exploration of Syntax and Semantics), MENOTEC (Medieval Norwegian Text Corpus), and LIA (Language Infrastructure made Accessible). CLARINO, the Norwegian node in the ESFRI project CLARIN (Common Language Resources and Technology Infrastructure), is also used by linguists, but may be relevant for other disciplines within the social sciences, including psychology and media and information science. Some infrastructure in other areas may also be relevant for humanities research, for example infrastructure for materials characterisation.

The need for the future will be better coordination and coordination between already established data infrastructures within the humanities and across disciplines and sectors. This is to ensure long-term interaction and reuse of data ("I" and "R" in the FAIR principles) in the services being developed. This is clearly highlighted in the Long-term plan. It is also important to use international standards in order to coordinate digital infrastructures both nationally and internationally.

The report Follow-up of evaluation of research in the humanities in Norway recommends a clearer focus on digitalisation and infrastructure for the humanities. Much of the research infrastructure needs in the humanities are directed towards collections and digitisation of these, in addition to digitalisation in general, standardisation, systematisation, linking and making data available through open archives and databases. There is also an increasing need for long-term storage of large amounts of data and high-performance computing facilities. The rapid development of AI depends on such supercomputers.

There is a growing need for access to, and analysis of, fresh and real-time data, such as language data, websites, online newspapers and content from social media that is harvested continuously. In addition, it will provide great added value to be able to harvest user-generated content and data for increased knowledge about the use of e.g. learning materials and learning platforms. The same applies to registry data and the need to share the large scope of registry data. All this will entail, among other things, ethical issues.

In some research areas, it will be necessary to have access to high-tech and expensive equipment to conduct high-quality research. Examples of this are archaeology and conservation, where analysis of finds requires advanced instruments, or linguistics, where cognitive research laboratories will make it possible to conduct neurological and psychological tests of language users.

Social sciences

The social sciences develop knowledge about how people and society interact in an increasingly complex world. This knowledge must be updated in pace with changes in the economy, demographics, technology and restructuring in the labour market and business sector. This presupposes that it is possible to access and share data that provide a basis for research, administration and policy.

Perspectives from the social sciences and humanities play an important role in a number of areas if we are to solve the major sustainability and social challenges we face. The Long-term plan also emphasises the need for social science perspectives, including legal perspectives, in order to further develop our understanding of, for example, how marine and coastal areas should be managed holistically. The major technological advances that are continuously taking place require sound and appropriate regulations, in which social science research will provide important knowledge.

The social sciences can contribute with research on how different emergency preparedness measures are understood and handled by different social groups, and how different groups understand and relate to risk in different situations. This is of great importance for how emergency preparedness works in the situation it is supposed to resolve. Social research also contributes to understanding the consequences of - and - evaluating public development and innovation projects.

In order to strengthen research on democracy, governance and renewal, and the research requested in the Long-term plan on trust, inclusion, societal security and emergency preparedness, it is important to facilitate increased use of experimental methods, longitudinal studies, and coordinated data collection in groups with different roles in society and public administration. Norway is known to have extensive registers with high-quality data on the entire population. Accessible infrastructure will provide opportunities for research of high relevance to society, e.g. by facilitating studies of major societal challenges related to democracy, education, business and industry, governance and administration. More concretely, such research can provide important knowledge about issues related to: climate and environmental challenges, the Norwegian working life and welfare model, migration, reforms and innovation in the public sector, participation in education and society, extremism, security, human rights and various forms of inequality. This is a necessary part of the knowledge base for policy development and for further development of the welfare society. Such research enables us to better understand trends in society and meet national and global challenges with targeted and effective measures, and will be relevant to the national social mission: "Include more children and young people in education, work and society".

The infrastructure landscape today and in the future

As shown in part 3, the Research Council has made several investments in infrastructures through INFRASTRUKTUR to upgrade services related to depositing, curating and making research data available. The Norwegian Open Research Data Infrastructure (NORDi) project is an example of this. The social science ESFRI projects European Social Survey (ESS) and Council of European Social Science Data Archives (CESSDA) give researchers access to data across national borders.

In the time ahead, there will be a need for better interaction and coordination between infrastructures, institutions and sectors. It will also be of great importance to maintain and further develop infrastructures for data storage and accessibility.

