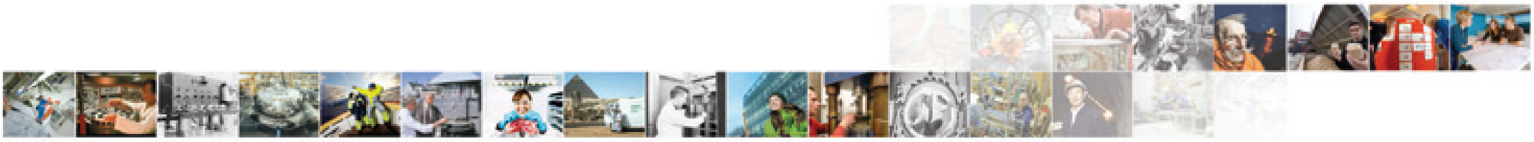
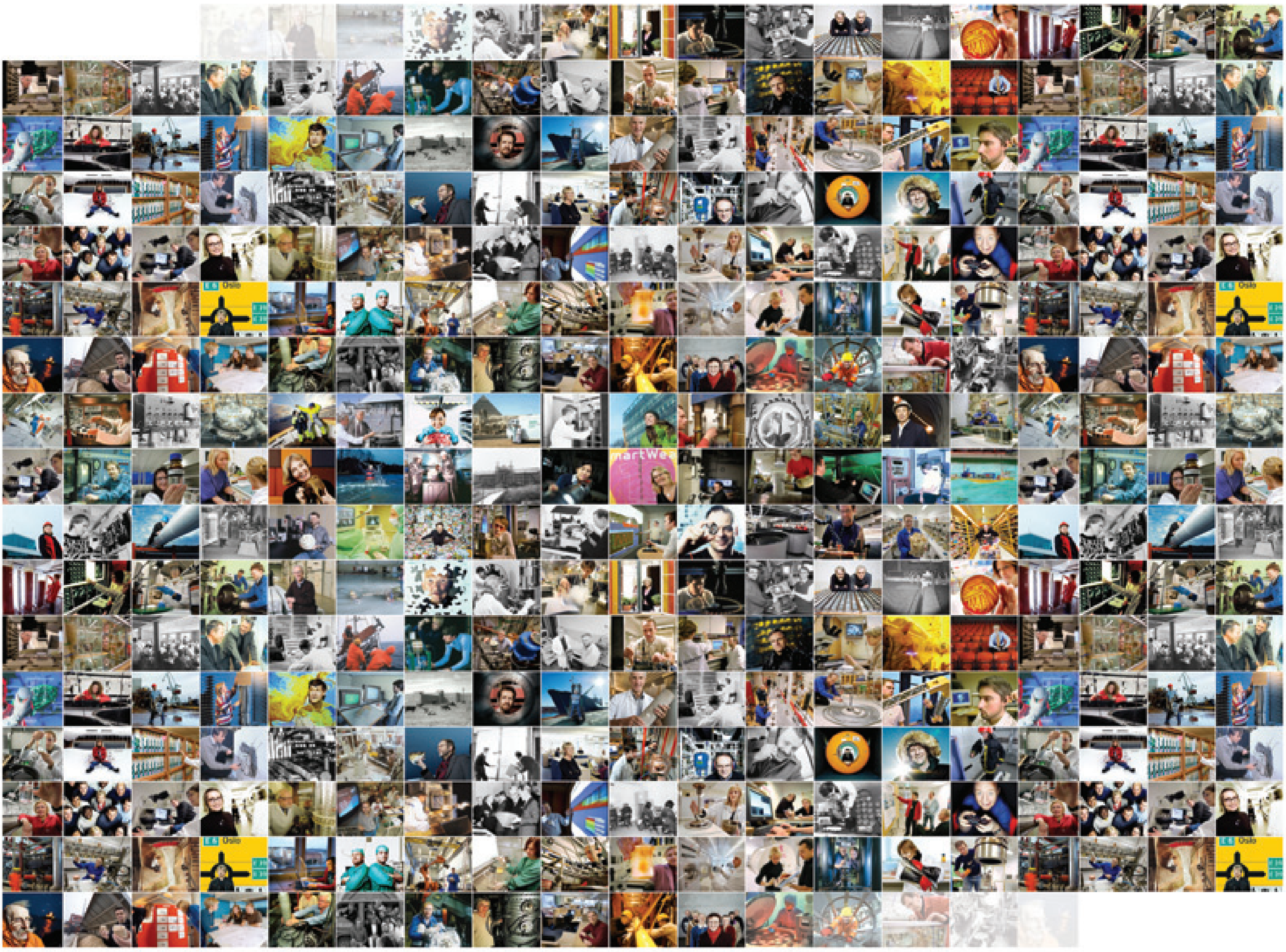
Recommendations for Research and Innovation in Norway



SINTEF



This Research and Innovation Report has been produced in connection with the celebration of SINTEF's sixtieth birthday. In this document, SINTEF presents some advice and recommendations related to Norwegian research and innovation policy. In addition to our general recommendations, we present a number of self-contained articles written by SINTEF employees, providing views on various themes. The publication also contains some reflections on SINTEF's first 60 years, on the future role of research institutes and on SINTEF's position in the European research environment.

November 2010

Research which creates wealth

Research extends the boundaries of what we understand and can achieve. It has value in itself. Knowledge enriches society. Research and research-based knowledge make it possible to find solutions to the major challenges facing society, such as global warming, health issues and access to water, energy, raw materials and food.

SINTEF's distinctive character and specialisation is in providing technical solutions to the challenges facing our society. This involves making use of knowledge and technology developed in collaboration with key partners in the academic community, commerce and government.

Collaboration of this type is developed over many years. This year it is 60 years since SINTEF came into the world. The decision to establish the Central Institute for Industrial Research (SI, Sentralinstituttet for industriell forskning) was made in Oslo in 1949, to provide a Norwegian facility for multidisciplinary industrial research. Shortly afterwards, professors in Trondheim took the initiative to create the SINTEF Foundation as a commission-based institute for industrial research affiliated with the Norwegian Institute of Technology. SI and SINTEF were merged in 1993. Some years earlier, a number of other institutes had merged with SINTEF, which became a leading research consortium in Norway and Scandinavia. Today we are one of the four largest research establishments in Europe.

Throughout these sixty years we have, in collaboration with our partners, developed a model for innovation based on close interaction between the educational, research, government and business communities. This interaction entails that we work simultaneously with fundamental understanding, multidisciplinary, problem-oriented research and industrial implementation. Using this tripartite model, we build up generic knowledge which we make universally available, while at the same time developing specific solutions and technology proprietary to those businesses which invest in the research. This is what we these days call "open innovation".

In the future we face significant challenges and opportunities. Research-based knowledge and the dissemination of that knowledge will be of increasing importance. From this knowledge, new opportunities will emerge. This also presents ethical dilemmas and difficult decisions, such as those faced in connection with biotechnology and the use of food and agricultural land for the production of biofuels.

There needs to be trust between the research community and society. More than ever before, researchers must shoulder responsibility both for their research and for the way the knowledge they generate is used. For their part, the authorities must respect the freedom to pursue new knowledge and cross new boundaries, and we must encourage open and direct dialogue between the research community and society in general.

This Research and Innovation Report is published on the occasion of our celebration of SINTEF's first 60 years. Here we present views on Norwegian policy regarding research, innovation and wealth creation. We would like this to be our contribution to the development of a pro-active knowledge policy in Norway

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Unni Steinsmo

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Unni Steinsmo, CEO of SINTEF

Recommendations for Norwegian knowledge policy

Research, innovation and commercial development are crucial to wealth creation and the future evolution of society. These are SINTEF's most important recommendations:

SINTEF is an international, private and independent research organisation which is also an integral part of the Norwegian research community. Based on experience in our first 60 years we would like to take this opportunity to make some recommendations regarding Norwegian policy related to research and innovation.

First we will provide some background information about our position and some reflections regarding important challenges.

Our distinctive character has created results and standing

In the field of commission-based research, SINTEF is one of the four largest establishments in Europe, alongside TNO in the Netherlands, VTT in Finland and Fraunhofer in Germany. Today we are a global research institute with colleagues of 69 nationalities. In 2009 we sold research services worth almost 2.8 billion Norwegian kroner to 57 countries around the world.

SINTEF has been created by our employees in collaboration with partners in commerce, research and government. We have developed a company with a solid research profile, well qualified to operate as an R&D partner for Norwegian and international business and industry. All our research, both pure and applied, is directed towards utilisation.

Our strategic and operational collaboration with the Norwegian University of Science and Technology (NTNU) and research institutes such as the University of Oslo (UiO) and the Institute for Energy Technology (IFE) is part of this.

Together we have supplied cutting-edge technology and expertise of international calibre, which has contributed to making Norway a wealthy nation.

Need for change

The world is faced with significant challenges and possibilities and there is a need for change.

We are living in a time of transition in which we must develop sustainable solutions for the future in a range of fields. The concept of sustainability is based on consideration of the environment, social responsibility and the efficient management of businesses and society.

Developments in the global economy are unpredictable and environmental challenges are increasing. Changes in climate are the most important factor, but by no means the only one. In 2050, there will be more than 9 billion[1] people in the world and we are already experiencing shortages of clean water, energy and food. There are still 1.5 billion[2] people who do not have access to an electricity supply.

A better balance can only be achieved if those with a high standard of living change their behaviour. At the same time we must develop the new economy and "green" technology which will make it possible to satisfy increasing demand for resources while protecting the environment. Sustainable development is impossible without new technology.

A new geopolitical reality

We are living in a new geopolitical reality with an open global economy and development towards better economic balance between regions and countries.

[1] IEA Energy Technology Perspectives 2010 and World Energy Outlook 2009
[2] IEA Energy Technology Perspectives 2010 and World Energy Outlook 2009

"New" economies like China, India and Brazil have emerged. Increasing numbers of people are experiencing an improved standard of living and better health, but at the same time more people on the planet are starving.[3]

It can no longer be taken for granted that the traditionally strong economies such as the EU, the United States and Japan will retain the technological lead. Advanced technology is one of the prerequisites for a high standard of living and welfare also in Norway. Being a world leader in technology for the exploitation of offshore oil and gas resources has created considerable wealth.

We are witnessing increasing competition between nations and regions to provide the most attractive conditions for commercial enterprise and research, as well as a race to develop the new technologies. Success in this competition is important for wealth creation and for employment in the future.

Nevertheless, this is not a perspective which has high priority in Norwegian political debate. The proposed national budget for 2011 represents an actual decrease in allocations to industry-related research.

General perspectives have returned to research

In science we are now witnessing closer connections between different specialist disciplines. New specialisations are being developed at the interface between, among other things, natural sciences and engineering, medicine and technology. There is increasing awareness of the value of interaction between experience-based and research-based knowledge.

Social and technological disciplines must work more closely together. We need better insight into the relationship between technology, people, culture and society.

Key technologies associated with advanced materials, microtechnology, nanotechnology, biotechnology and photonics will enable the development of new business enterprises and sustainable solutions which are unknown today. This will contribute to ensuring supplies of food, energy, materials and medicines.

Our recommendations

1. Establish an overall innovation policy

Research, innovation and business development are crucial both to solving the major social challenges and to maintaining competitiveness and wealth creation.

Norwegian policy with regard to research, innovation and business development is perceived as piecemeal. Responsibility is shared between a number of government ministries and departments which often appear to be poorly co-ordinated. However, we have seen good examples of general research policy efforts in recent years. The Norwegian parliament's consensus on climate-related policy has led to a considerable increase in research into environmentally friendly energy sources, and the authorities are working on a general strategy for environmental technology. A fund was set up in 2008 for investment in scientific equipment.

These are good steps in the right direction and indicate a development which must be reinforced. It is essential that society's most important decisions are based on the best possible assessments of available knowledge and an integrated approach to the issues.

Our recommendation:

- The Prime Minister and the Prime Minister's Office must assume overall responsibility for research and innovation.
- A working practice with involvement crossing departmental boundaries, with clear, overall leadership.
- Stronger involvement of expertise from industry and research in political processes.
- Reinforcement of technological expertise in all government ministries.
- Closer dialogue between research and politics.

2. Maintain open competitive arenas

In recent years, open competitive arenas have been reinforced in Norwegian research circles. The foundation of the Centre of Research Excellence (SFF), the Centre for Research Excellence and Innovation (SFFI) and the Centres for Environment-friendly Energy Research (FME) has created increased competition, improved quality and greater potential. The same applies to the Research Council of Norway's User Driven Innovation Arena (BIA), whose strength is that it also allows for rapid reorganisation.

In a situation with increasing international competition in research, there is every reason to question the balance between open competitive arenas and government funding to individual research institutes. A good balance between direct funding and open competition is desirable for reasons of openness, co-operation and not least the quality of research.

While positive growth has occurred in the field of health research, little use is being made of open competitive arenas. This should be remedied.

Our recommendation:

- Reinforce open competitive arenas.
- Grant independence to public sector commission-based research institutes.
- Reinforce open competition in health research. Channel a portion of the research funding from the health facilities to the Research Council of Norway.

3. Make room for strong knowledge-based communities which are capable of assuming social responsibility and international leadership

Norway is totally dependent on being part of the international development of expertise. We need internationally conspicuous, strong, knowledge-based institutions. SINTEF is one of these, as are the universities in Oslo, Bergen, Trondheim, Ås and Tromsø.

In a small country with a large number of small companies, it is important to maintain applied research environments which can supply high quality research to all sectors of industry.

It is important for us to have strong, regional knowledge-based communities. However, the existing rights-based fragmentation of the university sector presents a challenge in a situation with limited hu-

[3] Shenggen Fan, World Bank: CAETS Conference "Feeding 9 billion people", Copenhagen June 2010

man and financial resources. A college now has the "right" to become a university provided that it meets certain minimum requirements. This is not commensurate with the requirements that increased internationalisation places upon scientific quality, or with the need for robust, professional specialist environments in both pure and applied research. One may also question whether making colleges into universities has a beneficial effect on the quality of vocational training.

Our recommendation:
- Give clear priority and independence to the internationally strong institutions, with increased attention to the quality of research provided.
- Set up systems which co-ordinate teaching in colleges and universities in such a way that it is easy to progress from college to university.
- Facilitate improved interaction between Norwegian research centres to enable us to build robust environments in important areas of expertise.

4. Improve the internationalisation of Norwegian research

Our standard of living depends on us participating in the international development of expertise. This calls for capability and possibilities for participation in international research collaboration. Prioritising participation in EU-financed research is essential, as this is by far the most important international research arena for Norway.

The technical-industrial institutes are among the largest Norwegian participants in EU research, by far. SINTEF has amassed a great deal of expertise in important specialist fields through our participation in EU research programmes.

The technical-industrial research institutes in Norway receive low public funding. This is evident when we compare them with equivalent institutes in other countries, with universities and with government-financed institutes like NOFIMA[4].

While low funding has given rise to close industrial collaboration and market orientation, the weakness is that the institutes are highly vulnerable and do not have much freedom for strategic development.

Our framework conditions present a growing challenge in view of the way the international competition in research is now developing. Norway's strength is that it has one large research establishment which is able to operate in the international arena. Sweden, Belgium, Luxembourg and Spain are now building up institutes similar to SINTEF, while the United Kingdom is considering following the same course. Fraunhofer and TNO are increasing their presence outside Germany and the Netherlands.

Our recommendation:
- A result-based public grant which makes it possible for institutes with low basic funding to increase their international involvement.
- Channel a larger portion of public funding directly to the technical-industrial institutes.

5. Reinforce the interactive model

The Norwegian innovation model has resulted in close connections between education, pure research, applied research and industrial development. The model includes research-strategic tools such as user-driven research, expertise projects with user involvement and a requirement for training to doctorate level.

This is a model for open innovation. Generic knowledge which is built up through research becomes available to society as a whole, while at the same time, product-specific knowledge remains the property of the companies investing in the research. The model is in demand all over the world.

It is also inherent in the interactive model that knowledge flows in both directions between research establishments and users. As researchers we have a responsibility for what we are researching into and how the results are publicised and used.

The Norwegian Ministry of Education and Research has introduced incentives which result in disadvantages for the universities if they collaborate with research institutes. This represents a major challenge in a small country where we are completely dependent on collaboration for maintaining robust research environments.

In a study which was recently presented at a conference in Berlin, NTNU was ranked in fourth place among the universities in the world with the most collaboration with trade and industry. MIT is in first place. Collaboration with SINTEF is one of the factors which have put NTNU in this position.[5]

Our recommendation:
- Introduce incentives which promote collaboration between universities and research institutes, and between research, industry and public enterprises.

6. Build on Norwegian core skills – increase investment in research and innovation

It is crucial that expertise is available to Norwegian industry and the public sector. For industry, increased investment in both applied and pure research is necessary in order to maintain competitiveness.

We must dare to prioritise those fields in which Norway has internationally strong clusters. In Norway we have cutting-edge expertise in such fields as materials science, maritime science, biomarine technology and not least energy. The expertise in these clusters forms the foundation for success both in industry and in research, as well as providing solutions which the world needs.

This sort of focus can also contribute to the development of Norwegian high-tech industry in several areas, such as environmental technology and medical technology. New technologies are an integral part of this development. Thanks to our leading position in the oil and gas industry, Norway has been able to develop strong technological communities in the fields of ICT and microtechnology. In the same way, biotechnology and nanotechnology will be able to contribute to increased innovation and competitiveness in the established industrial clusters in the future.

Our recommendation:
- Increase investment in natural sciences and technology.
- Maintain the level of investment in social sciences and health sciences.

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[4] NOFIMA is financed by a combination of public funding and fixed subsidy income.

[5] The result of a study carried out by Professor Robert Tijessen which was recently presented at the IREG 5 (International Ranking Experts Group) conference in Berlin. http://www.socialsciences.leiden.edu/cwts/products-services/scoreboard

- Reinforce the work of upgrading and renovating laboratories and other research infrastructure.
- Prioritise the internationally strong Norwegian clusters.

7. Reinforce the value chain for the commercialisation of research results

The commercialisation of research results contributes to wealth creation and new jobs. A large part of the innovation work takes place in, or through interaction with, existing industry and independent research environments, while some takes place through the licensing of technology and establishment of new companies.

In Norway we have in recent years developed what we may call a sustainable business chain for the commercialisation or research results. Participants which collaborate have become more professional and public policy instruments have improved. However, there are still deficiencies and weaknesses which must be remedied.

It is particularly important to ensure access to capital in the so-called pre-seed phase, among other things so as to verify technology before new companies are founded. This phase is characterised by its lack of commercial profitability, and is the Achilles heel of the business chain.

Our recommendation:
- Reinforce the Research Council of Norway's FORNY programme.
- Reinforce and maintain the seeding schemes through new financing of national and regional seed funding.

Photo: Martin Harvey

Karl A. Almås, Managing Director, SINTEF Fisheries and Aquaculture AS

A knowledge-based bio-economy

It is necessary to develop a knowledge-based bio-economy in order to solve many of the world's most pressing problems. Renewable biomass must increasingly become the raw material for food, health products, textiles, energy generation and industrial goods.

Life is believed to have existed on Earth for 3.5 billion years – an incomprehensible length of time. The origin of mankind is debated, but according to the United Nations' Determinants and Consequences of Population Trends, modern Homo sapiens first appeared around 50 000 years BC.

We have become very numerous in a very short time

It is estimated that 8 000 years BC there were about 5 million people on the planet and that this number had increased to 300 million by the time of the birth of Christ. By 1200 AD, this number had grown by 50 per cent, to about 450 million. In 1850 the population was estimated at 1.2 billion, a number which doubled in a hundred years to about 2.5 billion in 1950. From that point, it was to take just 45 years before the population doubled again, with the number passing 5.7 billion in 1995. Today, the population of the world is estimated at about 6.5 billion.

Throughout most of this period, known as the *Holocene epoch*, mankind lived in a hunting-based, nomadic culture. In the course of 10 000 years we gradually moved towards a sedentary culture based on arable and livestock farming. Only in the past 150 years have we moved away from this to enter the *Anthropocene epoch*, in which the activities of people exert a greater impact on the environment than natural factors and their variations. The Industrial Revolution at the beginning of the 1800s is recognised as the event during which human activities started to create imbalance in the ecosystem. To put this into perspective we can say that:

If human beings have been on the Earth for a total of one hour, it is only in the last seven seconds that they have created ecological imbalance.

The cause of this imbalance is to be found not only in population development as such, but also in the fact that we have constantly striven to reach the top of Maslow's hierarchy of needs. This has called for greater access to resources and has resulted in greater consumption. Some of us have been successful in acquiring such resources, while others have not had the same opportunities. As a result of the differences in access to resources, the 6.5 billion inhabitants of the Earth occupy different levels in the hierarchy of needs. A growing number, about one billion people in 2010, are starving and even their physiological needs are not satisfied.

In addition to climate change, migration, poverty and energy needs, pressure on foodstuff resources and loss of biodiversity currently stand out as global challenges. For some time we have realised that to tackle these challenges we must desist from creating an additional imbalance in relation to the natural environment. The solution is to use our knowledge of nature and its processes to reverse the development. We must develop a knowledge-based bio-economy.

The knowledge-based bio-economy in Europe

A growing demand for sustainable supplies of food, raw materials and fuel, as well as scientific advances in, among other things, modern biotechnology, has been the driving force for the development and growth of a knowledge-based bio-economy (KBBE) in Europe in recent decades. The term bio-economy entails sustainable production and processing of renewable biomass as a raw material for various foodstuffs, health products, textiles, industrial products and energy generation. It is anticipated that this will provide a new basis for, and a play a significant role in creating, renewed economic growth.

The knowledge-based bio-economy is also expected to be one of the solutions for meeting global challenges. The starting point for the EU's objective of developing a knowledge-based bio-economy for Europe has been a desire to improve its competitiveness in the global arena. This demands excellence in life sciences and technology, as a foundation for innovation and future industrial development. The aim is to develop a smarter, more sustainable and less vulnerable foundation for future economic development in Europe.

