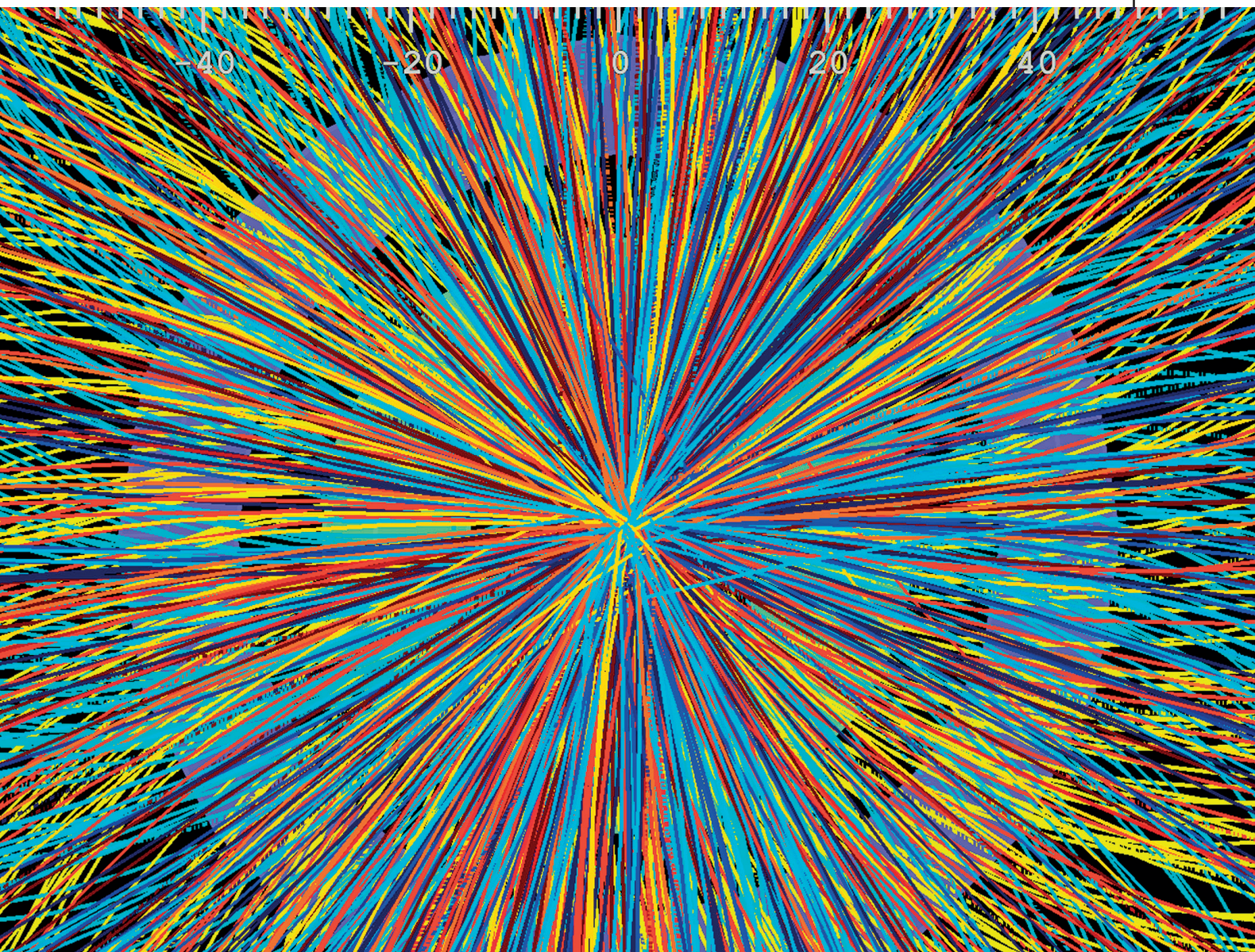
NORWEGIAN MINISTRY
OF EDUCATION AND RESEARCH

Meld. St. 7 (2014–2015) Report to the Storting (white paper)

# Long-term plan for research and higher education 2015–2024



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*Recommendation of 3 October 2014 from the Ministry of Education and Research, approved in the Council of State on the same date.*
*(White paper from the Solberg Government)*

## 1 Government policy for research and higher education

### 1.1 Introduction

The Government has high ambitions as regards the Norwegian knowledge society. In line with the Sundvolden Declaration, the Government will pursue a targeted commitment to research and higher education. Norway has many good academic environments, along with a highly developed business community in a number of areas, but we have the potential to be even better. In addition to a general commitment to quality in research and higher education, the Government will prioritise special efforts in world-class science. This is necessary to stimulate more breakthroughs and greater international visibility for Norwegian research, as well as to benefit from the knowledge found among the foremost international experts.

Knowledge and expertise are among our most important competitive factors. New insight and recognition together with capable people with sound skills form the foundation for how we deal with major social challenges. This is also the basis for facilitating value creation, both in the public and private sectors. Research and education impact the economy by enhancing the quality of the workforce and the services delivered, and enabling us to develop and adopt new solutions and products. This in turn contributes to adaptability and increased productivity. A knowledge-based approach is essential in finding solutions that can address many of the challenges facing our society. Some examples of this are a change-over to green growth and adaptation to climate change, improved health treatment methods, and how we can produce safe, healthy food. We also need knowledge that brings new recognition and helps us understand social development.

The effect of investments in research and higher education depends on how the investments are oriented. Increased investments must be arranged so they result in improved quality in research and higher education. This long-term plan outlines a framework for how the Government will reinforce research and education to meet the challenges and seize the opportunities in the Norwegian knowledge society in the period from 2015 to 2024.

## 1.2 An ambitious and predictable escalation

The Government wants to increase research and development (R&D) appropriations to 1 per cent of the gross domestic product (GDP). The objective is to increase R&D appropriations beyond the growth in GDP each year until the goal is achieved. Given the current outlook for future GDP growth, the Government aims to attain this goal in the 2019–2020 period. The Government will scale up appropriations to research and higher education within six long-term priority areas:

- Seas and oceans
- climate, environment and clean energy
- public sector renewal, better and more effective welfare, health and care services
- enabling technologies
- innovative and adaptable industry
- world-leading academic groups

As part of this commitment, the Government will augment some of the most important input factors in the research and higher education system during the period from 2015-2018. The Government will:

- fortify recruitment with 500 new positions
- increase appropriations to research infrastructure by NOK 400 million
- raise appropriations to programmes that stimulate good Norwegian participation in the EU Framework Programme for Research and Innovation, Horizon 2020, by NOK 400 million

Modern and functional building facilities with up-to-date equipment are required to achieve the objectives in the long-term plan. In its follow-up of the long-term plan, the Government will assign particular priority to two construction projects which support these long-term priorities: new building for Life Sciences, Pharmaceutics and Chemistry at the University of Oslo, and an upgrade of the Ocean Space Centre in Trondheim.

The Government will embark upon following up the long-term plan with an appropriation of more than NOK 660 million in the 2015 fiscal budget. The Government proposes targeted efforts including support for the Programme for User-driven Research-based Innovation (BIA), Commercialising R&D Results (Forny 2020) and leading global expertise based in Norway, cf. Proposition 1 S (2014–2015) for the Ministry of Education and Research.

The long-range priorities in the long-term plan are solidly anchored in national research and innovation strategies. They also have broad support in the 150 inputs on the work received from the Norwegian community, business and industry and the academic world during the development of the plan. These priorities are an expression of the Government's commitment in areas where Norway enjoys strategic advantages such as natural resources, strong industry clusters or top-notch expert communities. The resources are to be devoted to research and education at a high international level, including research and education that supports business development and productivity. The plan also contains priorities which elevate areas where there are major, unmet needs for knowledge and expertise. A common feature for all priorities is that efforts will be intensified in areas where research and higher education can make a significant contribution toward handling challenges or in creating and seizing opportunities.

## 1.3 Why does Norway need a long-term plan for research and higher education?

The long-term plan is a new tool in research and higher education policy. The long-term plan has ten-year objectives and priorities. It also contains more concrete goals for the efforts in the initial four-year plan period. The Government aims to review the long-term plan every four years.

In its publication *OECD Science, Technology and Industry Outlook 2014,* the OECD points out two typical characteristics of countries with highly-developed research and innovation systems. The first characteristic is that these countries pursue long-term investments in the knowledge base; that is to say, through investments in human resources (education, recruitment and capacity building) and equipment (such as laboratory equipment, data pooling, large-scale facilities for measurement and observation in connection with research and education). The second recurring characteristic is that these countries bolster competitiveness through prioritised efforts to address major social challenges.

Long-term, prioritised commitments create predictability and contribute to more coordinated policies for research and higher education. However, there must be a balance between the need for predictability through long-term priorities and the need for flexibility, which provides a window

for seizing opportunities we cannot foresee. If management is too detail-oriented, this could tie up resources in measures and policy instruments that impede renewal, and that do not address the problems they are intended to solve. Detailed management also impairs the ability to exploit knowledge about challenges and needs that can be found within the various academic groups. The long-term plan creates predictability in two ways. First, the long-term plan has ten-year objectives and priorities which provide clear signals for the academic community, industry and the public sector. Second, the Government is signalling a commitment to follow up the long-term plan in the annual fiscal budgets. The long-term plan contains both a concretisation of the resource input for recruitment positions, research infrastructure and instruments designed to contribute to good participation in Horizon 2020, and an ambitious goal for growth in appropriations to research and development, wherein measures to follow-up the long-term plan are to be prioritised. This provides opportunities for the business community, academia and the public sector to mobilise for cooperation. This also provides a better opportunity for a long-term perspective when these entities are to develop their own strategies and commitments.

Several parties have noted that coordination of Norwegian resource policy is not good enough, including the Office of the Auditor General, the OECD in its innovation assessment of Norway and Technopolis in connection with an evaluation of the Research Council of Norway. The long-term plan is an important tool for improving coordination and implementation of research and higher education policies. Chapter 9 of the plan addresses coordination and follow-up in greater detail.

## 1.4 Government objectives for research and higher education policy

The Government's objective is to earmark 3 per cent of GDP for research and development by 2030. Public R&D funding will be raised to 1 per cent of GDP. Long-term, predictable frameworks for public funding will also be geared toward facilitating more R&D in business and industry.

Previous white papers on Norwegian research policy have provided a general outline of the Norwegian research system. Report No. 30 (2008–2009) to the Storting *Climate for Research* listed

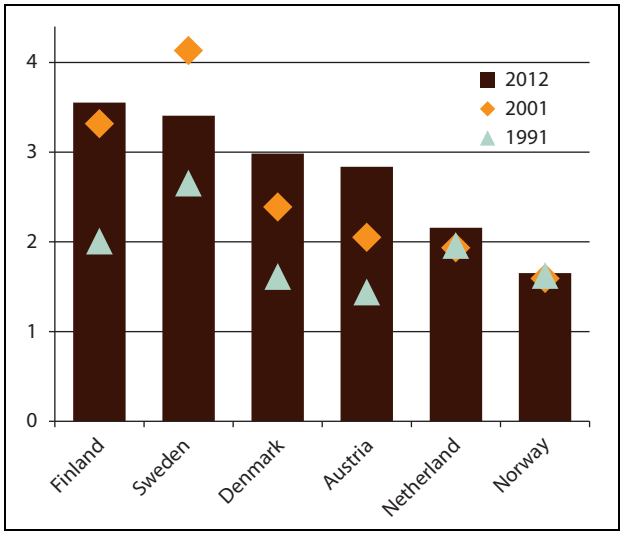


Figure 1.1 Total R&D expenses as a percentage of GDP

Source: *OECD Main Science and Technology Indicators 2014-1*

nine objectives for Norwegian research: five strategic objectives and four overarching objectives. The strategic objectives represent global challenges, better health and health services, research-based welfare policy and professional practice, knowledge-based industry throughout the country, as well as industry-relevant research in strategic areas. The four integrated objectives are a well-functioning research system, high-quality research, internationalisation of research and efficient use of results and resources. These goals were continued in the white paper *Long-term perspectives – knowledge provides opportunity* (Meld. St. 18 (2012–2013)).

The Government has set three overarching objectives for the long-term plan for research and higher education. These are consistent with the objectives in the two previously mentioned research white papers, but the long term planfurther elaborates the priorities for which areas will receive greater focus. The priorities for research and higher education are also linked more closely. The three objectives are:

- enhanced competitiveness and innovation
- tackling major social challenges
- developing research communities of outstanding quality

The objectives are inter-connected. Development of products, processes or solutions that contribute to addressing major social challenges can, in many cases, also be a springboard for business development, improved profitability and greater innovation. Furthermore, the effects will be mag-

nified by access to excellent candidates and cooperation with world-renowned expert communities.

*Enhanced competitiveness and innovation capacity*

Skills and knowledge-based assets are important competitive factors for the Norwegian economy. This is true for all modern economies, but is a particularly prominent factor in Norway because our cost level is far higher than that of our trade partners. The ability to develop, absorb and apply knowledge is a significant competitive factor. In many cases, we cannot be the cheapest, but we can work smarter and we can compete on products and solutions that deliver a level of quality which in turn warrants a higher price. This applies both for industry as well as the public sector. Norwegian industry needs innovation and adaptability to secure jobs and value creation in the future. The public sector needs innovation and adaptability to reinvent itself and deliver good social welfare services that society can afford to fund in the future. The Government will therefore prioritise resources for research and higher education that contribute to the objective of competitiveness and innovation within all of the priorities in the long-term plan.

Research on economic development and private investments in R&D reveal that public support plays a substantial role. The business community tends to under-invest in R&D without public investments, due to factors related to market failure and system failure. Frequently cited examples are high risk, the need for a long-term perspective, the fact that gains resulting from R&D often devolve to others, including competitors, and the intrinsic unpredictability of research results. The Government's point of departure is, nevertheless, that enterprises are the best judge of their R&D investments as regards their own competitiveness.

The Government allocates public investments to institutions that conduct research, such as universities, university colleges and institutes. These entities carry out fundamental and applied research with a long-term perspective, and train competent experts for posts e.g. in the business community. Public investments must also contribute toward making it more attractive for business and industry to invest in research and development. This may include programmes that reduce risk and stimulate research and development in the business community, such as programmes that promote cooperation between universities and university colleges and the business sector, and programmes that foster research excellence with relevance for business and industry. Programmes that stimulate growth of new enterprises and economic adaptation are also needed.

*Tackling major social challenges*

Many countries pursue targeted research and higher education that will contribute to addressing major challenges facing society. This is also the case in the European research and innovation programme called Horizon 2020. Global challenges such as climate change, security and preparedness, disease and epidemics, safe access to energy, water and food are huge and complex. The challenges posed by changing demographics will put the welfare state under pressure. Addressing these social challenges will require coordinated efforts across various professional communities and sectors, as well as international cooperation.

While these are comprehensive global challenges, the problems can often be specific and local. For example, municipalities must care for a growing percentage of elderly citizens who require care. Investing in new care facilities is a traditional approach. However, if good options are available for sound and effective home-based services, the municipality may be able to help its elderly population to achieve better, more active years in their own homes, while saving on investments in new buildings. New solutions are also important in being able to work smarter and more effectively in maintaining sound welfare, health and care services. Such solutions can be created through smart application of new technology.

Knowledge is put to use where people, organisations and cultures meet. The success of new solutions, whether they involve change, adaptation or new technology, requires a wide range of perspectives from the humanities, health and care disciplines and social science. This is crucial in achieving greater understanding of which solutions can actually be implemented in our society, and how this can best be accomplished.