It will be important to exploit the opportunities provided by digitalisation and larger amounts of data. There are several research infrastructures that facilitate the collection, quality assurance and sharing of different types of data. Nevertheless, major tasks remain to be done to further develop these and facilitate standardisation, increased access and efficient reuse of the data stored there. In addition, it is important to further develop data infrastructure in order to exploit opportunities to generate data in new ways by, among other things, facilitating new research methods, the use of new technology, social media and large amounts of data. Today, there are a number of legal challenges related to sensitive personal data and GDPR, and there is a need for better systems for data storage of this type of data.

In connection with crisis management and emergency preparedness, it is particularly important to have access to data across sectors, which in turn can have legal and ethical challenges. It is important to facilitate access to industrial data and commercial data, which may entail the use and development of ICT technology for, for example, encryption and anonymisation of such data.

Part 3: Description of research infrastructures under establishment or operation

Research infrastructures in Europe

For many decades, Norwegian researchers have participated actively in international research organisations. The cooperation in these organisations is based on international agreements where the fees for each member state are determined on the basis of a contractual calculation key where the gross domestic product or equivalent is a main factor. Table 1 shows which Norwegian memberships of international research organisations receive funding from the ministries.

Table 1 Norwegian participation in international research organisations funded by the ministries

Infrastructure short names	Project	Status

CERN	https://www.home.cern/	Member from 1954
EMBL/EMBC	European Molecular Biology Laboratory The European Molecular Biology Conference	Member since 1985
ESA	European Space Agency	Member since 1987
ESRF	European Synchrotron Radiation Facility	Member from 1989
IARC	International Agency for Research on Cancer	Member since 1987
OECD Halden	The Halden Project	Established 1958

Table 2 Norwegian membership of pan-European research infrastructures.

Short name(Legal entity)	Name	Status	Department
Technology and Science			
EISCAT 3D	European Next Generation Incoherent Scatter radar European Incoherent Scatter Scientific Association	SE is the host country. Member of EISCAT from 1975.	KD
ESS ERIC	European Spallation Source	SE and DK are host countries	KD
ESRF – EBS	European Synchrotron Radiation Facility – Extremely Brilliant Source	FR is the host country	KD
ECCSEL ERIC	European Carbon Dioxide Capture and Storage Laboratory Infrastructure	NO is the host country	OED
Euro Argo ERIC	European contribution to the Argo program	FR is the host country	NFD
EMSO ERIC	The European Multidisciplinary Seafloor and water column Observatory	IT is the host country	KLD
ICOS ERIC	Integrated Carbon Observation System	FI is the host country	KLD
EPOS ERIC	European Plate Observing System	IT is the host country	KD
SIOSSvalbard AS https://sios-svalbard.org/	Svalbard Integrated Arctic Earth Observing System	NO is the host country	KD
ACTRIS ERIC	The Aerosol, Clouds and Trace Gases Research Infrastructure	FI is the host country	KLD
Life Science and Health			
ELIXIR (EMBL)	European infrastructure for biological information, supporting life science research and its translation to medicine, agriculture, bioindustries and society	UK is host country	KD
BBMRI ERIC	Biobanking and Biomolecular Resources Research Infrastructure	The AU is the host country	HOD
EATRIS ERIC	European Advanced Translational Research Infrastructure in Medicine	NL is the host country	HOD
EU OPENSCREENERIC https://www.eu-openscreen.eu/	European Infrastructure of Open Screening Platforms for Chemical Biology	DE is the host country	KD
ECRIN ERIC	European Clinical Research Infrastructures Network	FR is the host country	HOD
Euro-Bioimaging ERIC	Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences	FI is the host country	KD
EMBRC ERIChttps://www.embrc.eu/	European Marine Biological Resource Centre	FR is the host country	NFD
Humanities and Social Sciences			
CLARIN ERIC	Common Language Resources and Technology Infrastructure	NL is the host country	KD
ESSurvey ERIC	European Social Survey	UK is host country	KD
CESSDA ERIC	Council of European Social Science Data Archives	NO is the host country	KD

National research infrastructures per sub-area

Table 3 - Information and communication technology

Name/short name of infrastructure	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
eX3	Experimental Infrastructure for Exploration of Exascale Computing	2017	Under funding	https://www.ex3.si
NAIC	Norwegian Artificial Intelligence Cloudhttps://prosjektbanken.forskningsradet.no/project/FORISS/322336	2022	Under funding	
NorNet	Norwegian Infrastructure for NetwOrk Experimentation	2011	Fully funded	https://www.nntb.n
ReRaNP	Reconfigurable Radio Network Platform	2015	Under funding	Reconfigurable Rad WISENET (uia.no)
Sigma2	E-INFRA 2020 - A National e-infrastructure for Science	2023	Under funding	https://www.sigma2

