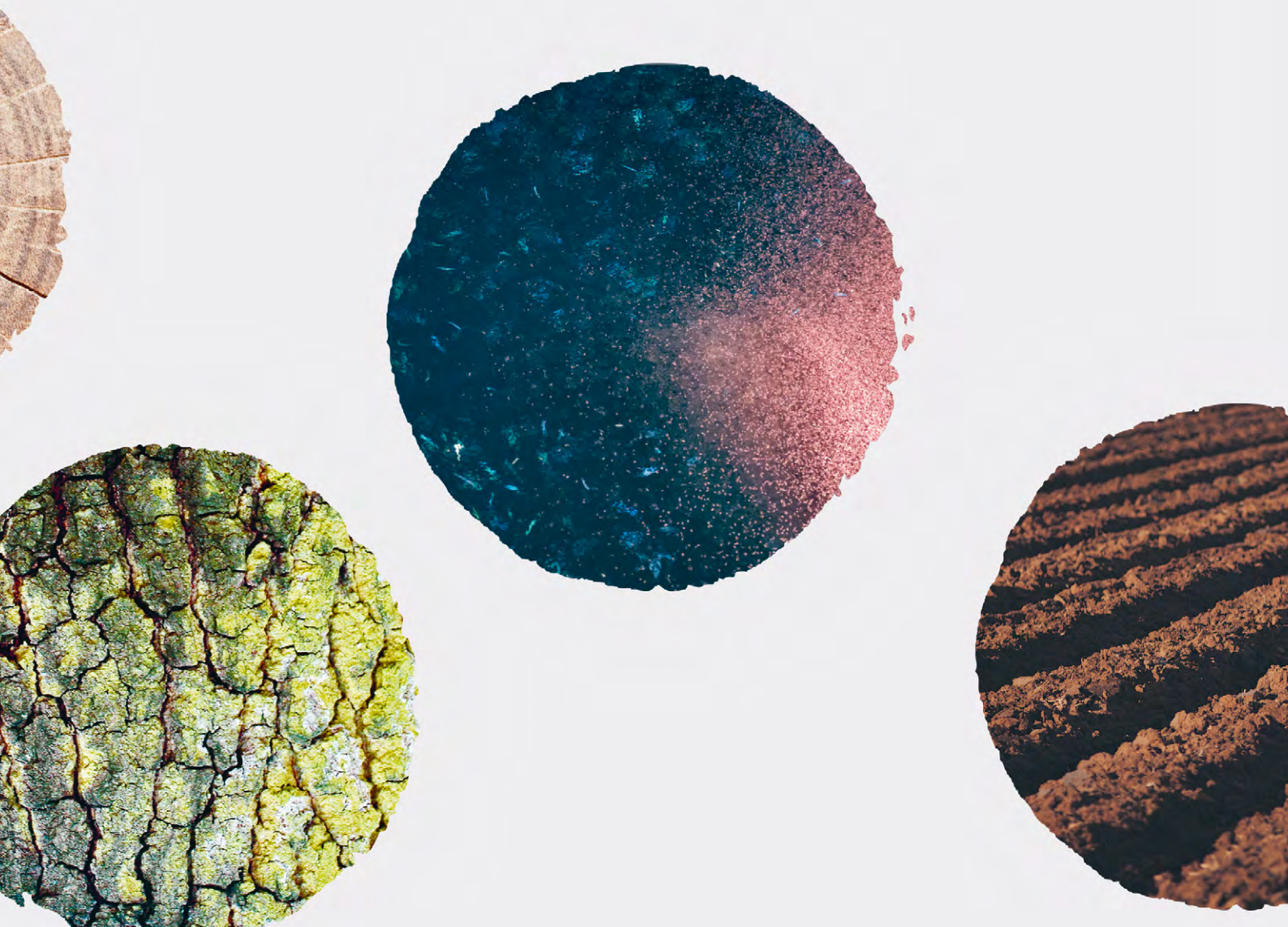
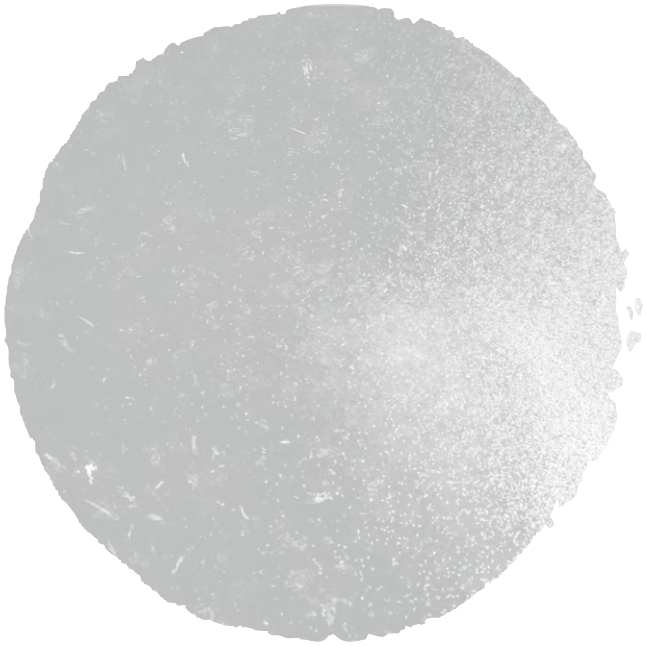
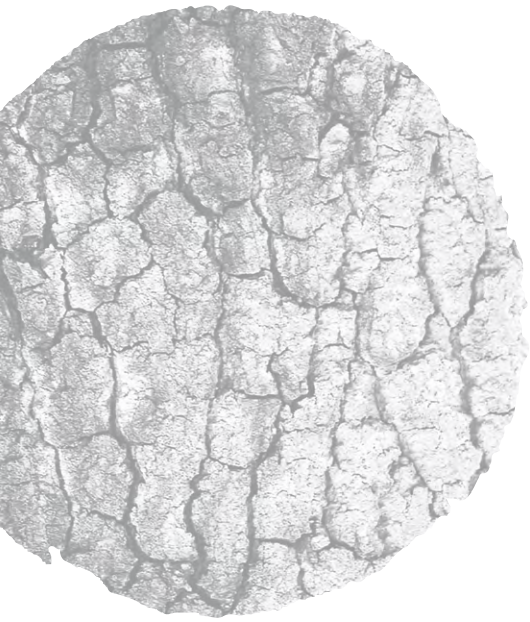
Norwegian Ministries

Strategy

Familiar resources – undreamt of possibilities

The Government's Bioeconomy Strategy




Familiar resources – undreamt of possibilities

The Government's Bioeconomy Strategy

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Foreword

The OECD considers the potential for value creation associated with the bioeconomy to be significant. Increased and more efficient use of renewable biological resources is also considered key to a shift toward a low carbon economy. Globally, the bioeconomy must also meet the need for food for an increasing population. Norway has an abundant supply of renewable biological resources both at sea and on land, as well as an industrial and knowledge base that is well-suited to exploit this potential. Through targeted and coordinated efforts, better use of renewable biological resources can contribute to renewed growth and a green shift in the Norwegian economy. The government has therefore decided to draw up a national bioeconomy strategy.

Developments within the bioeconomy could both contribute to restructuring and increased competitiveness in established businesses and lay the foundation for new commercial activities and knowledge-based employment throughout the country. Bio-based industries should be oriented towards more efficient and sustainable production and extraction of resources, and the processing of resources towards products that offer high returns. New know-how and technology make it possible to use resources in a more efficient, sustainable and profitable manner. Knowledge development and investment in research and innovation are therefore important prerequisites for developing a modern bioeconomy. A profitable bioeconomy also involves learning and developing new know-how and commercial activity across established industries, sectors and disciplines. Norway is well-positioned for this as well - but we must aspire to do even better. Developing new cross-sector value chains will challenge established patterns of interaction, public administration, regulation and support system. This creates a need for a holistic approach that a national strategy can help fulfil.

In addition to the EU and OECD, a number of countries have developed bioeconomy strategies. Considerable amounts have been invested in increasing know-how and commercial development within the bioeconomy. Given the international competition, it is essential that we exploit our national advantages. The government's strategy shall provide over-arching and long-term priorities for national efforts in this area. A key objective of the strategy will be to contribute to a common understanding of the national opportunities and challenges we have within the bioeconomy, and point out the long-term objectives in this area.

There is great variation in products, processes and general framework conditions for the various bio-based industries and the challenges of each industry will vary and depend on the practical, technological and competitive challenges associated with each product. Meanwhile, a number of challenges will be common to all and much of the potential for growth will be based on the exploitation of synergies across established value chains, sectors and disciplines. This strategy has a particular emphasis on cross-sectoral issues, while some more sector-specific opportunities and challenges will be addressed in other government documents, including strategies and white papers for the individual bio-based industries.

The strategy was developed in a collaboration between the Ministries of Trade, Industry and Fisheries, Agriculture and Food, Climate and Environment, Education and Research, Local Government and Modernisation, Petroleum and Energy, Transport and Communications and Foreign Affairs. The Research Council of Norway, Innovation Norway and the Norwegian Environment Agency were key advisors. There has been extensive dialogue and consultation rounds, including a national conference, an international workshop, six regional dialogue meetings and over 40 written contributions as part of the strategy efforts. There has also been separate dialogue with individual stakeholders. We are grateful for the high level of commitment of all those who have contributed and provided valuable input and we look forward to further dialogue on the implementation of this strategy!

Contents

Summary

The government's bioeconomy policy includes sustainable, efficient and profitable production, extraction and use of renewable biological resources for food, feed, ingredients, health products, energy, materials, chemicals, paper, textiles and other products. A national initiative on the bioeconomy shall promote value creation and employment, reduced climate gas emissions, and more efficient and sustainable use of renewable biological resources. Priority shall be given to measures considered to have a national effect on both value creation/employment and reduced climate gas emissions and/or more efficient and sustainable use of resources. The initiative will have a cross-sectoral approach along the following four priority areas:

i. Cooperation across sectors, industries and disciplinary fields
ii. Markets for renewable bio-based products
iii. Efficient use and profitable processing of renewable biological resources
iv. Sustainable production and extraction of renewable biological resources

Emphasis shall be placed on the potential that arises across sectors from the development and use of knowledge and technology in this field. Efforts shall in particular advance knowledge and technology platforms capable of using renewable biological resources from several productions and with application in several industries.

The following overarching principles shall apply for a productive and sustainable use of renewable biological resources:

1. The population's need for food is of paramount concern
2. Resources shall be used and re-used as efficiently as possible
3. Resources shall be used in the most profitable manner

The contribution of the bioeconomy to a more circular and environmentally friendly low emission economy is an important rationale for public policy initiatives. In this respect, the internalisation of negative effects on the climate and the environment in the product prices would be the most efficient way of promoting the bioeconomy. Another important measure would be to develop public policy through a more holistic and coherent approach, across industries and steps in the value chains. The authorities also have a role in ensuring adequate regulations and adjustments for different types of market failure.