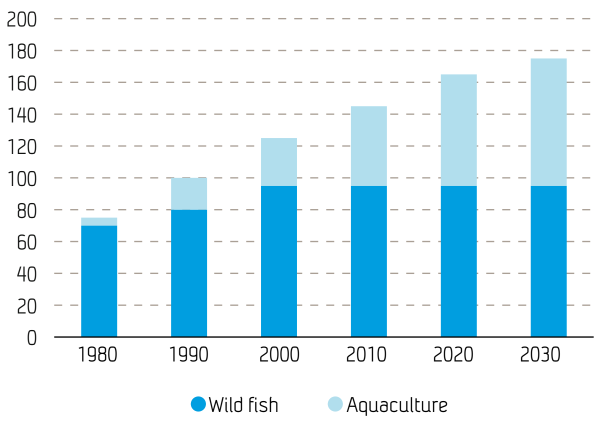
It is estimated that the European bio-economy currently represents a market worth more than 2000 billion Euros, that it employs 21.5 million people and that it has a highly optimistic starting position as regards growth potential. Besides contributing to future economic growth, the bio-economy will be able to make positive contributions towards maintaining human welfare which is currently threatened by global challenges. Examples are the aging population, urbanisation and population growth, increasing pressure on fresh water resources, limited availability of fossil fuels, climate change, the need for safe, healthy foodstuffs, and the prevention of infectious diseases.

Based on the accessibility of biological raw materials and the knowledge of how to exploit these in a sustainable manner, Norway already plays an important role in the development of a knowledge-based European bio-economy. This applies particularly in the marine science sector, in which Norway has long-standing traditions with regard to the management, harvesting and processing of wild fish. We have also developed unique expertise in the field of aquaculture, as a result of the industrialisation of salmon production. With the knowledge base which it has accumulated, Norway will be able to make significant contributions with regard to the exploitation of marine resources in the production of food.

Continued global growth in aquaculture

In recent decades, global production growth in the agricultural sector has been approximately 2 per cent (Duarte et. al 2009). Urbanisation, shortage of agricultural land and not least shortages of water have resulted in the stagnation of this production. Genetically modified plant and animal strains can contribute to increased production of agricultural raw materials. These developments will raise major ethical issues which will demand caution. The markets and society as a whole must provide their approval.

A transition from the production of beef to that of poultry and pork may also contribute, but will not be sufficient to satisfy future needs for protein and fat. An ever-increasing proportion of these nutrients must be obtained from marine-based production through harvesting and aquaculture.



The illustration below shows the FAO's figures for the development of world fish production (in millions of tonnes). If we consider the production of food based on catches of wild fish and fish-farming, an interesting picture emerges. The world's total fish production is currently approximately 145 million tonnes, of which 100 million tonnes is wild fish and the rest is produced by aquaculture. Global production of wild fish has stagnated and to some extent dropped in the past 10-15 years because of over-fishing and unsatisfactory management. Norway, in collaboration with Russia, among others, has succeeded in managing its fish stocks in a balanced manner and represents an honourable exception.

Global fish-farming production in the last decade has shown an average growth of 7.5 per cent, which is approximately the same rate of growth as in Norway. With modest growth in agriculture, production of marine-based foodstuffs must increase to satisfy demand for protein and fat, with the entire marine food chain being exploited in an integrated manner. If we cannot catch more wild fish, this demand must be satisfied by increased aquaculture production. This means that the total aquaculture production on a world basis must increase from about 45 million tonnes today to about 80 million tonnes in 2030 (FAO, 2008).

One of the greatest global challenges between now and 2050 will be achieving sustainable food production to feed 9.5 billion people. With its natural advantages, industrial experience and expertise, Norway should adopt a leading role. Existing fish-farming production in Norway represents only 1.7 per cent of world production. We should make it our goal to increase this contribution to 3.5 per cent in 2020, which corresponds to increasing our production from about 900 000 tonnes today to 2.4 million tonnes in 2020, in other words a 2.5-fold increase. This calls for an annual growth until 2020 of 10.3 per cent, which is 2-3 percentage points higher than the current growth rate.

There will of course be many challenges connected with achieving this in a sustainable manner, environmentally, economically and socially. One prerequisite for continued growth is that we succeed in solving the problems we have today and develop a strategy for the future development of operations while protecting the environment and ensuring efficient and integrated resource management. Knowledge-based solutions must be found to the challenges of the aquaculture industry with regard to salmon lice, escaping fish and the fouling of nets.

The entire marine food chain must be exploited to satisfy world food demands

Population statistics published by the UN's Food and Agriculture Organization indicate that by 2050 there will be 9.5 billion people in the world, compared with 6.5 billion today. In order to feed this population, world food production must be increased by 70 per cent. In reality, the number of people suffering from starvation increased by about 100 million between 2008 and 2009, and currently lies at about 1 billion. A programme commenced under the auspices of the World Bank in 1990, when the corresponding figure was 800 million, aimed to halve the number by 2015. In reality, the trend has been in the opposite direction.

The biomass production of the planet (plants and animals in the sea and on land), which creates the basis for food production, is divided equally between sea and land. Expressed in calories, we obtain 98 per cent from land-based production and only 2 per cent from the sea. When we consume agriculturally produced food, we exploit

Group		Annual production in 2004 (Million metric tons)	Production growth rate 1994-2004 (% pr. year)
Land	Agriculture (non-food items excluded)	7000	2,0 +/-0,1
	Livestock (meat)	260	2,6 +/-0,1
Aquatic	*Cultured*		
	Freshwater animals	26	7,3 +/-0,4
	Marine animals	20	7,4 +/-0,3
	Marine plants	14	7,5 +/-0,5
	Wild harwest		
	Fisheries	96	0,1 +/-0,2
	Aquatic plants	1,4	0,5 +/-0,6

mainly plants which are on the lowest trophic level of the food chain. When we consume food from the sea, on the other hand, we are entering at level two or three in the food chain. For each rise of one level in the food chain, the usable potential is reduced by a factor of ten.

The figure below (Duarte et. al 2009) shows that total world food production is approximately 7 billion tonnes. If we consider what is produced on land, the ratio between plants and animals is about 6:1. If we consider food produced by aquaculture, the ratio is 1:3, and if we consider catches of wild fish and harvesting of marine plants, the ratio is 1:53.

In other words, if we aim to increase the contribution of the sea to the world's food demands, we must focus not on fish alone, but must also consider how we can harvest at lower trophic levels. Norway has technological expertise which can contribute to this type of development. The harvesting and exploitation of krill and copepods, the development of multitrophic aquaculture in which fish, shellfish and algae are produced in the same system and the cultivation of macroalgae for human food consumption are fields which must be prioritised. The world's largest aquaculture species (4.6 million tonnes per year) is a plant, the Japanese kelp, which is harvested for human consumption. It will also be appropriate to make the production cycle in the sea independent of that on land, by releasing land areas which are currently used in the cultivation of feedstuffs for fish farming, and use them for the direct production of human foodstuffs.

With a strong biomarine cluster embracing producers, suppliers, research and education, Norway is the most advanced nation in the world with regard to the sustainable exploitation of marine resources. By placing further focus on this field, Norway will consolidate its position as a contributor to meeting the foodstuff requirements of an increasing world population.

Recommendations

- Norway must develop an integrated strategy for a knowledge-based marine bio-economy.
- Norway must in future contribute to meeting the world's increased food requirements through a sustainable expansion of Norwegian aquaculture production.
- Expertise and technology must be developed to obtain competitive advantages for Norwegian industry in the fields of new marine industries such as marine bioprospecting, production of macroalgae and harvesting at lower trophic levels in the food chain.

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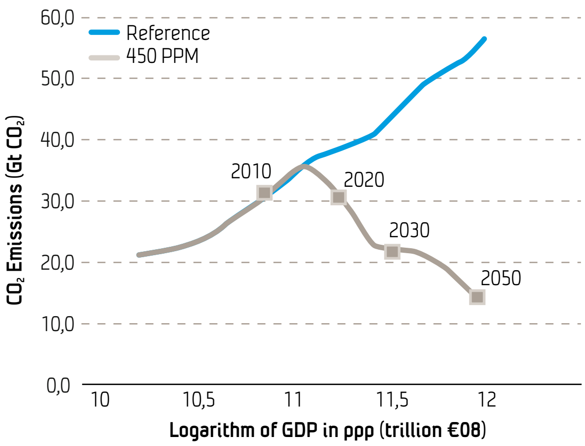
Illustration: STATOIL

Nils A. Røkke, Vice President, Climate Change Technologies, SINTEF

The energy revolution

Energy use and climate change go hand-in-hand and present two important global challenges. Estimates indicate that the world's energy requirements will increase by almost 50 per cent by 2030. So far, increased use of energy has been inextricably coupled with increased greenhouse gas emissions. "The energy revolution" is all about breaking this connection.

Economist Joseph Schumpeter popularised the concept of creative destruction more than 50 years ago to explain the essence of the term innovation. Innovation means abandoning old ways of thinking and doing things. Education, research and innovation become the most important tools for realising the energy revolution.



The energy revolution – changes in emissions necessary to comply with the 450 ppm scenario* (Eurelectric 2010).

The world's energy systems must be transformed; we need environmentally-friendly energy and our starting position is very poor – satisfying the world's energy requirements is principally based on fossil energy sources. The task consists of transforming the backbone of the world's energy supply while causing the least possible harm to the patient. This transformation has become known as one of the world's Grand Challenges. It is referred to in the Lund Declaration of 2009, which states that "Challenges must turn into sustainable solutions in areas such as global warming, tightening supplies of energy, water and food, ...".[1] This means that research and innovation must be structured to make it possible to tackle the major challenges facing the world.

The transformation cannot take place without significant investments in education, research and innovation. This is also the main message in the report "A business plan for America's energy future"[2], published by the American Energy Innovation Council. Investments in energy research and development are far lower than necessary to tackle the challenge, and have been practically disregarded in the last 25 years. As far as the US is concerned, the recommendation is for an increase in R&D investment to three times the existing level. The Stern Report[3] recommends a global doubling of R&D investment, while the IEA estimates that investment must be increased to two to five times the current level.[4]

[1] Research and Innovation for the next decade, see *www.vr.se/lunddeclaration*
[2] American Energy Innovation Council 2010, see *www.americanenergyinnovation.org/*
[3] The Stern Review on the Economics of Climate Change, 2006
[4] IEA Energy Technology Perspectives 2010
* The 450 ppm scenario refers to the maximum atmospheric concentration of CO2 which is compatible with global warming of 2-2.5 degrees Celsius.

Ever since Copernicus proved that the sun was at the centre of our part of the universe, the motive power behind development has been based on knowledge and technology. We have pursued the path of technology. This has provided major innovations and improved our standard of living, but with significant impacts on the environment. We must now use (the path of) technology to tackle the environmental challenge and create sustainable energy solutions for the world.

Norway has particular advantages in the field of energy supply. Hydro-electricity was a factor which made the development of the modern Norwegian society possible. The first electrical dynamo was produced in Germany in 1866, and enabled the production of electrical power from hydro-electric plants, first using water wheels and later turbine technology, transmission lines and electronic control systems: this was a true paradigm shift. There was a transition from fixed, local installations based on mechanical energy to distributed systems based on the transmission of electrical energy.

Access to reasonably priced energy promoted industrial innovation and the establishment of so called "industrial locomotives", and attracted foreign capital. The power of our waterfalls could be tamed to produce electricity for industrial development and general supply. This is expressed, for example, in such historical statements as, "Norway is undoubtedly in a better position than any other country in the world as regards hydro-electricity"[5]. Today we have an electricity supply which is unique on a global basis, with 96 per cent of Norwegian electricity generation coming from hydro-electrical plants. We have the largest hydro-electric production in Europe, at 122 TWh in a normal year.

Petroleum exploration on the Norwegian continental shelf has given the world an important and stable supply of oil and gas and has had major economic spin-off effects for the nation. In 2007 the petroleum industry represented about a quarter of the Norwegian economy. Thanks to visionary thinking leading to the ban on production flaring of gas on the shelf in the 1970s, we have become a significant gas supplier to Europe.

The availability of a reasonable and stable energy supply has been the cornerstone of industrial development in our country, and as a consequence we have been able to combine access to natural resources in a way which has created growth and prosperity. The process industry generates considerable wealth through knowledge-based processing of forestry products, minerals, hydro-electricity, oil and gas, and represents 50 per cent of exports from mainland Norway.

So, what will the energy revolution mean for Norway and what strategic crossroads are ahead? And what role can research and innovation play?

Choices

In contributing to the energy revolution, Norway has a number of different approaches to choose from. Two scenarios are described below to illustrate possible alternative outcomes:

- Consolidation: Attempt primarily to ensure one's own energy security and efficient energy supply. Contribute to a limited extent as a supplier of energy and power to Europe by means of a few transmission cables. Ensure the efficiency of society's energy use and produce the cleanest possible power from fossil fuels.
- Expansion: Use our unique natural advantages in power production to become a global shop window for the sustainable supply of several types of energy sources to Europe and the rest of the world. Realise the vision of "the battery of Europe" and become a significant supplier of clean energy and power to Europe. Increase the export of modern energy-intensive materials based on supplies of clean energy.

The consolidation model:

In the future, Scandinavia as an energy region may have a surplus of electricity: it is possible that more will be produced than is consumed. This is connected with improved energy efficiency on the part of the consumer, possible changes in industrial structure and the implementation of the EU Renewable Energy Directive. For Norway, this involves the export of clean energy and power, approximately as we know it today. Power-intensive industry in Europe will continue to operate without strict measures for reducing carbon leakage, something which in time will probably result in a certain amount of downscaling.

The European power market will however change dramatically in coming years as regards the dynamics of the production sector. The present situation is typified by a system in which nuclear and coal-fired plants account for base load production, with gas-fired generation handling peak demand along with a certain contribution from renewable energy sources. A new situation is arising which primarily uses nuclear generation[6] as the basic source, with requirements for the complete integration of the renewable energy generated at any given time. In this situation, the entire fossil based power production system with CO_2 treatment (CCS)[7] would have to compensate for power fluctuations.

As regards consumption, it is anticipated that an increasing proportion of passenger traffic will be based on electrical power. Natural gas will also gain an increasing role in transportation systems, for example in gas-powered vessels and heavy goods vehicles, especially in the form of LNG[8] and CNG[8]. The increased consumption of electricity will place new demands on the electricity production system. Eurelectric has estimated that by 2050, demand for electricity will increase from 70 to 1600 TWh in the European transport sector alone: electricity production in the EU is currently approximately 3500 TWh/year.[9] Both controlled (hydro-electric and tidal) and uncontrollable (wind and solar) energy will dominate the supply grid. This means that fossil fuel power stations must absorb the dynamics in demand, and energy storage will become extremely important. This indicates two important areas for R&D and innovation:

- Smart, robust power grid systems
- Energy storage and improvements in the efficiency of the production system

Smart, robust power grid systems: In a system with increasing numbers of active consumers and small producers, in which energy and

5 Thue, Lars, 2006, "Statens Kraft 1890-1947", Page 74 (The history of Statkraft) [in Norwegian]
6 Assuming that integrated solutions are found for the utilisation, storage and containment of nuclear materials in European countries.
7 CCS, CO_2 Capture and Storage, often referred to as CO_2 management.
8 LNG – Liquified Natural Gas, CNG – Compressed Natural Gas
9 Power choices, 2010, see *www.eurelectric.org/powerchoices2050*

power are suddenly phased in and out, the supply grid will be faced with new challenges. So-called "smart networks" will be needed, as well as smart metering, monitoring and control systems, facilitated by information and communication technology. Energy flow must be permitted to and from small consumers and local generators, and conditions must be created to enable more active participation in the energy markets on the part of the consumer.

Energy storage and improvements in the efficiency of the production system: There will be considerable demand for storage of energy in future energy supply systems, with as much as 20-30 per cent of production coming from uncontrollable energy sources. Increased use of pump-storage power stations clearly has potential for us. However, this places demands on environmentally-friendly operation with respect, for example, to water supplies and the cycling of fresh water in fjords. There will also be a need for investment in improving the efficiency of the existing hydro-electric power system in Norway.

The expansion model:

It may be argued that Norway should do its best to contribute to ensuring clean energy supplies to the rest of the world. Each country must contribute, based on its natural advantages with regard to resources, including expertise. Our own requirements will then become just one of a number of elements – the country will be bursting with energy!

This entails involvement in certain fields in which Norway can make a difference, and we must dare to be selective. We would like to draw attention to four areas of particular importance:

- Offshore wind power
- Environmentally-friendly expansion of hydro-electric power
- CCS (CO_2 capture and storage)
- Export of clean energy through the production of advanced materials

Offshore wind power because Europe must increase the proportion of renewable energy production. We have particularly good conditions for this in Norway as regards resources and in the operation of the research–industry–society triangle. EU's goal for 2020 includes the objective that 20 per cent of electricity supply in the EU shall be generated by wind power[10].

In Norway there is considerable potential for more hydro-electric generation: about 37 TWh/year in areas not protected from power generation developments[11]. Some of this potential can probably be made available for the production of clean energy under environmentally sound conditions.

Norway's involvement in CCS is unique and we must take care that the investments provide a broad-based return. Norway should be capable of building gas-fired power stations using CCS: we would deal with the "packaging" of the natural gas and supply clean energy. The storage of CO_2 presents considerable potential for wealth creation in Norway, and our storage capacity is important for the development of the European CCS market.

Our history in the refining of metals using clean energy has consequences in the form of, for example, the production of aluminium and silicon for use in solar cells. This role as a supplier of clean energy in the form of materials is often underestimated and must be enhanced. These are important contributions which Norway can make to the energy revolution. Improved expertise in the field of these products is an important theme in the ability to maintain global competitiveness. It is also important that Europe should find a model to provide framework conditions for this industry, so as to avoid so-called carbon leakage to other regions of the world. A possible model for dealing with this is to introduce tariffs on imports from countries which evade CO_2-related costs internally and export subsidies in connection with export to markets which do not impose adequate CO_2 penalties. This model is known as "border tax adjustment"[12, 13] and is considered by a number of economists to be an interesting approach to the issue.

The strategic role of the petroleum industry in the future is to a large extent dependent on R&D and innovation – how to combine considerations of energy supply and the environment. In the energy revolution, fossil energy sources, and in particular natural gas, are also needed. Through the introduction of CO_2 levies on emissions by means of quotas or taxes, gas will emerge as competitive as a consequence of its lower CO_2 emission per generated kilowatt-hour. With a quota price of approximately €30 per tonne of CO_2, gas-fired generation with CCS is competitive with coal-fired generation with CCS, and with increasing quota prices the advantages will generally be weighted in favour of gas. As a result of falling gas prices and expectations of higher quota prices, especially after 2013[14] we now see that gas-fired generation is being developed in Europe, while investments in coal-fired power stations are being put on hold. Quota prices and the need for load following in the energy supply are also important in this context. In other words, there is a need for investment in the sustainably improved extraction and exploitation of our petroleum resources on the continental shelf.

How to promote the energy revolution through investment in research and innovation

In a global context, most energy technologies in use today are the same as they were 50 years ago. They will become expensive, are vulnerable and lack sustainability. We need new technologies which are more efficient, more secure and sustainable. This viewpoint is supported by, among other things, the IEA , the EU's SET Plan[16] and the IPCC[17]. Energy innovation must commence now in the form of an energy revolution.

This energy revolution cannot be initiated without reinforced, long-term investment in research and innovation. A holistic strategy will

[10] *http://ec.europa.eu/energy/technology/set_plan/doc/2009_comm_investing_development_low_carbon_technologies_roadmap.pdf*

[11] Fakta 2008 Energi og vannkraftressurser i Norge (Key facts 2008: Energy and hydro-electric resources in Norway) [in Norwegian], the Norwegian Ministry of Petroleum and Energy, see *www.oed.dep.no*

[12] Jordan-Korte, Karin and Mildner, Stormey, 2008, " Climate Protection and Border Tax Adjustment: Economic Rationale and Political Pitfalls of Current U.S. Cap-and-Trade Proposals, see *www.aicgs.org/documents/facet/jordan.faceta01.pdf*

[13] Cosby, Aaron, 2008, "Border Tax Adjustment", see *www.iisd.org/pdf/2008/cph_trade_climate_border_carbon.pdf*

[14] From 2013 the EU quota system is expected to operate with quota auctions and gradual tightening of free quotas until 2020

[15] See, for example IEA – ETP 2010 and World Energy Outlook 2009

[16] SET plan; Strategic Energy Plan, see *ec.europa.eu/energy/technology/set_plan/set_plan_en.htm*

[17] IPCC, Intergovermental Panel of Climate Change, 4th assessment report, see *www.ipcc.ch/publications_and_data/ar4*

be needed to achieve this, as well as interaction between different disciplines: technology, society and economics. The EU's SET Plan indicates a need for closer connection between these elements and the linking of resources in Europe so as to deal with the major challenges. This is beginning to manifest itself, among other things through "Joint Undertakings", technological platforms, the application of Section 169 between member countries, the so-called "European Industrial Initiatives", and the establishment and application of the European Research Council (ERC).

The report "Norway – a global maritime knowledge hub" (Reve[18]) indicates two areas in which Norway can play a part on a global basis: the maritime sector and energy. The national strategy for energy is rooted in the advisory body Energi21, and that for petroleum operations in OG21[19]. The guidelines from Energi21's report "En samlende FoU-strategi for energisektoren" (An overall R&D strategy for the energy supply industry) [in Norwegian] and the broad climate policy consensus in the Norwegian parliament have given us the Centres for Environmental Friendly Energy Research(CEER) or FME (in Norwegian), dealing with the thematic fields of offshore wind energy, CCS, solar energy, hydro-electricity, bioenergy and energy use in buildings. What we now need to do is to reinforce and expand these investments into what we will refer to here as the "energy universe".

Energiunivers

According to Reve[18], the core of future innovation systems is education, research and innovation – which will, in the presence of capital, industrial association and the involvement of universities, be able to create so-called "global knowledge hubs". Norway's ambition should be to become attractive in the global context within energy and to attract human capital. We must be prepared to take chances if we are to get a return on investments and assume more than just a domestic role. The establishment of an energy universe[20] is essential if we wish to transform this potential into action. The foundation of a "national team" consisting of a close network of the strongest authorities in the disciplines of technology, social sciences and economics, along the axes of education, research and development, innovation and business development, will be a central element of this. There is a need to combine energy supply operations to achieve a critical mass, to become relevant internationally to have resources for promoting innovation, entrepreneurship and application in industry on a global basis. It is natural that NTNU and SINTEF, with their extensive laboratory facilities, should become the core of the technological part of such an energy universe. This sort of investment must be connected with new investments in infrastructure, since modern laboratories are an important prerequisite for success.