Table 4 – Material-, process technology and basic natural sciences

Name/short name of infrastructure	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
European Organization for Nuclear Research (CERN)	Enabling LHC Physics at Extreme Collision Rates II	2023	ESFRI Landmark	https://home.cern/
European Incoherent SCATter (EISCAT)	EISCAT_3D Norway 2014	2015	ESFRI Landmark	https://eiscat.se/
European Spallation Source ERIC (ESS)	ESS ERIC (European Spallation Source)	2015	ESFRI Landmark	https://europeanspallationsource.se/
HUNT-Neutron irradiation laboratory	Competence Hub for Neutron Technology	2022	Under funding	
Infrastructure for space physics related research on Svalbard	Infrastructure for space physics related research on Svalbard	2010	Fully funded	
MANULAB	ManuLab – Norwegian Manufacturing Research Laboratory	2017	Under funding	https://manulab.org/
MIMac	Norwegian Laboratory for Mineral and Materials Characterisation	2017	Under funding	https://www.ntnu.edu/mimac/project-infrastructure
National Surface and Interface Characterisation Laboratory	National Surface and Interface Characterisation Laboratory	2015	Fully funded	NICE (nicesurface.no)
NcNeutron	NcNeutron – Norwegian Center for Neutron Research	2016	Under funding	https://ife.no/en/project/ncneutron-norwegian-center-for-neutron-research/
NorFab	Norwegian Micro- and Nanofabrication Facility III B	2022	Under funding	https://www.norfab.no/
NORTEM	The Norwegian Centre for Transmission	2022	Under	https://nortem.no/

	Electron Microscopy II		funding	
OSCAR	New Generation Scintillator Detectors for Nuclear Research in Norway	2015	Under funding	https://www.mn.uio.no/fysikk/english/research/about/infrastructure/ocl/
RECX	Norwegian Centre for X-ray Diffraction, Scattering and Imaging Resource Centre X-rays	2011	Fully funded	http://www.recx.no/
TEMP	Transition to Sustainable Resource Efficiency in Metal Production and Recycling	2022	Under funding	TEMP - Transition to Sustainable Resource Efficiency in Metal Production and Recycling (sintef.no)

Table 5 - Energy and future energy systems

Name/short name of infrastructure	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
BIGCCS Laboratory	BIGCCS Laboratory	2010	Fully funded	BIGCCS (sintef.no)
ECCSEL Australia	ECCSEL Norway CCS RI – Phase 2 – The Norwegian Node of ECCSEL	2016	ESFRI Landmark	https://www.eccsel.org/
ELPOWERLAB	Future distribution and transmission electrical grid components lab	2018	Under funding	https://www.sintef.no/projectweb/elpowerlab/
HighEFFLab	National Laboratories for an Energy Efficient Industry	2017	Under funding	https://www.sintef.no/projectweb/highefflab/
HydroCen Labs	Norwegian Research Centre for Hydropower Technology Laboratories	2019	Under funding	https://www.ntnu.edu/hydrocen/hydrocen-laboratories
NABLA	Norwegian Advanced Battery Laboratory	2021	Under funding	Norwegian Advanced Battery Laboratory Infrastructure (NABLA) - Universitetet i Agder (uia.no)
NorPALabs	Norwegian P&A Laboratories	2019	Under funding	https://norpalabs.no/
Norwegian Fuel Cell and Hydrogen Centre	Norwegian Fuel Cell and Hydrogen Centre	2016	Under funding	Norwegian Fuel Cell and Hydrogen Centre (sintef.no)
Norwegian Infrastructure for Multiphase Flows	Norwegian Infrastructure for Multiphase Flows	2022	Under funding	INFRASTRUCTURE: Tiller Multiphase Flow Laboratory - SINTEF
NSST	Norwegian laboratory for silicon-based solar cell technology	2015	Under funding	https://www.sintef.no/projectweb/solarlab/
OBLO-NOWERI	Norwegian Offshore Wind Energy Research Infrastructure – Offshore Boundary Layer Observatory (OBLO)	2013	Fully funded	https://oblo.w.uib.no/
OpenLab Drilling	OpenLab Drilling	2015	Under funding	https://openlab.app/
Research infrastructure for environmental design of renewable energy research in Ceren.	Research infrastructure for environmental design of renewable energy research in Cedren	2014	Fully funded	CEDREN - About CEDREN
SAFFT	SAFFT - Shearing, fracturing and flow in geomaterials related to petroleum reservoirs, CO2 storage and geothermal energy production	2014	Fully funded	
SBHUB	Smart Building Hub – Norwegian e-Infrastructure for energy-flexible and healthy buildings	2022	Under funding	Smart Building Hub - SINTEF
Smart Grid	National Smart Grid Laboratory & Demonstration Platform	2014	Under funding	https://www.ntnu.edu/smartgrid
		2020	Fully funded	
ULLRIGG	Laboratory upgrade of Ullrigg Drilling and Well Centre	2012	Fully funded	https://ullrigg.norceresearch.no/
ZEB Lab	Norwegian Zero Emission Building Laboratory	2015	Under funding	https://zeblab.no/