Norway must be prepared for the challenges we will encounter, but we must also see the opportunities that arise as a result of this development. For example, climate change and environmental impact are some of the most comprehensive challenges we face in the next few decades. We must understand and adapt to the upheavals which will come, and we need new knowledge and technology to reduce emissions. The demand for change creates opportunities for business development

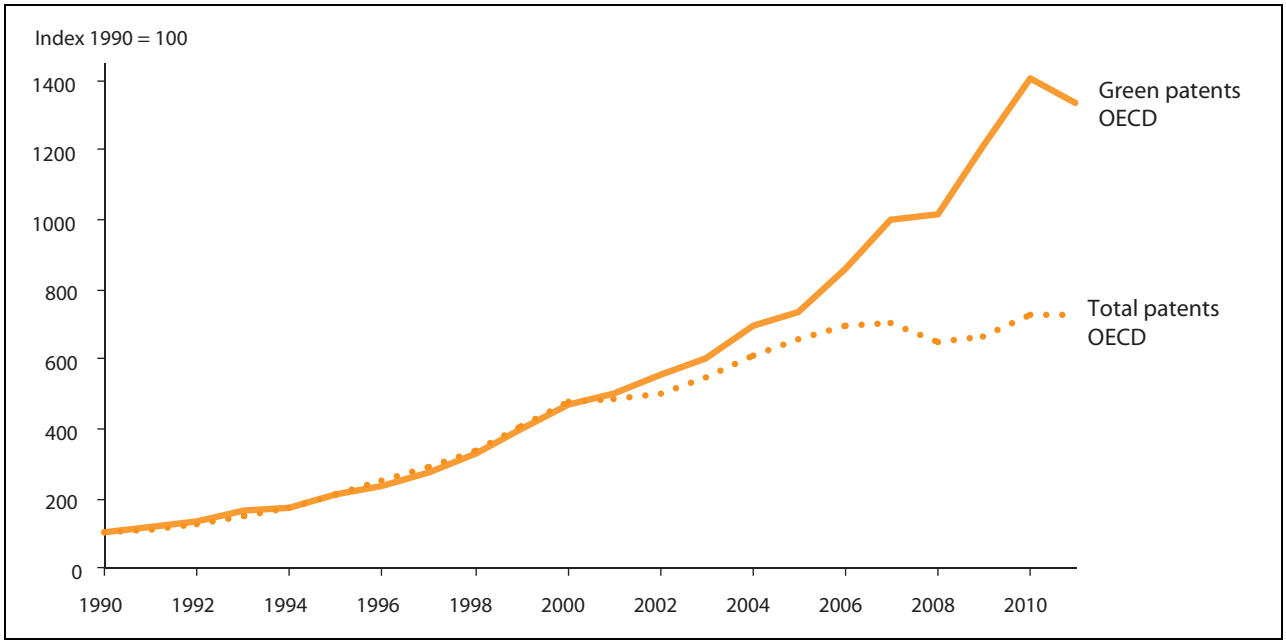


Figure 1.2 Development in number of patent applications in the OECD, total and within environmental technology, 1990-20111

Source: OECD: *Green Growth Indicators 2014*

and innovation. We must exploit these opportunities so that the overall costs of essential change are as low as possible. The number of patents for environmental technology (also called green technology) has risen substantially, cf. Figure 1.2, but a great potential remains for business development in this area. The priorities in the long-term plan support the need to understand these social challenges, contribute to addressing them in an optimal manner, and to exploiting the possibilities.

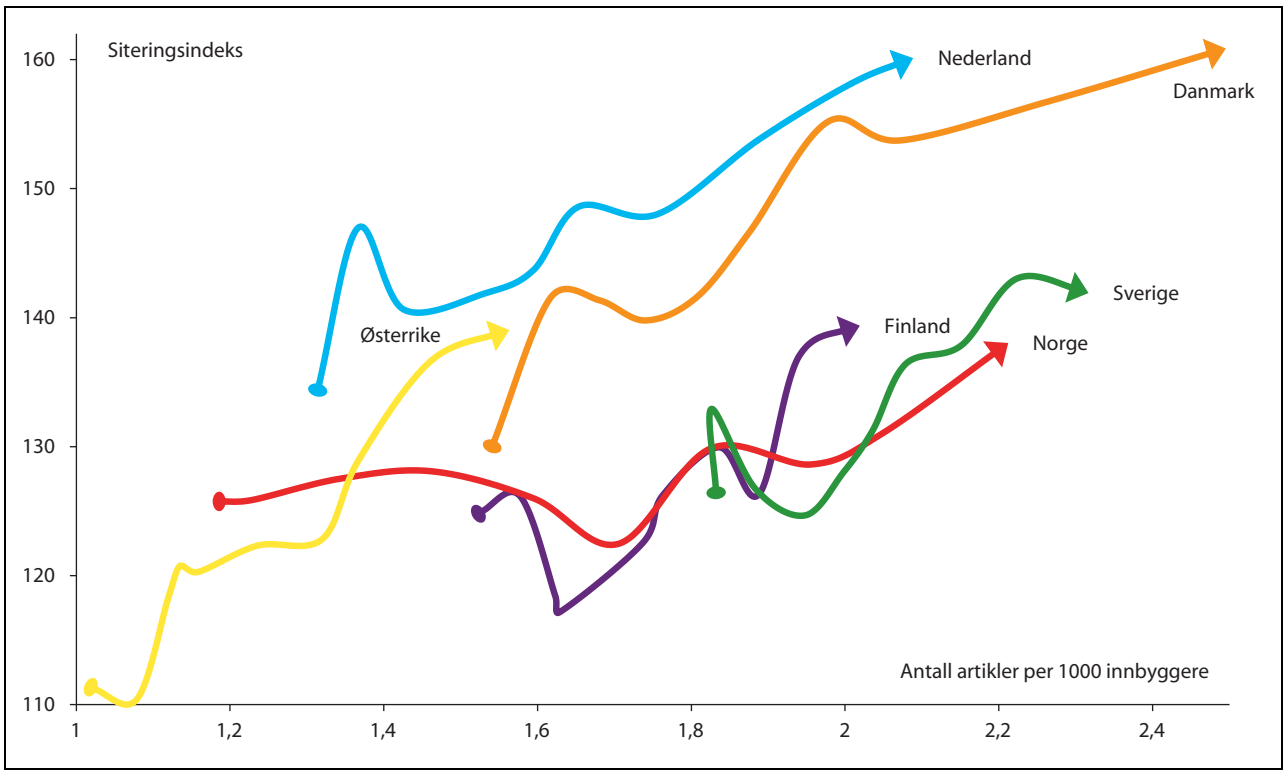


Figure 1.3 Relative citation index and number of scientific articles per inhabitant

Source: Thomson Reuters/CWTS: *Web of science*, adapted by NIFU

*Developing excellent academic communities*

Norway lags behind countries we tend to compare ourselves with when it comes to measuring the quality of research. Norwegian scholars are quoted less frequently than colleagues from other Nordic countries. Evaluations and reports that assess the quality of Norwegian research and higher education reveal overall good quality in Norwegian academic communities, with certain important variations. Regular assessments conducted by the Research Council of Norway show that quality varies between disciplines and between institutions. Some of the environments are outstanding while, at the same time, there are too many academic environments that do not conduct research of acceptable quality. High quality is therefore a consistent objective. In this context, the Government is working e.g. to examine the future structure and funding system of the higher education sector. The objective is for some institutions to attain a level where they can compete with the very best Nordic institutions, and more research groups should be able to assert themselves with the world elite. Public resources shall be used to promote research and education of top-notch international quality.

The Government is therefore escalating its efforts to develop excellent specialist environments. A research and higher education system with consistently high quality is necessary if we are to develop and utilise knowledge. While we are devoted to assisting the very best, it is also important to ensure good terms for high-quality research that is not part of a global elite class, but which is important in the development of quality education and social welfare services. Vibrant, high-quality specialist environments will attract the best students and researchers.

## 1.5 Flexibility for the future

Norway devotes considerable State resources to research, development and higher education. We will spend around NOK 53 billion on these areas in 2015. The Government will continue to increase appropriations, but that will not suffice to achieve these objectives. Where and how we invest are of great importance, along with how national and regional measures and programmes work in harmony with European and other international measures and programmes.

**Box 1.1 Ideas are born where disciplines meet**

A 2013 report financed in part by the U.S. National Science Foundation (NSF), the National Institutes of Health (NIH) and the National Aeronautics and Space Administration (NASA) describes the interplay and fusion between knowledge, technologies and society as being equally important for the future as the engine was for the industrial revolution. Unexpected and innovative ideas often emerge and can be developed in the interface between various types of expertise. The Research Council of Norway's "Idélab" is an example of how specialists from different disciplines can join together to develop projects that are ground-breaking and innovative. Allowing different professional points of departure and different understandings increases the relevance of the research. This contributes to ensuring that the resulting knowledge can actually be put to use.

The University of Oslo hired an expert advisory group to provide input on how the University could achieve its strategic objective of becoming a leading international research university. The group submitted its report in August 2014, citing interdisciplinary cooperation as one of the most significant points for improvement. The group emphasised that an interdisciplinary approach is equally important in education and in research. There is reason to believe that this is a challenge the University of Oslo shares with many other universities and university colleges in Norway.

The term "convergence" has also been introduced in recent years to describe an even closer integration of disciplines. The Massachusetts Institute of Technology (MIT) presented a report in 2011 on convergence between life science, physics and engineering. The report describes how convergence between different areas of expertise can contribute to an entirely new outlook and comprehension of the respective areas. This is an important springboard for developing innovative solutions.

Investments in research and higher education must have a long time perspective as these areas are, by nature, long-term commitments. It often takes quite some time before results of public sector investments become visible. It takes time to build laboratories and teaching facilities. It takes time to develop and refine outstanding academic environments. It takes time to establish good IT tools and collaboration systems which provide these specialist environments with the necessary terms and conditions for excelling in a global context. This long-term perspective means that it is not possible or desirable to micro-manage policies ten years into the future. We cannot know for sure which measures and systems will be best suited to address all of the challenges or opportunities presented in the long-term plan. History has shown us that surprising breakthroughs with subsequent rapid change make it difficult for us to know whether today's disciplines, technologies or industries will yield the best solutions.

It is impossible to predict exactly which effects we will achieve, or lose out on, if the investment level is increased or reduced. Nevertheless, firmly established research in economic development indicates that the totality of investments in research and higher education has a significant impact on economic growth, welfare, employment and sustainable development.

The concept that investments in knowledge are crucial for growth and social prosperity is also characteristic of European cooperation on research and innovation work. This is particularly apparent in the Horizon 2020 research and innovation programme. The reasoning behind the extensive public investments is that research and innovation activity should contribute to realising the Europe 2020 strategy objective of the EU becoming a smart, sustainable and inclusive economy. Norway shares the same objectives for research and education as our international partners, in a great many areas. This is one of the main reasons why extensive international cooperation is both useful and necessary. There is no “Norwegian cancer” or “Norwegian Alzheimer’s disease”. It would be counter-productive for each country to work independently to solve these types of problems. International cooperation allows us to share the burden of major investments in e.g. laboratories, data acquisition and other equipment. At the same time, it provides us with the opportunity to recruit talented people from all over the world. Norway is integrated in the international system for higher education, research and innovation through the Nordic and European collaborative efforts. A good balance is thus necessary between public investments in national and international policy instruments for research and higher education.

# 2 Predictable increase in efforts

## 2.1 Ambitious objectives

The Government wants to increase appropriations to research and higher education to follow up the priorities in the long-term plan. These funds will particularly target measures that contribute to high international quality in research and higher education, and to more research in the business sector. Proposals for increased appropriations to follow up the long-term plan will be made in the annual fiscal budgets.

The Government's objective is for research and development to amount to 3 per cent of the gross domestic product (GDP) by 2030. Achieving this target will require a public sector commitment to research and development of at least 1 per cent of GDP. The Government will boost research appropriations beyond GDP growth every year until the one per cent goal is achieved. Given current prospects for future GDP growth, the Government aims to achieve this goal in the 2019–2020 timeframe.

A few basic premises must be in place in a well-functioning system for research and higher education. Norway must have the right people with the right skills. We must have suitable buildings and equipment to promote education and research, and allow us to excel in international competition. And we must take part in international knowledge development. These preconditions are the most important input factors in research and higher education policies.

## 2.2 Human capital

### 2.2.1 The right – and sufficient – skills

There will always be a need for qualified labour. Highly-developed competence in the Norwegian workforce enables us to produce smarter and with higher quality. We need qualified professionals to provide good and effective public services. Capable people in business and industry do not just develop new products and solutions, but also enable us to utilise products and services developed abroad. We have to know that we have enough people, that their expertise is good enough, and that they have the right knowledge and skills. Therefore, following up the long-term plan entails assessing the future need for expertise within each of the six long-range priorities. Educational institutions, research institutes, the business sector and the public sector must also be closely interconnected to ensure necessary capacity, quality and organisation in these areas.

### 2.2.2 Good higher education

*Who is responsible?*

Educational institutions are responsible for the quality of the education. The content must be relevant and up-to-date, and students must benefit from what they learn. The institutions themselves put together and discontinue the programmes of education they offer. The Norwegian Agency for Quality Assurance in Education (NOKUT) is responsible for overseeing the education offered and the institutions' quality assurance systems. The various ministries are responsible for expertise and knowledge needs within their areas of responsibility. The ministries shoulder their share of this responsibility by highlighting the need for greater higher education capacity within their areas, in dialogue with the education authorities. Analyses and surveys of the future need for university places through projections may provide some direction. However, they are less suitable for discerning needs that arise as a result of changes along the way; for example the rapid development within ICT and other technologies.

*Need for capacity*

We can start with analyses of future needs and strategic objectives in order to gauge how many students and researchers we need in the future. In other words: we can examine projections to gain an impression of what society will need if the same development trends continue, and we can also determine the level we wish to attain based on political and strategic objectives. Statistics Norway

(SSB) draws up projections of supply and demand. For example, SSB's latest projections show that there will be steadily declining demand for people who have only completed compulsory schooling or just started on upper secondary education. At the same time, projections indicate a significant deficit in the number of people with vocational expertise from upper secondary education. People with training in health-related subjects will be in particular demand, while there may be a surplus of people trained in economic-administrative subjects, social sciences, law and the humanities. A need for more people with advanced ICT education has also been documented.

Educational institutions, employers and employees and the public authorities need good meeting places to achieve a common understanding of future needs for expertise and to ensure the availability of relevant education closely linked to practices in public services and industry. The Ministry of Education and Research has therefore established a project aimed at developing an overarching system for analysis, dialogue and communication of the competence required in working life. Such a system will provide a better foundation for scaling the education offered, i.e. how many students will be needed within the various subjects. This system will be incorporated in the knowledge base towards the next long-term plan.

*Content in the programmes of education*

The Government wants to promote excellent educational environments in Norway. An assessment of the state of affairs in Norwegian higher education reveals several good development trends, as well as areas that need improvement. The Government believes that high quality education built on solid expert communities is an all-pervasive objective for all Norwegian universities and university colleges. This requires the ability to set priorities and the willingness to adapt.

The Norwegian Centre of Excellence (SFF) has demonstrated that good research leadership contributes to the development of outstanding research communities. Similarly, leadership and management are probably significant factors in cultivating outstanding educational environments. Generally speaking, good research and education environments must be cultivated together, and joined even more closely. Developing clusters and interplay between education, research and innovation are important for several of the priorities in the long-term plan; take, for example, the importance of marine and maritime clusters. The educational institutions must also stimulate greater cross-discipline and international cooperation. This helps increase the relevance of the studies and can contribute to making academic environments more exciting for the students when they select the courses of study they wish to pursue.

Digitalisation and use of new technology in higher education can promote quality. Digitalisation makes the education more relevant for the needs in working life. Digitalisation allows students to work more actively with the subject matter in different ways. This opens the door for greater cooperation with other institutions, as well as with the business community, trade and industry. This also makes the education more flexible for each student, who can choose when he or she wants to work on the study material. The rapid development in massive open online courses (also referred to as MOOCs) in recent years is another example.

### 2.2.3 The best and brightest – the need for doctorates

People with tertiary degrees are in demand in working life, also outside professional academic communities. More people who possess such expertise are particularly needed within science and technology. The Government therefore intends to increase the number of recruitment positions by 500 by 2018.

We need experts with doctorate degrees to achieve our long-term plan objectives in several priority areas. For example, recruitment positions in nano-technology will both form the basis for developing leading expert communities in the field, and create business activities within green energy. There is a need to reinforce recruitment efforts within several of the priority areas in the long-term plan. The number of people taking doctorates has more than doubled over a little more than ten years. Compared with other Nordic countries, a lower percentage of doctoral candidates choose technology, while the percentage choosing medicine is high.