High-risk funds

Another pertinent question is whether we are promoting innovation well enough and encouraging the development of high-risk concepts – ideas of a transformative nature which involve high risk and high potential. In the United States this has been done with considerable success through the so-called ARPA-E[21]. This agency has become a breeding ground for venture creation and entrepreneurship, attracting considerable interest from private industry. ARPA-E was able to finance 1 percent of the project proposals submitted in response to the initial invitation, while 7 per cent of the projects were subsequently financed by private the business sector.

Technological pilot funding

One particular element of the innovation chain which is insufficiently stimulated in Norway is support for the financing of technological pilot projects. Except in the field of CCS, where considerable funds have been invested in Technology Centre Mongstad (TCM), investment in technological pilot projects is haphazard and more diffuse. Norwegian industry has also voiced its opinion on this, and on how to avoid the pitfalls between the development of a concept and the finished product. We propose the establishment of an appropriate scheme in Norway which can promote technological pilot projects, for example in the fields of wind power, new manufacturing methods for solar panel materials, bioenergy, and so on. In SINTEF's and NTNU's recommendations to the political parties before the last parliamentary election, we estimated this requirement to be in the region of NOK 1.3 million[22]. This will be needed to ensure the full effect of investments in research and development leading to products and returns on investments in green energy. This recommendation is in line with the initiative of the Confederation of Norwegian Business and Industry (NHO) for establishing a CO_2 fund for supporting such pilot projects[23].

Recommendations

Our recommendations for promoting the energy revolution from, for and in Norway are as follows:

- Consolidate the role of Energi21: efforts should be made to transform strategies developed in such bodies to a greater extent into active policy and to use the expertise which is generated more actively.
- In the same way, OG21 should be used actively to promote the sustainable exploitation of petroleum resources.
- Make use of our natural advantages with regard to access to clean energy to achieve a strong global position in the field of modern materials technology, based on extensive technology development and production in Norway.
- Double investments in R&D and innovation within energy.
- Establish an energy universe in Norway.
- Allocate funding for the development of new ideas for energy and climate science corresponding to the American ARPA-E, including petroleum activities.
- Allocate resources for a fund for the establishment of technological pilot projects.

[18] Reve, Torger, Norway – a global maritime knowledge hub, see *web.bi.no/forskning/papers.nsf/0/.../$FILE/2009-05-reve.pdf*
[19] OG21 – "Olje og gass i det 21 århundret" (Oil and Gas in the 21st Century) [in Norwegian]
[20] First used here in this sense
[21] ARPA-E : Advanced Research Projects Agency – Energy, see *http://arpa-e.energy.gov/*
[22] "En helhetlig satsing på klima og energi" (Aholistic approach to climate and energy) [in Norwegian], see *www.ntnu.no/info/klimasatsing-2009.pdf*
[23] NNHO's letter to Prime Minister Stoltenberg of 16 December 2008 [in Norwegian], see *www.nho.no/getfile.php/.../Finanskrisen_-_tiltak_10-12-08.pdf*


Photo: Nicolai Howalt / Scanpix Denmark

Gudrun Rudningen, Research Scientist, SINTEF Technology and Society

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The Hidden Treasure – an innovative public sector

Social innovation in schools, nursing homes or the railways is the new Norwegian platform[1]. Watch out for public services.

Mention the public sector to the man in the street and you can be sure that his immediate associations will not be with innovation. On the other hand, if you ask the same person for stories about how a primary school teacher, a nurse at the local nursing home or a railway ticket collector devised a new and improved way of doing the job, associations with creativity and innovation will much more readily spring to mind.

Social innovation[2] at a micro level creates considerable benefits for society. The people who daily perform invaluable public services to enable the population of Norway to live good, meaningful lives are assets for the future. Their innovativeness is a hitherto unexploited potential in the Norwegian public sector: in fact many would maintain that it is almost invisible, since it is not measurable in the same way as industrial innovation and is often drowned out by the noise of major reforms. Social innovation must be discovered, experienced, understood and communicated. It must be desired, consolidated and celebrated – and be associated with everyday work.

To be able to make use of their innovative potential, employees need freedom. *Freedom to* prioritise and *freedom from* over-management and paperwork burdens increase the individual's motivation and enhances creativity. Studies have shown that people are at their most creative when they feel motivated by interest, contentment and challenges in their work itself, not by external "carrot-and-stick" motivating factors. Through strategic grounding at organisational level, innovation can be achieved at all levels in the line of command. Today, the innovative initiative of public sector employees is used to make resources adequate for the purpose. In our opinion, learning is not facilitated by alarming messages or studies of the avarage, but by the good examples and stories in which creativity and multidisciplinary collaboration have been successful. We focus on people's presence at work rather than on their absence due to illness. Why do so many people turn up for work each day in spite of a sore throat or a destructive conflict with the boss? The need for manpower in the public sector makes Norway completely dependent on developing knowledge of those work conditions which are important for keeping people in jobs.

Technology is interwoven in service provision, also in the public sector. Every day, people are in contact with technology, from the least advanced (notice-boards, beds) to the most complex (robotics). By collaborating with researchers, people who work with technology each day can participate in and drive the development of new social practices. We would therefore like to ask the public sector to challenge the research community[3]. Much of the research going

[1] The value of the workforce in Norway is estimated to be ten times as high as that of the country's oil and gas reserves.

[2] Social innovation is a process of collective creativity in which the members of a specific unit learn about, invent or introduce new concepts and initiatives in order to overcome social challenges.

[3] Social innovation, despite being to a large extent already present in social systems, is so far an overlooked and underestimated phenomenon (Howaldt & Schwarz, *"Social Innovation: Concepts, Research and International trends"*, 2010).

on in the public sector is restricted – in the sense that it is largely carried out in the form of evaluations of already implemented projects – and inaccessible, since very few people actually read thick research reports. It should become a requirement for researchers to be participants in all phases of innovative projects. The people who provide the services know what must be done and often have very good ideas about how, but they perhaps lack the expertise needed to make an idea immediately relevant for others.

Laughing all the way to school

Mistrust is often a poor foundation for collaboration and a hindrance when the objective is to develop an integrated educational process for skilled workers, something which is an express goal of the Norwegian "Knowledge Promotion" educational reform of 2006. So how can we ensure that practical and theoretical expertise work better together? In the *Vandreboka*[4] (the Companion Book) project, implemented by several county administrations, students and apprentices, employers and teachers, county governors and examining boards met to discuss specific problem issues connected with education (Education and Development Teams). According to the participants, meeting in this way, getting to know each other and sharing experiences and know-how resulted in a higher degree of interaction between schools and employers, more integration in the educational process and better learning. Apprentices who participated in the Vandreboka project also achieved better results in their examinations than ordinary apprentices.

Challenges in schools: From failure to inclusion and collaboration
At present, far too many students fail to complete higher secondary education. This is a challenge, particularly in connection with vocational courses. At the same time, the labour market offers fewer jobs for people with no formal education. In efforts to reduce the drop-out rate in upper secondary schools, efficient transition possibilities and a more coherent educational process is extremely important. In order to realise this, it is essential to establish the right meeting places between different types of school, between schools and parents or guardians, and between schools and other bodies which also need to be involved in the work.

X-rays on the road

In future, specialist health services will be able to come to you, instead of you having to go to hospital. In Oslo, a collaborative project between Ullevål University Hospital and the municipal health service has made it possible for a mobile X-ray service unit to travel from one nursing home to another.[5] The radiographer rolls the 95 kilogram equipment into the rooms of patients suffering from dementia to X-ray aching shoulders and broken ribs. The whole examination is over in a quarter of an hour. The benefits are two-fold: The nursing homes do not need to take senile patients out of their familiar circumstances to carry out examinations which subject them to considerable stress, and the staff are able to concentrate on other duties.

Challenges in health and care services: Inter-disciplinary interaction, pilot projects and company involvement
Experience from Norway and other countries shows that the development of new products and services in the health care sector have the best chance of success when that development takes place in collaboration between the health sector, R&D institutions and domestic and international industry. Innovation also depends on municipalities and health services being informed about successful pilot projects and being able to make use of experience. There is a need for research, development and implementation of new products, services, treatment processes and organisational forms associated with a patient's entire medical history. Closer collaboration between a knowledge-intensive health sector and Norwegian companies with regard to the development and implementation of new innovative solutions, as well as an increase in Norwegian companies' involvement in the health care market, will enhance the quality and efficiency of the health service and increase the number of capable knowledge-based industry workplaces.

Two or three thousand in a flash

Every day thousands of people are transported on Norwegian railways. A major challenge for NSB is planning which trains are to be included in which shifts, where the crew shall change trains and from which depots employees shall man the trains. Until now such planning has been done manually. With complex regulations and an unknown number of possible combinations, preparation of a single day's personnel schedule can take several man-weeks. However, advanced mathematical optimisation methods developed by researchers mean that NSB is now beginning to experience a completely new world in the planning of daily schedules for its ticket-collectors and engine drivers. These tools make it possible for a planner to construct two or three thousand daily personnel schedules in a single day, and the plans are often better and more cost-effective for NSB and beneficial to both passengers and employees.

Challenges in public transport:
Efficiency, availability, safety and the environment
Norway has significant costs connected with distances and challenges linked to the low density and location of population centres, and at the same time we make considerable demands on accessibility in urban areas. Future innovations in public transport will take place in the fields of real-time information, dynamic decision support and active control of traffic and other operations. Technological tools which can compensate for perceptual and cognitive weaknesses will ensure that certain user groups do not become excluded from the services offered. Active systems which contribute to preventing accidents, and passive systems which reduce the consequences of any accidents, are necessary fields of innovation to achieve the objectives. Satisfying national and international obligations with regard to reduced greenhouse gas emissions calls for a high level of innovation directed towards environmentally friendly motor technology systems, fuel and operator support systems, along with social innovation which contributes proactively to influencing and if necessary transforming our expectations regarding standard of living and consumption.

Recommendations

How do we make room for innovation in the public sector?
We propose three specific approaches:

[4] http://www.vandreboka.no/

[5] http://www.innomed.no/prosjekter/mobile-helsetjenester/

1. Hands-on management

A large number of services are performed on the "front line" and this is where the potential for innovation is greatest. At the same time we must dare to give the front line responsibility for expertise and authority. In recent years the brutalisation of the public sector through the introduction of New Public Management has created a workforce which has to use their energy and resources to document their work and report deviations, instead of seeing new, creative solutions in their working day. Management in the public sector should make use of precisely that which is the sector's greatest strength: Professional and experience-based know-how and the idealistic attitude of being able to make a difference to people's lives. *We therefore recommend that managers in the public sector should once a month do a day's work among their own front line employees, and that management meetings should prioritise learning from actual success stories from the company's own front line.*

2. A time for innovation

Willingness to bring in resources from outside one's own organisation is essential if service providers are to reap the benefits of each other's innovation work. The greatest innovations often result from the combination of different know-how in new ways. This means that one must involve public sector enterprises and administrating bodies, research communities, private operators, citizens and participants, volunteers and organisations, and domestic and international communities. Inadequate control and predictability in the working day results in absence due to illness instead of effective time at work. At the same time the socio-economic potential associated with social innovation in the public sector is so significant that it will be profitable for employees to devote time to it. *We therefore suggest that 20 per cent of working hours in the public sector be earmarked for social innovation work, preferably crossing the boundaries of specialist fields or sectors.*

3. Welfare technology

A familiar challenge in welfare technology is combining technological and social science research to create a good foundation for decision-making when ethical, technological and social benefit assessments must be performed simultaneously. In the field of public transport, investment is now taking place in intelligent transport systems making use of sensor technology and robotics, among other things. We need arenas for testing new technology which support the development and stimulation of new services, such as a *national laboratory for transport research in which one can use experience from the front line in real traffic situations in combination with supplementary studies under controlled conditions.*

Finally:

Social innovation has often been described as invisible because the effects of such innovation are immaterial, cannot easily be measured and are not reflected in economic figures. Such innovation is therefore difficult to describe and evaluate. Focusing on innovation and technology among employees may provide the longed-for improvement in status the public sector needs in order to provide valuable service in the future. The time has come to place demands on Norwegian researchers, now that the innovative nurse has stepped up to Norway's new platform.


Photo: Berit Roald / SCANPIX

Jack A. Ødegård, Vice-President, Research, SINTEF Materials and Chemistry

Sustainable exploitation of geological resources

International competition for rare minerals and raw materials is increasing. Also in this field, Norway has considerable natural resources. If we wish, we can stand on the threshold to a new era of modern, sustainable mining industry in Norway.

Throughout the history of mankind, the development and use of raw materials has been a crucial prerequisite for technical progress and improved living conditions. Today, researchers all over the world are focusing on the development of new materials which are stronger, more durable, lighter and more environmentally friendly, or possess completely new properties. In particular, we have expectations that nanotechnology will pave the way for a new industrial revolution.

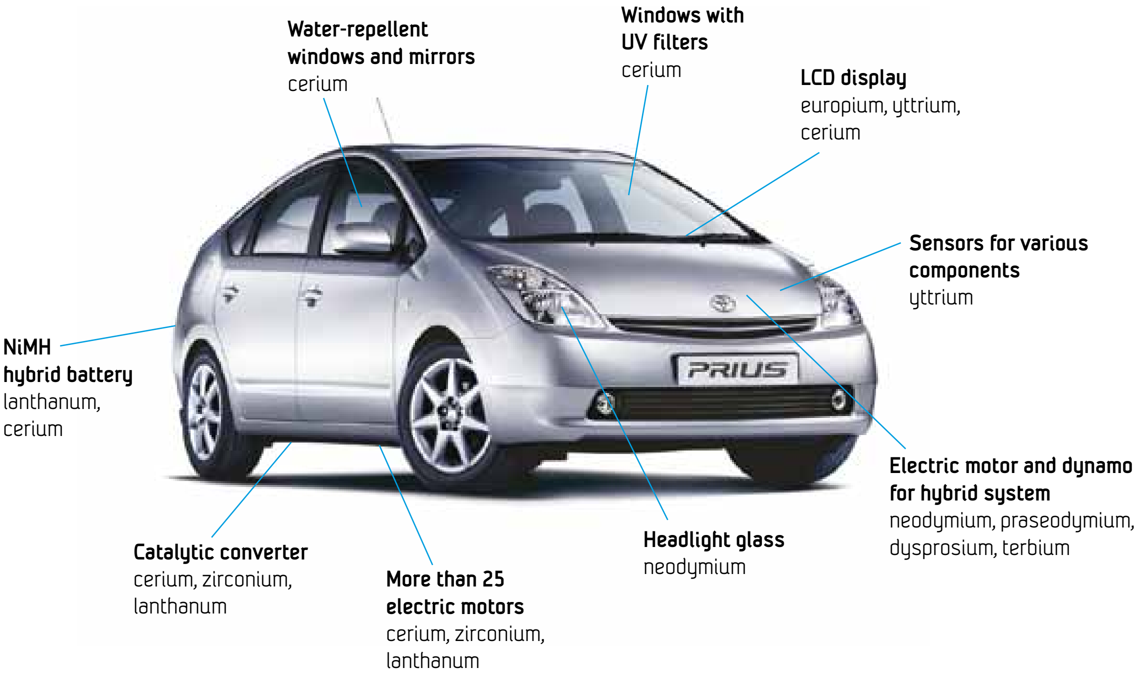
Materials science and nanotechnology form the starting point for wealth creation in other important sociological fields associated with health, transport, energy generation, environmental science and ICT. Mastery of materials science and nanotechnology, and the ability to translate them into industrial applications, will be crucial for the competitiveness of industrialised nations in this century. In other words, such expertise is extremely important for ensuring freedom of action, welfare and health (Avanserte Materialer 2020, (Advanced materials 2020) [in Norwegian], the Research Council of Norway, 2005).

In forty years, the population of the earth will have grown from the present 6.5 billion to about 9 billion people. At the same time it is expected that an ever-increasing proportion of the population will attain a higher standard of living and thereby also climb up the protein ladder. It is acknowledged that this will present significant challenges for the planet as regards access to food and energy, and issues connected with climate change and renewable energy are conspicuous in current debate.

In the international arena we see how broad-based political settlements lead to changed policy instruments "overnight". We also note that the university and research institute sector has responded rapidly, among other things by establishing Centres for Environment-friendly Energy Research (FME) in accordance with the Norwegian parliament's consensus on climate-related policy.

Another perspective connected with the future increase in population and prosperity is the generally increasing need for manufactured goods such as solar cells, guitar strings, roof tiles, toothbrushes, hairdryers, cars (conventional, hybrid and electrical), TVs, paint, batteries, concrete reinforcement bars, cosmetics, mobile telephones, iPads, cement, watches, bicycles (which are also gradually becoming electrified), agricultural equipment, kitchen utensils

All these products, and many, many more, have their origin in so-called geological resources (oil, gas, ores and minerals). Our acquaintance with this concept commences in the kindergarten sandpit (specialised sand products) and concludes with the gravestone. In the course of his life, the average man uses more than 850 tonnes of minerals or mineral-based products (including about 400 kg of iron and steel per year).



Rare earth elements in a Toyota hybrid car Source: Edmundson.com / A-Magasinet

Consumption of mineral raw materials has increased in step with the development of modern society. Some lines of development have progressed more rapidly than others. For example, in the course of the last 25 years we have consumed half of the cumulative volume of copper which has been found throughout history, and demand for the metal is expected to grow rapidly, among other things because of increasing amounts of copper in electric motors in universal use, increased electrical energy production (generators), electrical distribution grids, and so on.

Rare earth elements

Another example is the somewhat less well known element neodymium (Nd), which belongs to the group of rare earth elements (REE). This is an important material in magnets designed for use in, among other things, wind turbines. If all the wind turbines for which development licences have been granted or applied for were to be constructed using this technology, it would consume 2 500 to 5 000 tonnes of neodymium. The total world production of neodymium was approximately 22 500 tonnes in 2009, and demand is expected to increase by at least 50 per cent by 2014. This puts the concept of *sustainability* in a new light.

A similar situation is seen with regard to the element lanthanum (La) in the manufacture of hybrid cars. The battery of a Toyota Prius contains 10-15 kg of lanthanum. If the ambitious goals for the proportion of electrically powered road vehicles are to be achieved, this will require an increase in production of lanthanum exceeding what is practically possible. There are many similar examples, since so-called green technologies are often based on the use of rare raw materials. In other words: Sustainability in one context does not necessarily entail sustainability overall ...

The structure of a modern mobile telephone contains about 60 different elements, many of which are rare. These elements are often referred to as *special metals*[1] and *precious metals*[2]. China currently controls the production of and access to many of these materials and metals, including about 95 per cent of the rare earth elements (REE), while countries such as the Congo are important suppliers of others. China is among the three largest suppliers of 13 of the 19 most important ores and minerals.

A new strategy for the EU

The EU has inadequate supplies of mineral raw materials and in 2008 it focused attention on the issue by establishing the so-called *Raw Materials Initiative*. The ambition here is to develop a strategy which can be divided into three main elements:

- To ensure access to strategic materials and minerals (international trade agreements)
- to evaluate the basic resources in the EU's own region and establish a modern, environmentally-friendly technological platform, while creating a healthy climate for the establishment and development of its own industry
- recycling, re-use and substitution (reducing dependency on imports)

China and a number of other countries are increasingly tightening the screw through export restrictions for strategic raw materials, so the EU's freedom of action will primarily involve the last two elements above. In connection with this, a good deal of positioning is taking place, in which Norwegian R&D operators so far have not been particularly prominent. It is expected that *sustainable exploitation of mineral resources* will be an important theme in connection

[1] Tungsten (W), antimony (Sb), cobalt (Co), bismuth (Bi), selenium (Se), indium (In), among others
[2] For example, silver (Ag), gold (Au), palladium (Pd), platinum (Pt), ruthenium (Ru), rhodium (Rh), osmium (Os), iridium (Ir)

with the EU's 8th Framework Programme for Research and Technological Development in 2014.

Norway's situation

In the past 20-30 years, prospecting operations in Norway have been at a very low level – about one tenth of the level in Sweden and Finland. The industry has explained this in terms of unclear framework conditions (complicated laws) and inadequate basic data in the public domain. After fifteen years' work, the authorities have updated the legislation and combined it into the Minerals Act of 2010.

This is an important step towards clarifying the framework conditions and the mining industry's reaction has been positive, although it points out that it remains to be seen how the new legislation will function in practice. Some uncertainty is still associated with, among other things, the issue of indigenous peoples and the recognition that important ore and mineral deposits are national resources which authorities at several levels should take into account in their planning processes.

As regards estimates of resources, it is clear from the macro-geological picture that Norway has many exciting deposits. A number of new, interesting discoveries are expected if intensified prospecting commences.

The Geological Survey of Norway (NGU) has estimated that the value of our minerals can be compared with the size of the Norwegian Petroleum Fund (NOK 2 trillion, or about EUR 254 billion). The Bjørnevann iron ore deposits belonging to Sydvaranger Gruve AS have an estimated value of NOK 100 billion and the iron ore in Rana is estimated to be worth NOK 90 billion. Similar figures apply to the ilmenite deposits of Titania AS in Rogaland, and represent the value of a moderate-sized North Sea oil field. In comparison, industrial operations connected with ore and mineral *production* in 2008 amounted to a value of approximately NOK 11 billion.

Large potential

In the light of the increased global demand for both "traditional" raw materials such as iron and steel, copper and aluminium, as well as the emergence of major markets for special metals and rare earth metals for use in electronics and green technologies, it is interesting to note that the *Fennoscandian Shield* is becoming one of the most interesting regions in Europe. In this region there are interesting deposits of iron ore, base metals[3], industrial metals[4], precious metals and special metals[2], including rare earth metals[5], with the northern part, the Barents Euro-Arctic region being particularly interesting.

It is natural to conclude that, with the underlying trends towards continued growth, the market for refined products from these deposits will persist into the foreseeable future. With ever-stronger control on the part of dominant countries such as China and India, increased pressure is expected on a range of minerals, with subsequent rising prices.

Norway has natural advantages also in this field. Our geology indicates the existence of considerable potential for land-based industrial and commercial development. Norway is a long, narrow country with an ice-free coastline. This is a decided advantage in connection with logistics and transport, because the majority of deposits will be located in proximity to the sea and hence marine transport. This is also of interest to the neighbouring countries to the east. Sweden, Finland and Russia all envisage the development of shared infrastructure in the northern regions.