Table 6 - Earth science, oceans, climate and environment

Name/short name of infrastructure	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
ACTRIS Australia	Aerosol, Clouds, and Trace gases Research InfraStructure in Norway	2022	ESFRI Landmark	https://www.actris.eu/
Advanced mobile broad-band seismic stations	Advanced mobile broad-band seismic stations	2011	Fully funded	
Arctic ABC	Arctic ABC Development	2016	Under funding	https://www.mare-incognitum.no/arctic-abc/
AVIT	AVIT - updgrading and development of the NTNU membrane laboratory for environmental applications	2009	Fully funded	
COAT	Climate-Ecological Observatory for Arctic Tundra	2016	Under funding	https://www.coat.no/
Digital Ocean Space - Møre Ocean Lab	The Digital Ocean Space - Møre Ocean Lab	2022	Under funding	
EARTHLAB	Earth Surface sediment Laboratory	2014	Fully funded	EARTHLAB | University of Bergen (uib.no)
EMBRC Norway	EMBRC Norway – The Norwegian Node of the European Marine Biological Resource Centre	2019	ESFRI Landmark	https://www.embrc.eu/
EPOS Norway	European Plate Observing System - Norway	2016	ESFRI Landmark	
FARLAB	Facility for advanced isotopic research and monitoring of weather, climate, and biogeochemical cycling)	2015	Fully funded	https://www.uib.no/en/FARLABhttps://www.uib.no/en/FARLABhttps://www.uib.no/en/FARLAB
Goldschmidt Laboratory	THE GOLDSCHMIDT LABORATORY I Infrastructure for geochronological characterization of solid earth materials	2021	Under funding	https://www.mn.uio.no/geo/english/research/goldschmidt/
G3	Geosystem 3-D Seismic Imaging (G3)	2010	Fully funded	
ICOS Norway	Norway Integrated Carbon Observation System	2021	ESFRI Landmark	https://www.icos-cp.eu/
INES (NorESM)	Infrastructure for Norwegian Earth System modelling	2018	Under	https://nordicesm.bitbucket.io/