A survey conducted by consultant agency DAMVAD for the Ministry of Local Government and Modernisation (2014) revealed that the need for advanced ICT expertise will grow in the time ahead. The private services sector will show particularly robust growth, while needs are also rising in the public sector and in industry. Projections show that, starting in 2015, there will be under-coverage of ICT personnel in Norway. For

this reason, the Government particularly wants to devote resources to recruitment in this area.

Excluding private sector R&D, the research institutes were responsible for nearly half of Norwegian research efforts in 2011 in mathematics and natural science, and for two-thirds of research in technology subjects. The thematic specialisation of the institutes and close cooperation with industry, the greater community and the public sector means that the institutes play a key role in linking research, education and innovation. For example, the institutes can offer doctoral candidates experience from inter-disciplinary and project-oriented research that is relevant for both the private and public sector. The Government wants to utilise the research institutes' expertise to reinforce recruitment, particularly to mathematics, natural sciences and technology subjects. The Research Council will have the task of formulating financial or other instruments that can contribute to strengthen the role of the institutes in this work. The Government will consider introducing an economic stimulus scheme for research institutes that cooperate with an educational institution to train doctoral candidates.

## 2.3 The best equipment

Outstanding expert communities must have access to the best equipment. Two examples of such equipment are large DNA sequencing machines that are used to read genes to diagnose diseases and weather buoys that float along the coast and provide information about weather conditions and the environment.

Modern equipment is important if Norway is to attract good researchers and assert itself in international competition. High-quality modern equipment is necessary for the business community to see the benefit of collaborating with the research communities. It is also necessary if we are to develop expert communities at the global forefront. Not least, good laboratories with up-to-date equipment are important for the quality of education.

The Research Council's national research infrastructure scheme is a highly-developed tool to ensure that funding of major research infrastructures goes to high-quality, strategically important projects. In order to secure approval of funding applications, the institutions must join in national consortiums and submit plans showing how they will cooperate on laboratories, data acquisition, etc., how they plan to divide the work and how they will ensure access for all researchers who may have a relevant interest in such equipment. These demands have contributed to a better structure for the Norwegian research landscape. They reinforce quality and efficiency, and make it possible to realise projects that individual institutions could not carry out on their own. Based on the applications to the national infrastructure programme, the Research Council of Norway has drawn up a Norwegian roadmap for investments in research infrastructure. This roadmap is updated every second year, after each major call for proposals.

At the same time, investment growth in research infrastructure in the higher education sector and health trusts in recent decades has been much lower than the growth in research expenditures. The current investment level is not sufficient to meet the needs. The Government therefore intends to expand appropriations to these schemes by NOK 400 million by 2018. The Government also intends to raise appropriations for other equipment at universities and university colleges.

The national infrastructure scheme also contributes to Norway's active participation in the joint European collaboration on research infrastructure through the European Strategy Forum on Research Infrastructures (ESFRI). This cooperation gives us access to world-class equipment and data. One example is the national consortium on biobanks. Biobank Norway on the Norwegian roadmap has received funding to upgrade and collaborate on Norwegian biobanks. Biobank Norway is the Norwegian part, or the node, of the major European biobank collaboration, Biobanking and Biomolecular Research Infrastructure, on the European roadmap for research infrastructure. In other words, national investments gain admission for Norwegian researchers not only to Norwegian biobanks, but to all biobanks in Europa.

## 2.4 The most important construction projects

Norwegian universities and university colleges must fulfil their core assignments and adapt education and research to reflect society's changing needs if they are to contribute to achieving the objectives in the long-term plan. Modern, functional buildings with appropriate equipment are essential in order to solve the complex challenges of the future, as well as to promote value creation in Norway. Good buildings are also crucial for excellent quality in both research and education.

**Box 2.1 Campus Ås**

The Norwegian School of Veterinary Science in Oslo and the Norwegian University of Life Sciences at Ås were merged in 2014. The new institution, the Norwegian University of Life Sciences (NMBU) will be gathered in a single location at Ås in 2019. The National Veterinary Institute will also move to Ås that same year. The Nofima food research institute is also located at Ås. The research institutes Bioforsk, the Norwegian Agricultural Economic Research Institute (NILF) and the Norwegian Forest and Landscape Institute will merge on 1 July 2015 and the new institute will also be headquartered at Ås. The Government expects that when these institutions are located in the same place, a solid hub of knowledge will emerge for sustainable development, the environment and climate challenges, better human and animal health and animal welfare, food safety, clean energy, food production and land and resource management. The Ås Campus will lay an important foundation for developing new business activity within bio-economy (see Box 7.1).

High-quality buildings for teaching and research are necessary in order to attract the best students and researchers, and to be attractive partners for the public and private sectors.

*Need for facilities*

There is a significant need for investment in training and research buildings, particularly for state universities and university colleges. The most important reason is the need for modernisation and renewal. Social developments, new technology and new challenges lead to changes in the way we learn, and research methodology that requires new or upgraded teaching facilities, laboratories and scientific equipment. There is also a need for more space for students and employees. The overall activity level at the institutions has grown considerably since the late 1980s, and continues to rise. Higher activity means more employees and students who must have a roof over their heads.

Investments in buildings will always be an important element in research and higher education policy. It takes a long time to complete construction projects, often ten years from when planning starts until the building is finished. The Government's long-term plan places particular priority on two construction projects which are considered to be the most important projects for achieving the objectives in the plan. These projects are a building for life sciences, pharmacology and chemistry at the University of Oslo and upgrading the Ocean Space Centre in Trondheim for Marintek and the Norwegian University of Science and Technology. The projects are at different stages of the planning and engineering process, and the Government will make a decision on concept, management basis and cost framework when a sufficient basis for decision has been secured. The concept for upgrading the marine technology centre has not yet been selected. See also the discussion in 8.5.

*New building for life science, pharmacology and chemistry*

A new building for life science, pharmacology and chemistry at the University of Oslo will facilitate closer cooperation between different expert environments, as well as collaboration with business and industry and the public sector. Cooperation between the University of Oslo and Oslo University Hospital will be important in ensuring high quality and relevance in education and research. Life science itself is an interdisciplinary field, and the building will facilitate more cooperation within medicine, biology, pharmacology and odontology, supported by physics, chemistry and mathematics subjects. The investment will be an important contribution towards Norway being able to assert itself among the best within these areas.

*Upgrade of the Ocean Space Centre*

Investment in the upgrade of the Ocean Space Centre in Trondheim is a substantial commitment designed to assist Norway in remaining at the global forefront in marine and maritime research. Ocean space technological research and marine technology and expertise are key to innovation and future value creation within maritime industries, the oil and gas activity and the fishery and aquaculture industries.

## 2.5 Making the most of Horizon 2020

There are time-honoured traditions for international cooperation on research and higher education. Human beings searching for knowledge have

always travelled to other countries to seek out learning institutions or master teachers, or to check out conditions in other parts of the world. The international programme collaboration that has developed in Europe through the EU's framework programmes for higher education, research and subsequently innovation collaboration, have become the largest in the world over the last decade.

Through this European collaboration, we have created a competitive international arena for research and innovation, characterised by extensive cooperation and sharing of work between countries, where quality and European added value determine who receives research funding. Norway has taken part in this competitive arena as an associate member for more than 20 years. The new research and innovation programme, Horizon 2020, started in 2014. The Government's strategy for cooperation with the EU on research and innovation sets ambitious targets for Norwegian participation in Horizon 2020. The Government's clear expectation is that Norwegian expert communities will participate actively in this cooperation, and that they will, in some areas, be at the forefront of the European competitive arena. The Government's objective is for Norwegian expert communities to secure 2 per cent of all funding made available by Horizon 2020. If this is to occur, the scope of Norwegian activity must increase radically. Therefore, the Government wants to increase efforts and stimulus schemes to assist Norwegian scholars in succeeding in Horizon 2020. The Government will raise appropriations to such stimulus schemes by NOK 400 million by 2018.

Different sectors need different types of stimulus schemes. In order for the research institutes to expand their participation, support is needed to meet the gap betweencosts covered by funding from the European Commission and the actual costs of the project. The institutes play an important role in mobilising business and industry for participation. Measures that can assist the institutes in covering costs can therefore also increase participation by the business community. Cost coverage is not as important for the higher education sector and the health authorities. Here there is a greater need for information and support for positioning activities, to write applications, as well as to establish and run projects. As regards the business sector, the greatest need for support appears to be for funding that can mobilise companies to take part, and assist them in establishing the projects. There is an inherent potential of increasing the scope of participation in all sectors and in most expert communities. Therefore, the Government will develop a set of measures and instruments to respond to the needs in the various sectors, taking a point of departure in the strategy for research and innovation cooperation with the EU, and in cooperation with the Research Council of Norway.

The Government also expects Norwegian experts to participate in Erasmus +, the EU's new education programme which started in 2014. The programme emphasises cooperation between educational institutions, as well as between these institutions and workplaces.

**Box 2.2 EU Joint Programme – Neurodegenerative Disease Research (JPND)**

Right now, more than 70,000 people live with a dementia disease in Norway, and at least 300,000 have a family member afflicted with dementia. Estimates indicate that the number of people with dementia will double by 2040. Dementia ailments affect the entire society, but are still associated with a lack of expertise and knowledge.

We know too little about causes, development of the disease, treatments and organisation and facilitation of services for people with dementia. Norway is an active participant in the European joint programme for research on Alzheimer's disease and other neurodegenerative diseases (JPND). This programme is the largest global research commitment that addresses challenges associated with neurodegenerative diseases. Norway provides funding for this effort through the Research Council of Norway.

Norwegian research groups participate in several of the projects. The University of Oslo and Akershus University Hospital are taking part in a project to map gene combinations that increase the likelihood of developing such illnesses. Another project, where the National Resource Centre for Aging and Health takes part, will follow around 200 dementia patients in several European countries over a period of two years to chart development of the disease after the patients have received a diagnosis, and which treatment options they receive.

# 3 Seas and oceans

## 3.1 Direction

Norway is a seafaring nation in every sense of the word. The ocean and the coastline have permeated the development of Norwegian society, and shaped much of our identity. For many of us, the coastline means a holiday spot, a workplace, or our homes. The sea has been our most important means of transport, and the starting point for early international contacts. Norwegian trade and the economy are closely linked to the sea, from shipbuilding to fisheries and aquaculture, oil and gas. A significant portion of value creation in Norway comes from the sea and the continental shelf. Industries based on the sea are of crucial importance for settlement, value creation and employment throughout the country.

In spite of its past and present significance for Norway, we still know relatively little about the sea, compared with our knowledge about land areas. There are still great opportunities in the ocean that we are not yet aware of. In addition to its natural advantages, Norway has strong expert communities and industries connected to the sea. These include areas such as the petroleum activity, maritime industries, seafood, aquaculture, fisheries and harvesting and using other living marine resources, advanced ocean technology, fishery management and comprehensive maritime management. Important parts of higher education, for example in technology, have been aimed at exploiting our resources in, or under, the sea. The knowledge we possess about the sea is also essential to our ability to understand and deal with climate and environmental challenges both in Norway and worldwide.

The petroleum industry has brought us great prosperity. We can credit this growth to capable experts who have developed knowledge and technology in the petroleum activities, and in the supplier industries that serve that sector. We continue to need new knowledge and technology in order to exploit the remaining petroleum resources on the Norwegian shelf. The board of Norway's technology strategy for petroleum (OG21) provides advice on organisation and commitment areas for petroleum research. A revised strategy will be presented in 2016.

The expertise found in the petroleum cluster can also be exploited in other sectors and used to build up new industries. For example, new technology and know-how surrounding safer, more environmentally-friendly production of oil and gas will improve competitiveness for companies in the petroleum sector, and will have transfer value for other sectors.

Norway is a leading maritime nation. Global and technological development trends create new maritime opportunities. If we are to stay at the forefront of this evolution, we must develop and use knowledge that promotes innovation and paves the way for necessary change and adaptation.

Norway is also one of the world's largest exporters of seafood. Rising world population will mean a need for more food. The world will not have sufficient agricultural areas in the years ahead. This will make maritime food production even more important, which means that we must ensure a good basis of knowledge for fisheries and sustainable fishery and aquaculture industries.

We do not know enough about how the sum of various types of pollution impact life in the sea. Not least, we lack knowledge about the factors that affect the level of environmental toxins in the sea and in seafood. Norwegian seafood is supposed to be safe, and we must be able to document that this is the case. We need to know how we can preserve the seas as good production areas for safe, healthy food.

On the international scene, Norway occupies a leading role in developing knowledge regarding management of the maritime environment, the resources found there and on the continental shelf. This is particularly true for the northern areas. This management must also take place in cooperation with other countries. As a prime maritime nation, Norway has a vested interest in participating in the global effort to learn more about the sea.

A long-term commitment to knowledge and expertise related to the sea and the maritime industries will better equip us to exploit the resources in the sea and on the continental shelf. This will contribute to preserving the sea as a sustainable source of economic growth. This is also necessary to reinforce Norway's position as a responsible managerof the ocean and a leading international maritime nation. The Government's long-term plan includes prioritisation of an upgrade of the Ocean Space Centre in Trondheim.

The Government intends to boost its commitment to ocean-related research and higher education to achieve:

- greater value from industries in the sea, in coastal areas and on the continental shelf
- better management of ecosystems and resources in the maritime areas
- clean seas and healthy, safe seafood

## 3.2 Value from maritime industries, in the coastal area and on the continental shelf

*Knowledge and expertise for maritime-based industries*

We must strengthen our knowledge base for sustainable exploitation of maritime areas to stimulate more production of seafood. The core areas in fisheries and aquaculture must be further developed and refined to ensure continued profitable value creation growth. Continued development of the fishery and aquaculture industry must take place in cooperation with the supplier industry and new marine industries. We need more basic and applied research to find the answers to biological, environmental, commercial, technological and social questions.

The know-how, technological and business development in the petroleum industries is unparalleled in Norway. Norway leads the world in technological development related to offshore production of oil and gas.

Continued cost-effective and sustainable exploitation of the petroleum resources on the Norwegian shelf requires a further commitment to research, development and expertise. The petroleum sector in particular needs more basic knowledge about the seabed and the subsurface, as well for testing new technology under realistic conditions. The industry also needs new know-how to maintain high health, safety and environment standards in connection with the petroleum activity in more vulnerable areas.

**Box 3.1 Leading international industry clusters and expert communities in the petroleum sector**

The maritime-based industries must constantly adapt and develop products and solutions that can be used around the world. These industries must constantly acquire new knowledge in order to maintain the high pace of innovation. Their ability to innovate and adapt is based on market knowledge and insight, along with expert communities with close ties to the industry. Norwegian offshore and drilling engineering – NODE – is an industry cluster in Southern Norway consisting of around 60 companies. These companies deliver equipment and solutions to the international oil and gas industry. The cluster collaborates with outside expertise to develop technology, know-how and competence that will help these Southern Norway companies remain at the global forefront, regardless of competition. In 2014, NODE was designated a Global Centre of Expertise, a Norwegian system aimed at developing leading industry clusters that cooperate with Norwegian and international expert communities. The Research Council of Norway, Innovation Norway and Siva nominate these Global Centres of Expertise, and such clusters receive around NOK 10 million per year over a ten-year period.

New technology and equipment that can contribute to more environmentally-friendly production of oil and gas will make companies in this sector more competitive and may also have transfer value to other energy areas. Some of the companies that currently operate in the oil and gas sector are already engaged in R&D activities and business development within maritime energy production. However, we need more knowledge about environmentally-friendly offshore energy production.

The Norwegian maritime industry is an international leader, with competitive companies all across the broad maritime sector. Access to capable professionals is essential in maintaining and developing maritime competitiveness and value creation. Moreover, we need more expertise in safe, environmentally-friendly sea transport, which contributes to reducing greenhouse gas emissions from the transport sector. More activity

in the northern areas requires greater knowledge about maritime operations in demanding Arctic conditions. The Government is working on a comprehensive strategy for growth and value creation in the maritime sector. This strategy will be presented in the spring of 2015 and will describe the sector's need for expertise, and how the Government will contribute to addressing this need, as well as to bolstering the maritime field of study.