Norway is standing, **if you like**, on the threshold to a new era for the continued development of a modern, environmentally friendly mining industry. In the Norwegian parliament a broad-based positive attitude is emerging to support the growth of a new golden age in this sector of industry. The mining industry is in the process of revitalising itself after many years in the shadows, in part by creating a common trade association (Norsk Bergindustri) in 2008.

What is needed for Norway (and its neighbours) to succeed in making the best of the new situation? Some ideas:

- immediate increase in prospecting operations – What was not commercially exploitable yesterday may be today
- investments from both the authorities and private investors
- active use of tax incentives for exploration companies
- regular updating of framework conditions and legislation as we learn from experience
- establishment of value chain arenas (from prospecting to finished product). A goal must be to improve the level of processing and value creation in Norway: we should avoid becoming a raw materials supplier to the EU
- establishment of technology arenas (e.g. for clean-up and environmental issues)
- establishment of policy instruments with regard to R&D and innovation
- adequate educational capacity in technical colleges, university colleges and universities
- establishment of relevant R&D expertise and adequate capacity in research institutes
- establish an R&D strategy according to models from OG21 and Energi21 (MINERAL21?).

This industry will meet many of the same problem issues which are faced by the petroleum industry, smelting industry and others. Important issues connected with the environment and efficient energy consumption must be addressed. Companies' requirements with regard to profitability will necessitate the development of technological and transportation systems, and in the interface between the petroleum industry and the smelting industry *(where gas meets ore)*, ground-breaking new processes and products will be born.

A possible scenario

We can envisage the following desirable scenario: A broad consensus is reached regarding industrial policy which defines clear objectives for future industrial development on mainland Norway. Funding for R&D and innovation is arranged in accordance with this and new thematic areas of involvement are defined. In the field of minerals, the institutions in the mining community of "Bergbyen", Trondheim (SINTEF, NTNU, NGU and DirMin), in collaboration with other national knowledge-based communities, are given responsibility for preparing a national R&D strategy, seen in an international

[2] For example, silver (Ag), gold (Au), palladium (Pd), platinum (Pt), ruthenium (Ru), rhodium (Rh), osmium (Os), iridium (Ir)
[3] Copper (Cu), zinc (Zn), lead (Pb), tin (Sn), aluminium (Al)
[4] Quartz/quartzite, ilmenite, graphite, limestone and dolomite, anorthosite, nepheline syenite, olivine
[5] Lithium (Li), beryllium (Be), niobium (Nb), tantalum (Ta), scandium (Sc), among others

context. In the wake of this strategy (MINERAL21), a new thematic programme is established by the Research Council of Norway (NORMIN21), taking effect from 2012.

Recommendations

- Initiate work on an R&D and innovation strategy aimed at achieving *sustainable exploitation of mineral resources in Norway (MINERAL21).*
- Establish dialogue with the EU and the EU *Raw Materials Initiative.*
- Define objectives for new industrial activity

Important participants

NGU – The Geological Survey of Norway (www.ngu.no)
DirMin – the Directorate of Mining (www.dirmin.no)
Norsk Bergindustri – The Norwegian Mining and Quarrying Industries (www.norskbergindustri.no)

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Photo: Dale Sanders / Masterfile (RM)

Oddvar Inge Eide, President, MARINTEK

Jo Stein Moen, Director of Public Relations, MARINTEK

The conquest of the oceans

Norway is first and foremost a maritime country. The future and continued development of prosperity in Norway depends on how we manage the sea and invest in ocean space technology. Here lie the solutions to the great challenges of our time: energy supply, climate and food.

The oceans

From the beginning of time, the sea has been an important means of transport, as well as a provider of resources which we have harvested. To begin with, let us present two key figures: The oceans cover almost 70 per cent of the planet's surface. About 80 per cent of the oceans are deeper than 3000 metres, which is the maximum depth at which the offshore oil and gas industry operates today. It is an accepted fact that the oceans are the world's most important reservoir of resources for the future, which will be of crucial importance when global challenges connected with the food supply situation, energy demands and climate change are to be tackled.

At the same time – to put it bluntly – we can say that we currently have more knowledge of outer space than we do of the oceans. We still need to improve our knowledge of what lies below the surface of the sea. Research-based knowledge will be the key to conquering the oceans, and Norwegian research centres can make a difference here, contributing to solutions which can be applied globally.

For generations, Norway's most important resources and competitive advantages have been linked to the sea. Marine technology research and development has been at the centre of the development of the technological community in Norway, providing important contributions to Norway's development as a maritime world power, and not least to the nation's economic development. Today, maritime operations employ about 100 000 people in Norway and contribute about NOK 100 billion in wealth creation. We have the fifth largest registered shipping fleet, specialised shipbuilding yards adapted to our offshore operations and our coastal shipping infrastructure, a world-leading maritime equipment industry and marine consultants in addition to a large maritime services sector. Maritime technology and expertise are essential factors in oil and gas operations, shipyards and industry, as well as in the fisheries and aquaculture industries. Also in the context of renewable energy, marine technology research is likely to be essential in the future.

The starting point is that we are confronted by a new geopolitical reality. Countries which have been in the technological forefront for generations are now being challenged by aggressive world powers who are positioning themselves and taking the lead in the fields of research and development. In some fields Norway has been a world-leading supplier of expertise. Marine technology and experience in technology connected with the oceans has been – and still is – among these fields, and this has contributed to making Norway a maritime world power. It cannot be taken for granted that we will maintain this position in the future.

Few people doubt that the world today is confronted by major challenges. Food shortages, energy crises and climate change come readily to mind. The majority of the Earth's surface is, as is well known, covered by water. The enormous unexplored oceanic areas present great potential, and new levels of expertise must be reached in order to solve the major challenges of our time. There is no doubt that research-based knowledge is becoming more important than ever.

In deep water

Most human activities on and in the sea have an impact on ecosystems and the environment. That this applies to the petroleum industry was clearly demonstrated by the recent accident the Gulf of Mexico, which many people believe will result in a completely new era as regards oil and gas exploitation at sea. When we attended the major ONS Conference in Stavanger in August, a large number of journals and magazines were handed out to us and the other participants. Among these there were two in particular which held our attention, because their front covers illustrate an important point. The cover of the August edition of the Norwegian technical journal *Teknisk Ukeblad* bore the following headline: *"- BP-ulykken kunne ikke skjedd i Norge"* (The BP disaster could not have happened in Norway). In contrast, the headline of the journal *Industrien* was as follows: *"Oljekatastrofen kunne skjedd i Norge"* (The oil catastrophe could have happened in Norway).

From our point of view it is important to emphasise the need for research-based knowledge and for offshore petroleum exploitation to take place in as responsible a manner as possible. We must certainly hope that the Deepwater Horizon catastrophe was the last incident of this type ever to occur, although nobody can say in all honesty that such things could not also happen in Norwegian waters. Magne Ognedal, Director General of the Norwegian Petroleum Safety Authority, stated to *Teknisk Ukeblad*: *"The safety situation in Norway is good, but we have to admit that there is risk connected with petroleum operations,"* and he reminded us that, *"We have also experienced catastrophes and near-catastrophes here in Norway"*. The key to safer exploitation of natural resources at sea will continue to lie in the development of expertise and technology.

It is sometimes claimed that we have so far extracted the "easiest" oil, and that in future we are literally advancing into deeper water. Some years ago, "deep water" meant up to 1500 metres, but now it means 3000. Year by year the development moves in the direction of human activities and resource extraction in deeper waters, and at the same time operations move ever further north and south. In a number of areas operations are struggling with aging infrastructure, and there is an increasing need for maintenance in parallel with technological developments. This places additional demands on considerate, knowledge-based operations, and is a challenge for forward-looking knowledge-based communities.

Global responsibility

Early in September 2009, a few days before the Norwegian parliamentary election, Unni Steinsmo, President of SINTEF, and Torbjørn Digernes, Rector of NTNU, published a feature article in the major Norwegian daily, *Aftenposten*. Under the title *"En global veiviser"* (A global guide), they argued that, *"Norway has both a national and an international responsibility for mobilising the country's human and economic resources in order to create technological systems, knowledge and expertise in the fight against the negative impacts of global climate change"*. It is also natural to consider investments in marine operations and marine technology development in this perspective.

The Climate Summit in Copenhagen in December 2009 showed all too clearly that we have a long way to go before the necessary measures are adopted. The need for knowledge of the planet we live on will only increase as time goes by. Since its foundation, the SINTEF subsidiary MARINTEK's activities have been built on two pillars: The maritime sector and the oil and gas industry. At present, a reorientation is in progress which will lead to a third field to supplement these. Renewable energy connected with the sea will to an increasing extent become an important field of work. Experience gained from the testing of Hywind, Statoil's pilot project for floating wind power generation, indicated in an early phase in 2005 that MARINTEK will be able to play an important role in the development of offshore wind power. Marine-based renewable energy generation is an immature field which will call for considerable investment in research in the near future. It will be natural to view Europe as the domestic market with regard to offshore wind power. Incidentally, after six months' operation of the Hywind installation, floating in the exposed area between Utsira and Karmøy, off Norway's west coast, Statoil's project management stated in *Teknisk Ukeblad* in March 2010 that it "functions far better than anticipated". Time will show what potential lies in offshore wind power generation, but what is certain is that this is an extremely interesting field for research and development.

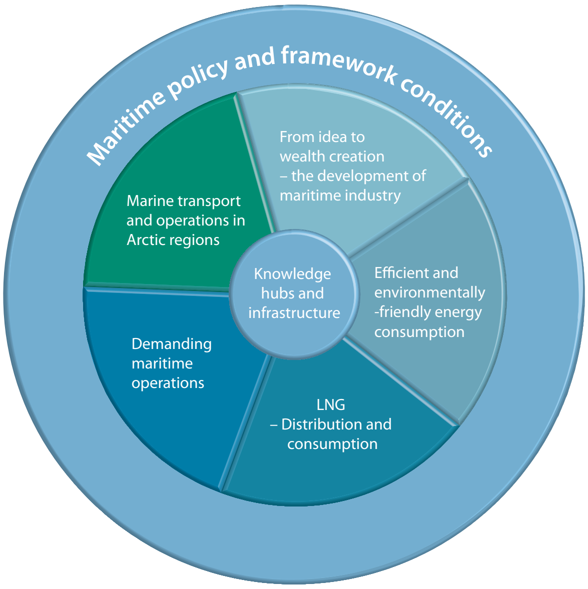
One of mankind's greatest challenges in the future will be food production, with the need to feed an ever-growing world population. According to the UN Food and Agriculture Organization (FAO), the world must produce enough food for 9 billion people in 2050. Norway's position as a supplier of marine products and related know-how and technology is unique, and involves both potential and responsibility. Unknown potential exists in the oceans for innovation and enhanced expertise which can be of benefit to mankind if the right investments are made.

Recommendation No. 1:
Follow up the "Maritim21" R&D strategy

Norway has perhaps the most comprehensive maritime cluster in the world, with leading operators in most fields. There has for a long time been a need for better collaboration between the various players in the Norwegian maritime cluster. The breakthrough may have occurred at the beginning of June 2010, when the entire Norwegian maritime industry sector presented *"Maritim 21 – en helhetlig maritim forsknings- og innovasjonsstrategi"* (Maritim21 – an integrated maritime research and innovation strategy) to Trond Giske, the Minister of Trade and Industry.

The strategy was developed by the industry at the request of the Ministry of Trade and Industry between September 2009 and June 2010, by means of a unique process in which several hundred people representing large and small players in the industrial and research communities throughout Norway participated in regional seminars, working parties, direct interviews and web-based consultation rounds. The outcome was a strategy report which recommended systematic, focused effort in seven high-priority fields of work. The first item, and the very core of the proposed areas of involvement, is "Knowledge Hubs and Infrastructure". Knowledge has been, is and will of course continue to be, the very driver of maritime development. Maritime policy and framework conditions define the field of potential for the industry.

The areas of involvement are demonstrated by the following model:



Specific plans of action shall be prepared for the implementation of the selected areas of involvement. These plans of action shall provide specific input on the best way for the public funding system and private sector industrial players to co-operate in order to implement the strategies. The work shall be led by MARUT (a collaboration between the Ministry of Trade and Industry, the Norwegian Shipowners' Association and the Federation of Norwegian Industries, with contributors such as the Research Council of Norway, Innovation Norway, MARINTEK, Det Norske Veritas and the Norwegian Confederation of Trade Unions).

MARINTEK has played an important role in the development of Maritim21 from its inception. In the near future, the principal focus will be on the implementation of the maritime research and innovation strategy which will realise the vision of Norway as *"the most attractive location for global, knowledge-based, environmentally sound maritime industry"*.

Recommendation No. 2: Build the marine technology research institute of the future

The question is how one can obtain more knowledge of the oceans, as well as securing a future with Norway as a world leader. One of the answers is, clearly, through modern laboratories and other research infrastructure. In the report documentation which was submitted with the pre-study for the Ocean Space Centre to the Ministry of Trade and Industry early in 2010, the gap between the existing laboratories and the coming demand was described in detail, as well as the infrastructure which will be needed in a long-term perspective, by 2050.

The principal elements of tomorrow's marine technology research institute are as follows: A larger and deeper ocean testing basin to enable complete modelling of systems in ultra-deep water. This is important in view of the challenges connected with oil and gas production at great ocean depths and renewable energy generation. A unique 3D flow tank for studying the effect of complex current conditions and internal waves affecting slender structures. A large, combined towing tank and wave action basin, as well as a combined flow tank and so-called cavitation tunnel, designed to meet the challenges connected with shipping operations, fisheries and aquaculture, advanced marine operations under extreme weather conditions and the development of offshore renewable energy generation. A wind tunnel capable of simulating cold climate, a laboratory for studying oil in ice, and laboratories with facilities for testing marine operations in marine ice conditions. In addition, a flexible coastal and oceanic laboratory.

The overall result will be facilities for research which currently do not exist anywhere in the world and which will set a new standard for infrastructure and laboratories for marine technology. This will give Norway new advantages and help effect an enhancement of expertise of global proportions. In addition, conditions must be created for modern methods of collaboration and working, as well as co-operation across disciplinary boundaries, with the industrial sector and the academic community interacting in new ways.

In our opinion, this project is visionary, realistic and necessary. Few people are in doubt as to its visionary nature, and in professional circles there is also little disagreement that a project like the Ocean Space Centre will be necessary to provide opportunities for knowledge development to meet future requirements. As regards the realism in the project, this is reinforced by the fact that Norwegian domestic decision-makers have, in a number of political key documents in recent years, emphasised the importance of renewing the infrastructure for marine technology R&D in Trondheim, and explicitly endorse the project.

In the spring of 2005, the Norwegian parliament's Standing Committee on Education and Church Affairs voted unanimously to issue a statement on the government's Research White Paper. The Committee pointed out that *"NTNU and MARINTEK in Trondheim represent Europe's most authoritative technical research environments"* and maintained that *"We have a common national responsibility for ensuring that MARINTEK becomes a European laboratory"*. This was in many ways the starting shot for a visionary, realistic and essential project for which MARINTEK took the initiative, and which today has become almost a household word.

In its maritime strategy for 2007, the Norwegian government established that there was *"a need for significant upgrades and new investment if the institutes are to be able to maintain their international competitiveness"*. In 2008 the government reiterated this in its Innovation Report, and went on: *"If the research centre and laboratories in Trondheim are to continue to maintain their internationally leading position, it is important that they satisfy the Norwegian maritime industry's needs today and in coming years"* . At the same time, the government allocated NOK 8 million in financial support for a pilot project to study the possibility of establishing a next-generation marine research and laboratory institute – now known as the Ocean Space Centre. The condition was that industry and the research communities should contribute a corresponding amount, which they did. This was followed up in 2009 when the government cited the project in its Research Report as an example of "public-private sector collaboration", and tomorrow's way to organise research.

We have noted that prominent politicians from all parties – from the Progress Party to the Socialist Left Party – have publicly expressed a desire for the project to be implemented and that the present Minister of Trade and Industry has referred to the institute as his "dream project" (in an article in the Norwegian newspaper *Adresseavisen* on

24 December 2009). All the political signals point towards a major development in Trondheim. We understand of course that nothing resembles writing in the sand more than the wording of a parliamentary white paper, and that statements of this kind are themselves no guarantee of realisation. We certainly shouldn't be taking anything for granted. If the Ocean Space Centre is to be realised, broad-based involvement and considerable effort will be required from many quarters.

In this context it is very promising that Maritim21, the maritime sector's above-mentioned integrated research and innovation project, highlights in one of its specific recommendations *"the establishment of the Ocean Space Centre and an associated network to facilitate research, development and education at the highest international level"*.

The project is not a MARITEK effort but a far more broadly based project supported by both industry and the research community throughout Norway. This is reflected not least in the fact that the management and reference groups studying and developing the project include important figures in DNV, Ulstein, Teekay, Statoil and Statkraft, in close collaboration with research communities such as MARINTEK, SINTEF, NTNU and the Institute of Marine Research.

In the report "Norway – a global maritime knowledge hub" (BI Research Report 5/2009), Professor Torger Reve documents that *"If an industrial research institute is to succeed in attracting the leading talent and the most demanding clients in the world, a specialised expertise-related infrastructure must be developed which will make outstanding research and development possible"*. He goes on to point out that there will probably only be room for two or three global concentrations for marine technology in coming years, and that positioning is clearly in progress internationally. In Reve's opinion, Norway can become "a global maritime knowledge hub", and he concludes his report by stating: *"What we must do is to develop, finance and establish the Ocean Space Centre, in order to develop future expertise in the field of marine technology. Investments in infrastructure for research and development at this scale call for close collaboration with the maritime sector and energy operators, as well as contributions from Norwegian authorities with regard to financing and implementation."* In *Bergens Tidende* on 10 September 2010, Reve stated that if the Ocean Space Centre becomes a reality, it will *"attain a place among the cream of the world's maritime research institutes"*. This must be the objective – and nothing less.

To promote future knowledge of complex relationships in the oceans – and the ability to find solutions to the great challenges of our time – there is a need for infrastructure. This is the very core of the Ocean Space Centre, which will provide opportunities for studying central issues connected with the oceans which are of great importance for the environment and climate, for the balanced exploitation of maritime resources, for access to energy and for development in the Arctic regions. Norway has special international obligations with regard to the management of resources in the oceans, not least in the Arctic. This international position is another powerful argument for Norway having a leading role in the maritime technology of the tomorrow.

In the future there will be room for very few globally leading maritime research communities. Norway should aspire to be one of these – based on the enhancement of the position which it has developed over many generations. It is 70 years since the private and public sectors jointly invested in the ship model testing tank in Tyholt – which is still in use. The Ocean Basin Laboratory was established 30 years ago. In their time, these facilities were ground-breaking and represent a national infrastructure for marine technology R&D which to this day attracts discerning clients from all over the world.

The ambition of making the next-generation of marine technology research institute a reality around 2020 brings new relevance to King Lear's pronouncement that "Nothing will come of nothing". The project depends on broad support from the political and academic communities, both locally and centrally. International participants must recognise the need for a project of this type and the commercial and industrial sectors must understand the value of it. And if society as a whole is to prioritise this, the Norwegian public must grasp the importance of reinforcing one of the sectors in which Norway already has special advantages. This will take a lot of work.

We do not know at present what requirements for expertise will exist in fifty years time. What we do know is that real advances will be made in expertise and technology. We also know that there is a need and potential for closer links between both national and international research institutes. Modern infrastructure, adapted to tomorrow's requirements for marine technological innovation and knowledge development, is a prerequisite for maintaining and reinforcing Norway's role as a maritime world power.

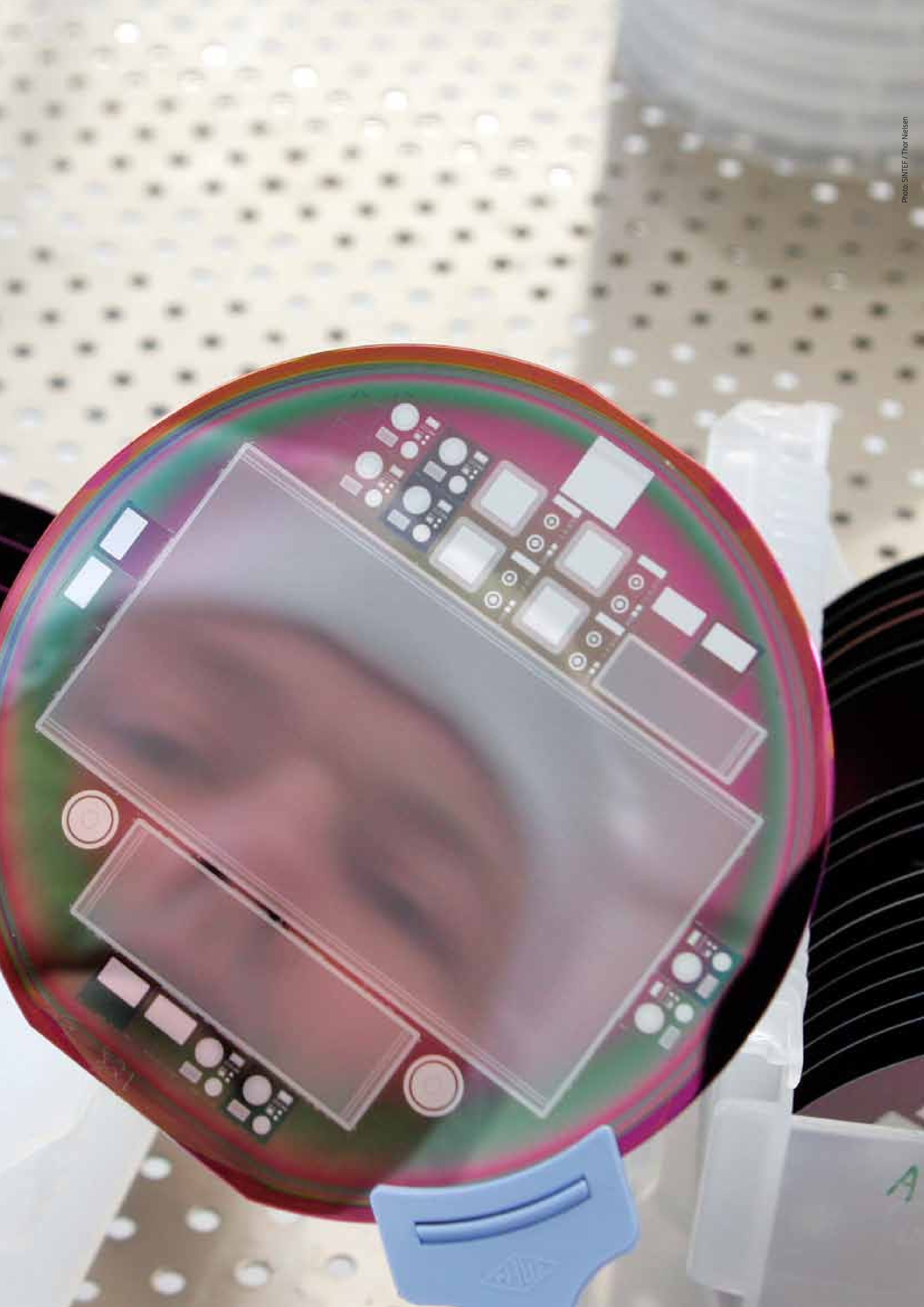
Knowledge is the driver

The avowed objective of the Norwegian authorities is that *"Norway shall become a world leader in the field of research and innovation"*. This sort of ambitious goal demands purposeful involvement and it is fairly clear that the knowledge-based communities in Trondheim will play an important role in its attainment.