			funding	
LoVe	Lofoten-Vesterålen cabled observatory	2015	Under funding	https://loveocean.no/
MARINTEK	The Marine Technology Laboratories- Required Upgrading and Developments	2016	Under funding	https://www.sintef.no/en/ocean
Motion Laboratory	Movement laboratory	2015	Fully funded	motion-lab – Norwegian Motion Laboratory
NGTS	Norwegian geotest sites	2016	Under funding	http://www.geotestsite.no/
NMDC	Norwegian Marine Data Centre	2012	Fully funded	https://nmdc.no/om-prosjektet/norwegian-marine-data-centre-nmdc-
NorArgo	A Norwegian Argo Infrastructure - a contribution to the European and global Argo infrastructure	2018	ESFRI Landmark	https://norargo.hi.no/
NorBol	Norwegian Barcode of Life Network	2014	Fully funded	https://www.norbol.org/
NorDataNet	Norwegian Scientific Data Network	2015	Under funding	https://www.nordatanet.no/
NorEMSO	The Norwegian node for the European Multidisciplinary Seafloor and water column Observatory	2020	ESFRI Landmark	https://emso.eu/
NORMAP	Norwegian Satellite Earth Observation Database for Marine and Polar Research	2010	Fully funded	
NORMAR	Norwegian Marine Robotics Facility - Remotely Operated Vehicle for Deep Marine Research	2014	Fully funded	https://www.uib.no/geo/128110/%C3%A6gir6000-rov
Norwegian Atlantic Current Observatory	Norwegian Atlantic Current Observatory	2010	Fully funded	The Norwegian Atlantic Current Observatory | Physical Oceanography | See also
NorSOOP	Norwegian Ships Of Opportunity Program for marine and atmospheric research	2018	Under funding	https://www.norsoop.com/
OceanLab	Ocean Space Field Laboratory Trondheimsfjorden	2019	Under funding	https://oceanlabobservatory.no/
Real time climate observations at the position of weather ship Mike	Real time climate observations at the position of weather ship Mike	2010	Fully funded	
Research Infrastructure for High-Precision Palaeoecological Analyses	Research Infrastructure for High-Precision Palaeoecological Analyses	2010	Fully funded	Palaeoecological Lab AVIT | Ecological and Environmental Change Research Group | See also
SeaBee	Norwegian Infrastructure for drone-based research, mapping and monitoring in the coastal zone	2020	Under funding	https://seabee.no/
SIOS KC	Svalbard Integrated Arctic Earth Observing System - Knowledge Centre, operational phase 2022	2022	Under funding	https://www.sios-svalbard.org/
The Oslo Geomagnetic Laboratory	The Oslo Geomagnetic Laboratory	2014	Fully funded	
Tone	Troll Observing Network	2022	Under funding	Troll Observation Network (TONe) – Norwegian Polar Institute (npolar.no)

Table 7 - Bioresources

Infrastructure name	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
Aquafeed Technology Centre	Aquafeed Technology Centre	2016	Fully funded	https://aquafeed.science
The NORwegian CELlulose laboratory	The NORwegian CELlulose laboratory	2022	Under funding	
Norwegian BioCentre (NBioC)	Norwegian Bioprocessing & Fermentation Centre-NBioC	2018	Under funding	Home - NBioC
Norwegian Biorefinery Laboratory (NorBioLab)	Norwegian Biorefinery Laboratory	2017	Under funding	norbiolab.no | Norwegian Biorefinery Laboratory
FoodPilotPlant	FoodPilotPlant Norway: Upgrading of the Pilot Plant	2020	Under funding	Food Pilot Plant | NMBU
PLANKTONLAB	Norwegian Center for Plankton Technology	2016	Under funding	Norwegian Centre for Plankton Technology - SINTEF
SEAWEED	Norwegian Test Center for Seaweed Cultivation and Utilization Technologies	2022	Under funding	Norwegian Seaweed Technology Center - SINTEF

Table 8 - Biotechnology

Infrastructure name	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
ELIXIR Australia	ELIXIR3 - Strengthening the Norwegian Node of ELIXIR	2022	ESFRI Landmark	ELIXIR Norway - Elixir NorwayELIXIR Norway - Elixir Norwayhttps://elixir.no/ ELIXIR | A distributed infrastructure for life-science information (elixir-europe.org)ELIXIR | A distributed infrastructure for life-science information (elixir-europe.org)https://elixir-europe.org/
LIPIDPLATFORM	Marine biochemical engineering- LIPIDPLATFORM	2009	Fully funded	
National Consortium for Sequencing and Personalized Medicine (NorSeq)	National consortium for sequencing and personalized medicine	2,017	Under funding	Norseq4
Network of Advanced Proteomics Infrastructure (NAPI)	National network of Advanced Proteomics	2,020	Under funding	Home - NAPI (uio.no)
Norwegian Advanced Light Microscopy Imaging Network (NALMIN)	Norwegian Advanced Light Microscopy Imaging Network Phase II (NALMIN-II)	2022	ESFRI Landmark	Norwegian Advanced Light Microscopy Imaging Network (NALMIN) – NALMINhttps://nalmin.no/
NOR-OPENSCREEN - the Norwegian EU-OPENSCREEN node	NOR-OPENSCREEN - the Norwegian EU-OPENSCREEN node	2016	ESFRI Landmark	Home - Openscreen (uio.no)
Norwegian Macromolecular Crystallography Consortium (NORCRYST)	Norwegian Macromolecular Crystallography Consortium	2,016	Under funding	NORCRYST (uit.no)

The Norwegian NMR Platform (NNP)	The Norwegian NMR (Nuclear Magnetic Resonance) Platform 2	2,020	Under funding	NMR (Nuclear Magnetic Resonance) Laboratory - Faculty of Natural Sciences - NTNU
NSC	The Norwegian Sequencing Centre - Phase II	2021	Done finansayst	NSC – Sequencing (uio.no)