To some extent, the need for knowledge and skills is specific to each separate industry, but there are also certain common challenges and a potential for cooperation and knowledge transfer across industries. This must be taken into consideration in the follow-up of the long-term plan, and we must facilitate inter-disciplinary efforts which place environmental and climate impact in context with social issues. There is a need to involve players from both the public and private sectors, as well as for international cooperation.

*Unexploited natural resources*

There are still major unexploited natural resources on the continental shelf and in the sea. These include biological raw materials, genes from marine organisms and mineral deposits that we lack knowledge about. Such natural resources could be the source of new industries, but we need more information and expertise in order to exploit them.

Research results, including in the fields of nutrition, bio-technology and process technology, have opened up doors for advanced industrial exploitation of marine raw materials. This includes seaweed and other algae for animal feed, clean energy and specialised products for the food and pharmaceutical industry. More research is needed to ensure even better utilisation of these marine raw materials.

Only around half of the Norwegian oil and gas resources have been produced. Much of the estimated remaining resources include deposits that have not yet been discovered. We must redouble our research effects in this area in order to prove and exploit these resources.

The oil and gas industry is characterised by strong groups of experts and companies in the fields of subsea and deep water technology. These clusters of expertise also provide opportunities to develop technology for exploration, assessment and possible future recovery of mineral deposits on the seabed.

*Strong Norwegian expert communities take part in furthering international knowledge*

Strong research communities and study programmes are a common trait of the sea-based industries, along with a healthy supplier sector. Norwegian research accounts for a high percentage of global research and added knowledge in many of these areas, such as marine research in the polar areas.

Strong Norwegian professional communities in marine topics can benefit greatly from the transfer of knowledge across disciplines, sectors and industries, including in the social sciences and the humanities. Facilitating development of close ties between the educational institutions, the research environments and the business sector is important in order for Norway to takes its place in the top international level of sea-related professions. Solid connections between the industries and the various study courses is also important as regards assessing future capacity needs, and to ensure that the education is relevant.

Marine and maritime research topics do not have separate research programmes in Horizon 2020, but these topics are integrated in other programmes, such as food, transport, the environment and climate. With the objective of fortifying European cooperation also at the regulatory level, Norway has participated in establishing a joint programme for ocean research – JPI Oceans. The objective of this programme is to achieve better coordination of the research funds that run through the various countries for marine and maritime research, and to facilitate sustainable growth by developing joint strategies. In addition to comprehensive research cooperation within Europe, there is also significant marine and maritime cooperation with Asia and North America.

Another area which is not prioritised in the EU's research programmes is petroleum research. This makes both national programmes and bilateral research collaboration particularly important for the petroleum sector. The petroleum-geared supplier industry is experiencing steady growth in a global market that is very vulnerable to competition. International cooperation with areas such as North America and Brazil on research, technology development and higher education receive high priority.

## 3.3 Managing ecosystems and resources in maritime areas

The ecosystems are crucial for value creation from the ocean. Knowledge about marine ecosystems and the changes that occur in them as a result of climate and environmental change and other human activity is fundamental for all activity and utilisation of resources, innovation and business development.

Future value creation based on use of marine resources depends on maintaining a sound environment and rich natural diversity in the ocean. That is why we need to know and understand more about the function of these ecosystems, and how they are affected by climate change, ocean acidification and human activity. One example is that higher sea temperatures and changes in ocean currents can lead to movement in the fish populations. This has already resulted in Norway having to monitor an ocean area that is 50 per cent larger than in 2003 to follow these populations. We need more information about such effects of climate change in order to have a good foundation for sound management into the future. We also need more information so that the impact of climate change on the fishery industry can be taken into account.

Norway leads by example when it comes to managing the ocean areas and there is extensive information available regarding the Norwegian ocean areas. This is an advantage we can continue to build on in Norwegian research. Our experience with ecosystem studies in Norwegian waters has substantial transfer value to studies in other ocean areas. These types of studies are also an important part of Norwegian activities in the northern areas. The shrinking sea ice in the Arctic regions has considerable impact on the global climate. Changes in the Artic regions will make it possible for marine and maritime industries to establish themselves in previously inaccessible areas. A commitment to research on Arctic climate and Arctic ecosystems will yield better forecasts and a foundation for business development, preparedness and adaptation to the changes. This will result in a better basis for assessing how Norwegian and international management should be designed to address these challenges.

Norway has a large coastal area with world-class environmental assets and values. Business activity in the coastal areas is rising, but we need additional knowledge to develop a more comprehensive, effective, economical and ecologically sustainable management of the coastal areas. Norway has many professional communities engaged in tackling these issues, but there is a need to obtain a better overview of the disciplines, and to raise knowledge levels to achieve a more comprehensive management of the coastal area.

## 3.4 Clean seas and safe, healthy seafood

The World Health Organisation (WHO) recommends eating more seafood to improve public health. Norwegian and international consumers are becoming increasingly aware of the environment and health issues. As a seafood nation, Norway must be able to document that its food is healthy and safe to eat.

A long-term commitment to knowledge that can contribute to ensuring clean seas and safe, healthy seafood must provide us with better information about what impacts life in the sea, and what consequences this has for the health of fish populations and human beings. We also need knowledge about seafood and health. Norway has a vested interest in taking part in global research on such topics.

**Box 3.2 EU project with Norwegian leadership to strengthen European aquaculture**

There is great demand for seafood and other products from the sea. The aquaculture industry is still young, and faces a number of challenges as regards sustainable and profitable operations. The Nofima food research institute heads a major European cooperation project financed through the EU's Seventh Framework Programme for Research. The objective of the project is to strengthen the aquaculture industry in Europe through researching and developing technology for better breeding methods for the most common fish species in the industry. New breeding technologies can help the industry become more sustainable, effective and profitable, and can deliver safe, healthy aquaculture products. The project includes all aquaculture industries that produce such products, such as algae, shellfish and plants, as well as fish farming operations.

If we are to ensure that fish and other seafood harvested in our ocean areas is safe to consume, we need good information about the levels of environmental toxins in seafood and how these affect both fish health and human beings. Norwegian management has sound documentation as to the content of environmental toxins in farmed fish and the most important commercial species harvested in our ocean areas. However, we have less knowledge about other species in the ocean and the coastal area. There is considerable variation in the content of environmental toxins in fish, and we need to learn more about which factors affect these levels. The presence of multiple environmental toxins simultaneously, such as plastic, heavy metals, radioactive substances, environmental toxins and oil components may have greater impact together than they would separately. There is also a constant stream of new substances that could prove to be environmental toxins when they enter the marine environment. Documentation of sources, deposits and effects of environmental toxins is important as a basis for international regulation of environmental toxins.

Continued growth in the aquaculture industry necessitates the use of new raw materials to produce fish feed. We need to know more about the connections between feed, fish health and safe, healthy food.

The industries need skilled labour in order to make use of the knowledge and the technology developed to ensure that the seafood is safe and healthy.

# 4 Climate, environment and clean energy

## 4.1 Direction

The climate and environmental changes we are seeing now will have major consequences for the natural environment, for society and for business and industry, both in Norway and globally. Norway has endorsed the goal of limiting global warming to two degrees, compared with the temperature before the industrial revolution at the end of the 1700s. We must cut greenhouse gas emissions to curtail rising temperatures and avoid more dramatic climate change that cannot be reversed. At the same time, we must make sure that we pursue appropriate adaptations to a changing climate.

The Government has an ambitious climate, environment and energy policy which includes objectives such as achieving long-term adaptation to a low-emission society by 2050, strengthening the climate compromise and a commitment to environmental technology and eco-friendly energy technologies. These are all important goals for addressing climate and environmental challenges, and they also provide a good opportunity for the Norwegian business community to compete in the growing technology markets in these areas.

Fossil energy consumption is the largest source of greenhouse gas emissions and many of the climate changes already observed. At the same time, global energy consumption is growing at a very rapid pace. This is due to factors such as population growth, significant economic growth in densely populated countries such as China and India, and the fact that an increasing number of people are able to emerge from poverty. In order to deal with the poverty issue and the climate challenge in parallel, growth in the economy and prosperity must take place without corresponding increases in emissions from fossil energy sources. This means converting to a low-emission society with increased production from clean energy sources, where energy is used more efficiently and where energy production from fossil energy sources is combined with safe and efficient capture and storage of $CO_2$. This change must also be carried out in a manner that is eco-friendly. We need more knowledge about how such a change can be achieved, also with a growing population.

According to the Intergovernmental Panel on Climate Change (IPCC), Norway can expect a warmer, wetter climate with more frequent occurrences of extreme precipitation. Among other things, this will lead to changes in fish populations and in the conditions for food production on land. There could be outbreaks of new plant and animal diseases, and we may see more pests and disease carriers that spread disease between animals and human beings. The changes will also result in more flooding, landslides, avalanches and erosion, which can in turn lead to hazards to life and health, and major material loss. We can expect more frequent interruptions in rail traffic and more closed roads, as well as more power outages and faults in the mobile network. We need to have a better understanding of climate change if society is to be able to adapt to the changes.

The effects of climate change on nature and society largely affect all sectors, and efforts to obtain new insight and to develop necessary expertise will be coordinated in the follow-up of the long-term plan.

Worldwide loss of natural environments has taken place on a large scale for quite some time. Next to climate change, the loss of natural diversity poses the greatest challenge for the environment and for human utilisation of what nature produces. Dealing with this challenge demands better understanding of the ecosystems and how we can make sure that social development occurs within a sustainable framework.

Norwegian research and education communities form the vanguard within several areas of climate and environmental research, as well as in important areas dealing with eco-friendly energy. Norway's business sector is also well-developed in many of the areas where greater efforts towards research and higher education have significant potential for value creation. This commitment must be integrated across technical disciplines such as natural and social science, technology and the humanities in order to understand and handle the effects of these changes, as well as to address

**Box 4.1 Norwegian researchers are solid contributors to the UN Climate Panel**

In 2011, the Research Council of Norway appointed an international committee to look at and assess Norwegian climate research. The evaluation revealed that Norwegian climate researchers published more per capita than any other country. Researchers around the world refer to Norwegian climate articles more often than the average for scientific articles related to climate issues. This confirms the good reputation of Norwegian climate research, and the substantial international significance of this Norwegian research. When the Intergovernmental Panel on Climate Change (IPCC) presented its fifth report in the autumn of 2013, much of the material could be credited to 19 authors from Norwegian expert communities. The Norwegian researchers contributed both to knowledge about the climate science basis, as well as to information about effects and measures designed to handle them.

the need for change in society and the business sector in a cost-efficient manner.

A long-term commitment to knowledge and expertise in the climate, the environment and eco-friendly energy will help us meet the challenges described above. The point of departure for this commitment must be based on the priorities and recommendations discussed in the national R&D strategies Energi21, Klima21 and Miljø21.

The Government intends to boost its commitment to research and higher education relating to the climate, environment and eco-friendly energy to achieve:

- developing Norwegian technology to address global climate, environment and energy challenges
- change-over to a low-emission society
- better understanding of climate changes and good adaptation to deal with them
- social development adapted to environmental considerations

Developing Norwegian technology and changing into a low-emission society will be our highest priorities.

## 4.2 Norwegian technology for global climate, energy and environment challenges

*Promising technology markets*

Norwegian technology will contribute to solving global challenges. Technologies that directly or indirectly benefit the environment are crucial in solving the major climate, energy and environment challenges facing the world today.

Products and solutions in the field of climate, environment and energy technologies currently comprise one of the world's most promising technology markets. Norway has a strong business sector, good expert environments and sound education within areas such as solar energy and materials, CCS, hydropower, eco-friendly ship technology, eco-friendly oil and gas production, waste management and recovery, environmental monitoring and green buildings. Research and higher education of a high international standard will contribute toward exploiting such advantages in the new technology markets. Norwegian communities will be attractive partners in international climate, energy and environment research. This relates particularly to participation in Horizon 2020, and the development of the European Research Area, ERA. One example is Norway's participation in ECCSEL, a Norwegian initiative aimed at coordinating investment and use of the research infrastructure for capture and storage of $CO_2$ in Europe. SINTEF and NTNU lead this effort. Building up modern laboratory facilities at NTNU is crucial. Up-to-date laboratories are also necessary for conducting fundamental technology research, small-scale testing, and to attract top-notch researchers and the best students from around the world.

*Knowledge and expertise for good, reasonable technology solutions*

A large part of the conversion to a low-emission society must take place in connection with production and consumption of energy. Efforts must particularly be devoted to energy efficiency, clean energy and carbon capture and storage. This is necessary to meet the energy needs of a growing population. Norway must be a vanguard nation in clean energy consumption and production of various types of clean energy. To accomplish this, we must fortify our basis of knowledge and we must train capable professionals who can utilise this knowledge to find good solutions. For example, we need more information that can unite technologi-

**Box 4.2 Best in the world on oil spill preparedness, also under difficult conditions**

Norwegian company NorLense has developed new oil spill response equipment. Traditional oil spill equipment has functioned best when the oil is on the water surface, and under moderate weather conditions. NorLense has taken response equipment a step further, developing an oil trawl and a separator boom capable of recovering oil under more demanding current, wind and wave conditions, including oil that has sunk into the sea. The company is a world leader in offshore boom systems, and delivers equipment to the oil industry and regulatory authorities around the world.

cal, environmental and socioeconomic aspects that can ensure sustainable growth in clean energy production. We also need new knowledge to enable us to develop better, cheaper low-emission solutions for the transport sector. There is already a large and expanding market for low-emission solutions.

Developing environmental technology requires close interaction between those who deliver technical solutions, and those who represent other strong sectors facing environmental challenges. Examples of such industries may include the aquaculture industry, where environmental impacts create challenges such as salmon louse, or the petroleum industry which faces challenges as regards emissions and use of chemicals.

## 4.3 Conversion to a low-emission society

The Government's long-term objectives of achieving a low-emission society will entail significant change. This will require a better understanding of what a low-emission society will look like, what it will take to bring us there, and the social challenges inherent in this process. We need to have a better comprehension of which social benefits and opportunities lie in low-emission development, as well as more insight into the economic foundation.

Conversion into a low-emission society requires comprehensive research and innovation efforts and broad-based cooperation between social science, the humanities, technology subjects and natural science. The education programmes must be designed to ensure that the experts we train in Norway will become positive forces and key players in this conversion.

Knowledge about progressive, modern urban development contributes to helping the public administration and authorities to plan and organise our cities for climate and environment-friendly transport and more efficient energy consumption.

Resource exploitation, development of environmental technology and eco-friendly energy technology, along with new production methods in industry are other important areas of knowledge. The business community is a key element in the conversion to a low-emission society. We need a better understanding of how business and industry can function as an engine of change. We need to know more about what stimulates the conversion processes, and about the interplay between business and industry, employers and employees, and the authorities. The social consequences of the conversion process are key elements in this context.

Norway has good prospects within the transport sector for making a change toward becoming a low-emission society. We have a shipbuilding industry that develops both electric ferries and gas-powered ships. Electrification in the maritime sector is a very real potential development. Norway has a high number of electric cars and represents an early market for such vehicles and for technology that can make it easier to charge the cars and pay for charging. Transport of goods accounts for almost half of road-based greenhouse gas emissions, and we need more information to ensure technology development and a transfer from roadways to seaways and railways.

## 4.4 Better understanding of climate change and good, relevant adaptation

What does adapting to climate change really mean? Who will have to make this adaptation and how? The scope largely depends on how well we manage to reduce greenhouse gas emissions, and how fast we can achieve such a reduction.

Climate change represents one of the greatest international social challenges the world faces – both today and most likely for a very long time to come. If we are to implement targeted, cost-effective measures across all sectors of society, Norway and the international community must have research-based knowledge about climate change and its effects at a local, regional and global level.

**Box 4.3 How vulnerable is your municipality?**

How vulnerable are the citizens in your municipality in the event of floods, wind, landslides or other natural events that may be due to climate change? Researchers at NTNU have drawn up maps showing physical and social vulnerability in Norway. Storm events cause the greatest material damage in Norway, followed by flooding. Landslides/avalanches claim the most human lives, but cause less material damage overall than storms and floods. There is great variation in how vulnerable municipalities are as regards various types of natural damage. At the same time, social aspects can have a significant impact on how a society can deal with extreme events. Several studies conducted after natural disasters show that age, gender, ethnicity, income and assets have a great impact on an individual's ability to deal with and emerge from a crisis situation. For example, children and the elderly are less mobile than others, and immigrants often have fewer financial resources, smaller social networks or language issues. These groups are often hard-hit by natural disasters, and knowledge about such social aspects can make municipalities better equipped to develop good emergency response plans.