In order to promote **cross-cutting cooperation,** the focus will be on:

- Ensuring that public support to networking activities and clusters promote the development of new and cross-sectoral value chains
- Coordinating project support along the entire value chain from R&D to innovation and market introduction
- Coordinating across thematic priorities and sectors in relevant instruments within Innovation Norway and the Research Council of Norway
- Ensuring that public support to research centres advance binding, cross-sector and interdisciplinary cooperation between research institutions, suppliers and product developers
- Stimulating international R&D cooperation relevant to the bioeconomy, including Norwegian participation in relevant parts of the EU Framework Programme for Research and Innovation and bilateral cooperation with selected countries
- Using Norwegian participation in the OECD and other international policy developing organisations to meet the needs for more knowledge as indicated in this strategy
- Examining how different bioeconomy related advisory bodies are organised, with a focus on cross-sectoral coordination, institutional efficiency and effective societal dialogue

In order to promote markets for **renewable bio-based products**, the focus will be on:

- Knowledge and information on market opportunities, technologies, processes and products that enable efficient, profitable and sustainable production and utilisation of renewable biological resources
- Considering the use of standards, labelling and certification for renewable bio-based products where relevant, to elucidate the advantages of various bio-based products
- Developing knowledge on the climate effects of increased use of bio-based alternatives to fossil-based materials and chemicals
- Establishing a new investment company which will contribute to the reduction of climate gas emissions
- Allowing Investinor to invest in mature unlisted companies within the earmarked funds for the forest and timber industry
- Strengthening Innovation Norway´s innovation loan scheme, enabling them to increase lending to investment projects related to start-up companies, innovation, adaptation, internationalisation and development, and where there is little private risk capital available
- Continuing the bioenergy initiative through the Bioenergy Programme and Enova
- Ensuring a public procurement practise contributing to the reduction of environmentally degrading effects and an advancement of climate friendly solutions, where relevant, which includes taking life cycle costs into consideration
- The public sector being a role model and motivator for environmentally friendly building solutions
- Scaling up the general turnover requirement for biofuel for roadgoing traffic, and the advanced biofuel part of this, until 2020
- International cooperation and agreements at the government level
- Placing new bioproducts in adequate categories in customs tariffs and trade agreements

In order to promote **efficient use and profitable processing**, the focus will be on:

- Allocating funds to investments in test and demonstration facilities that can be shared by several companies and R&D institutions
- Strengthening the focus on bioeconomy-related R&D in the Research Council of Norway
- Coordinating relevant public instruments promoting industrial processing within the Research Council of Norway and Innovation Norway
- Proposing a separate scheme for improving bottlenecks which hamper efficient transport of timber, in cooperation with the forest and timber industry, which is to be elaborated on in the National Transport Plan for 2018-2029
- Developing a White Paper on waste policy and the circular economy
- Developing a strategy for landing and use of residual waste from the fisheries
- Stimulating increased use of life cycle analysis in relevant areas
- Ensuring increased knowledge and development of technology for the recycling of biomass in manufacturing, including the reduction of unwanted substances, such as extraneous matter, environmental toxins and infective agents
- Revising fertiliser regulations and ensuring increased use of organic fertilisers/sludge, including regulations for depositing, storage and spreading
- Increased use of residual materials to make profitable products
- Ongoing evaluation of relevant regulations to ensure efficient use of resources

In order to promote **sustainable production and extraction**, the focus will be on:

- Utilising the potential for increased, profitable and more efficient production, extraction and use of renewable biomass from agriculture, forestry, fisheries and aquaculture within sustainable boundaries
- Knowledge-based adjustments of production towards new types of biomass, harvesting methods, processing, storage etc.
- Following up the forest related measures in the Climate Agreement, in order to increase carbon storage and access to environmentally friendly raw materials and building materials
- Stimulating the preservation and development of forest resources through active reforestation and plant breeding
- Developing the forest road network through targeted use of grants and forest funds, while safeguarding the diversity of nature and outdoor life
- Increasing the use of Norwegian raw materials in the development of feed and other intermediate products, where it is profitable and environmentally sustainable
- Developing regulations and resource management regimes as well as strengthening the knowledge base for cultivation, harvesting and exploitation of macroalgae
- Developing bioprospecting regulations ensuring that research communities and companies can extract biological material from nature within sustainable boundaries
- Increasing knowledge and area planning across local and regional government boundaries, for further development of the locality structure of the aquaculture industry
- Increasing exploitation of marine species, by facilitating multitrophic aquaculture, establishing a management plan for calanus and considering a concession system for mesopelagic fisheries
- Developing knowledge on how environmental impacts from increased production and extraction of biological resources can be kept within sustainable boundaries
- Dealing with potential conflicts between the cultivation of new species and established aquaculture, fisheries, shipping and outdoor life in a sound manner
- Upgrading industry skills regarding efficient, climate friendly and sustainable production and extraction
- Developing the interaction between public instruments and private environmental considerations, with an aim at increased knowledge and strengthened environmental considerations in sustainable forestry
- Mapping the location of old forests to ensure sound management, and together with the forest industry investigate the most appropriate measures for increased protection of key biotopes, cf. the Government White Paper No. 6 (2016–17) - Values in growth

The Research Council of Norway, Innovation Norway and Siva shall prepare a common action plan for the implementation of recommendations and instructions in the national bioeconomy strategy.

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About the bioeconomy

Foto: Thinkstock

What is bioeconomy?

Definitions and concepts

Renewable biological resources from land and sea include resources from agriculture and forestry, marine resources, as well as other uses of living and dead biological material from microorganisms, plants, fungi and animals.

Bioeconomy as a concept can be understood in many ways. Within the framework of this strategy, the concept includes sustainable, efficient and profitable production, extraction and use of renewable biological resources for food, feed, ingredients, health products, energy, materials, chemicals, paper, textiles and other products. The use of enabling technologies such as biotechnology, nanotechnology and ICT is, in addition to conventional disciplines such as chemistry, key to the development of a modern bio-economy.

Sustainability as a concept describes a development that meets present needs without compromising the ability of future generations to meet their own needs. This includes environmental, economic and social matters.

A modern bioeconomy includes several different sectors and industries, including traditional bio-based industries such as agriculture, forestry, fisheries and aquaculture, but increasingly also applications related to energy, transportation, waste, chemicals, health, climate and the environment. In the bioeconomy, value creation is based on the production and use of renewable biological resources as opposed to non-renewable carbon.

New knowledge and technology, including biotechnology and industrial process technology, enable the production and use of renewable biological resources in new ways. They can be produced and used more sustainably and efficiently - within and across different value chains and for the manufacture of profitable products with new properties or which replace products based on fossil carbon. Meanwhile, the increased use of space and natural resources can result in significant pressure on the environment and the ecosystems. The ability of ecosystems to continue to provide services important to the economy and public welfare is an essential basic condition for production and consumption.

Why focus on bioeconomy?

As for other high-cost countries, Norway must compete on knowledge as a basis for innovation and higher productivity. It is therefore an objective to promote a knowledge-intensive industry . A further objective is to ensure an adaptable and sufficiently diversified industry, which can be competitive in situations where industry face major global societal and market changes linked to climate and environmental challenges, access to resources, demographic changes, reduction in oil prices etc. We are also dependent on continued use of our substantial natural resources in an efficient, profitable and sustainable manner. A national commitment to a knowledge-based bioeconomy, where future value creation is largely based on the sustainable use of renewable biological resources must help solve some of the challenges we face.

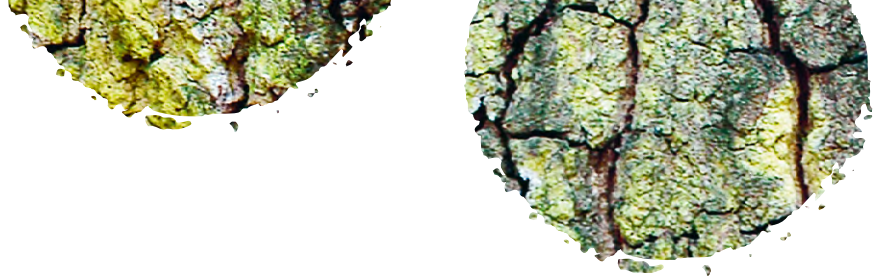
Increased value creation and employment

Based on a broad definition that includes all the bio-related industries in the EU, it is estimated that the bioeconomy has an annual turnover of EUR 2,000 billion and represents over 22 million jobs, i.e., approximately 9% of the total labour force. In Norway, traditional bio-based industries employ about 140,000[1] people, i.e., 5% of the total labour force, and have an annual turnover of about NOK 350 billion[2]. Total value creation for these industries in Norway is around NOK 100 billion[3], or about 5% of the value creation in mainland Norway. In addition, parts of the construction sector and the textile, chemical, pharmaceutical and waste management industries are included in the bioeconomy.

1) Preliminary figures for 2015 show that there are about 53,400 persons employed in the food industry including the seafood industry, 17,200 in the primary stage in fisheries and aquaculture, 52,100 in the primary stage in agriculture, forestry and 16,900 in the timber and wood products industry and the production of paper and paper products (Statistics Norway).

2) Preliminary figures show that the food industry had a production value of about NOK 200 billion in 2015, the primary stage in fisheries and aquaculture, NOK 73 billion, the primary stage in agriculture and forestry, NOK 44 billion and the wood products industry including paper production NOK 36 billion. (Statistics Norway).

3) The value creation calculated as gross national product shows that the food industry including seafood had a value creation of around NOK 42 billion in 2015 (also includes imported food), the primary stage in fisheries and aquaculture, NOK 31 billion, the primary stage in agriculture and forestry, NOK 19 billion and the wood products industry including paper production NOK 10 billion. (Statistics Norway).



Marine ingredient industry

Bio-marine industries include industrial communities that utilise marine raw material sources, such as fish oil, krill and calanus, residual materials and kelp for special ingredients for food, health food, feed, cosmetics and pharmaceuticals. In 2013, this industry's turnover amounted to more than NOK 8.5 billion, of which the use of Norwegian-based residual materials generated a turnover in excess of NOK 2.5 billion. Several of the largest global industrial players in this segment are now established in Norway (FMC, Firmenich, BASF and others). The bio-marine industry is considerably more involved in R&D than the traditional seafood industry. SINTEF has estimated that the greatest opportunities ahead are related to better utilisation of nationally produced raw materials, based on the residual materials, new aquaculture species (seaweed/kelp), microalgae, etc. Just under 680,000 tonnes of Norwegian-produced residual materials in 2015 were utilised, which were converted into fully and semi-processed products corresponding to more than 340 000 tonnes. The bulk of this is used for feed and feed ingredients. About 45 000 tonnes (13%) go directly or indirectly to human consumption.

BLUE LEGASEA is a bio-marine cluster in the Møre region based on a broad and complimentary cooperation for high quality use of marine raw materials and in particular residual materials. The cluster consists of locally owned businesses (fishing vessel companies, processing plants) and leading international players such as FMC/Epax (omega-3) and Firmenich (marine proteins). The network is aiming for Norway to become a global leader in marine ingredients. As of today, this region represents about 30% of the global production of omega-3 oils for health food products, pharmaceutical, functional food and feed. In 2016, members of the cluster received support via the Programme for User-driven Research-based Innovation (BIA) in the Research Council of Norway to study how marine proteins affect muscle mass and muscle performance in both the elderly who suffer from muscle loss and athletes. The cluster collaborates with healthcare institutions such as Møre og Romsdal Hospital Trust, University of Bergen/ Haukeland Hospital and NTNU/St. Olav's University Hospital for research and documentation of health effects. Increased knowledge on how these relate can contribute to an increased use of marine residual materials in human products as well as better utilisation of the unique properties in the context of feed.
Sources: Sintef (2014): "Norwegian marine ingredient industry - structure, economics and development from 2007 to 2013"; www.forskningsradet.no.

The potential for value creation within the bioeconomy depends on the availability of renewable biological resources and our ability to optimise their use and maximise value creation. The bulk of the biomass is used for food, feed, building materials, energy, chemicals and cellulose-based products. With an adequate supply of biomass at competitive prices, the bio-based products can replace fossil-based or energy-intensive products to a greater extent. Further development and use of biotechnology and adjacent technology areas such as nanotechnology and ICT will allow for new applications of renewable biological resources, such as products in health and nutrition.

The OECD considers there to be a significant potential for value creation associated with the bioeconomy. Globally, more than 40 countries have integrated bioeconomy into their national strategies, and amongst others, the G7 countries (Canada, France, Italy, Japan, UK, Germany and the US) and the BRICS countries (Brazil, Russia, India, China, South Africa), have launched comprehensive initiatives to promote the development of the bioeconomy[4]. Norway has an abundant supply of renewable biological resources both at sea and on land, and an industrial and knowledge base that is well-suited to exploit them.

4) Source: Communiqué Global Bioeconomy Summit 2015.