Among the reasons why Norway has been – and is – one of the world's leading nations in the fields of shipping and marine technology is that the industry and the state have assumed responsibility for the development of national infrastructure for technological advances and innovation. As we see it, the Ocean Space Centre will make Norway into a marine technology knowledge hub – a global "Centre of Gravity". The realisation of the marine technology research institute of tomorrow will be an important contribution to maintaining Norway's role as a maritime world power also in the future, as well as to solving the major challenges facing modern society. Because knowledge is the driver.

Recommendations

- Follow up the integrated R&D strategy in "Maritim21". www.maritim21.no
- Build the marine technological expertise centre of the future. www.oceanspacesentre.no



Rudie Spooren, Research Director, SINTEF Materials and Chemistry

Enabling technologies

The international community faces a number of major challenges in such fields as energy and the environment, health and welfare, and transport. Overcoming these will to a large extent depend on our ability to develop and exploit new knowledge. Some technological fields will be of particular importance and will demand special strategic attention.

An enabling technology is a generic technology which represents a major leap in technology development, which has reached a level of maturity making it available for widespread use, forming a basis for major advances in important areas in society. Enabling technologies contribute to the development of society in a long-term perspective and are developed continuously by linking basic and needs-driven research and development.

Different enabling technologies are often interlinked and contribute to each other's development. They combine different areas of expertise and depend on strong interdisciplinary interaction. The development of enabling technologies often calls for significant investment in laboratory facilities. The social return is often significantly greater than the yield in terms of commercial profitability. Hence, significant publicly funded R&D effort is required in order to realise the potential ofof enabling technologies.

High-priority enabling technologies

In the 2005 Parliamentary White Paper *"Vilje til forskning"*[1] the Norwegian government prioritised three technological fields of particularly high social significance:

- Information and communication technology (ICT)
- Biotechnology
- New materials and nanotechnology

The latest White Paper on research, *"Klima for forskning"*[2] – reiterates these priorities.

In 2009 the European Commission identified five Key Enabling Technologies (KETs)[3]. These are of considerable strategic relevance for European industry and commerce by virtue of their economic potential, knowledge-intensiveness and expected contribution to solving the major challenges of the international community. The key technologies identified by the European Commission are as follows:

[1] Parliamentary White Paper No. 20 (2004-2005): "Vilje til forskning" (Commitment to Research), the Norwegian Ministry of Education and Research
[2] Parliamentary White Paper No. 30 (2008-2009), "Klima for forskning" (Climate for Research), the Norwegian Ministry of Education and Research
[3] "Preparing for our future: Developing a common strategy for key enabling technologies in the EU", (September 2009)

- Micro and nanoelectronics
- Biotechnology
- Advanced Materials
- Nanotechnology
- Photonics

In addition, advanced manufacturing technology is emphasised as an important interdisciplinary field. The European Commission states:

"Those nations and regions mastering these technologies will be at the forefront of managing the shift to a low carbon, knowledge-based economy, which is a precondition for ensuring welfare, prosperity and security for its citizens. Hence the deployment of KETs in the EU is not only of strategic importance but is indispensible (sic) for Europe."

The status of Norwegian efforts in the field of enabling technologies

The high-priority technological fields in Norway correspond to a large extent with those of Europe. Of these, ICT has reached the highest level of maturity, and has attained considerable significance for industry and society. Also biotechnology, new materials and nanotechnology have already made significant contributions to value creation and benefit to society.

The NIFU/STEP report *"Tematiske prioriteringer og teknologiområder i det norske forsknings- og innovasjonssytemet"*[4] describes Norwegian efforts in the prioritised technological fields. Total public and private R&D investment in these technological fields was NOK 10 billion in 2005. The dominant field was ICT, with NOK 6.5 billion, while investments in biotechnology and nanotechnology/new materials were significantly lower, at NOK 1.9 billion and NOK 1.6 billion, respectively.

About 80 per cent of the R&D investments within ICT and nanotechnology/new materials were made by the private sector, while its share was just above 50 per cent within biotechnology. Total public R&D investment in these technological fields in 2005 was NOK 2,5 billion. The NIFU/STEP report points at a strong interdisciplinary effort in the high-priority technological fields.

In the Parliamentary White Paper *"Et nyskapende og bærekraftig Norge"*[5], the Norwegian government points out that long-term involvement in enabling technologies contributes significantly to the continued development of high technology industry. In a Parliamentary White Paper about ICT[6], the government points out that research is crucial for continued development and for ensuring that technology is put to use.

In 2003, the Research Council of Norway established its "Major Programmes" division, which is intended to contribute to a concentrated and integrated research effort in high-priority fields. In 2009, a Scandinavian expert panel carried out a mid-term evaluation of this initiative.[7] The panel pointed out many positive results but underlined that the full potential has yet to be achieved.

It is difficult tto quantify the results of the focused efforts within enabling technologies because of their generic and long-term nature. The technologies may be exploited in a wide spectrum of applications over an extensive period of time.

Recommendations

SINTEF supports the Norwegian parliament's resolution to maintain the focus on three high-priority technological fields. We suggest a name change from "new materials and nanotechnology" to "functional materials and nanotechnology", in order to emphasise the fact that known materials with new functions are also part of the initiative. SINTEF's recommendations are as follows:

A more balanced effort

In the high-priority enabling technologies it is the private sector which is responsible for the majority of R&D investment. It is positive that industry makes such a strong contribution, but the weaker public R&D share makes that the potential of the technologies is by no means realised. A better balance is necessary between "technology push" and "market pull", and the research system must facilitate "cross-fertilisation" between these. It is especially important that Norway invests more in basic research and reinforces the support to development and commercialisation of technology from research institutions. Moreover, better co-ordination and interaction is necessary between different programme initiatives generated by the Research Council of Norway, in order to achieve a more blanced effort through the entire R&D value chain.

SINTEF particularly stresses the importance of the Research Council of Norway's User Driven Innovation Arena (BIA), and which needs larger and more predictable financial resources.

Improved long-term thinking

The development and exploitation of ICT technology over time demonstrates the importance of staying power. Enabling technologies demand long-term public investment in a continuous, parallel and interactive process of sowing and harvesting. The authorities must make adequate investments and maintain these over time.

The "Nanomat" research programme is a good example: The programme commenced with great ambition in 2002, but did neither succeed to realise the planned intensity nor maintain an adequate continuity. In reality the programme has been put on hold since 2008. The result is that established expertise erodes and that the developed competence is not being exploited to its full potential in the Norwegian Industry. In order to ensure continuity it is necessary to employ financial measures that reduce the dependency of uncertain annual funding through through the state budget.

Invest in laboratories

Top modern scientific equipment and laboratories are crucial in order to realise the inherent potential of enabling technologies. The

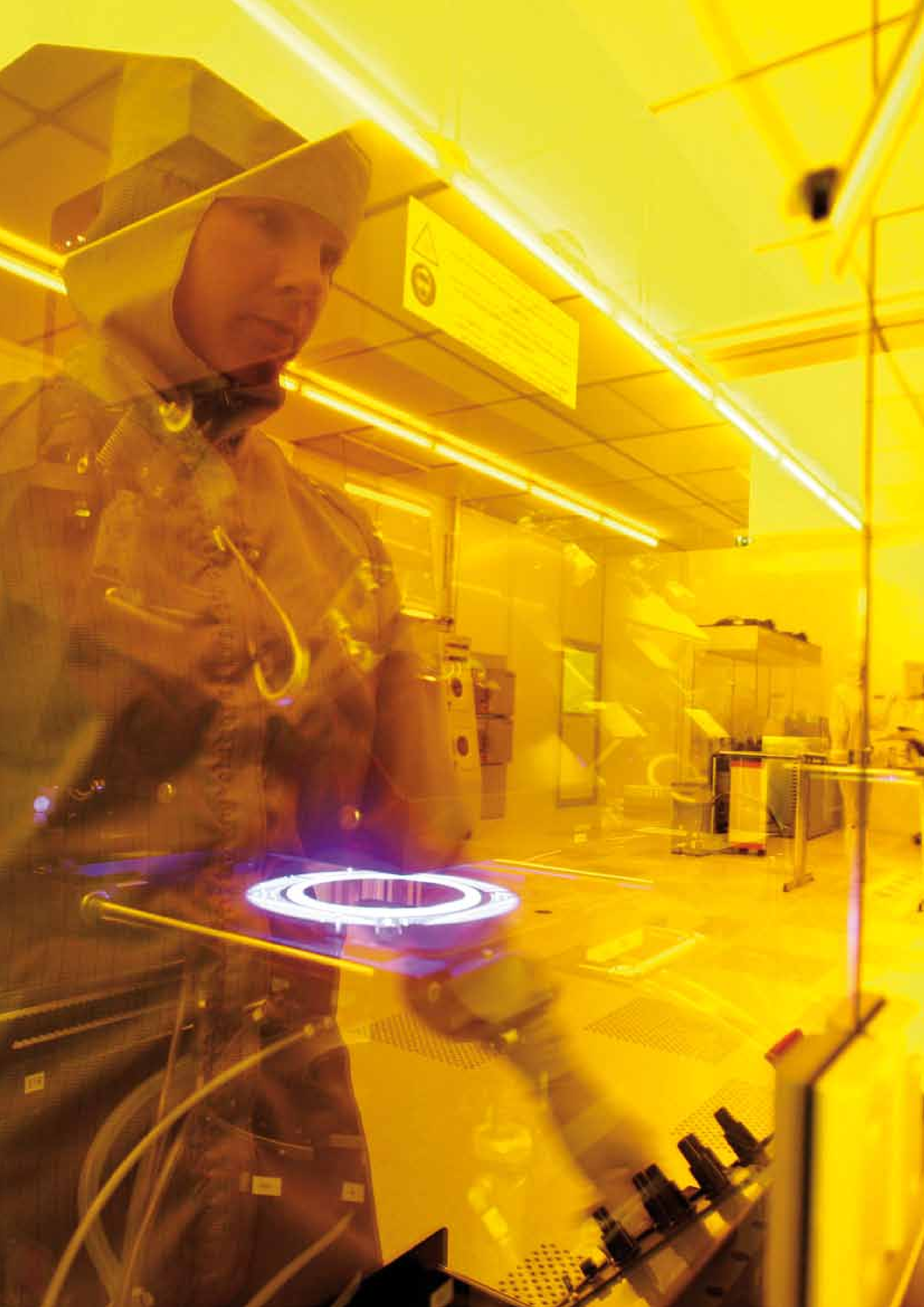
[4] "Tematiske prioriteringer og teknologiområder i det norske forsknings- og innovasjonssystemet" (Thematic prioritisations and technological fields in the Norwegian research and innovation system) [in Norwegian], NIFU/STEP Report No. 22/2007 (2007)

[5] Parliamentary White Paper No. 7, "Et nyskapende og bærekraftig Norge" (An innovative and sustainable Norway) the Norwegian Ministry of Trade and Industry (2008-2009)

[6] Parliamentary White Paper No. 17 (2006-2007), "Eit informasjonssamfunn for alle" (An Information Society for All), the Norwegian Ministry of Government Administration and Reform

[7] "Sats på forandring" (Concentrate on change) [in Norwegian], the Research Council of Norway (2009)

acquisition and operation of such equipment is often extremely expensive. The Norwegian authorities acknowledge that this area has been neglected, and have significantly increased the available funds for investment in important research infrastructure at Norwegian research institutions. Experience from the applications submitted to the infrastructure scheme indicate how critical the shortfall has become and in SINTEFs opinion it is necessary to increase funding of laboratories and scientific equipment further.



Inge R. Gran, Research Director at SINTEF Energy Research

The future role of the research institutes

Norway has unique opportunities to establish sustainable knowledge-based businesses in collaboration with the EU.

Introduction

The EU's strategy is to develop leading international European innovation networks, and Norway has several businesses that can act as key network hubs. As a global economic block, Europe is increasingly lagging behind Asia and America, and the EU views this challenge as its principal *raison d'être*[1]. EU strategies for addressing this challenge open the door to major opportunities for Norway. The rapid development of the European Research Area (ERA)[2] is leading to major changes which, with the help of proper political initiatives, will lay the foundation for new, knowledge-based wealth creation in Norway.

The Norwegian research institutes will continue to play a key role in the domestic arena. Norway possesses a business structure comprising a high proportion of small and medium-sized businesses whose future innovation processes will continue to benefit from active collaboration with the research institutes. In addition, Norway shares with other countries regional research needs which in the future will also be addressed to a large extent by its domestic research organisations.

This article addresses those elements of the research institutes' future functions which do not represent a direct extension of their current roles. It also describes the research institutes' key role in the European innovation arena, and concludes with recommendations to the Norwegian authorities as how we can make the most of the opportunities.

Key development trends

The future is uncertain, but there are a number of clearly defined development trends which are likely to continue. One of these is *globalisation*, which in practice entails that in many respects the relevance of national frontiers and the physical distance between organisations is reduced. A second development trend is the *increased complexity* inherent in products and services. The result of this is that the innovation system is becoming increasingly grounded in the concept of *open innovation*. Open innovation entails that principally we are making use of research and development taking place outside the business premises, and are exporting the results we have already exploited or do not wish to exploit [3].

Key characteristics of open innovation include working in networks and specialisation. Today, this commonly takes place via the utilisation of global innovation networks, and only to lesser extent within the boundaries of individual countries. Consequently, a limited number of regions develop into hubs within the global innovation networks[4]. The hubs represent a geographical concentration of companies and research institutes within a given sector, field of technology or value chain.

Globalisation and Europe

As far as Europe is concerned, these development trends generate major challenges, firstly because the countries themselves are small in a global context, and secondly because there is only lim-

[1] *Seeing through the hallucinations: Britain and Europe in the 21st century*, J. M. Barroso, 2006
[2] *SINTEFs posisjon i det europeiske forskningsområdet*, (SINTEF's position in the European Research Area. In Norwegian), Ernst H. Kristiansen, 2010
[3] *Open Innovation: Researching a New Paradigm*, H. Chesbrough, et al., eds., Oxford University Press, 2006
[4] *The new age of innovation: driving cocreated value through global networks*, C. K. Prahalad, M. S. Krishnan, McGraw-Hill, 2008

ited coordination at the European level. An overall target is thus to achieve a better distribution of research work across Europe as a whole. This will mean that unlike the current situation, not all countries will be able to carry out research into almost anything.

In the context of global competition, and in order to secure its future prosperity, it is essential that Europe succeeds with this strategy. Since Europe does not possess a strong central power base, this development must take place by means of a collaborative effort between the EU's central administration and its member countries[5]. The various European countries entertain ambitions to become hubs within the innovation network in fields where they feel they are particularly well qualified. For certain European regions, the achievement of hub status will provide major opportunities for increased wealth creation. We are thus entering a period during which it will emerge which European regions will assume dominance within key business areas, and the regions themselves are busily positioning themselves in order to claim roles corresponding to their respective aspirations.

This development has considerable significance for individual European countries, and not least for Norway. Norway is well qualified to assume a leading role in both a European and global context within a small number of fields among which energy and the environment[6], and the maritime cluster[7], represent the most conspicuous candidates[8].

Open innovation in Europe

The European innovation networks represent arenas for open innovation. The industrial sector forms the largest and most important organisational grouping because it is here that the majority of wealth is generated and captured. In order to survive in the short-term, it is essential that industrial companies offer products and services that are in demand at competitive prices. Their long-term survival requires that they employ parallel innovation processes from which they develop new or improved products and services that can be competitive in the future.

It is no secret that it is irrational for industrial companies to invest the high level of resources regarded as optimal from a socio-economic perspective[9]. The aim of open innovation is to achieve costs savings by drawing on research carried out outside the premises of the business itself. Open innovation allows us to bring together the disparate and sometimes contradictory considerations (paradoxes) linked to investment in research, such as:

- It is not possible to develop a framework for the creation of a market driven by supply and demand that regulates the level and focus of research activities[9]
- We achieve the highest levels of socio-economic efficiency by managing know-how as a common resource and by permitting free access to all those who are able to exploit it[10], e.g. by prompt publication in open literature.
- It is irrational for an industrial company to fund research that is published in the open literature before it has exploited the results in the form of the development of new products and services
- It is frequently impossible to patent the research results which form the basis of specific, wealth-generating industrial applications.
- It is often possible to protect the specific know-how required as the basis for the provision of certain products and services.

The core concept behind open innovation is to move major components of research into an area to which there is free access to all or, as appropriate, to a consortium of stakeholders. Open innovation thus has the potential to generate considerable costs savings for industrial companies by allowing them greater access to ideas and large economies of scale, while at the same time achieving high levels of socio-economic efficiency because the know-how developed is shared among many. Seen in this light, both the industrial companies and society as a whole have a common interest in carrying open innovation forward. A major and crucially important part of this exercise is to bring together a grouping of industrial organisations within which all parties achieve costs savings. This will depend on finding an adequate level of common interests and issues to the extent that the savings achieved by participating in a coordinated research activity outweigh the costs incurred by the coordination process and the possible costs incurred if the know-how should leak to competitors.

Open innovation is nothing new. Norway and other European countries have been working with open innovation on a domestic scale to a greater or lesser extent for many years. In Norway, the oil and gas sector has been a benchmark exponent for open innovation. The Research Council of Norway acts as a key facilitator for open innovation, in particular by means of initiatives such as Knowledge-Building Projects with User Involvement (KMB), Centres for Research-Based Innovation (SFI) and Centres for Social Science-Related Energy Research (FME). Open innovation is also carried out at a European level as part of the EU Framework Programme for Research and Development. However, the scope of this initiative has so far been limited in comparison to activities carried out under the auspices of individual member countries.

The role of the research institutes

As time passes, the distinction between basic and applied research is gradually being erased, and developments in the direction of open innovation powerfully reinforce and accelerate this trend. This is due to higher levels of specialisation and the fact that an increasing proportion of research is published very quickly. This has promoted changes in the way in which research providers allocate their respective roles. Traditionally, the comparative advantage enjoyed by the universities as providers of basic research funded by the public purse has been linked to the fact that they publish their results in the open literature.

The research institutes also want to publish, but their opportunities to do so are constrained by closed innovation processes. In an open innovation environment, the research institutes obtain a comparative advantage because they operate both in the restrictive and non-restrictive arenas.
It is a fact that the research institutes have a crucial role in open innovation activities carried on in Europe[11]. They act as *network en-*

[5] In this context, Norway can be regarded as a member country.

[6] During this century, renewable energy and environmental technology will constitute the largest global growth market.

[7] Maritime businesses, shipping, seafood and biomarine businesses.

[8] *Hva kan Norge lære verden?*, (What has Norway to teach the world? In Norwegian), F. Winther, et al., Kronikk Aftenposten 22.10.2009

[9] *Economic Welfare and the Allocation of Resources for Invention*, K. J. Arrow, 1959

[10] *The Simple Economics of Basic Scientific Research*, R. R. Nelson, 1959

trepreneurs which assemble and link together consortia made up of industrial companies and R&D providers. Together with the universities and the industrial sector, the research institutes also make important contributions towards shaping research policies. Among Norwegian organisations, the research institutes exert a dominant role in the open innovation arena, both on the domestic front and in relation to the EU. Even though the Norwegian research institutes were not established with this aim in mind, they possess the optimal attributes[12] to enable them to assume the role of network entrepreneurs in an international open innovation arena.

Norwegian opportunities in Europe

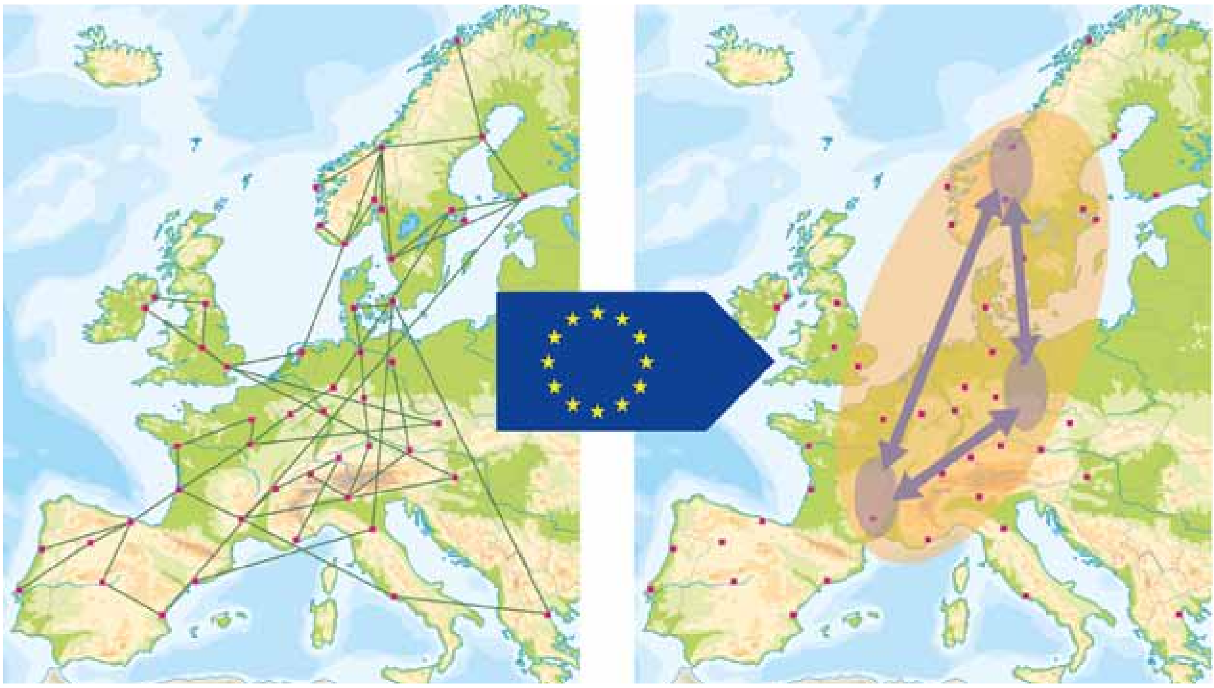
The current landmark event now opening the door for new and major opportunities is that the EU is preparing the ground for a massive increase in open innovation which will take place principally in the form of collaborative initiatives between the EU and its member countries. This development entails enormous opportunities for increased wealth creation in Norway.