We need greater insight into how climate change will affect ecosystems and different industries, including the primary industries. If we are to handle climate change, we must develop solutions and materials that are robust as regards climate, for infrastructure, construction and buildings, and the general surroundings.

Research-based knowledge and expertise can help municipalities map their vulnerabilities, prevent risk and carry out suitable measures adapted to local conditions. Norway has built up good climate research centres, particularly as regards climate system research, but also within social science climate research. We also need good professional communities that can train experts with the expertise municipalities need in their work to adapt to climate change.

Social science and humanistic pPerspectives from the social sciences and the humanities provide important contributions to understanding how climate research can be made more relevant. Social science and the humanities help to understand how climate and environment measures can be managed and implemented effectively.

Knowledge is also needed as regards positive opportunities that may arise from climate change, such as whether this could result in increased energy production from hydropower and wind power, or new areas for food production.

Climate change is particularly evident in the polar areas; therefore, climate research plays a key role in both Norwegian and international polar research. A number of research and monitoring systems are found in and around Svalbard for the purpose of studying climate and ecosystem changes, ocean currents and the atmosphere. The Norwegian authorities regulate and grant permission to conduct such activities, and facilitate making Svalbard attractive to researchers from all over the world. Norway's role as host and coordinator of the major international participation in operation and use of these research and monitoring systems will become even more important.

## 4.5 Societal development adapted to the environment

The greatest environmental threats in a global context are loss of natural diversity, pressure on land areas, natural resources and cultural history values, the spread of foreign species, outbreaks of new plant and animal diseases and more environmental toxins. These challenges are exacerbated by climate change. Moreover, they make nature less robust in relation to climate change. We need better comprehension of the interplay between climate change and other environmental impact factors, and new knowledge about how different environmental and climate measures can support each other. Many of the greatest challenges associated with climate change are linked to loss of and changes in the natural environment.

Healthy, functional ecosystems are necessary to address climate change, and sustaining such ecosystems is therefore a vital part of the solution.

Demographic changes and the emergence of larger towns and cities require a sound basis of information to develop policies for comprehensive design of residential and industrial areas and eco-friendly and efficient energy and transport solutions.

We also need more knowledge so we can curb pollution and reduce food wastage, as well as efficient resource exploitation throughout the chain from raw material production to consumption.

# 5 Public sector renewal, better and more effective welfare, health and care services

## 5.1 Direction

High-quality public services are a mainstay in the Norwegian welfare society. We devote substantial public resources to these services, and just under every third employee in Norway works in the public sector. The public sector is responsible for delivering life-long services to the entire population. These services include supporting safe conditions for children and young people growing up, and providing a good education for each and every one of them. The services encompass assistance in finding employment, and ensuring that everyone has an income. The public sector is responsible for providing safe, effective and high-quality health and care services, for preventing crime and promoting safety and emergency planning. Public resources must be used efficiently to ensure that we can continue to provide good welfare services in the years to come. At the same time, the population has high and growing expectations regarding these services, and the authorities respond with high ambitions as to what they will offer. Therefore, the public sector must be a driver for innovation by adopting new knowledge and new forms of organisation.

The private sector plays an important role in renewing the public sector. The private sector will develop much of the technology and expertise that will be incorporated in future public services. These services will also be carried out in cooperation between the private and public sector. Therefore, there is a need for efficient research and development collaboration between the private and public sectors. There is also a need for information on how this collaboration should be organised so as to yield the best possible public services, the best use of resources and profitable business development.

The Government will step up appropriations to research and higher education that will revamp the private sector, and provide the population with better and more effective health, welfare and care services. The Government wants to achieve:

- more knowledge-based production and development of services, with emphasis on research-weak and strategically significant cross-sector areas
- a public sector that drives and utilises innovation
- a knowledge system for better health and care services

## 5.2 Knowledge-based public services

Norway's commitment to knowledge about and for the public sector is lagging behind. The public sector is responsible for ensuring that the services provided are of high quality, and that they are effective. Public service development will be affected by major structural changes, such as changes in settlement patterns, demographic changes as a consequence of aging and immigration, vulnerability and security in the national infrastructure, and an altered health and illness pattern in the population.

The public services do not operate independently, but must cooperate and be coordinated in relation to users who often have very different and complex needs. These people may receive assistance from several different services in different sectors and at different levels. Good coordination between labour market measures, health services and education is particularly important. Research can contribute to mapping and evaluating cooperation, and contributing to develop the content of comprehensive services.

Complex contexts and the demand for high-quality services require knowledge and expertise. Several areas in the public sector can be characterised as “research-poor” in the sense that there is little research-based knowledge in these areas at present. Generally speaking, there is a need for more research on the effects of and content in the actual services, and the structures they are part of. This applies to both state and municipal services, and how these services function together. For example, there is little research on the care services, considering the fact that this is a sector that employs 130 000

**Box 5.1 Good programmes to put more people to work**

NAV (the Norwegian Labour and Welfare Administration) provides programmes aimed at giving the unemployed and those with reduced work capacity a greater chance of gaining or maintaining employment. NAV has many different measures that can be used. Some of the measures take place in a sheltered environment, others in normal workplaces or in ordinary education. The effects of the measures are varied and depend both on the individual's circumstances and on the labour market situation. The effects of the measures depend on both a varying labour market and on the challenges each individual has as regards their health and social situation.

Relatively advanced models have been developed in recent years to analyse the effects of measures. These methods have provided better tools for the authorities to learn which measures, or which elements of a measure, are effective for various groups. There is a potential here for obtaining information that can contribute to streamlining labour market and welfare policy. However, we do not know enough about what works and for whom for this to be a reliable tool for NAV officers and partners in the health and education sectors, as well as in working life.

**Box 5.2 Better services to prevent alienation of children and young people**

Norway spends about NOK 13 billion per year on child welfare. A more diverse population necessitates better, more targeted services. The children and families that are assisted by the child welfare service often face complex challenges. Research reveals that the help these children receive is not good enough to prevent negative development. In an overall lifecycle perspective, adults who have received child welfare services do not do as well as the rest of the population. Compared with the rest of the population of the same age, some of the traits characterising those of us who have been child welfare clients include poorer physical and mental health, lower education, weaker connections to working life and a greater need for health and social welfare services. Therefore, we need research-based knowledge and social science and child welfare personnel who can alter the application of child welfare measures towards actions that actually work, and that contribute to long-term positive change in the lives of children and young people. Good and targeted measures contribute to positive development for individual children, but also bring major socio-economic benefits.

people and accounts for annual public spending of NOK 95 billion. Several reforms have been initiated in the public sector in recent years, such as the cooperation reform, the pension reform and the NAV reform. The Government also plans to implement a municipal reform. We lack a good system for applying the available information, and we need more knowledge about the use and effect of measures and reforms that are initiated. New measures must be developed and tested. The effects of measures must be documented through relevant research, and followed up with implementation and consequence research. Accurate measures will provide the right assistance to help each individual, and while also benefitting society at large.

Areas of strategic, cross-sectoral importance shall be prioritised. We must reinforce areas where there has been little research, but where more knowledge is required in order to deliver and develop better quality. The accuracy of the services must be improved. Here it will be important to involve the people who will use these services, to ensure that the research is beneficial for them. There is also a need for research on organisation and management as well as decision and control models in the public sector. Relevant, hands-on research should be prioritised as a basis for planning and for promoting professional and service development.

Educational institutions and the public sector must cooperate to train a sufficient number of expert personnel to meet the needs for public services. High-quality and relevant education of candidates for the social welfare professions is important. Developments within ICT and other technologies mean that the public sector needs different expertise than previously. In addition, continuing and post-qualifying education must

ensure that expertise in the public sector is up-to-date and relevant. The interaction between research, education and work experience must be applied to a greater extent on the innovation and development work in the public sector. This necessitates cooperation between the educational institutions and the services.

## 5.3 Public sector as driver and user of innovation

The solutions of the future will come from both the private and public sectors. The public sector plays an important role in demanding innovation. It will be an important domestic market for Norwegian business and industry, and will contribute to the application of new knowledge.

These solutions must be developed through interaction between the users, the public sector, business and industry and the research communities. This means that the public sector shall be a good requisitioner of innovation, and shall be key in communicating to business and industry and research communities the challenges that can be solved through research and development. The public sector must also be a good partner, for example with other business organisations. Knowledge and innovation is put to use, both in individual enterprises and across sectors.

Public procurements and public-private cooperation are examples of collaboration that must be designed so they become instruments for addressing challenges that require research or innovation. Financial instruments can also support this interaction. Public support is needed for user-driven innovation projects which public enterprises can apply for, in cooperation with research and business communities. The public sector phd programme is another important instrument. The Research Council and the educational institutions can contribute a comprehensive approach to innovation in the public sector. This requires close cooperation with users and expertise centres in the national and municipal sectors.

Norway has what it takes to lead the way in applying new knowledge to produce public services and to facilitate appropriate infrastructure. We have a highly-educated population, along with good technology expertise and internet access. Norway also has well-developed public services combined with unique infrastructure in certain areas such as registry data and bio-banks. Norway already leads the world in promoting international use of public digital solutions such as Altinn and NAV's electronic service "Your pension".

**Box 5.3 Technological innovation in justice and preparedness**

There are several examples of technological and organisational innovation within the field of justice and preparedness that have contributed to better and more efficient development of services. This includes the violence alarms for persons at risk of violence, electronic imprisonment, DNA tools for use in investigation, biometrics to confirm identity, as well as digital communication solutions for the police and emergency services. Over the longer term, drone technology can be used for a variety of purposes by the police and search and rescue operations. At the same time, several of these technologies also give rise to legal and ethical challenges.

Production and development of services often takes place in smaller entities and in municipalities with little expertise and few resources to carry out innovation. The municipal reform will play an important role in achieving stronger and more innovative environments. Success in the changes that must be made in the future requires that the public sector masters and utilises innovation in technological and organisational solutions and in the services. While there are good examples of service innovation, we do not know enough about which mechanisms stimulate this in the organisations.

## 5.4 A knowledge system for better health and care services

Good health is important for each individual. It is also important for sustainable social development and good access to labour. The need for health and care services to adapt and change is primarily driven by developments within medicine and medical technology. At the same time, people live longer than before and contract different illnesses than was the case just a few decades ago. More people live with chronic illnesses such as cancer, diabetes and COPD. At the same time, we note a worrying development where resistance to antibiotics is a growing threat. In Europe alone, 25 000 people die

**Boks 5.4 Desired objectives and priority areas in the Health&Care21 strategy**

The desired objectives for Health&Care21 are three-fold: research and innovation shall contribute to good public health, ground-breaking research, business development and national economic development. Health&Care21 prioritises ten strategic efforts:

- increased user involvement
- the health care industry as an industrial policy priority
- knowledge mobilisation for the municipalities
- health data as national comparative advantage
- improved clinical interventions
- efficient and effective services
- meeting global health challenges
- increased, high-quality internationalisation
- development of human resource
- strategic and evidence-informedgovernance and management

The strategy also identifies some main priorities going forward. These are:

- Knowledge mobilisation for the municipalities with substantial, sustainable R&D funding; establishment of a national registry of municipal health and care services; and universities, university colleges and a new research institute sector that specifically aim to meet municipal needs.
- Health care as a focus area of industrial policy with sector-specific measures and greater interaction between the public and private sectors
- Easier access to and increased utilisation of health data.
- An evidence-informed health and care system based on user involvement and competence, with greater emphasis on developing new interventions and documenting the impact of these, both at the clinical level and at the organisational and system levels
- A strong commitment to internationalisation and increased participation in the competitive European research system.

each year after being infested with multi-resistant microbes, e.g. via food, livestock or pets.

We lack knowledge about diagnosis and treatment in several areas, such as dementia, substance abuse treatment, cancer, rare diseases and patients afflicted with multiple diseases all at once. These challenges must be met with knowledge about factors that impact health and illness, how these services can best be offered, which treatments work and how we can apply new solutions in future health and care services.

Research, education and innovation are important criteria for developing sound, high-quality health and care services. A knowledge system for improved health and care services must include cooperation arenas for user participation. The system must also be equipped to assess needs for trained personnel and expertise in these services, such as health workers, natural scientists or technologists, as well as schemes for assessing the quality of health and social science programmes. We need outstanding professional and research communities in the fields of prevention, treatment, care and service development. We also need good cooperation between these services, the professional clusters, the users and the business community in order to develop and apply the results of this innovation.

In June 2014, the Government received "Health&Care21", the first cross-sectoral, comprehensive research and innovation strategy for health and care services. This strategy forms the basis for long-term, comprehensive development of research, development and innovation for public health, and the health and care services. The strategy points to a pent-up potential for international research cooperation and business development in the health field. There are also areas with major knowledge gaps, for example within municipal health and care services. Second only to the petroleum industry, the health industry is the sector that invests most in research and development. The Government has great ambitions for exploiting the potential that lies in business development in the health sector, and therefore wants to establish health and care services as an industry policy commitment area, with appropriate policy instruments.

In Norway, we have expert communities that are world leaders in certain aspects of health, health research and innovation. We also have unique research tools through our stores of

health data and samples from patients and healthy individuals. These samples are stored in large biobanks and represent tools that give us a good starting point for developing our basis of knowledge, which is attractive for international partners and forms the basis for cooperation with business and industry.

Norway also plays a prominent role in clinical research, but this remains an area with major knowledge gaps. We lack information that can contribute to better prevention and treatment of both major widespread diseases such as dementia and musculoskeletal ailments, as well as more rare diseases such as chronic fatigue syndrome (also called ME). Not least, there is a huge need for knowledge in the municipal health and care services. The Government believes that HelseOmsorg21 provides a good description of the challenges faced in the municipal health and care services, and wants to enhance its commitment to a knowledge system that can contribute to better health and care services in the municipalities. The Ministry of Health and Care Services will develop a municipal health and care services register to further objectives such as development of infrastructure for research in the municipal health and care services. The Government will revert to the Storting as regards a plan for how to follow up the HelseOmsorg21 strategy.

There is also a great international demand for better and more effective public services. The development within e-health and welfare technology is important to address user needs for more home-based and adapted treatment and care services. A large part of the research funding in the European research programme Horizon 2020 is earmarked for research in health, demographic change and welfare. The Government is working to ensure that many Norwegian expert communities take part in the Horizon 2020 health programme.

A knowledge system for better health and care services depends on developing good arenas for cooperation which allow us to assess the need for expertise, user needs and the need for knowledge in the health and care services. In other words, closer cooperation must be achieved between the educational and research institutions and the local and regional authorities that are responsible for developing and delivering the services. The knowledge system must involve the users to a far greater extent throughout the entire course of research and innovation. Both the health enterprises and the Research Council have already embarked upon this.

**Box 5.4 Progressive medical equipment means opportunities for leading expert groups**

Rapid development is taking place in technical solutions for radiation treatment of cancer. Two new techniques are radiation therapy with protons and radiation therapy with carbon ions. Both have significant curative effect and result in less radiation damage to adjacent organs and tissue, compared with the current treatment. Establishing this type of treatment in Norway will require substantial investment in buildings, equipment and expertise. The expert communities claim that Norway could become the world leader in research on radiation physics, particle physics and radiation biology if Norway invests both in radiation therapy with carbon ions and treatment with protons. This could form the basis for a Nordic and European research collaboration with Norway taking the lead. At the same time, we can offer patients a gentler radiation treatment.

There is a particular need for intensified efforts targeting the municipal health and care services, and services in the interfaces between the hospitals and the municipal health and care services. Increasing demands are placed on developing, testing and documenting the effects of measures through clinical studies, implementation and effect research. This requires research infrastructure such as clinical test units and medical quality registers. The professional, medical and technological development requires a broader understanding of how illnesses develop, and the development of new, effective and more individually adapted and gentle treatment methods and diagnostics. The development of more tailored treatments based in part on genetic data and development of new medical technology is expected to have a major positive impact for individuals by reducing potential side effects. One example of new technology is new types of radiation treatment for cancer patients. Such treatments are currently being established in many countries.