International bioeconomy efforts

In 2015, the German "Bioökonomierat" (The Bioeconomy Council) issued a policy analysis of the G7 countries' bioeconomy strategies. Most of the G7 countries focus on national conditions and aim to help reduce climate gas emissions, support the transition to a cycle-based economy and preserve ecosystem services. All of the countries expect a strengthening of innovation and economic growth (green and blue growth) and that jobs will be created within the high technology sector. In addition, several of the countries believe that the bioeconomy will promote regional economic development. Countries that have good access to bioresources usually have a stronger focus on large-scale use of raw materials, such as for bioenergy and biofuels. In parallel, there are also efforts on technology development to increase value creation based on biomass through further processing into high value products.

Countries that have fewer natural resources but a strong industrial structure (e.g., Germany, France, Italy and Japan), primarily see a potential for innovation and industrial development within the bioeconomy. In these countries exploitation of residual materials, alternative biomass and CO_2 play a greater role. Re-industrialisation through bio- and knowledge-based value creation is the main objective in the UK. Economically emerging countries like Brazil, Russia, India, China, South Africa and Malaysia are promoting developments in the field and will become more prominent as suppliers of processed bio-based products rather than suppliers of raw materials.

In the short term, it is likely that an increased focus on the bioeconomy will contribute primarily to sustainable adaptation and increased competitiveness within established bio-industries, while in the longer run, it will also have an economically significant impact on the overall economy. If developments in the bioeconomy are to contribute to significant economic growth in terms of new economic activity and new jobs, this will likely require significant adjustment and renewal in the established structures and patterns of interaction in industry. A Nordic study conducted by Nordic Innovation, makes an analysis of cross-sectoral eco-industrial systems considered to have a particular growth potential in the Nordic countries[5]. Areas that were highlighted as particularly promising are aquatic biorefining, bio-based ingredients[6], advanced biomaterials[7], biorefining concepts[8], biocatalysis[9] and decentralised bioenergy systems[10].

5) Nordic Innovation (2014): «Creating value from bio-resources – Innovation in Nordic Bioeconomy».

6) Functional bio-ingredients are specific components extracted from biomass and possess potential functionality for end-use, for example in health food products, cosmetics and specialty chemicals.

7) Advanced biomaterials can both act as a substitute for fossil components and offer new functionality, and include for example bio-based composites, bioplastics and advanced cellulose materials such as nano- and micro-fibrillated cellulose.

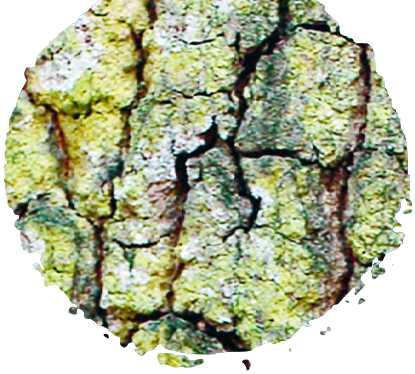
8) Biorefining is an integrated production system where the objective is to use each component of the raw material efficiently and produce as much value as possible.

9) In biocatalysis, bio-based catalysts are used such as enzymes and proteins to increase the rate of chemical reactions, and process and modify biomass highly selectively for the development of customised bio-based products and product features.

10) Decentralised bioenergy systems deliver renewable energy products while contributing to local development and may include biogas and combined systems for heat and power production to supply local municipalities, industry and transport.

Table 1: List of a selection of public instruments that can be used by the bio-industries
Innovation Norway
Innovation Norway provides services to businesses including: • The Bio Refining Programme (support for new production processes based on renewable biological raw materials), the Environmental Technology Scheme (support for pilot and demonstration facilities), the Bioenergy Programme (supports investment, studies and training measures) • General grants for establishing financing, research and development contracts and regional development grants, as well as innovation loans, secured loans, guarantees and seed funds • Advisory services related to international market opportunities and reputation management • A wide range of advisory and training measures for knowledge transfer related to intellectual property, design, regulatory work and market orientation • Clusters and networks in collaboration with the Research Council of Norway and SIVA: Arena, NCE/GCE and Enterprise Networks
Research Council of Norway
The Research Council of Norway funds research and development in the business sector, the institute sector, and the higher education sector. Programmes of relevance to the bioeconomy are: • Bionær (strategic programme for bio-based industries), Havbruk (strategic programme for the aquaculture industries), EnergiX (strategic programme for renewable energy) • BIOTEK2021 (strategic programme for biotechnology), NANO2021 (strategic programme for nano-technology) and IKTPluss (strategic programme for ICT) • Programme for User-driven Research-based Innovation (BIA), Forny2020, Skattefunn (tax refund scheme), Industrial Ph.D. scheme • Centres for Research-based Innovation (SFI), Centres for Environmentally Friendly Energy Research (FME), Centres of Excellence (SFF) • Funding for Independent Research Projects (FRIPRO) and the Infrastructure Scheme • VRI (Programme for Regional R&D and Innovation) and Regional Research Funds (RFF)
SIVA
• Invests in property and infrastructure that facilitates the bioeconomy such as industrial and innovation parks, manufacturing facilities, laboratories, testing and pilot plants and upscaling. Offers physical and organisational infrastructure for research, development and commercialisation by supporting various types of innovation companies and incubator businesses that develop ideas from research and development communities. • Incubator, NCE/GCE and ARENA cluster programmes • Mobilises private actors, investors and knowledge communities

Table 1: List of a selection of public instruments that can be used by the bio-industries
ENOVA
Enova shall be a driving force for progressive energy solutions by providing investment support for the implementation of new energy technologies and the development of new energy markets. Support is provided for the demonstration of new energy technologies in Norway under real operating conditions. Market introduction and support for technology qualification (demonstration) shall promote new and more cost-effective technology and energy solutions.
INVESTINOR
Investinor is a state-owned investment company which invests in new, internationally competitive growth companies. The company shall prioritise profitable investments in all sectors.
The Norwegian Patent Office
The Norwegian Patent Office helps Norwegian industry to strengthen its own business through its knowledge of industrial property rights, so that the companies ensure their investments and competitive position. The Patent Office's main task is to process applications for patents, trademarks and design registrations. The Patent Office organises courses and holds lectures on the importance of industrial property rights. Additionally, various types of feasibility studies are performed.
The Norwegian Fishery and Aquaculture Industry Research Fund (FHF)
FHF is a public administrative agency under the Ministry of Trade, Industry and Fisheries and is 100% financed by the industry itself through a 0.3% R&D tax on exports of all seafood. The funding managed for the seafood industry is invested in industrial R&D in order to contribute to profitability and growth.
Foundation for Research Levy on Agricultural Products (FFL)/Agricultural Agreement Research Fund (JA)
The fund resources consists of a tax on Norwegian-produced and imported food and are used for research in the food sector. The entire value chain is covered: agriculture, industry and the consumer stage. In addition to the agricultural settlement, there is annual research funding. The funding go to research in the field of agriculture and food. Both schemes allocate funds based on open advertising and competition. The fund board and agreement board cooperate in the administration of the schemes.
EU
A number of measures in the EU are of relevance to the bioeconomy, including: The EU Framework Programme for Research and Innovation, Enterprise Europe Network (global network of business advisory organisations), Eurostars (common financing mechanism for EU and EUREKA), the Joint Technology Initiative (long-term public-private partnerships), ERA-net (scheme for coordination of national and regional research programmes).



Reduction in climate gas emissions

It is a national goal for Norway to be a low-carbon society by 2050. The UN Intergovernmental Panel on Climate Change's latest Assessment Report stated that increased use of renewable biomass will play an important role in combating climate change, which the government also refers to in White Paper 13 (2014-15) for a new emission commitment for Norway. Meanwhile, climate change could affect the living conditions for biological production through changes in cultivation capabilities, species composition and habitats in the sea and on land. This can provide new opportunities but also limitations with respect to species, production volume and harvesting areas.

The Paris Agreement aims to limit the rise in global temperatures to under two degrees and to strive for an increase to as low as a degree and a half. Energy and raw materials from renewable biological resources can help to reduce emissions. Meanwhile, sustainable use and management provide valuable contributions to strengthening nature's carbon storage so that uptake and emissions can eventually be balanced. Some climate gases are difficult to avoid, such as methane and nitrous oxide emissions from the world's food production. According to the Paris Agreement, such emissions shall eventually also be balanced. This will require significant use of carbon negative technologies, such as the capture and storage of CO_2 combined with bio-based combustion[11]. Norway has some large industrial emissions and substantial biomass resources. Norwegian R&D communities are already cooperating with companies in Norway to develop solutions where biofuels are used in CO_2 management to achieve carbon-negative plants. Through gas fermentation, CO_2 can also be used for the development of sustainable feed and chemicals[12].

The Norwegian Environment Agency has pointed out that from a climate perspective, it is important to use bio-resources where we have no other solutions. Transportation and industry are sectors where opportunities to make use of bio-resources as a substitute for fossil energy are particularly big[13]. Globally, the transport sector today represents 14% of climate gas emissions and 27% of energy use. In Norway, the transport sector as a whole accounts for the bulk of emissions, with 31% of emissions in 2014. Use of low- and zero-emission technologies and sustainable biofuels can help reduce these emissions significantly in coming years.

The implementation of the Paris agreement could lead to a significant increase in the global demand for biofuels for the transport sector. A switch to battery- or hydrogen-powered cars affect the demand for biofuels. In the longer term, large parts of the heavy goods transport and other heavy vehicles (such as tractors and construction equipment) as well as, to a certain extent, maritime transport may also switch to electric motors, which could curb demand for biofuels. Aviation is expected to demand biofuels also over the long term. The uncertainty about future developments is largely related to the costs of production, raw materials and new technology. For new technology to be adopted, it must be cheaper than fossil technology. It requires that both the costs of new technologies fall sharply and that there be a cost associated with polluting. Globally, only 10-15% of emissions are subject to such cost.

11) The UN Intergovernmental Panel on Climate's fifth assessment report finds that between 40 and 100% of the biomass combustion must be associated with plants that capture and store CO_2 at the end of the century for us to reach a goal of two degrees. A half-degree goal depends on even more on carbon negative technologies.

12) This is an example of CCU (Carbon Capture and Utilisation).

13) The Environment Agency has described possible solutions for achieving a low emissions society in the report "Evidence for Low Emissions Development" from 2014 and 2015.

The climate gas emissions from industry in 2014 made up 23% of Norway's total emissions. Use of sustainable bio-resources can potentially provide large reductions in emissions from industry and possibly form the basis for new industries. For example, biochar can replace fossil coal in metal production. In addition, bio-based chemicals and materials can replace similar products based on fossil carbon. Increased production and use of renewable biomass for chemicals and materials may therefore contribute significantly to lower emissions in a life-cycle perspective.

From forest to metal and fuel

Elkem is a world leader in the production of metals and materials. Silicon and ferrosilicon are the company's main products. Silicon is a semiconductor material which is well-suited for electronics. Other important uses are as an alloy in aluminium and as silicone. Coal is used as a reducing agent during production, and the process results in CO_2 emissions. Elkem's research project Carbon Neutral Metal Production (CNMP), which is supported by the EnergiX programme of the Research Council of Norway has the goal of replacing fossil coal with carbon neutral charcoal to produce silicon. SINTEF Energy and Teknova are participating in the project. Elkem has also, together with Treklyngen, Avinor and energy company Vardar, partnered to develop industrial production of charcoal and bio-oil. The aim of the innovation project, which has been named "Norwegian Wood" is to develop an entirely new value chain for industrial processing of the entire log. Initially, a feasibility study will be conducted for an industrial pilot plant for pyrolysis production of charcoal and bio-oil at Follum in Hønefoss. In addition, this will produce energy for heat and power generation. The project has received support from Innovation Norway and was initiated in 2016. Both of these projects can help to create increased value, synergies across industries, and new green jobs.