Table 9 - Health and medicine

Infrastructure name	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
Biobank Norway – National node in BBMRI	Biobank Norway 4 - a national biobank research infrastructure	2022	ESFRI Landmark	Front page | Biobank Norway (bbmri.no)Front page | Biobank Norway (bbmri.no)https://bbmri.no/ Home - BBMRI-ERIC: Making New Treatments PossibleHome - BBMRI-ERIC: Making New Treatments Possiblehttps://www.bbmri-eric.eu/
Health Registries for Research	Health Registries for Research	2014	Fully funded	https://hrr.w.uib.no/
National Health Analysis Platform for Research	National Health Analysis Platform	2018	Fully funded	The Health Analytics Platform - eHealth
NORBRAIN – Norwegian brain initiative: a large-scale infrastructure for 21st century neuroscience	Norwegain Brain Initiative (NORBRAIN) Stage 2	2015	Under funding	Norbrain
NorCRIN – Norwegian Clinical Research Infrastructure Network	Continuation and strengthening of the Norwegian Clinical Research Infrastructure Network (NorCRIN) - "NorCRIN 2"	2020	ESFRI Landmark	Frontpage - www.norcrin.no
NorMIT – Norwegian centre for minimally invasive image guided therapy and medical technologies	Norwegian centre for Minimally invasive Image guided Therapy and medical technologies	2014	Under funding	NorMIT
NORMOLIM – Norwegian Molecular Imaging Infrastructure – National node in Euro-BioImaging	Norwegian Molecular Imaging Infrastructure	2018	ESFRI Landmark	Euro Bioimaging
PCRN – The Norwegian Primary Care Research Network	The Norwegian Primary Care Research Network	2018	Under funding	The Norwegian Primary Care Research Network | Department of Global Public Health and Primary Care | See also

Table 10 - Humanities

Name/short name of infrastructure	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
ADED	Archaeological Digital Excavation Documentation	2018	Under funding	https://www.khm.uio.no/forskning/prosjekter/aded/
CLARINO	Common Language Resources Infrastructure Norway Upgrade	2020	ESFRI Landmark	https://clarin.w.uib.no/
Digital corpus and dictionary of Norwegian Medieval Latin	Digital corpus and dictionary of Norwegian Medieval Latin	2022	Fully funded	Digital corpus and dictionary of Norwegian Medieval Latin | National Library of Norway (nb.no)
fourMs	fourMs Lab Upgrade	2022	Under funding	https://www.uio.no/ritmo/english/research/labs/fourms/
INESS	Infrastructure for the Exploration of Syntax and Semantics	2010	Fully funded	https://clarino.uib.no/iness/page
LIA	Language Infrastructure made Accessible	2014	Under funding	http://www.tekstlab.uio.no/LIA/
MENOTEC	Medieval Norwegian Text Corpus	2010	Fully funded	https://www.menota.org/forside.xhtml
COLLECTED	SAMLA: National Infrastructure for Cultural History and Tradition Archives	2020	Under funding	https://samla.w.uib.no/

Table 11 - Social sciences

Name/short name of infrastructure	Description of the most recently awarded project in the Project Bank	Start-up last assigned project	Status	Website
ACCESS	ACCESS Life Course Database: Upgrade and Expansion	2017	Under funding	https://norlag.nsd.no/
ACDC	ACDC – Advanced Conflict Data Catalogue	2010	Fully funded	
CESSDA	CESSDA – Council of European Social Science Data Archives	2013	ESFRI Landmark	https://www.cessda.eu/
eVIR	einfrastructure for VIdeo Research	2016	Fully funded	https://www.uv.uio.no/ils/english/research/projects/evir/index.html
HISTREG	Historical Registers	2022	Under funding	https://histreg.no/
Microdata.no	National Microdata Platform for Norwegian and International Research and Analysis	2020	Under funding	https://www.microdata.no/
NORDI	Norwegian Open Research Data Infrastructure	2016	Under funding	https://sikt.no/
PSI	Peace Science Infrastructure	2023	Under funding	

Appendix 1: Principles for prioritisation and allocation under the National Financing Initiative for Research Infrastructure

Funding for infrastructure is allocated under open calls under the National Financing Initiative for Research Infrastructure. The calls for proposals will be followed by an evaluation and prioritisation process in which both scientific quality and strategic relevance are emphasised through two respective sets of criteria. If strategic considerations so warrant, more targeted calls for proposals will also be considered.