Existing health data must be utilised more efficiently, and better data must be developed for the health and care services in the municipalities, as well as better data for measuring that the services offered are safe and of high quality.

We need more knowledge about special needs and social problems, prevention and effective nutrition and lifestyle-based strategies to optimise health and reduce risk, or to delay early onset of nutrition-related diseases. New technology and new organisation models must address the needs of the users and requirements for effective, high-quality and safe services. To achieve this, we must train and update personnel and experts who can use these new technologies and who can work in a public health service which constantly adapts to new types of services.

# 6 Enabling technologies

## 6.1 Direction

Enabling technologies are technologies that prove to be so radical that they lead to major change in society. They also lay the foundation for many other new technologies. Historic examples include the art of printing, railways, steam engines, electricity and modern mass production. Countries that have spearheaded development, refinement and application of enabling technologies have experienced stronger economic growth than others.

An international race is under way to develop and commercialise today's enabling technologies, such as information and communication technology (ICT), biotechnology and nanotechnology. These are knowledge-intensive technologies; that is, they are based on research and development, cutting-edge expertise and rapid innovation cycles. ICT's emergence as a fundamental infrastructure in society and a common part of Norwegians' everyday work and private lives is an example of the social formative aspects of today's enabling technologies. The fact that most bank branches have been replaced by online banking and mobile banking has, for example led to lower costs for the banks, and has made it easier for most customers to obtain and use bank services.

In the next decades, we can expect that society will be fundamentally altered by products and solutions created with the help of enabling technologies. If we look back, one of the examples we see is that less than 10 years have passed since the first smart telephones with touch-screens entered the market. These types of products were made possible by the development in screen technology, sensors, battery technology and software. The European Commission views enabling technologies as the most important driver for modernisation of European industry and the transition to a knowledge-based, low emission society. The same is the case in the US.

We must pave the way for inquisitive researchers to conduct creative experiments that subsequently prove to yield surprising breakthroughs. Cooperation and projects in the intersection between technological science and other disciplines is a precondition for ground-breaking research. It is also a precondition for using technology solutions to address social challenges and develop trade and industry.

Enabling technologies are an input factor in the development of new products and new industry. Developing enabling technologies contributes to new solutions that can be applied in most areas of society, such as food production, energy efficiency, transport/communication and better health and care services. ICT is crucial for value creation and efficiency in the private and public sectors. There is a very substantial socio-economic benefit from improved ICT solutions. Using advanced biotechnology, products based on renewable biological material can replace nearly all petroleum-based products, including energy. Nanotechnology is also important in realising a low-emission society with extensive use of clean energy sources.

Biotechnology and nanotechnology have been prioritised technology areas for the last 10 years, while ICT has been a priority even longer than that – yet still not sufficiently. Valuable and fundamental competence, quality and capacity have been developed and refined in the research system, in higher education and in business and industry. We have strong expert communities in several areas, such as secure communication, biorefining and the materials industry. Technological development is rapid and Norway, as a high-cost country, must take part in the research front.

Competition between manufacturers and producers in high-cost countries is sharp. The OECD believes that we are on the cusp of a new industrial revolution where use of new technologies will enable us to produce a number of products in entirely new ways using more advanced production processes. Maintaining Norwegian industry and service production and Norwegian jobs that can compete in new markets requires that we are able to streamline production and reduce costs. When international competitors produce more efficiently and with more customer adaptation, Norwegian enterprises come under increasing

pressure to improve the efficiency of their own production.

The enabling technology areas have originated from a number of fundamental disciplines such as mathematics, natural science and technology. However, development of enabling technologies also demands perspectives from the social sciences and the humanities and legal research. This is needed to ensure understanding of how the technology areas, and the people who will apply and use them, work together and impact each other. For example, a number of important issues are linked to how the technologies can change our society in ways that challenge us ethically, socially and politically, and that have consequences for the safety and security of our society. In historical terms, changes related to enabling technologies have challenged the existing power structures, and have in part led to significant social costs. If enabling technologies are to help promote innovation and address social challenges, research in advanced technologies and systems must be combined with research on e.g. institutions and organisations, regulation and policy, communication and interaction in the home and in society.

Enabling technologies will support the other priorities in the long-term plan and will contribute toward achieving the objectives of increased competitiveness, solving social challenges and developing excellent expert communities. The Government aims to reinforce its commitment to the enabling technologies. These efforts will target:

- biotechnology and nanotechnology
- information and communication technology (ICT)
- advanced production processes

## 6.2 Biotechnology and nanotechnology

National R&D strategies have been drawn up for biotechnology and nanotechnology to ensure good interaction between the various parties, as well as improved overall resource exploitation. These strategies provide an up-to-date overview of status and opportunities, highlight challenges and needs and stake out a direction for further development of technology areas in Norway. The strategies have been well-received and are actively used by both those who fund public research, and those who conduct this research. Using these strategies as a starting point, Norway will exploit the opportunities provided by biotechnology in a responsible manner to secure value creation and health, and to safeguard the environment. This will be done by means of cross-sectoral research, competence development and cooperation. Biotechnology is important for the development of the marine sector, agriculture, health and industry. Future efforts must be tailored to the various needs and special features of each sector. Nanotechnology will provide a significant contribution toward Norwegian business development and social benefit, assuming that it is developed responsibly. Within this area of technology, we see both a need for further commitment to fundamental knowledge development and a stronger commitment to innovation and commercialisation. We also need more knowledge about potential undesirable effects of nanotechnology on people, the environment, and society in general.

The national biotechnology and nanotechnology strategies form the technical groundwork for how we organise our ongoing commitment in these areas. Our efforts will be scaled up so as to allow Norway to exploit the investments already made, and to reinforce resource input in the areas where this is needed.

The knowledge enhancement that has taken place within biotechnology and nanotechnology will be further developed. There is still a need to build up fundamental and interdisciplinary expertise, and this need is expected to persist for the foreseeable future. In addition, it is now important to facilitate realisation of the potential for innovation and business development in earlier investments. Norway has a large, pent-up potential for biotechnological innovation and business development within health, food production and the process industries. Nanotechnology and advanced materials will have a major impact on innovation and value creation in areas such as energy, food, health and medicine, ICT and electronics, as well as consumer products. We need to use the expertise we have acquired and refined to exploit the knowledge found in Norway and abroad. Accomplishing this will require closer cooperation between industry and commerce and the expert communities. We need to integrate research on ethical, legal, environmental and social aspects of this commitment to promote responsible technology development. Ensuring broad-based and critical research on the application of these technologies will require fundamental humanistic, social and legal research.

A new research and teaching building for life science, chemistry and pharmacy at the University of Oslo is in the planning stages. The new

building will facilitate development of expert communities within enabling technologies.

## 6.3 Information and communication technology

*Major impact, not enough research*

The enabling technologies are in different stages of development in all countries, particularly in Norway. ICT is a mature technology compared with biotechnology and nanotechnology. Advanced information and communication technology is widespread, and is an integral element in all areas of society. This includes everything from remote control of cabin heaters to remote control of complex oil installations on the seabed. Therefore, much of the ICT area is about applications, adaptations and user-driver innovation. ICT and research and development collaboration within ICT are important for both the private and public sectors. The Norwegian ICT industry enjoys high revenues and high value creation per employee. For business and industry overall, as much as 45 per cent of the total investments in research and development work are linked to ICT. However, this is mainly related to development activities. Most of the research activity in the ICT area takes place in the academic communities and the research institutes. Therefore, the public sector has an extra responsibility for further developing the research-based knowledge for innovation and business development based on ICT. At the same time, good ICT applications require information on how we, as individuals and as a society, put this technology to use.

Evaluations were conducted in 2012 of publicly financed ICT research in Norway, and of the Research Council of Norway. Both evaluations pointed to a need to increase public investments in ICT research, particularly in relation to the importance of this technology in addressing key challenges in our society.

As is the case for biotechnology and nanotechnology, a national R&D strategy has also been developed for ICT. This forms the basis for how further initiatives will be organised. ICT must be utilised to the fullest to achieve more growth and value creation in Norway. Future efforts will target ICT-R&D of high international quality, business development and value creation. Our efforts will also be aimed at addressing major social challenges, particularly as regards information security, the public sector and infrastructure, and health care.

**Box 6.1 Personalised medicine**

Personalised medicine is the new way to classify, understand, prevent and treat disease. This approach is part of life science, which is the study of the structure and function of living organisms. The enabling technologies all contribute to this development. This type of treatment is based on each patient's unique genetic make-up. The objective is to identify the treatment and the preventive measures that work best for each individual patient, and not for an average of all patients with the same diagnosis or risk. So far, this approach is most relevant for patients with rare diseases and patients with common, widespread ailments such as cancer, diabetes and Alzheimer's disease, and for more effective treatment of infectious diseases. Personalised medicine can also contribute to avoiding over-treatment and unnecessary side effects in patients where treatment is not effective. Progress in this field depends on significant cross-sectoral cooperation and top-notch equipment.

*A commitment to general research and recruitment*

Information and communication technologies undergo constant change, and it is particularly important that we have strong expert communities in fundamental ICT research and education. In this way, we can rapidly address new challenges or exploit technological breakthroughs that may take place in this area. For this reason, basic ICT research must receive more attention. In addition, basic ICT research must be linked with sector and topic-based ICT research. Only by doing this can e.g. the health and care services sector ensure that research on topics such as e-health is based on the best and most up-to-date ICT research.

ICT research must include both ICT-heavy research, such as sensor technology and more applied research, for example on tools for electronic interaction and communication with patients and research for service innovation. There is also a need for ICT research within disciplines where ICT is an essential tool, e.g. in research on tailored personal treatment, where medical treatment is tailored to the individual patient based on factors such as genetic data. Those who are to use this new technology must have the right expertise. This applies equally to the newly-qualified and to those

who have been employed for many years. This requires that education programmes must be updated within new fields, particularly within ICT. Opportunities for learning and skills-development for workers should be available.

The percentage of employees holding doctorates is low in the Norwegian ICT industry. Therefore, we must increase the number of scholarships in ICT. This conforms with analyses and projections of recruitment needs, cf. Chapter 2 on predictable increase in efforts. The business sector also needs people trained in ICT at the bachelor's and master's level.

*Information security and protection of personal information*

Many Norwegian enterprises have been the target of major cyber-attacks over the past year, yet information security research is still lacking in Norway. Information security is an area where national expertise is especially important. If conflict situations should arise, reliance on expertise from other countries could be unfortunate.

At the same time, an increasing number of basic functions in public sectors such as electricity, water, health, communication, transport and finance require that electronic communication networks and services function everywhere, and at any given time. We should have domestic expertise and research in this area so we can identify the best solutions for Norway.

One objective is to introduce the principle of built-in personal information security in all sectors of society. A prerequisite for good ICT products and services is that solutions that safeguard personal privacy considerations are built into all stages of the technological development. This is relevant not only in legal research, but also in ICT research.

## 6.4 Advanced production processes

Norwegian industry must constantly enhance the quality of its products, without increasing costs, if it is to survive international competition. Norway can rarely compete solely on price. We must compete on productivity and smart solutions.

Many Norwegian enterprises employ quite advanced automated production processes. For example, both the furniture industry and Norwegian dairy farmers make extensive use of robots in their production.

A number of service providers have also largely automated their products and services. While in the past, we went to a travel agency, received our ticket by post, and paid with a bank giro, we can now purchase flights from our cell phones – anytime, anywhere. While we used to queue to submit our tax return or to file a change of address notice, we can now do all of this from our computer. These types of advanced ICT solutions in more and more areas mean that we spend less time, we conserve the environment, and receive services that are more suited to us, and are delivered faster.

High-level expertise and considerable research and development cooperation are needed to develop these smart solutions. Researchers and experts must be able to work across disciplines and draw on knowledge from technology areas such as biotechnology, nanotechnology and ICT. New technologies can also spring from putting together advanced technology from different disciplines to improve a complex production process.

We need to follow this development closely, understand the forces that drive it, and the impact this development may have for production of goods and services in the Norwegian private and public sectors. We must ensure that people are trained with the right expertise to use and develop advanced production processes. High-level ICT expertise is particularly important. We must create arenas and initiatives that stimulate Norwegian enterprises to develop advanced production processes. We must strengthen our preparedness to adopt the latest technological solutions in production, whether it is in manufacturing, the primary industries or service industries.

Use of increasingly advanced technology means that a number of enterprises in high-cost countries can move production home from low-cost countries. Domestic production yields better quality control, faster transport to customers and makes it easier to respond quickly to changes in demand. Development of new products is also easier when one has detailed knowledge of how to produce the product.

The development of new production technology, changes in demand and a new understanding of where and how one can and should produce things, will change international competition. The EU's Horizon 2020 research and innovation programme prioritises advanced production processes in line with biotechnology, nanotechnology and ICT. Research and expertise within advanced production processes will be prioritised to improve competitiveness and adaptability in the Norwegian economy, and to secure Norwegian jobs.

**Boks 6.2 Robots and 3D printers**

We are currently witnessing the emergence of a broad selection of increasingly advanced technologies for providing products and services. According to the Norwegian Board of Technology, robots and 3D printers are two trends that will characterise the development of increasingly advanced production processes.

The latest generation of industrial robots can produce faster, more flexibly and with greater precision, and are safer and more stable in relation to people and operations. Kleven Verft in Ulstein municipality is an example of a company that uses robots. Kleven produces advanced ships for customers such as the oil and gas industry. Kleven has moved its production of hulls home to Norway and has invested in new high-precision welding robots that can work around the clock and are very fast.

Using data files, 3D printers (machines that "print out" three-dimensional objects) can automatically build very complex objects in a single piece, rather than assembling them from several parts. 3D printing is currently being tested for production processes for e.g. car bodies, parts for aircraft engines, prosthetics, buildings and several different consumer goods. Examples of Norwegian enterprises that use 3D printers can be found among architect offices, furniture manufacturers, design agencies and model-maker workshops that assist customers with product development and industrial design.

# 7 Innovative and adaptable industry

## 7.1 Direction

The Government wants to enhance competitiveness in the industry and has an ambition of making Norway one of the most innovative countries in Europe. Therefore, the Government has made a commitment to commercial research and innovation, and will use the long-term plan to lay the foundation for a more knowledge-intensive business community with a robust ability to adapt and create value.

Norway is a prosperous country after 150 years of economic growth. The growth in prosperity is due to factors such as efficient utilisation of labour and production factors, and our success in productive and less work-intensive industries. We have a stable society and we have exploited our natural advantages. High workforce participation rates, extensive trust and cooperation in working life, efficient domestic markets and openness to international markets have contributed to good framework conditions for the business community. At the same time, wage levels in Norway are high, causing particular challenges in labour-intensive industries. More effective organisation and higher work productivity can offset this, to some extent.

Like other high-cost countries, Norway must compete on knowledge as a basis for innovation and higher productivity, in order to maintain its high standard of living over time. The ability to develop and apply new knowledge is among the most important competitive factors for Norwegian trade and industry. This is crucial both for change and adaptation in existing industries, and as a basis for new business.

The Norwegian economy has a relatively high and growing degree of specialisation. This means that just a few sectors account for a large share of the country's gross domestic product (GDP). This is not uncommon in a small country. Small countries must exploit their natural and social advantages in order to use these resources in an effective manner. However, excessive specialisation in the economy can create vulnerability to business cycles.

The Norwegian economy is affected by major social change. The business community must be prepared for the transition to a low-emission society. Emerging economies are challenging the countries that have dominated production of high-profit, knowledge-intensive and innovation-driven goods and services. An ageing population will entail significant challenges as regards access to labour, and will lead to changes in society's demand for goods and services. Over the long term, petroleum activity on the Norwegian shelf will also decline, e.g. as a consequence of reduced access to resources, technological breakthroughs in alternative energy sources, products based on renewable biological material or altered framework conditions for greenhouse gas emissions. A reduction will have consequences not just for petroleum revenues, but also for business activity associated with operation and development throughout the entire petroleum-related business segment. To counteract this vulnerability in the Norwegian economy, it is important that we pave the way for rejuvenation and change towards even more knowledge-intensive business activity.