In May 2016, the Federation of Norwegian Industries presented a roadmap for the process industry where the vision is to increase the value creation in the industry while climate gas emissions are reduced to zero[14]. Many materials and alloys cannot currently be produced without carbon as reducing agent. The roadmap is thus based on a massive increase of biomass for industrial purposes. By 2050, the measures will require about 10 million m^3 per year. This is of the same magnitude as the entire current logging from Norwegian forests.

Activities related to the construction and operation of buildings represent over the life-cycle nearly 14% of total CO_2 emissions in Norway[15]. The largest share of emissions come from the industry's production of building materials[16]. Wood is renewable and has lower production emissions than many other building materials[17]. If wood or other bio-based materials can replace more energy-intensive or fossil-based materials, this will provide climate benefits.

In 2014, agricultural climate gas emissions made up approximately 8% of total Norwegian emissions. Climate gas emissions from the agricultural sector can be particularly reduced through changes in consumption and improved production methods with lower emissions per unit produced. In addition, efforts must be undertaken to reduce CO_2 emissions from fossil energy and fuels in machinery and buildings, as well as CO_2 emissions from soil.

14) The Federation of Norwegian Industries (2016), "Roadmap for the Process Industry. Increased Value Creation with Zero Emissions in 2050".

15) Production of building materials 7%, transport of building materials 1%, the construction sector 1.2% and building operations 4.3% (KanEnergi (2007), "The construction s ector's greenhouse gas emissions").

16) Emissions are accounted for in the sectors where the emissions occur - such as in the transport sector for transport emissions, the land sector for the extraction of wood, and in the industrial sector for emissions from processing. This ensures that emissions are only counted once.

17) Asplan Viak (2015): "Comprehensive Environmental Assessment of Building Materials."

More efficient and sustainable use of resources

There is generally extensive waste of resources in the current economy. It has been estimated that 93% of the resource flow in Western economies is lost along the value chain, while just 7% is left in the products that reach the end-user. 85% of the products (measured in kg) become waste after one or no repeated use[18]. From a sustainability perspective, it is desirable to adjust to a circular economy with more sustainable production, use and exploitation of resources. This implies minimising the amount of waste through reuse, recycling, reducing waste and increasing the use of residual materials from different types of productions. A national commitment to the bioeconomy could contribute to such developments. The objective is to exploit and create value from renewable biological resources, even after a product is no longer used for its original purpose, as opposed to a more linear "use and throw-economy" which assumes that resources are unlimited and easily manageable as waste.

Well-functioning ecosystems are a prerequisite for growth and prosperity in all societies. The most efficient utilisation of raw materials and resources will have a direct positive impact on both the climate and safeguarding biodiversity. We must come up with a cycle whereby the resources in waste are optimally used. With the potential for more efficient use of resources, there are also business opportunities. Norwegian industry can benefit from it.

A goal of better use and reuse of raw materials can both increase the profitability of existing companies and form the basis for new, profitable and sustainable industrial activities in Norway. We have the raw materials, energy, access to water and a good skills base to build on. More profitable value chains and more sustainable development are created when residual materials from one production process are incorporated as a valuable resource in new production. In this context, it is important to have a cyclical approach and lifecycle analysis in order to ensure that new products contribute to a green adaptation in all phases of production, use and recycling.

National facilitation of more efficient and sustainable use of resources must be seen in connection with policy development in international forums, including the European Commission's action plan for the circular economy of December 2015[19]. The aim of the action plan is better economic and environmental development through more efficient use of resources throughout the value chain (production, consumption and waste management) and through innovation that facilitates the development of new markets and business models.

18) Hawkens, Lovins (2010): «Natural Capitalism: Creating the Next Industrial Revolution».

19) Which in turn is based on the European Commission's Europe 2020 strategy, Roadmap for Resource Efficiency and the Seventh Environment Action Programme.

National knowledge base for a circular bioeconomy

CYCLE is an interdisciplinary research project led by SINTEF Fiskeri og havbruk (Fisheries and Aquaculture) AS, with the main purpose of improving resource utilisation in the food chain. The project will improve the overall utilisation of raw materials from vegetables, fish and chicken through increased use and reduced waste throughout the value chain. The project focuses on increased value creation by developing new technologies and bioprocesses together with optimum logistics solutions and socioeconomic considerations. Sensor systems are used for optimal quality differentiation and sorting between e.g., ripe/unripe and good/poor quality of vegetables, sorting livers and roes, skin etc. from fish and automated chicken fillet processing. The R&D institutions collaborating with SINTEF Fisheries and Aquaculture are NOFIMA, Norwegian Institute for Bioeconomy Research (Nibio), Norwegian University of Science and Technology (NTNU), Consumption Research Norway - SIFO, SINTEF Raufoss Manufacturing AS, SINTEF Energy, VTT (Technical Research Centre of Finland), University of Copenhagen. There are a number of participating companies including: Bama, Norilia, Produsentpakkeriet (Producer Packing Centre), Nergård, Felleskjøpet Fôrutvikling (Feed Development Cooperative), ECOPRO, Global Green Energy, Epcon, Orkel. etc.

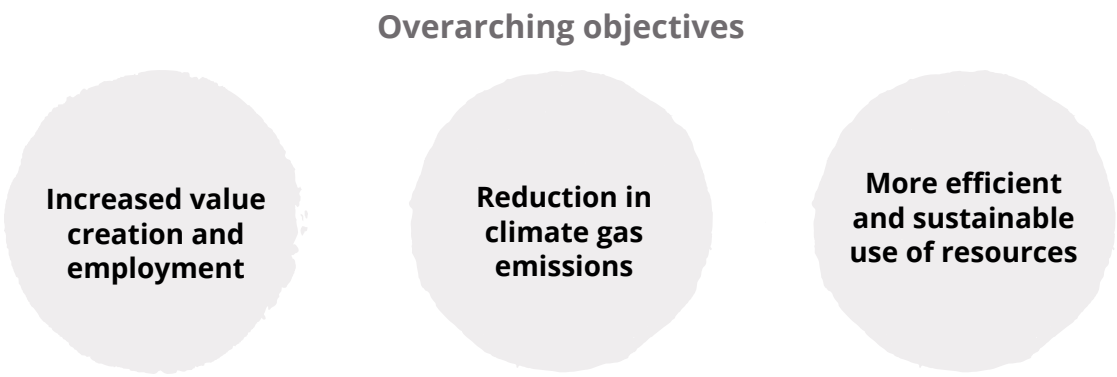
The SusValueWaste project analyses value chains within and between the various sectors of the bioeconomy. Waste from bio-industry and households have been expensive to get rid of, but now represents a valuable resource. Utilisation of these growing resources requires innovation, system changes and better adapted regulations and management. The project aims to identify new opportunities for the utilisation of such resources and to point out deficiencies and bottlenecks that require new policies and measures. Among the case-companies in the project are major players such as TINE, Carlsberg, Norilia, Lindum and Treklyngen. The project is led by the Nordic Institute for Studies in Innovation, Research and Education (NIFU) in close collaboration with research partners in Norway, Sweden and Denmark.

BIOSMART is a project that studies how a transition to a modern bioeconomy will require development across and between sectors, and may involve a number of changes in many different socio-technical systems from production to use. At the same time, the societal changes must be acceptable to the population. The project is a collaboration between SINTEF, NORUT, Norwegian Institute for Bioeconomy Research (Nibio), University of Oslo (UiO), Norwegian University of Science and Technology (NTNU) and the Centre for Rural Research Norway, in addition to a number of international partners. The project will carry out a comprehensive foresight analysis involving relevant stakeholders and players in the bioeconomy. An initial survey is involving 1,500 companies in agriculture, forestry, aquaculture, fisheries, industry and life sciences, and shall result in separate industry scenarios for bioeconomy development.

All three projects are funded by the Research Programme on Sustainable Innovation in Food and Bio-based Industries (Bionær) of the Research Council of Norway.

2
Objectives and focus areas

Foto: www.cambi.com



Collaboration across sectors, industries and disciplinary fields	• Increased collaboration within and between value chains • Increased interdisciplinarity and societal dialogue
Markets for renewable bio-based products	• Better information on bio-based products • Reduced market uncertainty
Efficient use and profitable processing of renewable biological resources	• Increased processing towards products with high returns • Increased use and reuse of resources
Sustainable production and extraction of renewable biological resources	• Increased profitable and sustainable production and extraction • Appropriate framework for sustainable production and extraction

Figure 1 - The strategy goals: The strategy has three overarching objectives which an intensified national effort within the bioeconomy will help trigger. To achieve these objectives, the efforts are to be concentrated around four focus areas. Each focus area has two sub-objectives.

Overarching objectives

A national initiative on bioeconomy shall contribute to increased value creation and a green shift in the economy by facilitating sustainable, efficient and profitable production, extraction and processing of renewable biological resources. The initiative is to promote value creation and employment, reduced climate gas emissions, and more efficient and sustainable use of renewable biological resources. Priority shall be given to measures that are believed to have a national effect on both value creation/employment and reduced climate gas emissions and/or more efficient and sustainable use of resources. It is a goal that the bioeconomy should be developed within a sustainable framework with an appropriate consideration for climate, biodiversity and other environmental, economic and social values.

Much of the potential for value creation in the bioeconomy lies in exploiting new knowledge and technology for more efficient use of resources and development of profitable products. Similarly, there is an untapped growth potential in exploiting synergies and develop-

ing new value chains across established industries, sectors and disciplines. On this basis, the initiative shall in particular advance knowledge and technology platforms capable of using renewable biological resources from several productions and with application in several industries[20]. Such generic knowledge and technology platforms may contribute to increased collaboration across sectors and lay the foundation for new knowledge-intensive and profitable commercial activities.

Focus areas

In order to promote development of a modern bioeconomy in Norway, the government will facilitate:

Collaboration across sectors, industries and disciplinary fields

Efficient use of resources, where waste and side streams from one value chain is used as a resource in another, will require new collaboration across established sectors, industries and disciplinary fields. Cross-collaboration is thus a prerequisite for the other focus areas. It is also important to allow for an effective societal dialogue on the desired development in this area. The government will therefore facilitate greater collaboration within and between bio-based value chains as well as increased interdisciplinarity and societal dialogue.

20) Recent examples of such platforms are biorefining, functional bioingredients, advanced biomaterials, biocatalysis, fermentation and decentralised bioenergy systems.

Markets for renewable bio-based products

An important prerequisite for value creation based on renewable biological resources is domestic/international markets that demand and value renewable bio-based products, for instance as an alternative to products based on fossil carbon. The government will facilitate this through better information on renewable bio-based products and reduced market uncertainty.

Efficient use and profitable processing of renewable biological resources

Key to the bioeconomy is more efficient use of renewable biological resources with a transition towards a more circular economy where waste is minimised and residual materials are optimally used. There is simultaneously a need for profitable processing and development of products providing high returns. On this basis, the government will both facilitate increased use and reuse of resources, and increased processing towards products with high returns.

Sustainable production and extraction of renewable biological resources

Increased use of renewable biological resources on a worldwide basis, including replacing fossil carbon, will require access to significant amounts of biomass. Norway has the potential for increased production and extraction of renewable biomass. Meanwhile, attention to climate, nature and biodiversity creates restrictions on how the increase can be implemented. The government will therefore facilitate increased profitable and sustainable production and extraction, and an appropriate framework for sustainable production and extraction of the renewable biological resources.