Recommendations

In order to release this potential, Norway must create an environment that is attractive for the establishment of innovation hubs[13] within the fields in which Norway is especially qualified to assume key positions.

In order to make a success of this, it is essential that the Norwegian authorities are proactive and visible in the relevant European arenas. They must understand the processes, identify Norwegian opportunities, strategically position Norwegian interests, and get the relevant Norwegian organisations involved. SINTEF believes that the Research Council of Norway has understood this at all levels within its organisation, and that in the course of a relatively short time has established an exceptionally expert and functional organisation dedicated to addressing these issues. In SINTEF's opinion it is crucially important that the Research Council of Norway is granted terms of reference that provide it with the opportunity to continue and develop this work.

Another key qualification permitting Norway to create innovation hubs is that we possess organisations that can assemble and maintain such a network. In both the energy and maritime sectors Norway possesses recognised research institutes that are making their mark in competitive European and global environments. These institutes are already major international network entrepreneurs in their respective fields. The technical-industrial Norwegian research institutes operate under terms of reference that are entirely different from those in other European countries[11]. This is a true barrier that prevents Norway from taking advantage of the great opportunities on offer to us. In this context, the author refers to the article addressing SINTEF's position in the European Research Area[2]. SINTEF recommends that the Norwegian research institutes obtain terms of reference on a par with other European countries as soon as possible.



The EU is focusing on promoting Europe's global competitiveness by developing concentrated innovation networks that include both industrial companies and research institutes. The figure illustrates one such possible development of an innovation network within a predefined field. Norway should aspire to become a network hub within selected fields since this provides opportunities for sustainable and knowledge-based business development.

[11] *Europeiske forskningsinstitutter*, (European research institutions. In English), Ernst H. Kristiansen, 2010

[12] Independent non-profit project organisations which depend on winning research projects on the basis of competitive tenders, are involved in integrated collaboration between academia and the industrial sector, and which are familiar with handling both restricted and openly available information.

[13] *Et kunnskapsbasert Norge: Et agendasettende nasjonalt forskningsprosjekt.* (A knowledge-based Norway: an agenda-setting national research project. In Norwegian). Torger Reve, 2009.

In fields where Norway has ambitions to establish European innovation hubs, the authorities must ensure that the research institutes maintain a high international standard. It is in the nature of things that the focus must be directed towards certain selected fields. SINTEF believes that a major emphasis on competitive tendering processes by which only the best projects are successful, is essential in order to guarantee efficiency and international competitiveness among the Norwegian research providers.

In addition to factors such as the technical quality of the research, its relevance on an international scale, innovation potential and the potential for wealth creation, greater focus must be directed than before on robust international industrial consortia. SINTEF recommends that the Norwegian authorities establish relevant targets and strategies within the fields in which Norway can make its mark on the international stage. This is vital both for Norway's position in Europe, and for its future growth in prosperity. The issue thus concerns several of the technical ministries. The Research Council of Norway should assume a key role in this work.

Photo: SINTEF / Thor Nielsen

From SINTEF's Multiphase Flow Laboratory at Tiller, near Trondheim.

Ernst H. Kristiansen, Executive Vice-President, SINTEF

SINTEF's position in the European Research Area

Since 1984 the European Research Area (ERA) has developed enormously through seven Framework Programmes for research. As a result, the EU exercises considerable influence over the participating countries. Closer national follow-up will be needed if Norway is to benefit from the possibilities provided by the ERA.

This article provides a summary of the development of the European Research Area (ERA). It includes a review of the ERA's various policy instruments and brief explanations of a number of abbreviations in use. The article focuses on the areas which are of greatest interest for SINTEF.

Introduction

There is agreement throughout Europe that the European Research Area is a major arena for research activity. The ERA will play an increasingly important role as it is developed. The fact that Norway in a few years' time will contribute up to NOK 2 billion annually means that it will also become an even more important arena for the financing of research.

Norway is a fully qualified member of the existing ERA, with SINTEF being the leading Norwegian participant. Norway's ambition is to make use of the ERA technically and financially, and SINTEF is well qualified to ensure Norway's position in the ERA of the future.

To date, focus has been mainly on the EU's Framework Programmes for research, and this in particular is what comes to mind when European research or the ERA is mentioned. However, the ERA is already much more than the Framework Programme itself and new programmes and initiatives will come, for which funding is only partially provided by the European Commission. There will also be completely new mechanisms for the selection of research themes and participation. The role of the European Commission will become less direct, though its role in forming research policy will probably become much greater. This article provides an overview of initiatives currently represented by the ERA and of some of the challenges ahead.

Historical development

The European Research Area as we know it today has developed gradually through the Framework Programmes for research which commenced in 1984. The first programmes were combinations of sub-programmes with no distinct common superstructure. In the earliest years, Norwegian participation was funded project by project through the country's research council system, something which entailed both advantages and disadvantages. One of the disadvantages was the unpredictability in Norwegian funding. Would a project receive support even if it were accepted by the EU? A great advantage was that it was easier to enter and position oneself in a consortium where one could contribute technically and financially without competing for project funding. This put Norwegian participation in a good position early in the 1990s and laid the foundation for long-term co-operation.

Norway became a fully qualified member of the Framework Programmes from the fourth one which commenced in 1994. This

quickly had an effect on the way in which one operated. Participation in the ERA was no longer a competition for Norwegian public R&D funding, but a European competition involving two new aspects: Technical competition with the best research institutes in Europe, and the authorities' requirement for a good return on the Norwegian investment.
SINTEF was involved in the EU research from an early stage, and good contacts have been developed in the course of over twenty years of participation. This has been a contributory factor in making SINTEF Norway's foremost representative in technical collaboration as regards both the number of projects and funding through the Framework Programme.

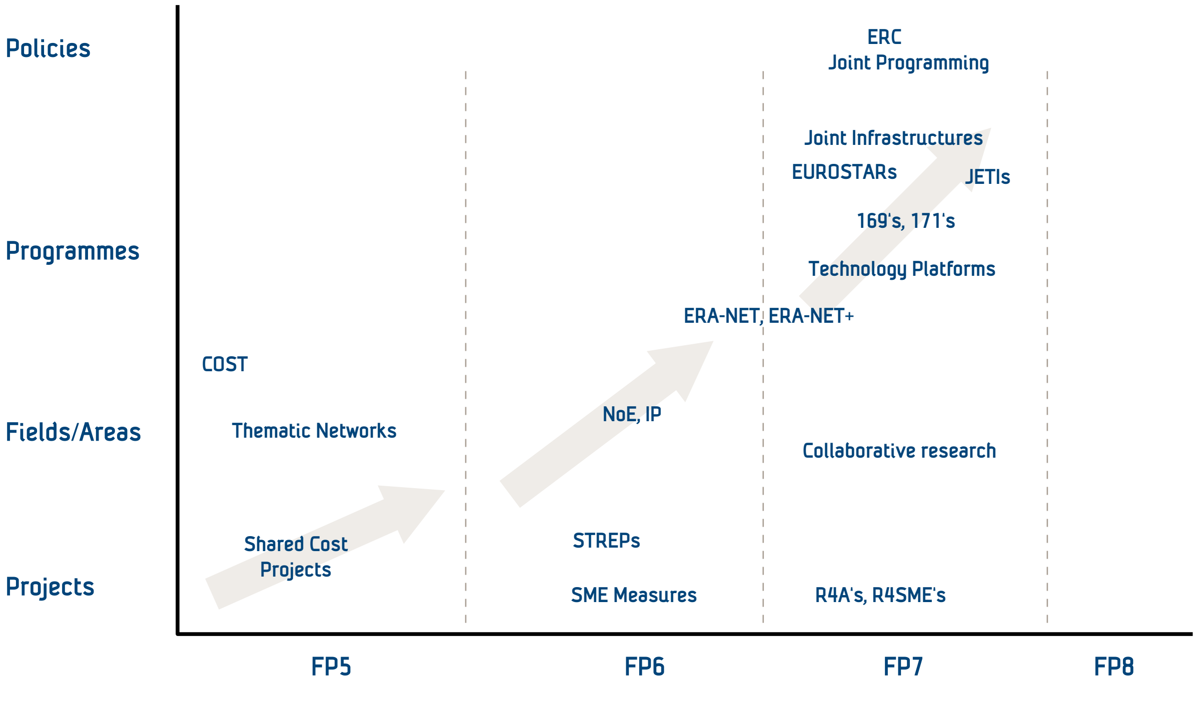
The objective of the programmes has changed a good deal and rather than catering to the needs of big industry they are now directed at finding solutions to social challenges. As a result, the technical foundation of the Framework Programmes has become significantly more broad-based. The financial allocation has changed from being purely project based to involve a large number of new funding mechanisms. These increase the European Commission's influence on research policy but result in less direct support from the EU. National co-financing and combined prioritisation are necessary if one is to benefit from the potential in the ERA.

In the Framework Programmes each country pays in to the community in proportion to its Gross Domestic Product (GDP)[1]. Luxembourg is the only country which contributes more per head of the population to the Framework Programme than Norway.
Norway's challenge of ensuring a good return on its investment is a demanding one. The Norwegian GDP is increasing and it is becoming increasingly difficult to obtain what amounts to a fair return. The rate of return for Norway has sunk from about 1 in the EU's Fifth Framework Programme to about 0.84 in the Sixth and to 0.75 so far in the Seventh. Not only do the other Nordic countries achieve more support per head of the population than they pay in to the Framework Programme, but they also manage to receive more support per head than Norway has so far. In SINTEF's opinion, there is significant potential for Norway to achieve a better return, both in connection with projects and in support within the Framework Programme.
At the beginning of the Fifth Framework Programme (FP5), the Commission founded the European Research Advisory Board (EURAB). From the initial appointment of the Board, Norway had two representatives. When the Board was re-appointed in connection with FP6 and after the expansion of the EU, there was a single Norwegian representative. At the beginning of FP7, EURAB was replaced by the European Research Area Board (ERAB), which had a different mandate and was more closely associated with the European Commission. Also in this connection Norway was represented, this time by SINTEF's President, Unni Steinsmo, who was also the only representative from the institute sector in Norway.

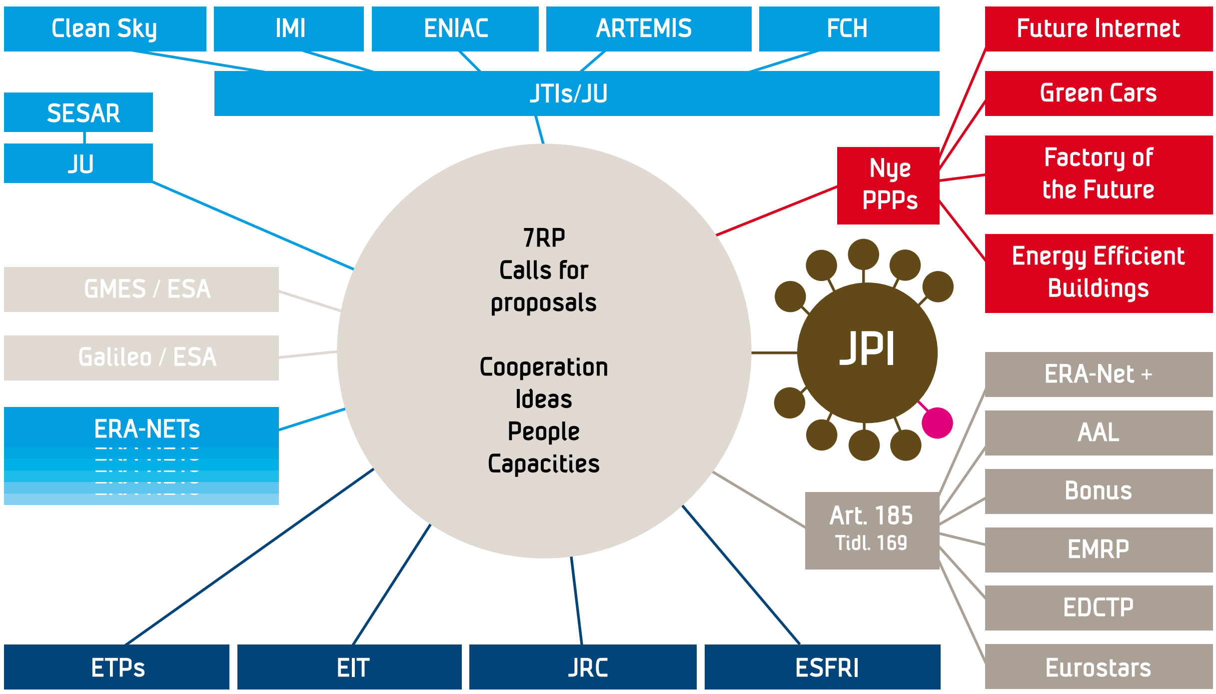
The ERA today

The ERA is in a continuous process of evolution, effected by way of somewhat unpredictable political processes. Providing a good overview is therefore both complicated and time-consuming, involving many terms and many abbreviations. To assist in the understanding of the ERA, the Research Council of Norway has produced the diagram on the following page. This shows the elements of the ERA which are of greatest interest to the Norwegian research communi-

The diagram below shows how the Framework Programmes have developed more in the direction of policy formation without relinquishing direct project funding. The diagram has been developed by Chris Hull of the European Association of Research and Technology Organisations (EARTO).



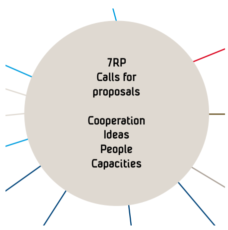
[1] *From the Norwegian government's budget for 2011, Page 185: "The combined budget for the Seventh Framework Programme is approximately EUR 50.5 billion. The total Norwegian membership subscription will be approximately NOK 10 billion at today's exchange rate. The subscription for each individual year is therefore determined by the budgetary profile of the Framework Programme, the development of Norway's Gross Domestic Product, compared with the GDPs of the other participating countries, and the development of the exchange rate".*



Elements of the ERA which are of major interest to Norwegian research communities and which are affected by funding from the Seventh Framework Programme. The diagram has been developed by Simen Ensby of the Research Council of Norway.

ties and which are affected by funding through the Seventh Framework Programme.

When the Seventh Framework Programme was adopted, the budget to be made available in the period from 2007 to 2013 was well over EUR 50 billion. Annual allocations in the first few years will be about half of what will be allocated towards the end of the programme. The annual Norwegian subscription will also be more than doubled between the first and last years of the period. Many of the elements illustrated in the diagram were not known when the programme was adopted. The easiest way to explain this is to divide the diagram up and consider each individual part.



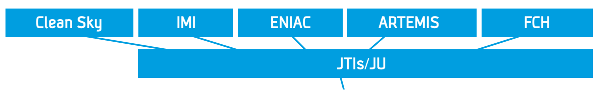
The core of the Framework Programme consists of the programmes called Cooperation, Ideas, People and Capacities. These four programmes in turn have their sub-programmes which allocate funding through "Calls for proposals" for sub-programmes in specific themes. A theme is often repeated every two years. Three years into FP7, project support amounting to almost EUR 15 billion has been allocated. Norway's share of this is EUR 250 million, or about 1.67 per cent. SINTEF's share is about EUR 60 million, representing 75 to 80 per cent of the volume of projects SINTEF has in the ERA.

The ETP's (European Technology Platforms) are an important political tool for special interest groups. There are about thirty ETPs which are largely self-financing. Participation here is demanding but necessary if one wants to have any influence. SINTEF is involved in a number of ETPs and in the governing bodies of a few selected ones. The most important output from an ETP is a Strategic Research Agenda (SRA), which, if it is a good one, forms the foundation for a Joint Technology Initiative / Joint Undertaking (JTI/JU). This has been the case for IMI, ENIAC, ARTEMIS and FCH, which are mentioned below, and for the recently introduced Public-Private Partnerships (PPPs).

EIT (European Institute of Innovation and Technology) selected its first three technical fields in 2009. In this process, no Norwegian institutes qualified. This is only the starting phase and success depends on comprehensive domestic funding in addition.

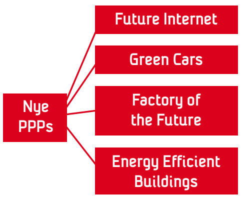
The **Joint Research Centre** (**JRC**) is the EU's own research centre and is funded as part of the Framework Programmes for research. The JRC has its headquarters in Brussels and comprises seven institutes located in five different countries. Its activities consist of essential goal-oriented basic research projects directly applied to EU policy development.

ESFRI (European Strategy Forum on Research Infrastructures) prioritises the major research infrastructure elements in Europe. The host nations have a right to make major contributions so as to attain status as part of the strategic European infrastructure. Norwegian technical communities are connected with 21 of 44 projects. Norway is host nation for two of the projects: SIOS (Svalbard International Arctic Earth Observing System) and ECCSEL (European Carbon Dioxide Capture and Storage Laboratory Infrastructure). NTNU and SINTEF are in the driving seat of ECCSEL.

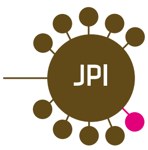


The first JTI/JUs have been initiated, following a good deal of work in the associated ETP, and they represent powerful industrial interests. Funding from the EU is comparatively low, but is derived from the budget of the Framework Programme. The national authorities must provide partial financing, and just how much Norway may have to contribute to the total funding is unclear right up to the commencement of the projects. SINTEF has had much success in the FCH (Fuel Cell and Hydrogen), ARTEMIS (embedded computer systems) and ENIAC (European Nanoelectronics Initiative Advisory Council) projects and has been selected for several major projects and participates in steering committees. SINTEF's participation in IMI (Innovative Medicines Initiative) and Clean Sky (Aeronautics and Air Transport) is modest.. The first major challenge for a JTI/JU is to achieve total financing if a good job is to be done. Moreover, each JTI/JU has its own rules regarding the basis of calculation for approved costs. These rules are not necessarily the same as those applying to the Framework Programme. The EU's contribution is moreover so small that significant national funding is necessary for success.

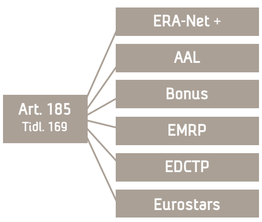
SESAR (Single European Sky ATM Programme) is an ambitious programme for operations in European airspace. SINTEF is heavily involved and several projects are in the process of initiation. As with JTI/JUs, adequate supplementary funding at a national level is a challenge if one is to contribute actively to the programme.



The first PPPs: "Green Cars", "Factory of the Future" and "Energy Efficient Buildings" were established in the autumn of 2008, as part of the EU's action plan to combat the financial crisis. The structure is very reminiscent of that of JTI/JUs. Here, financing is split between the Commission, the national authorities and the industry which is being reconstructed. The "Future Internet" project was established during 2009. Calls for proposals for all these PPPs are integrated in funding announcements connected with the Framework Programme's sub-programmes in the autumn of 2010.



JPI (Joint Programming Initiatives) are a new instrument for achieving binding research collaboration. The countries decide where they wish to participate and finance their own participation by way of their national research funding. Ten themes have been selected so far, of which the first is a pilot project connected with Alzheimer's disease. Norway has taken the initiative for, and will lead, the "Healthy and productive seas and oceans" theme area.



Another instrument of which a great deal is expected is the so-called "Article 169" initiatives (now Article 185). The number denotes which Article of the EU Treaty the collaboration refers to. This was initially Article 169, but became Article 185 after the adoption of the Lisbon Treaty. Such initiatives are partially financed by the EU and partially through national research funding, but financial support is awarded according to national rules and may vary from country to country. Among specific programmes are AAL (Ambient Assistant Living), Bonus (Baltic Sea Research), EMRP (science of measurement), EDCTP (Health in developing countries) and Eurostars (research-performing SMEs and their partners).

ERA-NET and ERA-NET+ are network programmes which are partially financed by the Commission in order to co-ordinate different countries' research programmes and activities. It is primarily the research-financing organisations in Europe which participate in ERA-NET. The objective is to achieve shared activities and develop multinational allocation announcements in selected theme areas.

GMES (Global Monitoring for Environment and Security) is the initiative for European capability in earth observation from space. This is co-financed by the ESA and FP7. The same applies to the Galileo satellite navigation system, for which Norway and the EU have signed a bilateral collaborative agreement.

Conclusion

The European Research Area has developed enormously through seven Framework Programmes for research. After initially focusing on a few shared challenges connected with the needs of industry, the EU has involved itself strongly and achieved much clearer influence over the research priorities of the participating countries.

The focus has been transferred to dealing with the major social challenges rather than industrial growth. Many different policy instruments have been tried and new ones are being added. The connection between shared funding from the EU and the participating nations' own funding has become stronger. Active countries achieve success and see significant benefits, both professionally and as regards a fair return on the research financing. Those countries which are successful allow their national priorities to form the foundation of the ERA's activities.

If the Norwegian research communities are to achieve optimal benefit from the ERA, stronger national follow-up will be necessary. From the point of view of the research institute sector, this means predictable terms of reference which are comparable with those of other European countries. The ERA will develop to encompass a wide range of programmes and initiatives. This is something which Norway will have to adapt itself to. If Norway wants the best possible return on what it contributes to the ERA, this will call for major changes in research policy in Norway.