The business community conducts nearly half of all research and development in Norway, and most of this is financed by the companies themselves. Investments in research and development in Norwegian trade and industry account for a lower percentage of current value creation than the average for OECD countries. Much of this can be explained by the industry structure in Norway, although Norway is also below the OECD average after correction for the industry structure. The Norwegian business community consists of a substantial percentage of industries with relatively small investments in research and development, as compared with value creation. In addition, Norway has relatively few large companies, which normally undertake the largest investments. Nevertheless, it is not acceptable that a high-cost country like Norway invests less than the average in commercial research and development.

The Government wants to boost its commitment to research and higher education that can

contribute to an innovative and adaptable business community. The Government wants to achieve:

- mobilisation for more research and development, and sound expertise across the full breadth of Norwegian industry
- more research-based innovation, new establishments and commercialisation
- business development based on social challenges

## 7.2 Mobilisation for more research and development and sound expertise throughout the Norwegian business community

The Government wants to promote a business community that embraces the most up-to-date knowledge available, and that develops new knowledge through research, development work and cooperation with expert knowledge environments. This applies to industries that already invest heavily in research and development, industries that traditionally invest little, and new industries.

Each enterprise must obviously consider what type of investments it will make in research and development. For society at large; however, the overall research commitment in the business community may be too low. The explanation for this is, in part, that society as a whole often benefits considerably more from such investments as compared to individual companies. Therefore, the Government wants to encourage public investments that spur the business community to invest more in research.

Public schemes stimulate private sector investment in research and development in several different ways. The threshold for investing can be lowered through tax relief, such as the Skattefunn tax deduction scheme. The public sector also creates schemes that directly stimulate research in trade and industry, and that also contribute to cooperation with research institutions. This applies, for example, to programmes under the Research Council of Norway and Horizon 2020.

The business community receives its greatest contribution to research-based knowledge through the stream of graduates with expertise based on up-to-date research. Some of these people proceed on to research careers, but most go straight into vocations within their expert fields and professions. The business community of the future is formed, in part, by how many people choose to pursue higher education, what they learn and how they continue to build on this expertise. Good and relevant courses of study and arenas for continuous development of expertise must be developed in closer dialogue and cooperation with the business community. This is particularly true for the highly-specialised segment of trade and industry. The State also contributes to the business community's ability to apply research-based knowledge through recruitment to researcher programmes and through the private sector Ph.D. scheme. The Government therefore wants to establish 500 new recruitment positions, with particular emphasis on the business community's need for doctorate personnel within mathematics, natural science and technology subjects, cf. Chapter 2.

Public spending also finances expert communities that are of such excellent quality and relevance that this alone encourages trade and industry to invest in research to gain access to knowledge which results in global advantages. The Norwegian Centre of Excellence (SFF) scheme is such a policy instrument.

The Government wants to strengthen general business schemes to encourage the full spectrum of business and industry to conduct more research, and to convert research into business development. Many companies have little experience in research and development, and need guidance on how to make use of regional, national and international programmes. The application processes must be simple, and involve minimal bureaucracy.

In 2012, public sector procurement amounted to around NOK 408 billion, or 14 per cent of the gross domestic product. The potential for using public procurements to mobilise the business community toward more research and innovation is considerable. A public sector that demands expert goods, services and solutions, and that cooperates with the business community, can be an important catalyst for more research and innovation. Continued development of public procurement schemes is an effective tool for promoting more R&D in trade and industry.

## 7.3 More innovation, start-up and commercialisation based on research

Established trade and industry often invests in research and development based on the need to improve its own products and processes. When

the State wants to contribute to renewing the current structure of business and industry, it is therefore not enough to merely stimulate self-defined R&D activities. While new business activity is often based on existing activity, it is important to facilitate curiosity-driven and potentially more creative research and innovation that can form the basis for the emergence of brand new commercial activity, in both established and new businesses. Ground-breaking research and technological progress can be translated into new business activity.

Flexible schemes are needed that can elevate new, knowledge-intensive areas of business. This can take place in interaction between public and private expert communities, or as support to areas with special adaptation challenges. The ability of the research institutions to develop strategic, long-term knowledge will be intensified. The Government wants to make use of the institutions' expertise to strengthen recruitment of candidates with doctorates, particularly in math, science and technology subjects, cf. Chapter 2.

The Government wants to facilitate research-based new businesses, and commercialisation of public research results. Commercialisation of research results that originate in the public knowledge environments are more closely tied to the academic research front, and are to a lesser degree initiated by the needs for knowledge in the established business community. This means that the adaptations provided by research-based ideas may be original and rejuvenating, but may also encounter challenges in the form of a lack of expertise needed for commercial exploitation. New businesses that originate from existing companies may encounter the opposite problem, with substantial expertise in commercialisation, but fewer innovative ideas.

Developing new business activity is therefore not only a matter of developing new knowledge, but of combining knowledge and expertise found in different places. Programmes that provide interaction and sharing of knowledge between the business community, academia and investor groups are important. The same applies to the commercialisation system, and incubator schemes that promote commercialisation, good cooperation and help to remove bottlenecks in the value chain from knowledge development to the market.

Many input factors are necessary for success, but they are often not available at the same time or in the same place. Those who manage publicly funded programmes aimed at promoting research, innovation and business development – such as the Research Council of Norway, Innovation Norway and the Industrial Development Corporation of Norway (SIVA), are organised with separate areas of responsibility that, all together, cover much of this need. These agencies must further develop the possibility of coordinated and cohesive commitment to prioritised areas.

## 7.4 Business development based on social challenges

An innovative and adaptable business community is important in addressing many of the major challenges facing our society. With its strong point of departure in existing expertise and natural advantages, Norwegian industry has excellent prospects for developing products and technology that can contribute to solving problems related to climate, the environment, energy, health, safety and emergency planning, food safety, population

**Box 7.1 The bioeconomy**

The world faces major global challenges as regards sustainable strategies to secure enough food and promote good health. The biosciences and biotechnology can provide important contributions through new or improved services, industrial processes and energy production. The term knowledge-based bioeconomy is used more and more often to refer to such a development, both in Norway and internationally. The OECD uses the term bioeconomy to describe an economy where biotechnology accounts for a significant portion of overall value creation and is used in primary production, industry and health. The knowledge-based bioeconomy includes all industries and economic sectors that produce and use biological resources, including agriculture, forestry, health and medicine, reindeer husbandry, aquaculture, fisheries and associated industries. The European Commission refers to the bioeconomy as sustainable production and processing of biomass into food, various health and fibre products, industrial products and for energy. In this context, biomass includes biological material as a separate product, or as a raw material.

growth and changes in demographic age distribution. The challenges are complex, require the involvement of many contributors and a broader connection between business development, social challenges, research efforts and knowledge development. The social challenges give business and industry opportunities to develop new, progressive activities. The companies that make use of these new opportunities and acquire a competitive advantage are better equipped to meet future adaptation challenges.

Climate and environmental challenges create new markets, and climate and environmental technology is considered one of the world's most promising markets. Norway has good opportunities here, cf. Chapter 4 on climate, environment and environmentally-friendly energy. Norway also has abundant opportunities to succeed within the bioeconomy, where e.g. products based on renewable biological material can reduce greenhouse gas emissions and develop new business activity, cf. Chapter 6 on enabling technologies.

The range of use for forestry raw materials is extensive. Targeted research and development efforts will contribute to the forestry industry extracting its potential for industrial growth within the bioeconomy. Therefore, the Government has invited participation in the work on Skog22, which will become a broad, uniting strategy for research, development, innovation and information in the forest-based value chains.

Norway also has good criteria in place for successful business development within universal design, welfare technology and health and care services. The health care sector is uniform and well-organised, there is good cooperation between the research environments at the universities and university hospitals, and also increasingly between the health trusts and the municipalities.

# 8 World-leading academic groups

## 8.1 Higher ambitions

World-leading research communities have global impact. They achieve research results that provide completely new insight. They train candidates who are sought-after worldwide. They create innovations that achieve broad application. There are academic groups and schools that have convinced politicians to organise entire economic communities in new ways. There are academic groups that have changed how we, as human beings, understand our presence in and the world around us. Other expert communities have developed new technologies so powerful that they have changed the lives of billions of people worldwide.

The Norwegian contribution to overall world research is less than one per cent. Therefore, one could question whether we should refrain from comparing ourselves with the best, and leave the resource-intensive, ground-breaking research and innovation to the larger countries. The answer is no. Investing in the world's best expertise is in Norway's best interest. We also have a moral responsibility to contribute to tackling global social challenges. The greatest challenges of our time can only be dealt with by investing in research that has a genuine impact on the world. Research that leads to technological breakthroughs. Research results that lead to a smarter way to organise society.

Norway is among the world's foremost nations in certain areas of research, such as marine research. If we are to continue our role as one of the world's most prominent seafood nations, we cannot just build on research conducted in other countries. We must contribute to this development and to the breakthroughs. However, there are many areas of research where Norwegian expertise does not make a substantial global difference *on its own*. Nevertheless, we need excellent expert communities in important areas so we can work together with the best, and bring home and exploit cutting-edge research results from leading centres of expertise in other countries.

If we pursue a defensive strategy, we risk falling behind as the best researchers and students will gravitate to exciting environments in other countries instead of coming to Norway. In other words, we run the risk of becoming a country that other countries are not interested in cooperating with. Only through participation at a high international level will Norway emerge as an attractive partner for researchers and talented students and, not least, for both national and global business and industry that use increasingly advanced technology to compete in global markets.

Cluster development, that is, cooperation between related companies and institutions, is important for strengthening our ability to innovate and compete. The maritime cluster in the Møre region is an example. In this cluster, students at all levels can benefit from a network, which in turn contributes to good interaction between education, research and innovation.

Evaluations and reports that review Norwegian research confirm that we have outstanding expert communities and that the quality in the Norwegian system is generally good. However, they also indicate that our ambitions are too low, and that we could do much better. Norway has too few expert communities that are actually among the best in the world. Norwegian researchers are cited less often than researchers from other Scandinavian countries. Norway has fewer researchers that publish in recognised publications such as Nature and Science, and fewer researchers among the world's top 10 per cent most cited researchers. Norwegian researchers do not make it to the top of the European Research Council (ERC) to the same extent as their Nordic colleagues. Norwegian universities have fewer publications per employee, although good progress has been made in recent years. For this reason, we must have higher ambitions.

We do not have the same opportunity to compare the quality of education between countries, yet different national evaluations reveal that higher priority must be assigned to quality development in Norwegian higher education.

## 8.2 Direction

The world's leading research is expensive, in most areas. Therefore, both large and smaller countries must target their efforts more carefully. To a greater degree than previously, we must concentrate on asserting ourselves in areas we are particularly good at, and where we have particularly good criteria in place.

Norway has made a substantial commitment to excellent quality in research and higher education. Through the last decades, we have put programmes in place that lift up outstanding individual researchers, excellent research centres, educational centres and young talents. These programmes have made it possible for experts such as climate researcher Eystein Jansen at the Bjerknes centre and brain researchers May-Britt and Edvard Moser at NTNU to build up some of the world's leading expert communities in Norway, to mention two examples. When the Government has decided to develop more world-leading expert environments, this includes an ambition to take the quality commitment a step further.

Research-based knowledge is crucial for maintaining positions and strengthening existing companies, and for laying the foundation for future trade and industry. The business community needs to recruit and cooperate with students and researchers with relevant expertise at the very forefront of international knowledge. The business community has many expert environments that are already world-class in their fields. The Government's commitment to these environments will largely be handled within the other priorities in the long-term plan.

If Norway is to assert itself alongside other countries we must compare ourselves with, we must have policy instruments in place that give the very best researchers the very best opportunities to create new knowledge, understanding and technology. We will further develop the quality instruments we already have, and we will also develop new policy instruments that cultivate high ambitions more clearly. A larger share of the public funding of institutions that conduct research and higher education shall target top-level quality.

The Government will accelerate its commitment to research and higher education that contributes to achieving more world-leading expertise in Norway. The Government wants to achieve the following:

- that Norway has world-leading research communities that contribute to new understanding, better competitiveness and the ability to address the challenges facing society
- that Norwegian research communities attract and develop the best talents
- that the best researchers and students have world-class buildings and infrastructure

## 8.3 World-leading research communities for new understanding, better competitiveness and the ability to address social challenges

Today's society demands research-based knowledge in an ever-increasing number of areas. At the same time, this research must not have excessive focus on short-term needs, or be tied too strongly to specific challenges and solutions. Research that seeks out new understanding and research that seeks out solutions to practical problems must therefore be viewed in context.

Scientific breakthroughs cannot be planned. New know-how can arise in unexpected ways and in areas impossible to predict. Therefore, it is important to have a long-term commitment to developing expert communities that can become international leaders in their fields.

Creating policy instruments that stimulate quality and facilitate development of world-leading expert communities is possible, but it is up to the respective expert groups and institutions to encourage, and support, a high level of ambition among their employees and students. The institutions must lay the groundwork for a culture of quality that cultivates and looks after the best and brightest. This may entail that the institutions prioritise individual subject areas and researchers higher than others. For example, the Norwegian University of Science and Technology (NTNU) in Trondheim has a star development programme which is a systematic commitment to the elite among young researchers.

At the same time, this means that the institutions must sharpen and prioritise their efforts. Not even the largest universities and university colleges can be good at everything. For example, the University of Oslo has launched life science as a main commitment area.

Development of world-leading expert environments can also entail facilitating the emergence of new subject areas through more cross-disciplinary cooperation. Recruiting researchers who are already world leaders within their fields could constitute another policy instrument. This depends on

the institutions having good recruitment practices, and can be viewed in context with the trial scheme for tenure track positions, cf. Recommendation 221 L (2013–2014) and Proposition 59 L (2013–2014) *Changes in the Universities and University Colleges Act.*

Both Norwegian and international discussions on high quality in research often highlight the open competitive arenas as key instruments for stimulating excellence in research. Such instruments ensure that the resources go to projects that are quality-assured through professional international assessments. The Government will continue to strengthen long-term basic research. Programmes such as the Research Council of Norway's FRIPO (Independent projects support) are well-suited to contribute to the development of expert communities into world leaders. The European Research Council, ERC, is another competitive arena where the quality of the project proposal is the most important criterion for receiving support. Grants awarded by the European Research Council are also of such a size and degree of prestige that they can help elevate expert communities to a world-class level. Such programmes must be designed to contribute to innovation and boldness, and to cultivate talented researchers. It is particularly important in this context that the policy instruments open doors for projects from technical disciplines or combinations of disciplines that may be untraditional, but that may contribute perspectives that foster innovation. It is also important that the project financing works together with more comprehensive commitments at the institutions so that the expert communities are not split by many, relatively small projects. This means that universities and university colleges must, to a greater extent than is currently the case, designate and prioritise their best and most promising researchers and expertise.

There is good documentation to the effect that competitive instruments such as the Norwegian Centre of Excellence (SFF), Centres of Excellence in Higher Education (SFU) and the Centre for Research-Driven Innovation (SFI) have had a good effect on quality. These programmes will continue to be important in the ongoing commitment to excellent environments, but there will be a need to further develop these programmes, e.g. to support the work to achieve more excellent professional environments that are also world leaders in their fields. Together with the Research Council of Norway, the Ministry of Education and Research will e.g. examine how the SFF scheme is organised, before the next round of announcements.

International cooperation is a prerequisite for carrying out top world research. The Government will continue its work to stimulate institution-based, long-term international collaboration. The opportunities we have through the Horizon 2020 European research and innovation programme will be exploited more fully. Therefore, the Government is raising appropriations to stimulus instruments for Norwegian participation in Horizon 2020, cf. the discussion in Chapter 2.

While the long-term plan assigns high priority to taking part in the EU's research collaboration, it is essential to reinforce cooperation with expert communities in important countries outside the EU. Prioritised countries include both established knowledge nations such as the US and Japan which have outstanding research communities in a number of prioritised areas; and countries like China, India and Brazil which together account for a substantial portion of world knowledge production. A systematic, long-term collaboration with outstanding expert communities in these countries is an important supplement to participation in Horizon 2020 in the work to promote development in several leading expert communities in Norway.

