Norwegian Roadmap for Research Infrastructure 2023

CONTENTS

PUBLISHED 04 SEP 2023

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 t 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 infrastructure and future needs to achieve better coordination of infrastructures across disciplines and technology areas. The establishment c 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 anc operating costs, and the number and types of users, the descriptions will vary somewhat in length and level of detail. There will b 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

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 objective

Long-term plan for research and higher education 2023-2032 (Long-term plan)

Long-term plan for research and higher education 2023 - 2032					
Enhancing competitiveness and innovation capacity					
Environmental, social and economic sustainability					
High quality and accessibility in research and higher education					
Oceans and coastal areas	Health	Climate, the environment and energy	Enabling and Industrial Technologies	Societal security and civil preparedness	Trust and community

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 f 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 t 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 funde 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. Tl means sharing data in a way that safeguards ethical, privacy and security considerations, while making the data available to oth researchers in a simple and accessible way – as open as possible, as closed as necessary. Achieving this requires a high degre 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 FAII data and related research services (see Part 1). The Long-term plan emphasises that Norwegian data infrastructures, services a research data must comply with the internationally established FAIR principles and be compatible with the international ones, ar 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 infrastructure 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 softwa 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 advantage 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 greer 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 emissio 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 t 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 t 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 us 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, us 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 servic 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 a 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 i 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 bas 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 challenge The internet and digital technologies are transforming not only industries, but also work processes and tasks and the dynamics 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 a 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, -administratio 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 dat 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 th user experience in various technological systems.

The eX3 research infrastructures offer an experimental heterogeneous high-performance computing facility for experimentatio 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 metho 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 artifici 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 th 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 a 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 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 radiopharmaceuticals.

Nanotechnology and advanced materials

The Long-term plan emphasises the importance of research in nanotechnology and materials technology, and the importance o 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 microtechnolog 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 suc 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 an 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 wi 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 th 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 satell 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 fo nuclear research. In order to exploit the European Spallation Source (ESS), expertise in neutron research is needed, and we hav 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 planne 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 nee 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 fo 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 t 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 neec for a broad approach in the energy transition, and for increased capacity build-up both solar and battery technology are importa 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 moı 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 th sector in a sustainable direction and to help ensure that expertise and solutions from the sector can be used in new industries. 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 cos 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 additio 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 lin 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 European project that brings together R&D infrastructures from several countries. The infrastructure has received funding from t 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 oce basin) are of great importance. Climate and environmental infrastructures, as well as generic infrastructures for high-performanc 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 researc 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 activiti based on real volumes and the complexity of the value chain. It is important to look at the development of infrastructure in Norwa 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 th 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 ne to develop technology for shipping and assembly of floating offshore wind, and for maintenance and repairs. There is also a nee 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 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 meta 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 environmen

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 adaptatior 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 tc 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 ocear land (biosphere) and atmosphere and how these interact and affect the Earth's climate. Knowledge about the carbon cycle is ke 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 fo 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 anc 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 biodiversi 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 tc be the most important source of proliferation today, and greater research efforts in this area are required to map the origin, spre 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 coordinati 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 i 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 mos 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 frienc maritime transport, and reference is made to the recommendations from the Maritim21 strategy. It states, among other things, thɑ 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- anc 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 ocear 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 cooperatior 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. Autonomou and/or mobile observation systems can play an important role here. There is also a need to link different observation systems tc 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 wate 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 acces 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 th 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 upgrad 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 anc 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 dete 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 availab and highly detailed data sources in this area. Nevertheless, there is a need for a breadth of infrastructures that together cover ar 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 i 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 a 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 perspecti 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 fores 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 ar 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 th 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 variatio 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 utiliz 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 launche 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 a 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 researc 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 enab 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 fisl 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 ar resources in marine and coastal areas. This is also prioritised at European level through the EU Mission: Restore our Ocean anc 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 c 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 Europe 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 b 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 bioeconom based on Norwegian bioresources, piloting and scaling up to industry. In addition, there are several infrastructures for utilisation 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 the future in a sustainable manner. Several of the research infrastructures within climate and environment, biotechnology, energ 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 resource 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 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 hav the potential to prepare primary production both on land and at sea, and contribute to research to meet major societal challenge 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 initiati aquaculture industries; aquaculture. When it comes to future sustainable and circular utilisation of Norwegian biomass, efficienc improvements (digitalisation, robotisation) in the use of limited bioresources are important. In the development of the bioeconom 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 f 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 publi 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 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 establish 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, marir 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 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 fro 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 researc 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 (ESF 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 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, a 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 imaging technologies, clinical research and biobanks.

There is an increasing need for cooperation across research infrastructures, both in health and medicine and with infrastructure 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 da

This is important for competence building, and within health data it is particularly important to have national cooperation for bett 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 m 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 resear on antibiotic resistance in a one-health perspective. Here it is important to share data across sectors, which can provide valuabl 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 manageme 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 Norwa 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 researc 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, tissu 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 comparativ 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 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 ir 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 t 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 psycholog and media and information science. Some infrastructure in other areas may also be relevant for humanities research, for examp 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 internatior 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 availabl 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 oth 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 knowled 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 t 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 methoc 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 glol 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 upgrad 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 Europea 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

← Previous page

Next page →