The world's largest Cambi plant for the production of biogas from sludge and waste, Washington DC. Photo: www.cambi.com

3
Collaboration across sectors, industries and disciplinary fields

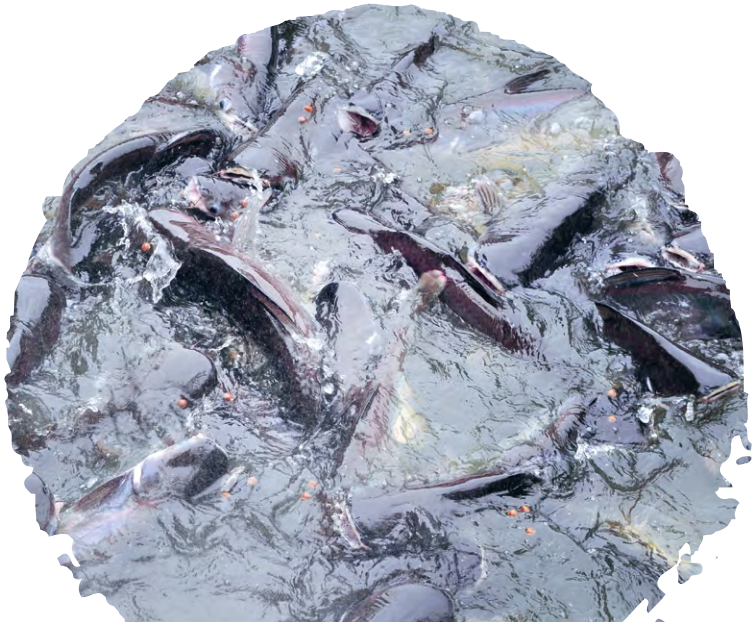


Photo top: Powdered fertiliser from fish sludge can contribute to the recycling of valuable phosphorus. Photo: Morten Lund/Åsen and Flatanger hatcheries. Photo bottom: The feeding of farmed fish. Limited access to marine oils creates the need to test new feed ingredients, including those based on cellulose. Photo: Thinkstock.

Much of the potential for increased value creation in a modern bioeconomy can be released through greater collaboration across industries, sectors and disciplinary fields.

Development and use of knowledge and technology make it possible to utilise the renewable biological resources more efficiently and profitably. In addition to this, transfer of knowledge, skills and technologies between disciplines, sectors and industries should be facilitated. Investments in interdisciplinary research and expertise is crucial to releasing the potential in this field. In the Government's Long-term plan for research and higher education, the bioeconomy has emerged as a key area for economic development based on key societal challenges.

Innovation and economic development in a modern bioeconomy presupposes the establishment of interaction between stakeholders in knowledge and technology development, raw material production and the processing industry, as well as collaboration between players within each of these groups. Together these groups represent a possible arena of national innovation, where dialogue and interaction between the groups and the market can create new opportunities. The transition to a more bio-based economy will be a broad society-altering process over the long-term, where the market and the consumers are key parts of the whole.

Development of new cross-sectoral value chains will be able to challenge established patterns of interaction and the public support system. The policy implementation system and related measures must facilitate cooperation and knowledge transfer. It is important that the various administration regimes for harvesting, processing and use of renewable biological resources support the development of bioeconomy and do not hinder interdisciplinary measures and collaboration. The responsibility for public instruments that are relevant to the different players is distributed among many ministries and subordinate agencies and enterprises. Various directorates are responsible for formulating regulations and their implementation in specific areas which often engage with each other across sectors. This requires cooperation as well as understanding of common challenges.

The government wishes to encourage collaboration across sectors, industries and disciplines through facilitating:

A. Increased collaboration within and between value chains
B. Increased interdisciplinarity and societal dialogue

A. Increased collaboration within and between value chains

Consideration of a value chain perspective is an important aspect of the bioeconomy, since each stage depends on the next for the resources to be utilised efficiently and profitably. This has amongst others become evident in the forest and timber industry, where profitability in the woodworking industry is challenged by weaker domestic demand for sawmill by-products from the wood processing industry.

The industry structure in the primary stage is characterised by many relatively small geographically dispersed entities. This can be a challenge for efficient production and advanced processing methods, which often require larger volumes. Increased collaboration between the players in the primary stage and with other stages of the value chain will help to optimise expertise, logistics and localisation. Some challenges have been solved, but business opportunities and jobs can be created across the country by mobilising and involving multiple entities.

Existing clusters have mainly been established within traditional sectors, similar topics and are geographically co-located, which can potentially impact existing commercial structures. The cluster solutions should increasingly encourage dialogue and innovation across disciplines as well as encourage flexible geographic solutions. The solutions must also include participation from international players.

New and established cluster projects within the bioeconomy

Aquatech Cluster in Central Norway is a cluster that builds on the results obtained through the ARENA clusters Technology akvArena and Smart Water Cluster. The cluster was the only new cluster in 2016 taken up in the Norwegian Centre of Expertise (NCE) cluster programme supported by Innovation Norway, SIVA and the Research Council of Norway. The cluster has a large resource base of more than 100 members, and develops and supplies world-leading technology for aquaculture food production, both domestically and internationally.

One of the four new projects taken up in Innovation Norway's cluster programme Arena in 2016 was established by the 46 players working within forestry having joined forces in the Arena Forest Industries in Trøndelag. Here we find larger companies which cooperate closely with small and medium-sized companies, public players and research and development communities. The project's main vision is to have a leading role in the development of the bioeconomy. In addition, five established clusters, including Blue Legasea Møre (cf. the box on marine ingredient industry in Chapter 1), have had their status extended as an Arena project in 2016.

Arena-Heidner in Hamar is a research-based industry cluster which had its status extended in 2015. The cluster consists of a world-leading research community in animal breeding, fertility and plant breeding which also focuses strongly on innovative solutions for feed production and utilisation of residual materials and waste. Other established Arena projects are Biotech-North in Troms that seeks to stimulate the development of an attractive and growing biotechnology industry, and Innovasjon Torskefisk (Innovation Cod Fish) centred mainly in Lofoten and Vesterålen which includes the entire value chain within the harvesting, processing and marketing of cod.

National research project

NorZymeD is a major research project focusing on the development of enzymes and enzymatic processes for biomass and value chains within lignocellulose from forestry and agriculture and marine by-products from fisheries and aquaculture. The project is led by the Norwegian University of Life Sciences (NMBU) and aims to develop enzyme technology that can help make industrial processing of biomass more efficient and environmentally friendly. The project is financed by the Research Council of Norway's Biotech 2021 programme, and combines the expertise in thermophilic enzymes in Bergen (University of Bergen and Uni Research) and cold-adapted enzymes in Tromsø (University of Tromsø), with the expertise from enzyme engineering and applied enzymology in Ås (NMBU), fermentation and screening facilities at SINTEF and structural characterisation in Tromsø. The project follows the entire value chain to industrial trials with participation from companies like Borregaard and Biomega. By linking enzyme development within two different value chains (green and blue), the goal is to generate significant synergies. Ethical, legal and societal aspects are addressed as well.

There is much to be gained from transfer of expertise between types of raw materials and sectors. The petroleum industry has expertise that can be used directly in the bioeconomy, including expertise related to offshore aquaculture facilities. Technological expertise in the oil and gas industry may also be essential to developing technology for carbon capture and storage related to the production of bioenergy. Similarly, there are opportunities for a transfer of expertise between companies in the marine sector and land-based industries. Chitin from prawn shells/crab and cellulose from wood/straw for example, are both sugar compounds that can be decomposed with related processes and enzymes, and there is little difference in exploiting protein from salmon waste and protein from chicken. Biotechnology will be

a common enabling knowledge base in many different processes and value chains, in everything from the development of new medicines to biorefining. In a more circular economy, development of new cross-sectoral value chains and knowledge-intensive products may require increased collaboration across disciplines and sectors. An example of this is closer collaboration between the food industry and health research for the development of health-promoting ingredients.

Development of new value chains across traditional sectorial boundaries can challenge established structures and requires proper coordination mechanisms in the public support system. When asked about deficiencies in public R&D support, companies provided feedback on weak links between research and industry (vertical links), and weak links between disciplines (horizontal links)[21]. The viewpoints regarding missing horizontal links between different themes at the same level, for instance in research, and vertical links between the different research phases and on to the markets, suggest the potential for improvements in the organisation of publicly funded research. Both the Research Council of Norway and Innovation Norway highlight the need and opportunities for better links between the various research programmes and grant schemes, both in the design of programmes, allocation of funding and the use of research results. Better organisation of R&D support can provide more economic benefit from the research funding.

The Research Council's bio-related programmes have had the tendency to grow larger in recent years. Also within the programmes, the projects are larger and more interdisciplinary. The programmes have experience with increased emphasis on interdisciplinary efforts and sustainability. Innovation Norway has found that the interaction between research and development and marketing activities has produced good results in relevant programmes. Such experiences can be further developed within a broader bioeconomy engagement.

21) Vista Analysis (2015/07): Framework conditions for bioeconomy in Norway.

To achieve effective flow and interaction, there may be a certain overlap in many contexts between the instruments of the Research Council of Norway and those of Innovation Norway[22]. The Research Council and Innovation Norway have different working methods and are in many ways complementary. The Research Council generally makes calls based on programme plans made in close cooperation with research and industry, as well as calls on innovation projects. Innovation Norway has consulting and dialogue-based processes. The Research Council's approach and work methodology ensure that the focus is on the best projects assessed in terms of quality and relevance. Innovation Norway can work from a somewhat broader basis to promote new business, see research and development in the context of market-oriented business and product development, and stimulate international partnerships where there is a need for technology import. At the same time, there is a potential for more interaction and awareness of differences in working methods and for developing better systems and cultures for cooperation.

Government policy

The development of a modern bioeconomy in Norway will require a greater degree of interaction and knowledge transfer within and between various bio-based value chains and industries, and between bio-industries and other industries. The current structure and interaction patterns will be challenged. Such a development will also challenge the organisation of the public support system. The government wants to develop and strengthen the links between the relevant instruments of the Research Council of Norway and Innovation Norway, and it will be considered how the support agencies' networking programmes can promote the development of new and cross-sectoral value chains. At the same time, the bio-based industries must become better at taking advantage of the possibilities that are in the public support system.

22) This applies in particular within "Technology Readiness Level (TRL)" 4 (testing and validation in a laboratory-like environment) and 5 (testing and validation in the relevant environment in which the technology is to be used). In the TRL system, a technology or a concept is classified according to a scale of nine steps that illustrate stages in the technology's maturity.

To promote increased cooperation within and between value chains, the focus will be on:

- Ensuring that support for networking activities and clusters promote the development of new and cross-sectoral value chains
- Increased coordination of project support along the entire value chain from research and development, innovation and market introduction
- Increased coordination across thematic priorities and sectors within relevant instruments in Innovation Norway and the Research Council of Norway

B. Increased interdisciplinarity and societal dialogue

The knowledge-based bioeconomy will to a large extent be based on competence and methods from the life sciences, but also build on chemistry, physics, materials science, information technology and engineering. In addition, synthetic biology creates new opportunities within microbial production, which increases the range of bio-based products. The need for diverse expertise within biorefining is a perfect example of this. In a typical biorefinery, there will be a need for collaboration between engineers, microbiologists, biotechnologists and chemists, nutritionists, material scientists and designers.

To identify market opportunities, expertise from several different disciplinary fields is needed - both process understanding, knowledge of what the raw material contains, technical skills, economic understanding and knowledge of consumers and customers. Equally important is to increase understanding of the social and economic impact of the development of a more bio-based economy at both the national and regional level.

Norway has a high degree of expertise in many areas that are key to the bioeconomy, including strong research communities within basic life sciences, technology and industrial processes, agricultural and forestry research, the marine sector and environmental impacts. It is particularly important to achieve better interaction between these areas of expertise. Closer collaboration and research at the intersection of food and health may, for example, be an important measure for strengthening the development within this area of industry in Norway, and giving rise to higher value products. It will be necessary to further develop our relevant research and innovation communities, including through interaction between land and sea-based industries and research communities, and stronger interaction with the health sector. The opportunities to develop research that cuts across the generic technology areas of biotechnology, ICT and nanotechnology must also be explored.

We must aspire to be the top international leader in some areas within the bioeconomy. This will lay the foundation for increased competitiveness and export of knowledge and technology, under the assumption that important national knowledge bases and nationally developed technology remain in Norway. National world-class expertise will also make Norwegian research and innovation communities attractive as international partners, which in turn will contribute to the consolidation and strengthening of the national knowledge base. We must also develop and maintain an adequate level of expertise within a broader spectre of the bioeconomy. This is important for taking advantage of the wide range of knowledge developed in other countries. Import of knowledge through project cooperation, retail and technology exchanges, etc. will be important.