Recommendations

- Support for project establishment for participation in the ERA must be improved.
- The research institutes' approved research projects with EU support should be co-financed by the Research Council of Norway so that the actual costs are covered.
- The Research Council of Norway's programmes should prioritise projects which are complementary and which extend and develop EU-funded projects with Norwegian participation.

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Presentations

Simen Ensby, ERA presentation for SINTEF, August 2010

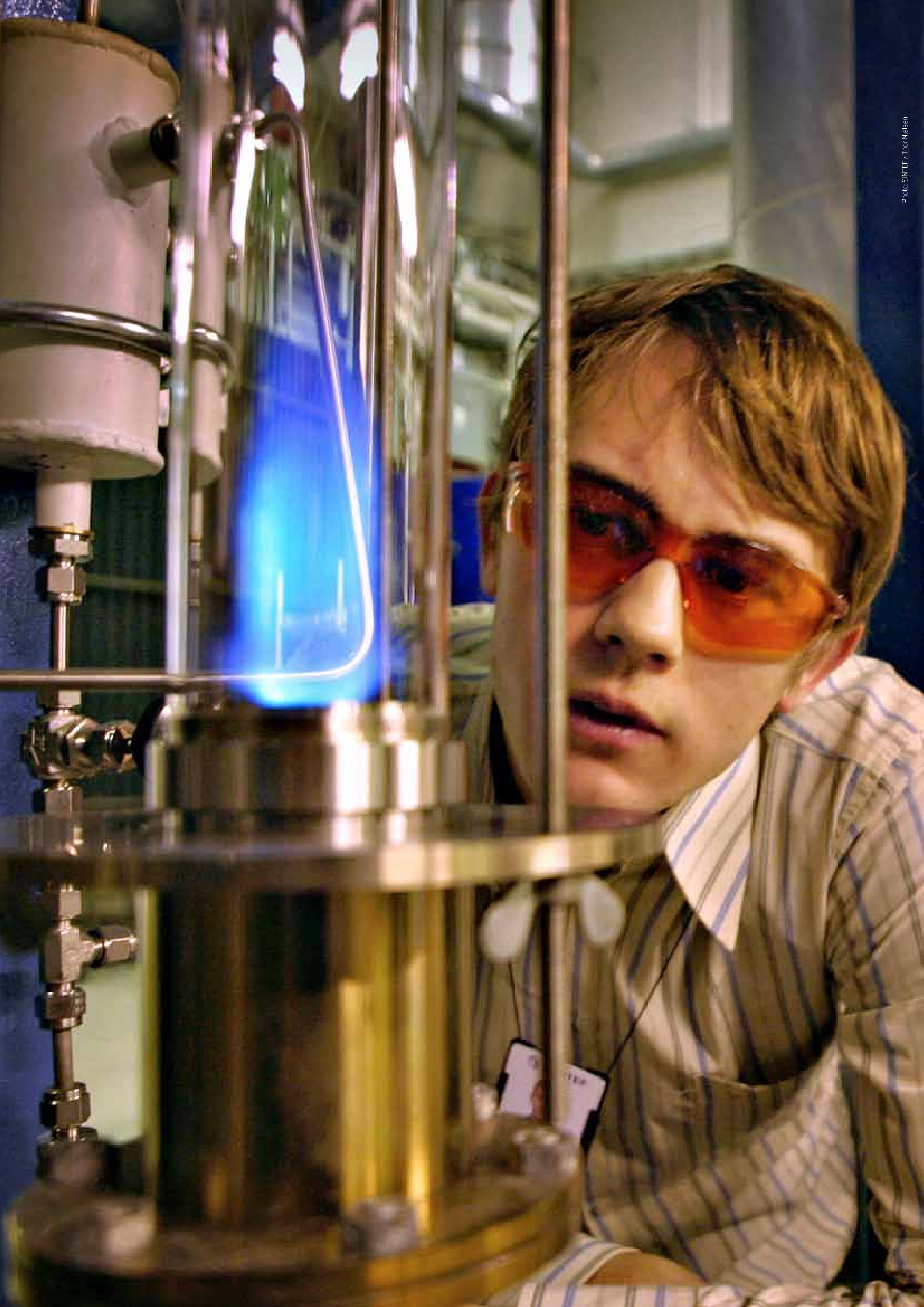


Photo: SINTEF / Thor Nielsen

Ernst H. Kristiansen, Executive Vice-President at SINTEF

Research institutes in Europe

Major growth among research institutes in Europe has been the result of a conscious political effort. Levels of public grant funding have risen in many countries, and Norwegian financing initiatives in the sector can no longer be described as particularly significant. This article presents a review of the technical-industrial component of the institute sector in some European countries.

Introduction

The Norwegian institute sector was given a clean bill of health in the Government's Research White Paper of 2005. The clean bill of health asserted that the research institutes played a key role within the innovation system, and that dramatic organisational changes would result in major negative consequences in the short term.

The White Paper reflected positively on the institute sector, but the myth that the Norwegian sector is disproportionately large compared with other countries lives on.

Both the 2005 and 2009 Research White Papers promised increased levels of investment in terms of public grant funding, in particular in the technical-industrial institutes, and to those centres focused on the environment. Five years later, the situation is such that "comparable" countries have taken the contents of the Norwegian Research White Paper seriously, and have directed focus on their own respective institute sectors. They have directed their focus towards that part of the institute sector that has the greatest relevance for innovation. Growth in several countries has been goal-oriented, and that which once could be defined as a difference is no longer so easy to identify.

From an external perspective, it appears that many EU countries are adopting an active institute policy, and that the relative dominance of the institute sector within EU research activities has caused a shift in focus towards the sector in certain countries. The research institutes enjoy a higher priority than they did ten years ago.

In Norway, the authorities' policy towards the institute sector continues to be relatively passive. The institutes constitute the backbone of Norwegian participation in the context of European research collaboration, but insufficient effort is being made to prepare the ground for further advances.

Using examples taken from a number of European countries, this article will show that EU countries are establishing an innovation policy built around the consolidation of their respective research institutes, and in particular the technical-industrial project-based centres.

The article goes on to provide a general review of how different parts of the institute sector have developed in some European countries. It focuses on the commercial- and basic research-oriented technical institutes. In the case of the social science and administrative-oriented institutes, many countries have opted to incorporate this expertise either within public sector institutions or by means of linkage to the universities. For this reason it is much more difficult to present a corresponding review of this aspect of research activities.

Historical development

The first European research institutes were established in the early part of the 20th century with the aim of contributing towards industrial development. After the Second World War the newly established Norwegian Council for Scientific and Industrial Research (NTNF) published a report prior to the establishment of the Central Institute for Industrial research (SI) and SINTEF. Emphasis was placed on the fact that the "establishment of dedicated research institutes" contributed towards Germany outpacing England in terms of industrial capacity, and eventually assuming a leading position in world research. The recognition of this fact, combined with the USA's massive investment in research during the Second World War, demonstrated that industrial growth would proceed much more rapidly when backed-up by research institutes focused on industrial development. The majority of countries not already in possession of this type of research institute established such centres in order to assist in meeting the post-war "Grand Challenges", and "elevate the country" in the wake of a period of destructive conflict. This was probably a factor that contributed towards the fact that countries in most need of reconstruction, such as Germany, the Netherlands and Finland, built for themselves a more robust technical-industrial institute sector more quickly than countries that emerged less damaged from the war.

In some countries during the 1980s, policies changed by means of the comprehensive privatisation of state-owned research institutes. This was especially the case in the UK. The UK is an example of a country in which former research institutes were transformed into today's listed companies. Other countries have adopted the opposite approach and have focused on research institutes designed to make a contribution towards the development of a given region or the country as a whole.

At the onset of the new millennium, the participation of the research institutes in the European Research Area (ERA) has had much greater relevance for the individual host countries in question than might be justified by the status of the institutes themselves. Institute sector policies in several countries appear to reflect this, and this article will outline some of the development trends observed in the countries in question that support this assertion. The figure below shows what proportion the institute sector (research centres) in the countries selected received of the country in question's grant funding from the EU's 6th Framework Programme for Research and Technological Development (6FP). The German and French institute sectors are large, and together received one eighth of the total EU funding linked to the 6FP. The institutes described either individually or as groups in the following text received well over 10% of the contribution allocated through the 6FP.

Research institutes in selected countries

Austria

During the last decades, a number of organisational changes have taken place within the Austrian technical-industrial institutes. Public authorities have established new research institutes, or have become stakeholders in existing institutions. Salzburg Research was founded ten years ago under the ownership of the Salzburg state administration and has between 50 and 60 employees. Joanneum Research, which has its origins in the 1950's, underwent major restructuring between 2002 and 2003, and is co-owned by the Styria state administration (90%) and the TNO (10%).

In an Austrian context, Joanneum is a relatively large organisation, with 430 employees. Austrian Cooperative Research (ACR) represents an amalgamation of 15 smaller institutes employing a total of 640 people. The largest institute in the country is the Austrian Institute of Technology (AIT) which employs 900 people and has a turnover of €120 million. The state owns just over 50%, while the remainder is held by industry stakeholders. AIT has its origins in the 1950's, but changes in ownership structure and organisation were implemented in 2009. About 40% of its turnover is in the form of basic funding.

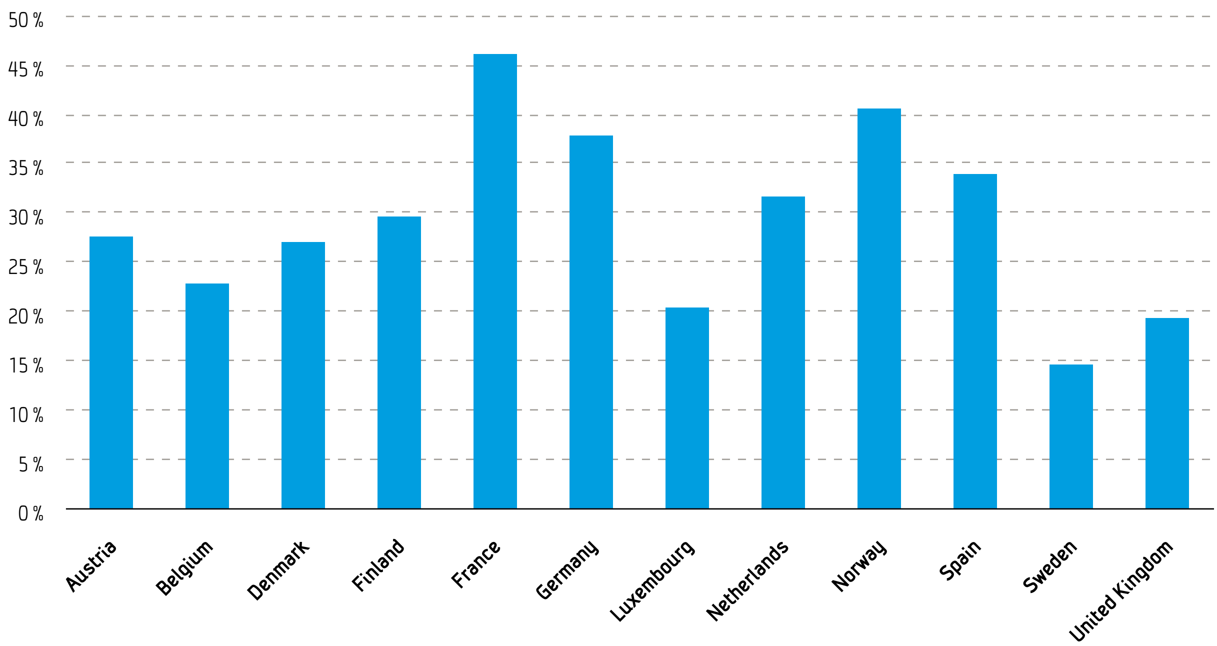


Figure illustrating the RTO sector's (research centres') proportion of the individual countries' contribution from EU in the 6th Framework Programme.

Belgium
In the past, Belgium possessed a small research institute sector, and commercial companies obtained research assistance from the universities. However, since the middle of the 1980s, the research institutes IMEC and VITO were established and both have enjoyed massive growth based on regional investment in the Flanders region.

IMEC was established in 1984 and has become Europe's leading research institute in the field of advanced micro- and nanoelectronics. IMEC has expanded into the Netherlands and employs more than 1,000 research scientists and a total of 1,783 employees, including researchers on secondment from industrial concerns. IMEC receives € 52.7 million in the form of grant funding. These grants, amounting to 20% of turnover, are derived from the Flemish regional administration (€ 44.7 million) and the Dutch national authorities (€ 8 million).

VITO was established in 1991 by the Flemish regional administration, and has a multidisciplinary technical profile somewhat similar to that of TNO, VTT and SINTEF. At the beginning of 2010, VITO had 631 employees and received grant funding amounting to 49% of turnover (€ 40 million) from the Flemish regional administration.

Denmark
A large part of the Danish research institutes were incorporated into the universities in 2007. For the most part, this process involved research institutes with governmental duties and high levels of state funding. Much media attention was devoted to this process, and the high levels of publicity gave the impression that all research institutes were merged into the universities.

Considerably less attention was paid to the fact that the applied research institutes were gathered under the umbrella institute grouping GTS (Approved Technology Service Institutes), made up of nine institutes employing a total of 3,500 people. In 2009, GTS had a turnover of DKK 3,225 billion. Basic funding amounts to 10% of the turnover, and income from foreign sources accounts for approximately 40%. During the recent decade, the proportion of turnover derived from overseas has increased by almost five-fold.

The Danish Technological Institute (DTI) is the largest single research institute with a turnover of DKK 842 million in 2009, well over 900 employees, and a basic funding source (contract-based research) amounting to 12% of turnover.

Finland
The state-owned research institute VTT dominates the research institute sector in Finland. VTT has undergone a major restructuring in recent years, but has succeeded in maintaining a total workforce of approximately 2,700. In 2009 the institute had a turnover of € 269 million, of which 14% was derived from overseas and 31% (€ 85 million) were basic funding. The basic funding awarded to VTT amount to approximately the same order of magnitude as those distributed by the Research Council of Norway to the entire Norwegian institute sector.

France
In France there are a number of smaller research institutes, and the majority of these are oriented to dedicated sector in the industry. Moreover, France is the country that hosts the most members of EARTO (European Association of Research and Technology Organisations).

CEA is the French research organisation with responsibility for energy research and in particular nuclear research and the operation of nuclear reactors. CEA has a total of 15,500 employees distributed among ten research centres and a turnover of € 3.9 billion. CEA has both a civil and a military division. The civil division receives basic funding amounting to 45% of turnover. Two of CEA's centres are also members of the Carnot Institute Network.

The Carnot Institute Network is an umbrella organisation established a few years ago in order to create an institution similar to the German Fraunhofer-Gesellschaft, with the aim of meeting the needs of the commercial sector. In 2009 the network comprised 33 research institutes with centres located all over France. A total of € 60 million has been made available in the form of grants from the French state authorities in order to develop the Carnot system. The Carnot system has a workforce totalling 13,000 permanent staff, making up 12% of all the public sector research employees in France. 7,000 Ph.D. students are linked to the Carnot institutes.

In addition to the Carnot network, the CNRS (the French National Centre for Scientific Research) employs approximately 25,000 employees across the whole of France. As a legal entity, this organisation should be regarded as a governmental research facility dedicated to basic research. The CNRS is the largest organisation within the EU's Framework Programme.

Germany
Germany has a well-functioning technical-industrial institute sector enjoying excellent collaboration with the universities. It is dominated by four major institutes; Max Planck-Gesellschaft, Leibniz-Gemeinschaft , Helmholtz-Gemeinschaft og Fraunhofer-Gesellschaft. All have enjoyed unhindered growth since the fall of the Wall in 1989, and are currently among the largest organisations within the EU's Framework Programme. There are also some smaller independent institutes in Germany but, in comparison with the four majors, these constitute only a minor component in terms of turnover and manpower.

Max Planck-Gesellschaft (MPG) was founded in 1948 and has grown to embrace a total of 80 research organisations currently employing a total of 14,300 people, of which 5,510 are research scientists and 7,000 Ph.D. students. The most expansive growth has occurred following German reunification. MPG is closely linked to the universities and has a funding of 50% federal and 50% from the states.

Leibniz-Gemeinschaft is an umbrella organisation for academic institutions which also receives 50% of its funding from federal sources and 50% from the state administration. Leibniz-Gemeinschaft has doubled in size since German reunification, and currently employs 16,000 people, of which over 7,000 are research scientists. It is currently linked to 86 institutes, with an aggregated turnover amounting to € 1.6 billion.

Helmholtz-Gemeinschaft is an umbrella organisation comprising 16 German research institutes employing 30,000 people. They are subdivided into a variety of legal entities, but receive joint public sector grant funding of which 90% is obtained from federal sources and 10% from the state administration. The precursor of today's organisation was founded in 1958. Gradually, more organisations were brought into the fold, and the institute has enjoyed extensive growth most notably in the wake of German reunification. The institutes are assigned clearly-defined projects, many of which are almost administrative in nature. They carry out relatively little project-based research funded by the private sector. The institute has an annual turnover of € 3 billion.

Fraunhofer-Gesellschaft was founded in 1949. On its 60th anniversary last year it had expanded to embrace 59 institutes employing 17,000 people, inclusive of its part-time employees, and had a turnover of € 1.6 billion. As is the case for the other organisations, German reunification triggered expansive growth. In the case of the Fraunhofer, this growth has continued at a steady rate. Fraunhofer is a project-oriented organisation defined as a single legal entity, and is the institution with which SINTEF has most collaboration in the EU-framework programme. In 2009, Fraunhofer received basic funding amounted to 38% of its total turnover with a 9 to1 ratio in terms of federal and state funding respectively.

Luxembourg
During the period 1987-1989, three public research institutes (CRPs) were established in Luxembourg. They are primarily publicly funded and a large part of the activity is basic research. The majority of project-based research is carried out by the CRP Henri Tudor, which is also the largest research institute, with a workforce in excess of 400 employees. CRP Henri Tudor is 20 years old, and has expanded by 150% during the last nine years. The three research institutes together employ a total of approx. 850 people. In relation to the population it is more staff than in the Norwegian institute sector.

The Netherlands
The Dutch research institutes have a considerable role within the innovation system. The technical-industrial institutes are made up of nine smaller research institutes, 4 larger and the Netherlands Organisation for Applied Scientific Research (TNO). In 2009, TNO had about 4,350 employees, a turnover of € 576 million, and received basic funding amounting to € 203 million (35% of turnover). TNO was hit hard by the financial crisis in 2009 and incurred a loss of € 14 million. Together with the Belgian IMEC institute, TNO has established a co-operative research constellation (the Holst Institute) in the field of micro- and nanoelectronics. This is located in Eindhoven close to Philips. Restructuring within the industry has resulted in a movement of expertise in electronics and telecommunications from the company to the research institutes.

ECN (energy research), together with its subsidiary NRG (nuclear research), represents the second largest institute, employing about 1,000 people, with a turnover of € 141 million and grant funding amounting to EUR 45 million in 2009.

In total, the TNO and ECN employed 5,350 employees and received about € 250 million in basic funding during 2009. In comparison, the entire Norwegian technical-industrial institute sector combined to deliver 3,500 man-years during 2009, with total funding amounting to NOK 0.96 billion (€ 120 million) from the Research Council of Norway for both basic and project-based research.

Norway
In Norway, SINTEF is the largest research organisation with 2,100 employees, a turnover of NOK 2.75 billion and basic funding amounting to 7% of its turnover during 2009. The Norwegian technical-industrial institutes had a turnover of NOK 4.9 billion in 2009 and their basic funding was NOK 413 million (appr. € 50 million).

About 45% of the contribution from the EU-funded research programmes FP7 finds its way to the research institutes. The research institutes carried out about 22% of the R&D in Norway. Basic funding to the Norwegian research institutes through the Research Council of Norway constitutes 11% of the institutes turnover .

Spain
The research institutes in Spain have enjoyed a massive expansion since the country became a member of the EU. Great emphasis has been placed on the development of technology centres, and in 2008 74 such centres were organised together in the member association FEDIT. The centres are distributed throughout Spain, with many concentrated in the Basque region and in the area around Valencia.

In total, these centres employed 7,400 people and had a turnover of € 481 million. 35% of the centres employed more than 100 people. Project-based revenues from private sector companies constituted 48% of turnover, while basic funding from the EU and national and regional sources made up 39%. They also succeeded in procuring revenues from the EU's Framework Programme, comprising as much as 9.6% of turnover. In comparison, approximately 5% of SINTEF's revenues are linked to EU-related research.

In the Basque region, ten of the centres are assembled together as part of Tecnalia which has enjoyed a 10% increase in turnover in the period 2008-2009. Tecnalia currently employs 1,650 people, and in 2009 had a turnover of € 141.5 million, of which 22% was made up of grant funding.

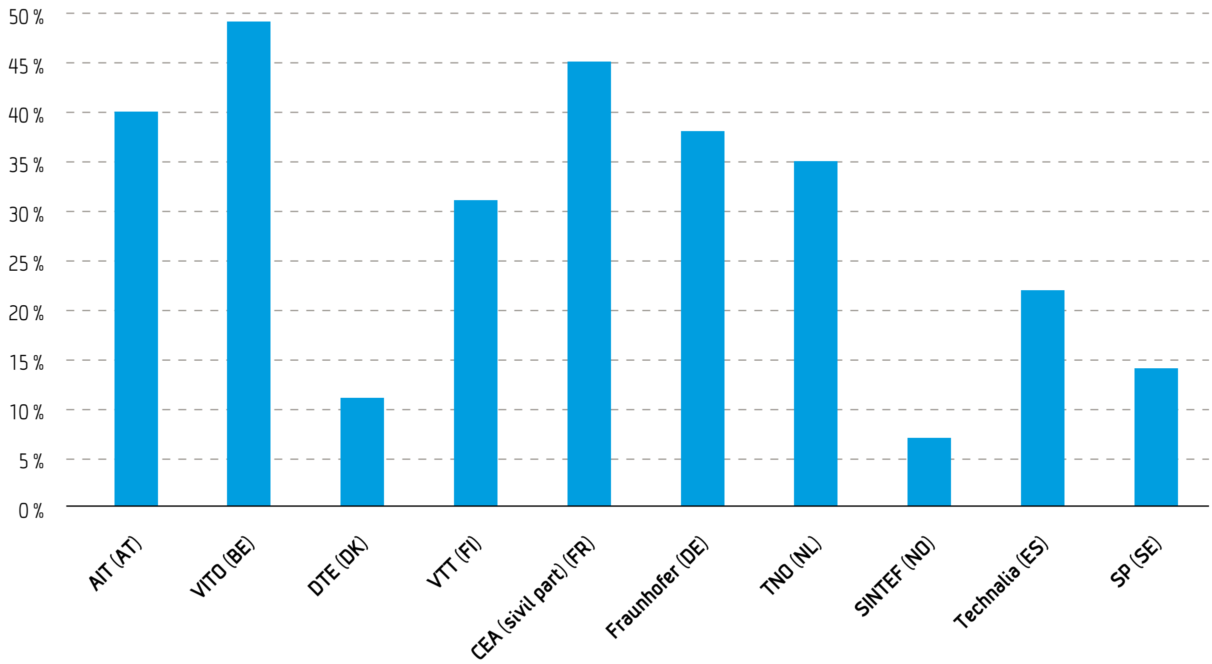
Sweden
The Swedish research institute sector has been small and fragmented, but with a significant state ownership. A study carried out a few years ago concluded that a restructuring ought to be implemented, and that a large research organisation should be established. Sweden has made great advances in this regard. The state-owned holding company RISE (Research Institutes of Sweden) was established at the end of 2008 as an umbrella federation bringing together all the technical-industrial research institutes.