High scientific quality is decisive for whether the research infrastructure is considered worthy of funding. The application review process comprises a scientific evaluation carried out by external referees and a strategic evaluation carried out by the Research Council administration. The evaluation work carried out by the international referees assesses whether the research infrastructure will be able to contribute to research of high scientific quality. This assessment serves as an advisory basis for the Research Council's further processing of grant applications, where the Research Council administration carries out an assessment of the national importance and strategic relevance of the research infrastructure.

Points considered by the experts are:

- The research importance of the infrastructure in terms of quality and impact of the research that needs the infrastructure
- The extent to which the infrastructure contributes to promoting the internationalisation of Norwegian research
- The industry-related relevance of the infrastructure for existing industry or start-ups, contribution to the international competitive position of Norwegian industries
- The societal relevance and potential of the infrastructure to contribute to knowledge and expertise of societal importance

- The extent to which the infrastructure project is technically, competently, resource-wise and financially feasible
- The extent to which the plans for establishment and operation are well adapted to the tasks in the project
- Interaction between new infrastructure and any existing infrastructure
- The quality of the project plan and the quality of project management

In the Research Council's assessment of grant applications, the strategic guidelines set out in the call text are important. The first stage of the strategic processing of grant applications will be assessed on the basis of the following criteria:

- National importance of infrastructure
- The extent to which the infrastructure will utilise national research expertise and promote national networking
- Whether the infrastructure contributes to an appropriate national division of labour between relevant academic communities
- The extent to which the plans for establishment and operation are well adapted to the tasks in the project
- The extent to which responsibility for administrative management, establishment and operation of the infrastructure is safeguarded
- How the infrastructure is anchored institutionally and its importance in supporting strategic priorities and national strategies
- Whether good plans for making the infrastructure available to relevant users outside the host institutions exist
- Whether the infrastructure supports national business priorities (where relevant)
- Whether the infrastructure contributes to long-term competence building in research areas that are expected to be of importance to Norway
- Whether the infrastructure has strategic anchoring in the host institutions and there are plans for financing operations after the project period exists
- Whether the infrastructure is of societal relevance to Norway

The assessment criteria used by the referees and the Research Council administration respectively are summarised in more detail on the website of the call.

In the second part of the strategic assessment, the final selection of the projects recommended for funding is made. This overall assessment across disciplines and portfolios. The following points are emphasized:

- Each project addresses the priorities and overall objectives of the Government's Long-term plan for research and higher education 2023-2032 - the national importance of the research infrastructure within strategic priority areas
- Ranking and assessment from the administration panels
- Provisions in the call
- Coupling between investments in research infrastructures and research funded through the Research Council's other policy instruments. Investments must be proportionate to the scope of research and the need for research infrastructure in these areas.
- The degree of urgency to establish/continue research infrastructures
- Breadth of the portfolio: all the national priority areas should be supported over time with research infrastructures if high-quality applications are available
- International obligations, including management of host roles where Norwegian institutions have important roles in international infrastructure cooperation
- Whether there is a sufficient financial framework available to finance the project
- How well-prepared the establishment or upgrade is to achieve rapid initiation of the project

Appendix 2: Mandate for preparation of the Norwegian roadmap for research infrastructure 2023 and composition of committee

Background to the assignment

The Research Council will follow up the recommendations in the policy instrument evaluation of the National Financing Initiative for Research Infrastructure (INFRASTRUKTUR) to develop a more prioritizing roadmap that takes into account international trends, the need for new investments and upgrades of existing research infrastructures in a 15-year perspective.

According to Tools for Research – National Strategy for Research Infrastructure (2018-2025) (in Norwegian), the main purpose of the national roadmap is to highlight Norway's need for updating research infrastructure in the time ahead, within a realistic budget framework. The roadmap describes the strategic basis for the Research Council's thinking and priorities regarding research infrastructure and plays a key role in the selection of projects awarded funding.

The Research Council will update the roadmap prior to each call for proposals for funding from INFRASTRUKTUR. This edition will be the seventh in a row. There are still major unidentified needs for research infrastructure nationally. A more long-term and prioritizing roadmap will contribute to the process of achieving a good balance between investing in upgrading existing infrastructures that are still important for future research, and at the same time having room to invest in new ones.