Norway's tradition of collaboration between private and public players must be exploited and further developed within the bioeconomy. Effective dialogue between research and industry to identify research needs and ensure skills will be crucial. SINTEF, NOFIMA and other research institutes are highly competent in the industrial processing of bio-based raw materials. Fermentation, thermal processing and other industrial processes will have to be developed in close cooperation between the research communities at our universities, research institutes and the industry itself. An independent institute sector in close contact and cooperation with the private sector constitutes a national competitive advantage. In many areas, we also have close cooperation between the research institute sector and the higher education sector, while the latter sector has significant activity aimed at innovation and economic development.

Borregaard – world-class biorefinery

Borregaard has one of the world's most advanced biorefineries based on utilising wood. Borregaard has developed Exilva micro-fibrillated cellulose (MFC) since 2007 through research, pilot testing and in close cooperation with potential customers. The raw material is special cellulose which is split up into a complex network of fibrils in a custom-developed, proprietary technology. Exilva has unique properties with regard to viscosity, stabilisation and water-binding, as well as consistency. The product can be used in a variety of applications such as adhesives, detergents, cosmetics, composites and other industrial purposes, and as a replacement for petrochemical products. Borregaard is investing NOK 225 million in a full-scale commercial plant for the production of MFC in Sarpsborg, scheduled to begin in 2016. The Research Council of Norway and Innovation Norway have helped to finance the R&D project that is paving the way for the factory. The project builds on innovations both in terms of the product itself, the production process and the application opportunities.

The EU framework programme for research and innovation, Horizon 2020, is contributing about NOK 230 million to the focus on Exilva which is defined as a "flag-ship" technology of major European interest. The support comes from the "Bio-Based Industries Joint Undertaking" which is a collaboration between Horizon 2020 and European industry. The support will reduce the financial risks associated with the development and market introduction of new technologies in a commercial phase. In the project, Borregaard will lead a consortium of European companies and research institutions consisting of Ayming (France), Chim (Greece), KTH (Sweden), Unilever (UK) and Østfold Research (Norway). The support will cover up to 60% of project costs, up to EUR 25 million over three years, starting from 1 May 2016. The support will be reduced if the project makes a profit.

Training skilled candidates is the most important contribution provided by universities to value creation, innovation and societal benefit – this is also true for the bioeconomy. It is important that educational programmes are well connected to research and innovation and that they cooperate with relevant parties about the content of the curriculum. A national commitment to bioeconomy involves educational institutions ensuring educational programmes that are tailored to the needs within both established and new bioindustries, including biotechnology, advanced material and process technology. Increased interest in bioeconomy-related subjects should be stimulated.

New technology and new products can pose ethical, environmental and other societal challenges that require in-depth knowledge and consideration of these issues across disciplines. New areas of knowledge such as synthetic biology and digital life make up additional challenges, and the technological development is rapidly advancing in several biotechnology fields. It is important that we have both coordination and delineation in these new areas. It is also important that the different societal actors, including individuals, have the opportunity to present their views on developments in the bioeconomy.

A number of government agencies have been established over the past 20 years which provide advice to the authorities and conduct information activities relevant to the development of the bioeconomy. These include the Norwegian Biotechnology Advisory Board, Norwegian Technology Council, Norwegian Scientific Committee for Food Safety, the Norwegian National Research Ethics Committees and the Norwegian Council for Animal Ethics. These bodies have different roles, but have over time had partially overlapping mandates, while some responsibility areas are left partially uncovered. From a bioeconomy perspective, it is desirable to have a holistic approach where different disciplines, sectors and industries are seen in relation to each other. It should be considered whether the organisation of this advisory apparatus is optimal for developments within the bioeconomy, focusing on cross-sectoral coordination and institutional efficiency.

New centre initiatives within the bioeconomy

Bio4Fuels
The Norwegian University of Life Sciences (NMBU) is hosting and SINTEF is the director of a new centre for environment-friendly energy research (FME) to develop sustainable biofuels from Norwegian and Nordic forest resources. The centre will have a special focus on biorefining, where biofuel production is seen in relation to efficient use of side streams for the production of other valuable products. The other research partners include the Norwegian University of Science and Technology (NTNU), the Norwegian Institute for Bioeconomy Research (Nibio), the Paper and Fibre Institute (PFI), the University College of Southeast Norway (HSN) and the Institute for Energy Technology (IFE). Numerous Norwegian user partners are participating in the centre, in addition to several foreign research and industrial players.

Foods of Norway is a centre for research-driven innovation (SFI) which is led by the Norwegian University of Life Sciences (NMBU). The centre has five international academic partners from Europe, Australia and the United States, and 18 industrial and innovation partners with high expertise in both green and blue sectors. Foods of Norway develops protein-rich feed ingredients based on trees, macro-algae and chicken, pig and fish by-products using biorefining. Tests are performed to find out how the new feed ingredients affect the production animals and the quality of the food products, and aspects of sustainability are evaluated. The centre also develops new methods to measure feed efficiency that can be used in breeding.

Government policy

Norway has a well-developed education, research and innovation system, which is characterised by a historically close cooperation between many different players with different roles. The emergence of a modern bioeconomy will require cooperation to an even greater degree between players who already interact today, but also across established patterns of interaction. The knowledge institutions themselves have an important role in assessing whether and how the bioeconomy should affect the organisation of their own institutions and cooperative activities. The establishment of the NOFIMA and the Norwegian Institute for Bioeconomy Research (NIBIO) are examples of appropriate consolidation of national research institutions in this field. The government is committed to increased consolidation and cooperation reflecting, to the extent possible, the cross-sectoral nature of the bioeconomy by encouraging interaction across the entire width of the Norwegian bioeconomy. This will help to ensure knowledge transfer and growth impulses across established disciplines and value chains. Much of the knowledge is developed in research-intensive communities abroad, and it will therefore be important that the institutions be involved in international cooperation in the field of bioeconomy.

The government may in turn have an important facilitative role for increased cooperation across the institutions' own structures and arenas, and across disciplinary and national boundaries. For example, binding cooperation between research institutions and enterprises can be stimulated through time-limited centre initiatives[23] that contribute to concentrated and long-term research efforts at a high international level.

23) Recent examples are the Centres for Research-based Innovation (SFI) and the Centres for Environment-friendly Energy Research (FME).

The government also has a role in stimulating the development of knowledge and increased societal dialogue on professional and ethical issues related to the development of a modern bioeconomy.

To foster greater interdisciplinary efforts and societal dialogue, the focus will be on:

- Ensuring that the support of research centres promotes binding, sectoral and interdisciplinary cooperation between research institutions, suppliers and product developers
- Encouraging international R&D cooperation of relevance to the bioeconomy, including Norwegian participation in relevant parts of the EU framework programme for research and innovation and bilateral cooperation with selected countries
- Utilising Norwegian participation in the OECD and other international policy developing organisations to meet the knowledge needs that are highlighted in this strategy
- Reviewing the organisation of advisory bodies linked to bioeconomy, focusing on cross-sectoral coordination, institutional efficiency and effective societal dialogue

Table 2: A selection of national knowledge institutions within the bioeconomy field	
Institution	**Expertise**
Cicero	Research, analysis, advice and information on climate-related issues
Norwegian Institute of Public Health	Food safety, drinking water, environmental health, communicable diseases, antibiotic resistance, diet and nutrition
Fridtjof Nansen Institute	Biodiversity conservation
GenØk	National biosafety centre. Environmental, health and social consequences of the use of biotechnology and gene technology
Institute of Marine Research	Mapping and monitoring, resource research, ecosystem processes in sea and coastal areas as a basis for aquaculture, fisheries and other marine-related industries
Hedmark University College	Biomass processing, applied ecology, agriculture/agricultural technology
Sogn og Fjordane University College	Renewable energy, landscape planning, climate change management
University College of Southeast Norway	Bioenergy, sludge treatment, fisheries, ecotoxicology, biofuels
Institute for Energy Technology	Renewable energy systems, complex materials
Iris	Fermentation, reactor technology, environment mapping
Møre Research	Biomass processing, biorefining, macroalgae
Norwegian Institute of Bioeconomy Research	Plant health, biotechnology, environment and resources, forests, uncultivated land, agricultural and food production, economics, social sciences
National Institute of Nutrition and Seafood Research	Safe and healthy seafood, monitoring of undesirable substances in fish and fish feed, the nutritional needs
Nordic Institute for Studies in Innovation, Research and Education	Statistics, analysis, innovation, research and education studies
Norwegian Institute for Nature Research	Research and consulting in land use, industrial and social development based on natural resources, management of biological resources, harvesting and sustainable use of fish and wildlife populations, the environmental impact of human activity and disturbances to the environment
Norwegian Institute for Water Research	Aquatic environment: climate effects, biodiversity and pollutants.
Norwegian Institute of Food, Fisheries and Aquaculture Research	Bioprocessing, breeding, genetics, nutrition, feed technology, fish health, production biology, seafood, process technology, consumer and market research, food and health, raw material, sensorics, food safety
Nordland Research Institute	Sustainable growth and exploitation of natural resources
Northern University	Environment, resource management, climate and social responsibility, aquaculture

Table 2: A selection of national knowledge institutions within the bioeconomy field	
Institution	**Expertise**
Norwegian University of Life Sciences	Enzymes, fermentation, biomass processing, genomics, agriculture and plant science, forestry, livestock production incl. health and welfare, aquaculture, resource economics, natural resource management
Norwegian University of Science and Technology	Biomass processing, fermentation, metabolic networks, biological diversity and ecosystem services, environmental and sustainability analysis, land use, life sciences
Norwegian Polar Institute	Research, environmental monitoring and environmental surveys in the polar regions, climate, pollution, ecosystem processes and biodiversity
Norwegian Centre for Rural Research	Rural sociology, communities, resource management, business development, local government and regional development
Norwegian Institute of Wood Technology	Characteristics, preparation, production processes and the use of wood
Northern Research Institute	Technology and social sciences, with particular expertise in the northern regions
Paper and Fibre Institute	Wood fibre, pulp, paper, new bio-based materials, biofuels
SINTEF Energy	Bioenergy, energy efficiency, waste management and recycling
SINTEF Fisheries and Aquaculture	Utilisation of renewable marine resources, fishing, aquaculture and processing
SINTEF Materials and Chemistry	Biomass processing, fermentation, reactor technology, metabolic networks, biorefining, biopolymers, circular economy
Uni Research	Bioinformatics, protein, microalgae and biobanking, optimal assessment and use of energy resources, health and quality of life
University of Agder	Innovation, research and education studies
University of Bergen	Marine research, climate, seafood and health, aquaculture, fish diseases, marine biology, marine microbiology
University of Oslo	Life sciences
University of Tromsø	Biomass Processing, enzymes, metagenomics, bioprospecting
Western Norway Research Institute	Renewable energy, biofuels, energy technology, industrial ecology
Norwegian Veterinary Institute	Food safety, feed safety, animal health, animal welfare, antibiotics, immunology
Østfold Research	Energy and waste resources, life-cycle assessment, circular economy

4
Markets for renewable bio-based products

Photo top: Omega-3 capsules. Photo: Thinkstock.
Photo bottom: Wooden ceilings at the Breheim Centre, Jostedalsbreen National Park. Photo: Lone Ross Gobakken/NIBIO.

Profitable and innovative industrial communities that develop products the markets demand are an important prerequisite for the successful development of the bioeconomy. In most cases, Norway represents a limited market. Access to international markets and a profitable bio-based industry is important for commercial activity to be competitive.

An international development where renewable biological resources are increasingly used as a substitute for fossil resources could affect many traditional value chains and create new supplier-customer relationships. Although many bio-based markets are still immature, there is already strong competition for future positions within the new value chains. Such international developments create new opportunities in terms of markets and value creation which are important for Norway to address.