In addition to the open, competition-based programmes, the Government will also consider stimulus measures that reward environments that exhibit clear results, that succeed in obtaining funding from external schemes, and that are widely published and cited. This can be done both through national schemes, and within the respective institutions and institutes. This means that the institutions must give successful professional environments particularly good terms.

We need universities and university colleges that develop cross-sectoral expertise in order to succeed in creating values and addressing social challenges. The institutions must tear down barriers and cultivate cooperation between today's disciplines in such a way that these subjects are strengthened, not weakened. International cooperation and inter-disciplinary approaches are necessary in order to identify solutions that can address future social challenges, to bolster Norway's competitiveness and to contribute to development of social prosperity.

## 8.4 Norwegian research communities should attract and develop the best talents

One consequence of the high ambitions for strengthening competitiveness and addressing social challenges is that Norway must have similar high ambitions for training excellent experts and researchers that can contribute to Norway actually achieving these objectives. Therefore, the Government wants Norway to be one of the countries that the world's most talented students and researchers want to go to.

Norwegian industry clusters, such as Blue Maritime, are major global business forces. The Blue Maritime cluster has more than 200 member companies, and has gained the status of *Global Centre of Expertise*. The cluster builds and outfits some of the most advanced vessels in the world. Attracting talented people and developing the right expertise is important for the success of an industry cluster. While Blue Maritime is in the elite business division, they work closely with university colleges and universities on research and education. Blue Maritime has exhibited great involvement in developing new, resource-intensive studies adapted to the needs of the cluster.

Education programmes that are tied closely to clusters give the individual student a very good framework for professional development. If the cluster is in the international forefront, the education can also be in the forefront as long as the universities and university colleges make good use of this opportunity. The same applies to world-leading research communities at universities and university colleges, hospitals and research institutes. Here too, the objective is to exploit the research communities' strength and reputation to attract the best students and give them a top-notch framework for professional development. In order to stimulate this development, programmes that reward outstanding education will be developed.

The fact that Norwegian researchers, to an increasing degree, work with international research organisations and laboratories is also important for enhancing the quality of the research and developing promising research talents. One example is the European Molecular Biology Laboratory (EMBL) or the particle accelerator at CERN, where Norwegian researchers can access the best equipment and have contact with the best researchers.

The Government proposes a targeted commitment to institutions and research communities that can document good quality, and thus have special advantages as regards reaching for the very top. One of the measures is a commitment to recruiting top-notch researchers. The institutions also have a responsibility for bringing their best experts forward.

European mobility programmes such as Erasmus+ and Marie Skłodowska Curie Actions shall be used. These programmes shall also be used in multiple fields. Norwegian research communities do not make sufficient use of the opportunities provided by these programmes to bring in international experts and talented students. The opportunities for Norwegian students and researchers to study and work abroad are also not sufficiently exploited.

## 8.5 Researchers and students must have access to top-quality buildings and infrastructure

Modern, practical buildings and the most outstanding research infrastructure are important for developing top-notch expert environments. They are also important in terms of being attractive partners for the business community. The equipment in itself provides the opportunity for breakthrough research. In addition, these places attract the foremost international expertise. Norway participates in the European infrastructure collaboration, in part to attract top international researchers, but also to give Norwegian experts access to the best equipment in Europe.

Educations that can offer students access to the best modern equipment can both be more relevant for employers, and for attracting the best talents. Programmes that enhance and improve modern equipment for students and researchers are therefore important for developing world-leading academic groups.

As described in Chapter 2.4, the Government has prioritised two construction projects that make particular contributions toward achieving the three paramount objectives of the long-term plan – to reinforce competitiveness and adaptability, to address the major social challenges and to develop outstanding research communities. One project is the life sciences, pharmacy and chemistry building at the University of Oslo, and the other is an upgrade of the Ocean Space Centre in Trondheim. These projects will also provide good conditions for developing world-leading academic communities within the long-term priorities enabling technologies and oceans.

The investment project at the University of Oslo will facilitate development of a world-leading research community within life science and enabling technologies through innovative and inter-disciplinary research. International interaction characterises this research, and considerable investments are being made in life science in most industrial nations. Modern life science and biotechnology will play a key role in addressing major challenges such as loss of natural diversity, access to clean energy, sustainable food production and improved health for the world's population.

Investments in the Ocean Space Centre will pave the way for Norway to remain a world leader in ocean space technology research and marine technology. The national research laboratories at the Ocean Space Centre in Trondheim are more than 30 years old, and the maintenance lag is substantial. The laboratories do not meet the functional requirements that are necessary to address the challenges of the future.

# 9 Following up the long-term plan

## 9.1 Coordination and latitude

The long-term plan for research and higher education 2015–2024 is the Government's most important tool for ensuring good coordination and implementation of the policy for research and higher education. The long-term plan is also an important part of the Government's comprehensive quality injection for education and research that also includes the task of taking a closer look at the structure and financing system in the higher education sector.

The sector principle in research policy will be continued. The sector principle means that each ministry is responsible both for formulating policy and long-term knowledge development in their respective areas. The sector policy objectives have been set to solve important social challenges. Research and education is an important contribution to this. The long-term plan thus takes its starting point in both research policy and sector policy.

Research and higher education touch on most policy areas and involve the business community, the public sector, universities and university colleges, research institutes, expert environments and regional health authorities. Norway is also part of the global knowledge development trend and participates extensively in international cooperation on research and education with countries throughout the world. Norway is well-integrated in the European collaboration on research and higher education. This places great demands on coordination and cooperation, both at the political level and between institutions and parties, also as regards ensuring a good connection between national and international efforts.

However, better coordination is not synonymous with the closest possible coordination. The unpredictable nature of research means that very coordinated research systems may not be sufficiently adaptable, and that important signals on the need for change are not noticed. Therefore, it is important that the research communities have the latitude to act as strategic parties themselves.

## 9.2 Collaboration arenas for coordination and implementation

In the follow-up of the long-term plan, there must be sound connections between the institutions that offer higher education, the research communities, the business community and the public sector. In connection with the work on this plan, the Ministry of Education and Research received around 150 suggestions in the autumn of 2013. These suggestions have been highly significant for the Government's selected priorities and objectives. Assessments from sector players as regards the need for knowledge, expertise and capacity are very valuable, both in a long-term perspective and when the long-term plan is to be followed up with additional measures and commitments. Good cooperation arenas for these players are important in order to make long-term assessments of the need for knowledge and expertise within the six long-term priorities. Today, such assessments are based on information from projections of competence needs, national condition evaluations and international assessments and reports.

The Ministry of Education and Research is responsible for coordinating the policy for research and higher education. The long-term plan will lay the foundation for more comprehensive coordination of public commitment to research and higher education. Implementation of the plan will take place in cooperation with the parties that manage the public programmes for higher education, research, innovations and business development, such as the Research Council of Norway, Innovation Norway and the Industrial Development Corporation of Norway (SIVA). The Research Council will play a key role in this work.

The Government has set up annual summits with research and higher education communities on challenges and priorities in research and higher education policy. These summits will be utilised in following up the long-term plan.

The long-term plan is a new tool for coordinating and governing research and higher education

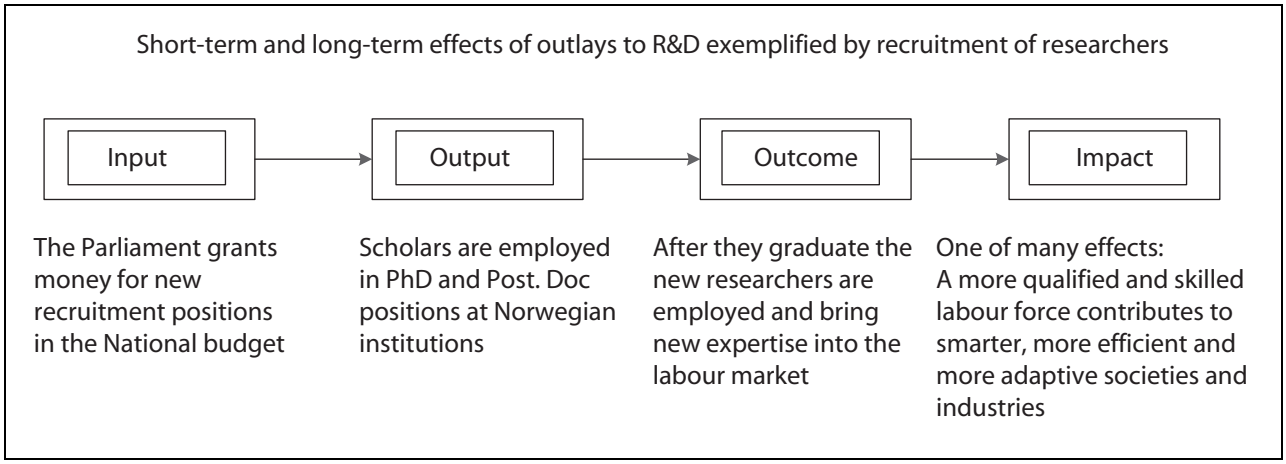


Figure 9.1 Effect chain

policy. The follow-up of the plan therefore necessitates an assessment of how this new tool functions, and whether the objectives in the plan have been met.

The long-term plan aims for results and effects that take a long time to realise. While results can be measured in the form of indicators such as volume, quality and relevance in the research conducted, social effects depend on a number of factors in addition to research and higher education. Research and higher education can contribute to the adaptation to a low-emission society, while other adaptations and changes are also needed, for example in legislation regarding construction of new buildings. Therefore, we cannot automatically observe effects of research and education in the shorter term. Analyses are needed that utilise good and relevant indicators and explicit objectives that can be operationalised. As is the case with many social phenomena, the objectives in the long-term plan cannot simply be turned into quantifiable indicators. Assessments of the results must therefore combine quantitative and qualitative analyses.

Nevertheless, some results can be followed from an early point in time. For example, it will probably be possible to see whether the trend is running in the desired direction. One way of observing this is to check whether the increased commitment as a consequence of the long-term plan triggers increased activity in research institutions, higher education and in the business community. This can tell us something about whether the long-term plan has had an impact on mobilisation of activity, and whether the resources are being diverted toward the objectives and prioritisations in the long-term plan.

## 9.3 Knowledge base for continued work

In its work on the long-term plan, the Government has benefitted from knowledge from several sources, including national and individual ministry strategies and reports, input from academia and society, business and working life, and particular consultations with the Research Council of Norway.

An improved knowledge base for research and higher education policy is still needed. This is an international challenge, and not something that is specific to Norway. Work must continue to develop an understanding of how the system for higher education, research and innovation actually functions. This work can be viewed in context with comparable international work, for example in the OECD and through Horizon 2020.

A better knowledge base should include analyses of the cooperation between the business community, research communities and the public sector, and analyses of control systems in research and higher education policy. This is particularly relevant in connection with the upcoming White Paper on the structure of the higher education sector. Another relevant topic is a review of the relationship between national and international policy instruments for research and education, and to what extent there is good correlation and work distribution between the instruments.

There is also a need for a better basis of knowledge on commercial research policy, and on how research and higher education can become more relevant for trade and industry. In line with the Sundvolden Declaration, the Government will review the system of policy instruments for innovation, and will refine and develop the instru-

ments that have the greatest innovation impact. A broad-meshed mapping has been undertaken of all commercial policy instruments with public financing where the objective is innovation and value creation, either direct or indirect. In connection with this mapping, it will also be relevant to implement a portfolio assessment of the Research Council's business policy instruments with particular focus on the relationship between open arenas of competition and thematic efforts.

# 10 Economic and administrative consequences

## 10.1 Economic consequences

The Government's goal is that 3 per cent of GDP shall go to research and development by 2030. The Government will increase public appropriations to research (R&D appropriations) until they amount to 1 per cent of GDP. The Government will increase R&D appropriations beyond the annual growth in GDP each year until this goal is achieved with reservations made with regards to short-term fluctuations in GDP. Given the current outlook for future GDP growth, the Government aims to achieve this goal in the 2019-2020 period. The Government will prioritise the measures that best support the objectives and priorities in the long-term plan, even though other isolated measures could lead to earlier achievement of the one per cent target.

The Ministry of Education and Research estimates that research appropriations in the 2015 fiscal budget will be around NOK 30 billion, and account for 0.93 per cent of GDP. This is a growth of 4.2 per cent in real terms from the 2014 balanced budget. The Ministry of Finance estimates that the revenue loss as a consequence of the Skattefunn scheme is about NOK 2.35 billion in 2015. In accordance with international guidelines, this lost revenue is not included in the estimated R&D appropriations.

The gap to the one per cent goal will be about NOK 2.35 billion in 2015. All or parts of the appropriations totalling around 260 items on the fiscal budget are included in the R&D appropriations, and there may be fluctuations in R&D appropriations as a consequence of changes e.g. in international dues and the phase-in and phase-out of investment projects. It is expected that the overall. contribution to the EU's research and innovation programme Horizon 2020 and the EU's seventh framework programme will rise in 2015 and 2016, and then level off. Several major construction projects in the higher education sector will contribute to an increase in R&D appropriations in 2015 and 2016, and a decline in appropriations as these projects are gradually completed. This relates particularly to construction of the ice-going research vessel *RV Kronprins Haakon,* scheduled for completion in 2016.

The Government wants to increase the number of recruitment positions by 500 during the period from 2015–2018. The estimated cost of this measure is around NOK 570 million.

The Government will reinforce the infrastructure scheme in the Research Council by NOK 400 million.

The Government will strengthen funding for schemes that contribute to good participation in Horizon 2020 to the tune of NOK 400 million kroner.

Proposed additional funding for follow-up of the long-term plan will be promoted in the annual fiscal budgets.

## 10.2 Administrative consequences

The objectives and priorities set out by the Government in the long-term plan, cf. Chapter 1, are consistent with the targets laid out in the white paper *Long-term perspectives – knowledge provides opportunity* (Meld. St. 18 (2012–2013)), but expand on the objectives and entail stronger prioritisation of which areas will receive targeted efforts. The long-term plan also goes further in linking priorities for research and higher education. The long-term plan is in line with the trend in OECD countries where research and innovation policy targets certain major challenges in society, toward reinforcing competitiveness and strengthening outstanding environments. This approach also necessitates an examination of higher education, research and various disciplines in an overall context. The objectives in the long-term plan are also in accordance with the three pillars in Horizon 2020: excellent science, industrial leadership and societal challenges.

The Government expects that the objectives and priorities in the long-term plan will eventually lead to skewing resource use in the direction of the priorities. Through the management systems for the Research Council of Norway, universities, university colleges and other relevant underlying

agencies, the ministries will follow up the implementation of the long-term plan. The objectives and priorities in the long-term plan will be an important basis for the objectives and control parameters the Ministry sets for relevant underlying agencies. The objectives for the Research Council of Norway will be in line with the objectives and prioritisations in the long-term plan.

The Ministry of Research and Education has revised the sector objectives for universities and university colleges for 2015 cf. Prop. 1 S (2014–2015) for the Ministry of Research and Education. Within the framework of the natural objective structure and the Government's expectations and priorities, universities and university colleges shall stipulate their own business objectives adapted to the institution's distinctive nature/profile, and develop dedicated strategies and plans for achieving these objectives. The Ministry expects that the institutions will develop a profile in line with their strengths and their nature, and that institutions that have a basis for doing so will cultivate educational and research environments that can assert themselves among the best in the world. The results, the strategies and the objectives of the institutions are key elements in the management dialogue between the ministry and the institution's board of directors.

The Government emphasises clear objectives, distinct priorities and simpler reporting in the management of underlying enterprises. The objectives and the priorities in the long-term plan shall not entail increased reporting requirements for the educational and research institutions.

The Ministry of Research and Education

r e c o m m e n d s :

That the recommendation of 3 October 2014 from the Ministry of Research and Education regarding the long-term plan for research and higher education 2015–2024 be submitted to the Storting.

**Appendix 1**

# Literature


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Cover: Lead ion collisions. Particle tracks from the first lead ion collisions seen by the ALICE (a large ion collider experiment) detector at CERN.

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