Mission

An external committee will prepare an overall draft of the new Norwegian roadmap for research infrastructure. The composition of the committee shall ensure that the roadmap has a broad national foundation, and that professional breadth, geographical spread and gender balance are safeguarded. The main tasks of the committee will be to:

- describe the national and international infrastructure landscape and needs from a national point of view in a 15-year perspective.
- make recommendations on which of the existing infrastructures are of great value to maintain and further develop in all relevant areas.
- make recommendations on areas where it is particularly important to establish new infrastructures nationally or cooperate at international level.

The Research Council will act as secretariat for the committee, convene meetings and ensure good stakeholder involvement. The secretariat shall facilitate an open process with opportunities for input so that all relevant stakeholders can make suggestions and present their views. This should be achieved by the following involvement:

- Stakeholder input meetings: The secretariat will involve the institutions through both written and digital rounds of input on the future needs of research for research infrastructure. Input will be requested on which existing national research infrastructure they consider to be of great value to maintain and further develop, and in which areas it will be particularly important to establish new national research infrastructures or collaborate on international research infrastructures. The input will serve as supporting material for discussions in subsequent workshops.
- Workshops: Proposed candidates that the Research Council does not include in the committee will be invited to participate in thematic workshops together with representatives from relevant portfolio boards, business and industry and public administration. The division into workshops is proposed to be related to the landscape analyses in the ESFRI Roadmap 2021. The proposed structure for the new roadmap will be part of the committee's process. This classification must be related to the Research Council's strategy and the Government's long-term plan for research. The workshops will have a common agenda with the purpose of describing:
  - the need for research infrastructure to solve challenges within a strategic priority area;
  - which existing national research infrastructure they consider to be of great value to maintain and further develop
  - which thematic areas it will be particularly important to establish new national research infrastructures and/or cooperation on international research infrastructures
  - what gaps can be covered through the development of existing national and/or collaboration on/access to international research infrastructures

The summaries from the workshops will be included as a knowledge base for the committee.

The committee shall make recommendations on the following:

- In which areas do we need infrastructure to help solve challenges within the strategic priority areas
- Much of it has already been established
- In which areas there is a need for completely new research infrastructures
- Which gaps may be covered through the development of existing national research infrastructures and/or cooperation on/access to international research infrastructures
- The need for research infrastructure that applies to groundbreaking research and radical innovation is addressed, but which does not fall within priority areas
- How to achieve good interaction with business, public administration and strategic initiatives to promote innovation and regional development
- The roadmap can provide clear priorities for future allocations, and we can ensure that this does not prevent us from investing in new infrastructure that we currently do not know will be needed
- A suitable structure for the new roadmap

The Research Council will prepare the committee's draft and propose the design and content of the new roadmap. The final roadmap is decided by the Research Council's board.

Committee members

- Per Morten Sandset, Vice-Rector for Research and Innovation, UiO (committee chair)
- Camilla Brekke, Pro-Rector for Research and Development, UiT
- Trond Martin Dokken, EVP Climate and Environment, NORCE
- Øyvind Fylling-Jensen, CEO, Nofima AS
- Ole Hjortland, Vice President for Research and Dissemination, UiB
- Kristiane Marie Fjær Lindland, Vice President for Research and Innovation, Faculty of Social Sciences, UiS
- Sveinung Løset, Vice Dean for Research, NTNU
- Eli Aamot, Executive Vice President, SINTEF
- Knut K. Bjørgaas, former Deputy Director General of the Norwegian Digitalisation Agency and new Director of the land division at the Norwegian Mapping Authority
- Katrine Vinnes, Technical Director, Federation of Norwegian Industries

Knowledge foundation for new roadmap:

- National strategy for research infrastructure (2018-2025)
- Norwegian Roadmap for Research Infrastructure 2020
- ESFRI Roadmap 2021 incl. the landscape analyses
- The Government's long-term plan for research and higher education 2023-2032
- The Research Council's strategy
- The Research Council's strategy for open science
- The portfolio plans
- Report with recommendations from the Data Infrastructure Committee: Investment in data infrastructures for FAIR research data and particularly relevant management data for research. Organization and financing of data infrastructure for best utilization, May 20 22
- Report from Sikt: Infrastructure and services for FAIR research data - Status and proposals for further work Input from the institutions
- The evaluation report: Evaluation of the INFRASTRUKTUR initiative as a funding instrument
- Horizon Europe
- European research area (ERA)

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