The bioeconomy includes many different markets, some of which are well-established, such as food, paper and woodworking products, while others are qualitatively new products or products that will compete directly as a substitute for identical petroleum products. These three market types, ie. established products, new products and products that replace petroleum products, follow a different logic and different criteria for success.

The traditional industry already has a market. The challenge for the companies is to acquire updated knowledge of market trends and translate this knowledge into profitable and competitive business strategies and products. This applies to the food industry where an important trend is a focus on nutrition, food safety and sustainable production. It also applies to the forest and timber industry where developments in market conditions for the Norwegian paper industry have led to a surplus of timber that is not suitable for use in the current woodworking industry. If the market demands greater use of wood in construction, it will be a great potential for the development of the woodworking industry.

The market can be a major challenge for new products or new ways of utilising bio-based products. Examples of new products may be new types of bioplastics and composites, while an example of new applications is the use of wood in long spans, tall buildings etc. There will be many barriers to entry associated with the use in existing production lines. Another part of this market is associated with high value products created in small volumes for niche markets. Here we find for example ingredients for health foods, micro-cellulose for PC monitors or spider silk for bulletproof vests. These are advanced products with high development costs where the competitive position is often secured through patents.

Challenges related to changing established processes and product specifications, with implications for approvals and established customer relationships, lead many to choose a strategy where a petroleum-based chemical building block is replaced by an identical building block from renewable biological raw materials. Use of such biochemicals makes it possible to gradually increase the proportion of biological raw materials in the end product. The market for this type of product is price sensitive and directly follows developments in the oil price.

The government will facilitate the development of the various markets for renewable bio-based products through:

A. Better information on renewable bio-based products
B. Reduced market uncertainty for renewable bio-based products

A. Better information on renewable bio-based products

A pre-requisite for well-functioning markets is access to full information about products and prices. Within the bioeconomy, the investors' lack of information about properties, market potentials and profitability of the new products in the research and development phase has been noted in particular[24]. For new products, there's also the challenge of revealing new information to consumers. For example, a lack of documentation and lack of standardisation may result in wood not being the preferred material for many projects. If consumers do not have access to information such as how much energy can be saved with the use of new energy sources and technologies, health benefits of new food items, the environmental impact and product properties of new materials, it may prevent profitable investment and beneficial gains for consumers. Relevant measures will be to raise the awareness of various societal actors including investors and consumers through publicly funded information campaigns, the educational system and effective labelling. Life cycle analyses should be used to emphasise climate and environmental impacts where relevant.

Government policy

For market participants to gain awareness of testing and commercialisation opportunities, there must be sufficient vertical communication from research and development to the market and back to research. Similarly, there must be sufficient horizontal communication so that other areas of development can benefit from new research. It is also important that the public have factual information about societal benefits, the environmental impact and risks of new technologies to create acceptance and markets for products that can provide better utilisation of society's resources.

Relevant measures could be to strengthen the companies' expertise on international trends and customer needs so that the product is best suited to market trends. In the outset, such measures relates to knowledge transfer, but also design and product development, marketing communications and innovation with regard to business model and customer segment. The government may also contribute to the development of standards and requirements for product descriptions, as well as documentation of research effects, on the climate and the environment etc. Such measures will minimise the risks and uncertainties related to product characteristics and opportunities and thereby lead to bio-based solutions becoming easier to choose. Use of existing instruments such as companies' knowledge and information requirements in the Environmental Information Act and reporting requirement on climate and environmental impact in the Accounting Act can also contribute to the dissemination of information.

Important target groups for information are decision-makers in the public and private sectors, financial communities, architects, consulting engineers, contractors, suppliers and consumers. To identify which areas have the greatest need for an improved flow of information, it is necessary to examine the individual bio-industries and especially in the link between research and the market.

24) Vista Analysis (2015/07): Framework conditions for bioeconomy in Norway.

To promote better information about renewable bio-based products, the focus will be on:

- Knowledge and information on market opportunities, technologies, processes and products that enable efficient, profitable and sustainable production and utilisation of renewable biological resources
- Considering the use of standards, labelling and certification of renewable bio-based products where appropriate, to clarify the benefits of bio-based products
- Developing the knowledge base on the climate impact of increased utilisation of bio-based alternatives to fossil-based materials and chemicals

B. Reduced market uncertainty

In addition to for the promotion of skills development and information dissemination, the government can promote the demand for renewable bio-based products through active market stimulation, i.e., direct measures to increase profitability and thus reduce market risk so that industry turns the investments in the desired direction. A main reason for this may be a desire to promote activities that support change toward a low-carbon economy. In such cases, measures should be targeted and limited in time. Sustained financial support does not create longevity and new jobs. Support depending on political decisions can also be perceived as an additional risk factor for investors. The most effective policy to promote fossil-free solutions would be to associate a cost with those products that pollute. In Norway, the use of almost all fossil products are either taxed or included in the quota system.

The lack of information about new products may in turn lead to a lack of risk capital. The market uncertainty is greater for new products than for known and established products, and it is difficult to obtain risk capital for investments in full-scale plants. There may be different reasons for the lack of investment capital in different phases of the innovation chain and it could vary between different parts of the bioeconomy (food, feed, materials, ingredients, bioenergy etc.). Expectations from financial or industrial capital can also be different. A fundamental challenge in the bioeconomy may be that the returns are lower than what is socioeconomically ideal. Globally, it is a market failure that the price of climate and environmentally harmful emissions related to production and transport are not fully included in the equation. If such a market failure is not corrected, it could prevent the development and market uptake of new bio-based products and therefore willingness to invest. Lack of investment capital may also occur because many bio-based value chains need to be developed as a system where profitability depends on factors upstream (e.g., raw material production) and downstream (e.g., income from side streams) that investors have limited control over[25].

As regards the production and extraction of new resources, there may also be challenges in the current concession regulations and administration plans. In the new marine bioindustries, for example, there is a perceived need for updated administration plans related to new use of marine resources, concession rules that govern the use of resources and production, health documentation of new products, and more flexibility with regard to rules for vessel design so that operators can easily land the marine raw materials[26].

25) For example, the production of cellulose sugars for feed or fuel production will require that saw-wood is produced and extracted for processing. This stimulates extraction of pulpwood (a material that to a large extent has gone to paper production in the past) that is made available for processing in a biorefinery. The same applies to the marine field. Trends in technology and automation that contribute to increased breeding of fish will increase access to valuable residual material.

26) Vista Analysis (2015/07): Framework conditions for the bioeconomy in Norway.

There may also be trade barriers for the development of the bioeconomy, for example, when the industry needs to deal with tariff protection and legislation on food safety in various export markets.

The bioindustries are facing different barriers that may lead to market failure. Several of these, however, are barriers that are not necessarily specific to the bioindustries but common to multiple industries, albeit at varying degrees and in particular related to the development and market introduction of new products.

Government policy

Cross-sectoral economic instruments in the form of fees on emissions and participation in the EU emissions trading system are the main instruments in Norwegian climate policy. In line with this, socio-economically appropriate pricing of production and consumption that are harmful to the climate is considered to be the most effective starting point to stimulate the development and use of renewable bio-based products. If climate gas emissions are appropriately priced through taxes, regulations or quota system, the social costs of reduced emissions can be minimised. The price of emissions should initially be set equal to the marginal damage cost. Climate change is a global problem and requires international cooperation. To solve the problem of climate change, there should ideally be a cost associated with all emissions and the cost must increase over time. Today, around 10-15 percent of global emissions are subject to a fee. Policy development in this area must therefore look to developments in the EU and internationally.

Standards, agreements and subsidies are used to reduce emissions in addition to quotas, fees and regulations. Public procurement practices could also contribute to more climate-friendly solutions.

The government has implemented several measures to increase value creation in the Norwegian economy through increased access to capital and infrastructure support. The government is focusing on nationwide and broadly oriented schemes to ensure that support is given to the best projects with the greatest potential for value creation and socioeconomic impact, regardless of industry. If these projects meets the quality criteria and parts of the financing is covered by private investors, projects within the bioeconomy will also be able to receive funding through these schemes. The government proposes to strengthen several of the national schemes and this will also improve access to capital for bioeconomy projects. Beyond this, the government proposes to allow for investments in mature unlisted companies within Investinor's forest mandate. The government is also proposing to create a new investment company aiming to help reduce climate gas emissions, as a follow-up to the request decision by the Storting to prepare the establishment of a Fornybar AS (a publicly funded investment company) in renewables[27].

27) In Recommendation 2 S (2015-2016), Parliament adopted on 3 December 2015 request no. 69, "Parliament requests the government to prepare the establishment of Fornybar AS ("Green fund"). The fund together with the private sector shall be able to invest in companies that develop and use green technology such as renewable energy, hydrogen, energy storage, transport solutions with low climate impact, reduction, removal, transport and storage of CO_2, energy efficient industrial processes, and arranged so that the company is expected to provide a market return over time. Parliament asks the government to examine how such a company can made operational with regard to investment mandate, organisation, budgeting and whether it will have a catalyst effect on this type of investment in light of existing instruments and whether such investments should be limited to Norway or have a global mandate, and be elaborated in the revised national budget 2016. It is intended that the fund over time will have total assets of NOK 20 billion".

To promote a reduction in market uncertainty, the focus will be on:

- Establishing a new investment company which will contribute to the reduction of climate gas emissions
- Allowing Investinor to be able to invest in mature unlisted companies within the earmarked funds for the forest and timber industry
- Strengthening Innovation Norway´s innovation loan scheme, enabling them to increase lending to investment projects related to start-up companies, innovation, adaptation, internationalisation and development, and where there is little private risk capital available
- Continuing the bioenergy initiative through the Bioenergy Programme and Enova
- Ensuring a public procurement practise contributing to the reduction of environmentally degrading effects and an advancement of climate friendly solutions, where relevant, which includes taking life cycle costs into consideration
- The public sector being a role model and motivator for environmentally friendly building solutions
- Scaling up the general turnover requirement for biofuel for roadgoing traffic, and the advanced biofuel part of this, until 2020
- International cooperation and agreements at the government level
- Placing new bioproducts in adequate categories in customs tariffs and trade agreements

5

Efficient use and profitable processing of renewable biological resources

Photo top: Biotep national facility for test processing of biological raw material, Kaldfjord. Photo: Jon Are Berg Jacobsen/Nofima.
Photo bottom: The biotechnology company Regenics AS uses residual material in the form of unfertilised salmon eggs from the breeding company AquaGen for the development of a wound healing product (against burns and frostbite). Source: Regenics AS, Oslo.

The development of a modern bioeconomy should be based on certain principles that ensure optimal use of renewable biological resources. The principles should be viewed as ambitions for gradual developments over time, and not as requirements in all phases of a development process.

In the outset, a well-functioning open market economy will favour the most profitable use of the raw materials. For limited resources, it can be a challenge if products covering basic needs such as food are to compete with more profitable products. A first principle of optimal use of renewable biological resources, therefore, is that the population's basic needs for food must come first. This means that increased demand for biomass should not be to the detriment of necessary food production.

A second principle for optimal use of renewable biological resources is to facilitate a more circular economy where the various components of the biological resources are used in the most efficient manner and where waste and side streams from a single value chain can be used as a resource in another. This includes biological resources being made available for further utilisation, and that as much of the quality as possible is maintained so that the raw material's full potential can be used. In a circular economy, the value chains will no longer be linear, but increasingly intertwined.

A third principle is that the renewable biological resources should be used in the most profitable manner. As a high-cost country, Norway should increase the proportion of processing in the production and development of products that yield high returns. Market participants should consider alternative value chains where the greatest possible amount of the various biomass fractions are used for products with the greatest earnings. In order to achieve such a development, long-term investments and preparations must occur in parallel with the short term. Companies should continuously optimise the balance between the various products within all the value chains.