RISE is subdivided into four groupings/organisations, of which the largest is the technical research organisation SP with a turnover of SEK 947 million. RISE's total turnover amounts to SEK 2,215 million, and the organisation has well over 2,000 employees. RISE is responsible for allocating state-sourced expertise funding (basic funding) to the technical-industrial institutes. In 2009, this funding amounted to SEK 310 million, and on average constituted 14% of turnover. This followed a massive increase of 25% recorded in 2008.

The Swedish Defence Research Agency (FOI) was formerly the largest research institute in Sweden, but downsizing of Swedish defence capabilities during the last five years has resulted in a reduction of 33% in total man-years, although the institute continues to employ over 900 people.

The United Kingdom
The research institutes in the UK was in a large extent privatized in the 1980s and 1990s. Basic financing fell almost completely away, and the resarch insitites were more oriented towards consultant work. The privatization of defense research has led to what was once the Dera is now the listed company QinetiQ. QinetiQ sells expertise to the UK defence establishment on the basis of large long-term contracts that incorporate a research component.

This development, or rather lack of intended development, has resulted in the "Hauser-report", which was published in March 2010 by Department for Business Innovation and Skills. The report recommends the establishment of a series of "Technology and Innovation Centres" (Maxwell Centres) in selected locations across the UK, and refers to policies practised in countries such as Germany, Finland and the Netherlands. The description of the intended operation of



The figure shows basic funding as a percentage of turnover for some of the technical-industrial institutes.

these centres is almost identical to that currently practised by the technical-industrial research institutes in the rest of Europe.

Pan-European institutes

As well as the national institutes described in the foregoing, there exist several major pan-European institutes which emerged in the wake of an early recognition of the fact that some challenges are best tackled with a collaborative approach. They have arisen either by means of direct EU membership, via the EU system, or as a result of some other form of organisation.

The Joint Research Centre (JRC) is the EU's own research centre and is funded as part of the research framework programmes. The JRC has its headquarters in Brussels and comprises seven institutes located in five different countries. Its activities consist of essential goal-oriented basic research projects directly applied to EU policy development. Almost all its funding is direct from EU. In order to preserve its independence, major constraints are imposed on the JRC in terms of the kind of project-based research it can carry out outside the terms of reference of competition within the framework programmes. Norway is currently paying its share towards funding of the JRC via its EU subscription, although there are considerably fewer Norwegians employed at the institute than the size of the payment would suggest. JRC employs 2,750 people, and has a turnover of € 300 million.

There are also several pan-European research institutes operating in the fields of basic and/or applied research which are not focused on the contract market. Norway makes an active contribution to the funding of these institutes, but does not always reap the full potential benefit of its investments. Three of the largest of these institutes are CERN, ESTEC and ESRF.

The largest is CERN (the European Organisation for Nuclear Research), located on the border between Switzerland and France. CERN was founded in 1954, and now employs about 2,500 people. At any given time it also plays host to a considerable number of guest researchers from its member countries.

ESTEC (the European Space Research and Technology Centre), is the ESA's research centre. It is located in the Netherlands and employs 2,000 specialists dedicated to space-related projects.

The ESRF cyclotron is located in Grenoble and focuses on basic research in physics. It employs a staff of 600 people, and in 2009 had a turnover of € 94 million.

None of these institutes carry out research projects under contract in competition with the project-related institutes described in the foregoing. For the most part, they act either as clients or contract partners.

Conclusions and development trends

For the majority of countries where a conspicuous institute sector exists, the sector's participation in EU-related research is proportionately greater than for other sectors. There is a growing awareness of this trend in many countries.

In recognition of the fact that competition for European research funding is not getting any easier, there is a considerable focus on exploiting this advantage.

Basic funding is for the most part higher in most other countries than in Norway. The institutes that enjoy a particularly high level of basic funding have somewhat more obligations in terms of the direction of their research and laboratory activity than is the case in Norway.

Basic funding provides guaranteed running costs and increases the opportunities for success in terms of participation in EU-related research activities. We see the clearest signs of this trend in Belgium, Luxembourg and Spain. Countries with a traditionally weaker institute sector, such as Denmark, Sweden, and perhaps in time also the UK, are now taking initiatives to strengthen the sector. The most conspicuous efforts are those directed towards that part of the institute sector that represents an asset within the innovation system.

A trend is also emerging by which the larger institutes are more successful within the EU system. They are also increasingly working more closely together.

In highly simplified terms, development trends appear to indicate that the big are getting bigger, the specialised institutes are consolidating, and the smaller institutes are finding it difficult to compete for funding that is allocated on the basis of technical and academic criteria.

Our recommendation

Our recommendation to the Norwegian authorities is simple enough: Adhere to your own recommendations as set out in the last two research White Papers and increase basic funding to the institute sector.

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Presentations

- The Dutch R&D Landscape. Jan van Steen, March 2009

Professor Olav T. Onsager photographed in SINTEF's and NTNU's high-pressure laboratory. The laboratory was an important tool in the work of developing a new process for the manufacture of methanol.

Photo: SINTEF

Jann H. Langseth, former Research Director and Special Adviser, SINTEF

SINTEF turns 60 – personal reflections

SINTEF came into being as a result of the provocation of professors in Trondheim. In sixty years the company has developed from a modest consultancy organisation for the Norwegian Institute of Technology into an internationally-recognised research institute.

Since SINTEF's history was described in great detail in connection with our fiftieth anniversary, this will not be another review, but simply some reflections from a person who has had various roles in the organisation during the last forty years.

Following the Second World War, research councils and institutes were founded in many countries. The origin of this development lies in a question which Franklin D. Roosevelt, the US President at the time, asked of his scientific adviser, Vannevar Bush: "What can the Government do now and in the future to aid research activities by public and private organizations?" The response appeared in the form of the report "Science – The Endless Frontier", published in 1945, in which Bush postulated the responsibility of the government to develop new expertise and sketched a system of research councils to manage the necessary public funding. The development of new expertise was viewed as the prerequisite for increased prosperity and a better standard of living.

The foundation of NTNF

In Norway, a committee for the organisation of technical research was appointed in September 1945. There was a distinct sense of urgency, and the conclusion was clear: "The war has demonstrated more clearly than ever that organised technical research is crucial to the industrial exploitation of the pure sciences and thereby to victory in technology-based warfare. However, it will inevitably be equally decisive in the peacetime contest which is now approaching. Those who are not able to compete will automatically sink into economic dependence." With this sombre warning in mind, the Norwegian parliament passed a resolution to found the Royal Norwegian Council for Scientific and Industrial Research (Norges Teknisk-Naturvitenskapelige Forskningsråd – NTNF) in 1946.

Reaction from Trondheim

NTNF quickly set to work with the planning of research institutes. Plans for the foundation of the Central Institute for Industrial Research (Sentralinstituttet for industriell forskning – SI) in Oslo emerged in 1949, and the reaction from the Norwegian Institute of Technology (NTH) in Trondheim was not slow in coming. "The Institute's vital interests are being jeopardised," claimed the Rector of the time, and work commenced on NTH's reaction. On 26 January 1950, a committee of professors resolved to establish the "Company for industrial and technical research at NTH". The Norwegian title, "Selskapet for industriell og teknisk forskning ved NTH" gave rise to the slightly contrived acronym "SINTEF", on the grounds that it was an abbreviation of "SINT" (angry) and "EFFEKTIV" (efficient). The acronym was adopted by 13 votes to 12 and its implication remains applicable to this day.

SINTEF was intended to be a tool for the use of NTH, something which is clearly indicated in its mission statement: "[to] promote industrial and other technical research at NTH and to develop collaboration in this field between NTH and the country's commercial and economic life, as well as with other research institutes". This mission statement was to remain almost unchanged for the next fifty years. By means of a board and general assembly, which was the professorial council of the Institute, NTH maintained full right of control over SINTEF's operations and development.

Pragmatic collaborative model

Karl Stenstadvold was appointed the first Director of SINTEF in 1951. In the reasoning given for the appointment, it was stated: "Here we need a man with good diplomatic abilities, since we must remember that NTH consists of 40 autonomous "republics", each under the leadership of a professor. Hence the Director will be obliged to make progress by negotiation, as it is no use trying to force the individual institutes to collaborate with SINTEF". These were very wise words, and Stenstadvold fulfilled the role in an exceptional manner. He engendered confidence among the professors that SINTEF was an instrument for the benefit of NTH, and under his leadership the collaborative model was developed, not by force, but through pragmatic adaptation.

Stenstadvold was SINTEF's Director until 1976, by which time it had grown to an organisation with 800 employees. Growth occurred by virtue of the fact that NTH's institutes found it interesting and profitable to establish a SINTEF department with which they were associated. The result was that SINTEF gradually came to consist of many rather small departments which evolved under the management of, or in close understanding with, their respective NTH institutes. Research was principally financed by means of third-party assignments and by NTNF. Collaboration with NTH was a prerequisite for success in this market, since NTH provided a guarantee of technical quality.

An oil nation with new potential

In 1976, Johannes Moe became the next Director of SINTEF. His "reign", which lasted until 1989, was marked by major upheavals, both for SINTEF and for Norway as a nation. Norway became an oil-producing nation, resulting in inconceivable growth for SINTEF, which became one of the country's most solid knowledge-based communities in the field.

When Moe took over SINTEF, it consisted of many small departments, with new ones constantly being added. SINTEF had become a large institute but at the same time had lost the ability to make full use of its technical diversity. Finding mechanisms which could realise the multidisciplinary potential of SINTEF became one of the most important tasks at hand. Many attempts were made, but the breakthrough came much later as a result of comprehensive reorganisations.

SINTEF the research consortium

NTNF had founded a number of research institutes for which it retained responsibility. In 1981, the Thulin Committee proposed that the institutes should become autonomous. Then in 1984 it was proposed that the NTNF institutes in Trondheim should be converted into limited liability companies under the ownership of SINTEF. The intention was to create a research consortium with uniform management. This took place, but not without skirmishes. Seven hundred people changed employer and the NTNF institutes NSFI, IKU and EFI became subsidiaries of the SINTEF Group in the form of the majority-owned limited companies MARINTEK, SINTEF Petroleum Research and SINTEF Energy Research.

As a result, the SINTEF Group had almost 2000 employees and was the predominant Norwegian research institute. In the opinion of some, it had become too large, but size provides strength and attractiveness. Thanks to Moe's determined efforts, in his period of office Trondheim acquired several large research facilities, such as the Ship and Ocean Laboratory and the Multiphase Flow Laboratory.

Norway's entry into the age of oil resulted in major assignments for SINTEF, and almost half the company's activities were in some way connected with the petroleum industry. The technological agreements were of great importance. However, this dependence on the petroleum industry resulted in vulnerability, as was demonstrated by the drop in the price of oil in 1986. The most exposed institutes had to reduce their activities by 15-20 per cent, and the period of expansion was over, for the time being.

Nationwide merger

Thor O. Olsen succeeded Johannes Moe in the post of Director. When Olsen assumed responsibility for SINTEF its economic position was weak and there was growing unrest about the future – an unrest which also pervaded the other institutions. NTNF wanted to combine the institutes in the Oslo area, but this was not met with enthusiasm. So the management of SI contacted SINTEF and proposed a merger across the country, which in many ways was an astonishing concept, since SI and SINTEF were keen competitors in a number of fields.

In the letter of intent which formed the background for the proposal we find the vision of transforming the new SINTEF into Europe's leading commission-based research institute as well as a vision of creating a national consortium of technological institutes. This last did not come to pass, but the merger was agreed. In this way, SINTEF became one of the largest independent commission-based research institutes in Europe and was ready and waiting to enter into the European research collaboration which was to come. Mergers are never easy. As somebody said at the time, "The merger has been agreed. Now the work starts". The work is still going on.

Reorganisation

For various reasons, differences arose between Olsen and some of the employees. Olsen left SINTEF in 1995 and was followed by Roar Arntzen, whose first and perhaps greatest challenge was to create a new organisational structure for SINTEF. To a large extent the numerous small departments had lives of their own, and the organisation was not optimal either technically or economically. The central administration was slimmed down and the approximately 30 departments became 12 divisions which closely corresponded to the arrangement of NTNU's institutes. All the managerial personnel were "released" and many changed jobs, both in and outside SINTEF. The reorganisation was dramatic but necessary. SINTEF had to be capable of reaping the benefit of its size.

In 1996 NTH became the Norwegian University of Science and Technology (NTNU). SINTEF's relationship with the university was at times strained, since SINTEF was considered too large and dominating. Karsten Jakobsen, Rector of NTNU said it all in his expression of concern: "Industry was our father and mother and gave us good assignments, while SINTEF was our big brother who took everything from us". There was a need for a tidying-up and a clarification of what the joint activity entailed. The solution was the formation of the Gemini Centres. These are shared groups in which SINTEF and NTNU commit themselves to strategic collaboration. There are now twenty or so such centres which have given both parties greater influence. The arrangement has subsequently been expanded to include the University of Oslo and St. Olav's Hospital in Trondheim.

Joint efforts

Under Arntzen's leadership, multidisciplinary collaboration really took off. Some of the community's resources were allocated to large collaborative projects directed towards new market niches. These investments have in addition led to new contacts between groups of researchers and provided new opportunities for assignments. This applies particularly to contact between technological disciplines and social scientists.

In 2002, Arntzen retired and was succeeded by Morten Loktu. Loktu was an industrialist, and this was to characterise his regime. A new reorganisation was implemented in which the twelve divisions became six, plus three limited liability companies. Loktu emphasised the importance of creating an efficient SINTEF with the ability to tackle the major technological challenges, especially in the petroleum industry. At times this led to ambiguity with regard to SINTEF's profile: Was SINTEF becoming an advanced consulting firm?

Loktu was with SINTEF for two years before being enticed back into the industrial sector. This time the board decided to recruit a new leader from among its own employees, and Unni Steinsmo, who was Director of SINTEF Materials and Chemistry, was appointed in 2004.

Focus on science

The first test for Steinsmo was what was to become known as "the Iran affair". A subsidiary, SINTEF Petroleum Research AS, was accused of corruption and a corporate fine was imposed on the company. This was a wake-up call. Ethical conduct was placed high on the agenda and SINTEF created ethical guidelines and an Ethics Council. Ethics and HSE became important themes of both internal meetings and in-house training.

So far, Steinmo's regime has been characterised by three principal objectives: The first is to focus on science. SINTEF shall be a research institute. SINTEF is to work in Pasteur's Quadrant, in which the distance between pure science and practical application is short. SINTEF has also become science-based. The number of publications is on the increase, as well as the number of research scientists with doctorates and close association with the universities. The second objective is to ensure efficient operation and thereby also good economic conditions. SINTEF's economic results have always been modest, with sometimes no profits at all. The focus on efficient operation has in recent years resulted in a good, stable profit. This enables internal technical investment and new infrastructure. The third objective is to maintain efficient collaboration with NTNU. NTNU and SINTEF have different socio-economic duties. Efficient collaboration entails respecting the differences and combining forces where common interests exist. This is achieved through joint management meetings, among other things.

New mission statement

In 2009, SINTEF's mission was finally modified to "to contribute to the development of society by carrying out research in natural sciences, technology and health and social sciences in co-operation with NTNU. This objective shall be achieved through the acquisition of our own expertise at the highest level and through close co-operation with NTNU, and in collaboration with industry, government and other research and educational institutions". This change is at present the keystone in comprehensive efforts to provide an integrated corporate management of SINTEF. With its 2100 employees and sales of NOK 2.8 billion, SINTEF has become a major undertaking. Although the mission statement is not something that one reads daily, it is important that it is related to reality.

SINTEF's visions are worthy of detailed analysis. The starting point was "research first and foremost". This shows that SINTEF is fully engaged in what the organisation is doing, namely conducting research. That research shall be of high quality and world-leading, but the vision says no more than this. To put it rather bluntly, this could easily be the vision of a purely academic community. When the vision was introduced in the 1980s, it was an expression of the need to reinforce SINTEF's own expertise. SINTEF had grown out of its role as described in the original mission statement. The desire was to stand on one's own academic strength.

The next version, which came during the 1990s, sets a completely different tone: "Technology for a better society" Here, the emphasis is placed on SINTEF's role in society. Research shall provide results – results which shall be made use of and provide benefits for society. With this vision, SINTEF assumes a role in social development, through results and through providing termes of reference for the development of society. The vision signals technological optimism. SINTEF has also become bolder. In recent years we have seen the creation of SINTEF-like views on the development of important social functions with high technological content. SINTEF has become a provider of terms of reference.

An international research institute

SINTEF is currently one of Europe's biggest commission-based research institutes. The goal is to become the most widely recognised, and in a number of technical fields this goal has already been achieved. International assignments and considerable involvement in European research indicate this. What has SINTEF meant for Norway? SINTEF has been a source of expertise and ideas for Norwegian industry and government. Each year about 7000 assignments of various sizes are carried out for approximately 2000 clients. Long-term strategic collaboration has been established with many clients. Because 10 per cent of the research staff are replaced annually, SINTEF has also supplied highly qualified personnel to Norwegian society. This has provided society with valuable technical and managerial expertise.

Sixty years is not a remarkable age for an academic community, but in the course of these sixty years, SINTEF has developed from a fairly modest consultancy organisation for NTH into an internationally-recognised research institute. That's no mean achievement, and well worth celebrating.

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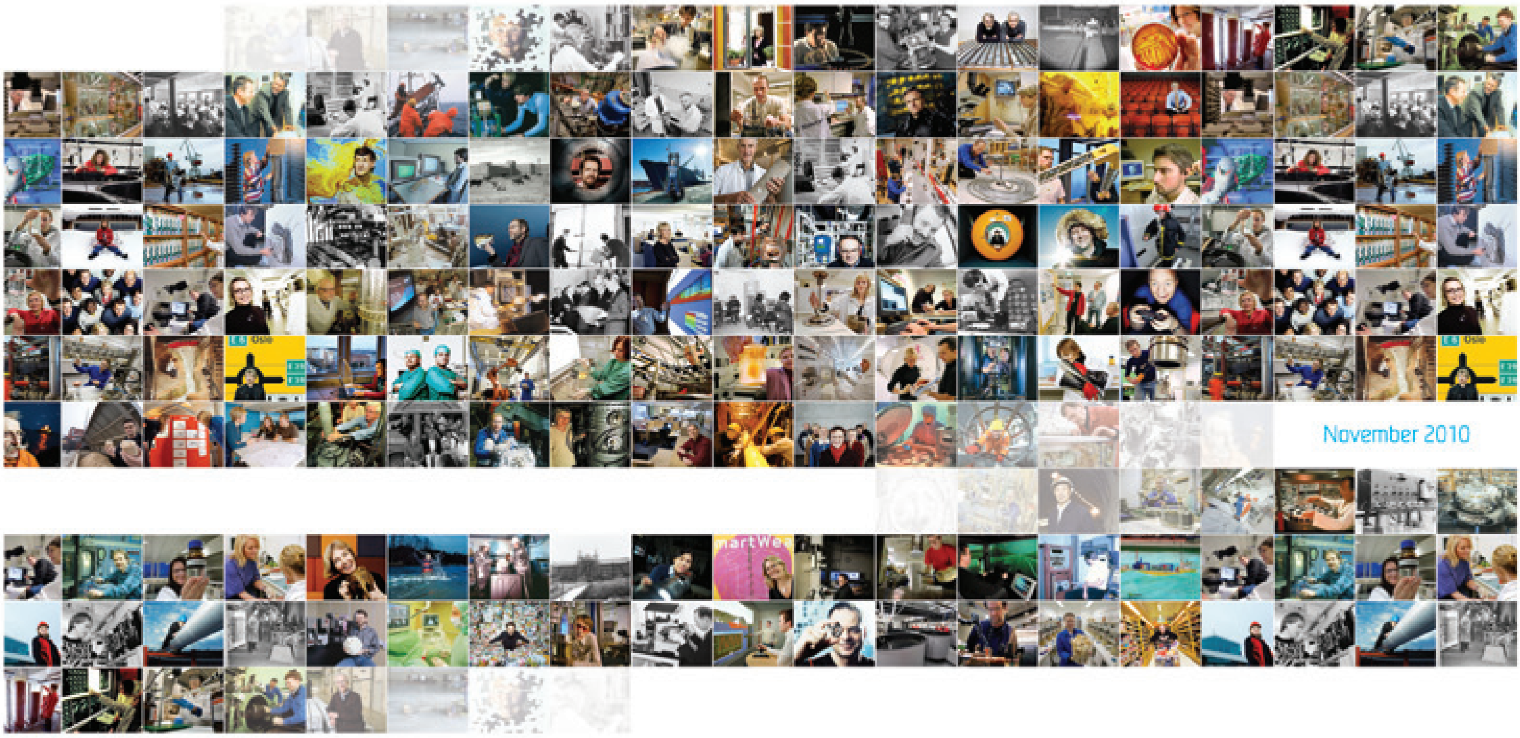

November 2010

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Technology for a better society

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