The government will promote efficient use and profitable processing of renewable biological resources by ensuring:

A. Increased processing towards products with high returns
B. Increased use and reuse of resources

A. Increased processing towards products with high returns

Norway has a high level of industrial, technological and environmental expertise in areas such as petroleum and other energy production, wood processing and construction industries, aquaculture, fisheries, maritime activities, crop production and processing, animal breeding and production, and in the food processing industry. This forms a solid basis for pursuing the development of new bio-based products and industries. The challenge is to maintain profitable value chains, while a higher proportion can be developed towards more knowledge-intensive products with higher returns. It is at the intersection of the traditional value chains and modern application of biotechnology, nanotechnology and ICT, that the bioeconomy has its greatest potential for development. Furthermore, it is essential for Norway to allow for the flow of expertise, processes, technologies and innovations across the established sectors.

New knowledge, automation and biorefining processes are needed to increase the use and value of the raw materials and to reduce waste throughout the value chain. This applies to both raw materials from the sea and land. New technology and market-oriented product development are essential to increase processing for consumer products. In many cases, processes and industrial infrastructure for processing will be the same and the challenge is more in terms of adapting a generic technology base for the different types of raw materials used.

There has been a structural change in the processing of land-based food production in recent years in the

form of fewer and larger plants with higher capacity. This promotes increased productivity and development of new value chains. Improved manufacturing processes and improved utilisation of biomass from agriculture have been part of this development. Use of residual materials in agriculture and the land-based food industry is also growing along with increased production of ingredients and chemicals. Quite a few companies in the industry are developing new products, but there is a need for increased interaction between companies and research related to innovation and knowledge. A commitment to the development of niche products where the consumers' willingness to pay is high can yield high returns without climate gas emissions increasing accordingly. In biogas, Norway has leading technology for both small and large scale plants. Through anaerobic fermentation it will be possible to produce methane from all types of organic waste, including manure or sludge from closed aquaculture facilities.

A geographical spread of aquaculture facilities and the fishing fleet and processing plants provides an advantage with regard to freshness and a quick transfer to the processing stage. In parts of the fishing fleet, the geographical spread simultaneously provides challenges in terms of limited volumes and scale disadvantages, which in particular affects technically advanced processing of residual material. The growth of the aquaculture industry has had an impact on the development of associated sectors based on advanced knowledge in feed, breeding, marine biology and medicine, technology and other knowledge services related to aquaculture. There is growing interest in more advanced use of residual materials, and in recent years more efficient and advanced small-scale processes have been developed to preserve and process residual materials on board and locally where fish is landed. Access to fresh residual material is considered an advantage for this industry, and there has been a development of strong clusters in this area e.g., in Sunnmøre.

Global health trends (such as functional food) have helped develop strong knowledge-based industrial communities in Norway in advanced processing and refining of bio-based raw materials, characterised by rapid innovation and increased value creation. Within the marine industry, a number of companies that have built up a solid business related to marine raw materials have been sold to large foreign companies[28]. This development illustrates a great potential and also shows how difficult it is for small and medium companies to reach international markets. In addition to developing omega-3 products and alginates, research and development work is occurring in a number of fields where both proteins and other marine biochemicals based on residual materials can give rise to new businesses. This research has a broad application area (feed, pharmaceuticals and health foods, cosmetics, biomaterials, bioenergy, etc.).

Useful genes or other biochemical substances are sought in land and sea organisms through bioprospecting, where the goal can be increasing the value creation of residual material or developing new products from an untapped resource. The development of new bioactive compounds or enzymes can create a new knowledge-based industry. The value creation can be extremely high, but it often requires long development times and expertise in chemistry, biotechnology and the market. Meanwhile, a high degree of risk is involved and Norway has a limited number of industrial communities that can commercialise this type of product, such as in medicine.

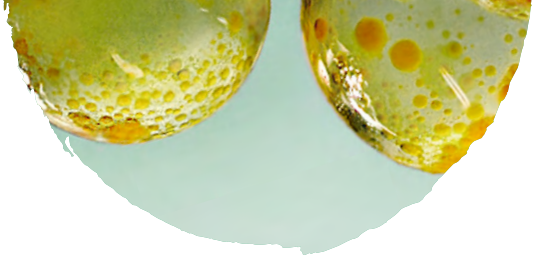
28) FMC Health and Nutrition (formerly FMC Biopolymer) in Haugesund, is one of the world's leading producers of alginate and harvests 150,000 tonnes of giant kelp along the Norwegian coast. They are in the process of developing into a full marine biorefinery with a growing portfolio of advanced products from super thin sausage skins for medical 3D printing of new organs. Other Norwegian examples are Bjørge BioMarine, acquired by Firmenich, Pronova which was acquired by BASF and Ewos which was acquired by Cargill.

Products based on marine residual materials

Nutrimar AS
Nutrimar AS is a Norwegian-based biomarine company that processes fresh residual materials from amongst others salmon from Salmar's processing plant, InnovaMar. They produce high-quality oil, protein concentrate and flour from fresh salmon raw material, and they supply products for pets, livestock and aquaculture. The company participates in development projects in both feed ingredients and human applications. Nutrimar is owned by Kverva AS, which also owns Salmar. The company is located in Frøya. Nutrimar currently has 21 employees, three of whom are working on innovation. Nutrimar's goal is to be a leader in processing technology and product development, and the company collaborates within research, innovation and with other partners internationally.

FMC Health and Nutrition
FMC Corporation was established in Norway through FMC Health and Nutrition and Epax Norway AS, both of which are part of the FMC Health and Nutrition division. FMC is a global supplier of natural ingredients for use in food, pharmaceuticals and biomedicine. Production of alginate from seaweed and kelp occurs at FMC Biopolymer's factory in Haugesund, while Epax produces high quality omega-3 oils in Ålesund. NovaMatrix in Sandvika, west of Oslo, develops and manufactures biomedical products based on alginate and other biopolymers. The operations in Norway have an extensive cooperation with universities and partners worldwide. FMC has been conducting research and development of products from giant kelp at the international level for over 65 years in Norway. Extraction of alginate from seaweed and kelp is a global industry, with significant competition including from Asia. FMC has harvested giant kelp for alginate production along the Norwegian coast for over 50 years, and currently harvests from Rogaland to Nord-Trøndelag.

Biotec Pharmacon
Biotec Pharmacon is a biopharmaceutical company that develops and manufactures new immunomodulatory products and cold-adapted marine enzymes. The company focuses on new and effective solutions for use in wound treatment, cancer therapy and prevention of other immune-related diseases, with the goal of becoming a leading provider of new enzymes for use in diagnostics and genomics. The company's is headquarter is in Tromsø and it is divided into two subsidiaries; Biotec Beta-Glucan and ArcticZymes. Biotec Pharmacon is also connected to BioTech North, which is a biotechnological collection of companies and organisations.



The logging of Norwegian forests for industrial purposes has for a number of years been between 8 and 11 million m^3. The part of the timber known as sawtimber is used for wood products and building materials, while the part known as pulpwood is used for paper, cellulose, chemicals and energy. The by-products, such as wood chips from sawmills, are included as raw material in other wood processing or is used for heat production. In the timber industry, Norway is regarded as a global leader in the development of large wooden structures. In 2015, the world's tallest (until recently) wooden building opened in Bergen, and the world's largest bridge constructions in wood have also been developed in Norway. The wood processing company Borregaard represents one of the most fully integrated biorefineries with a range of high-value niche products based on forest raw material. Using its own market-oriented research, development and innovation, the company has built a unique expertise and competitive edge in advanced chemistry on a global level. In paper production, companies such as Norske Skog have in-demand paper qualities based on long-fibre Norwegian spruce. Although the markets for paper production are undergoing major changes, this area represents a long Norwegian industrial tradition that can bridge the gap towards new biorefining.

Norwegian companies that establish a strong technology base and business activities based on local raw materials will be well-positioned to use raw materials outside Norway. Such an expansion is illustrated by Borregaard and their role as market leader in the use of lignin at factories in a number of countries.

Government policy

The government will contribute to a predictable and competitive framework that facilitates investment for the future, both in existing companies and in new businesses. In respect of this, the government will present a White Paper on the industry's framework conditions. The report will discuss important trends for the companies and look at how industrial policy can help promote effective adaptability, increased sustainability and continued high competitiveness in Norwegian industry. A solid resource base, sustainable management and efficient transport from raw material producers to industry are some important conditions for the competitiveness of the processing industry. The development of the bioeconomy will require a commitment from the larger firms which have the market access and power to industrialise new processes and products. Regional authorities will be able to influence the creation of new manufacturing industries, such as new biorefineries, through their policies in administration, concessions, land and infrastructure plans. School, education and culture will be another very important area for attracting relevant expertise in both technology and the market.

In order to promote industrial processing of renewable biological resources Innovation Norway should ensure the best possible coordination between relevant instruments, including the Biorefining Programme, which is aimed at testing and validating technology, and the Environmental Technology Scheme, which is aimed at demonstration and prototype development. Beyond this, the government will present proposals for aligning general support for investments in testing and demonstration facilities that more companies and research communities can share as part of the White Paper on the industry's framework conditions in spring 2017. The Research Council also has a number of schemes relevant to increased investment in the industrial processing of renewable biological resources, including Biotech 2021, Research Programme on Sustainable Innovation in Food and Bio-based Industries (Bionær), the Aquaculture Programme, Programme for User-driven Research-based Innovation (BIA) and the focus on advanced manufacturing processes. The government proposes to strengthen the commitment to bioeconomy-related research and development. The focus on industrial processing should be strengthened within the relevant schemes, and efforts should be cross-coordinated.

To promote increased processing towards products with high returns, the focus will be on:

- Allocating funds to investments in test and demonstration facilities that can be shared by several companies and R&D institutions
- Strengthening the focus on bioeconomy-related R&D in the Research Council of Norway
- Coordinating relevant public instruments promoting industrial processing within the Research Council of Norway and Innovation Norway
- Proposing a separate scheme for improving bottlenecks which hamper efficient transport of timber, in cooperation with the forest and timber industry, which is to be elaborated on in the National Transport Plan for 2018-2029

B. Increased use and reuse of resources

A profitable circular economy assumes that the markets have been developed and regulations adapted to such production. It is useful to distinguish between the potential that can be extracted in the short term, and what is necessary for the long term in order to fully use the potential of a circular economy. An effective use in today's markets means that one also takes into account the cost of preserving and using the raw material, as compared to the value it provides in the market and the prevailing prices of alternative raw materials. Meanwhile, development of the bioeconomy, in terms of expertise, technology, implementation, markets and social acceptance could quickly change the current assumptions of what is an efficient and profitable use.

Norway is an elongated country with many small and medium sized manufacturers, which means that the access to raw materials will vary from large to small quantities and be spread over relatively large distances. Infrastructure which ensures that the raw materials are preserved and can be further used, adapted to regional challenges and advantages, is therefore important to ensure profitability. A circular economy can only succeed if all stages are profitable. This requires that the various value chains be seen in context and interact with the aim of ensuring utilisation of the raw material. Harvesting, logistics, processing and product design which preserve the quality and original properties of the raw material increase the possibility of reuse and recycling, and provide such a basis for increased profitability.

Innovative utilisation of residual raw materials

Biovotec AS
Biovotec AS is developing a product that enables wounds to heal faster and gets chronic wounds to heal at a cost that will be competitive with similar products in the current market. In a BIA project supported by the Research Council of Norway, the company, together with national and international research partners, has demonstrated that eggshell membrane contains wound-healing properties. The raw material is separated from eggshells at Nortura's egg hatching facility in Revetal in Vestfold. The membrane on the inside of the shell is separated from the calcium and Biovotec uses its patented process to activate the substances in the membrane so that they can be used in wound healing. The company will conduct clinical trials on patients under a project funded by the EU. The support from the EU is EUR 1.3 million for the 2015-2017 project period. Globally, there are currently around 20 million people greatly suffering as a result of chronic wounds. This method can solve a major problem in health care, and could become a trendsetter in wound care. The partners are Finesse Medical in Ireland and NOFIMA AS. The goal is to reach the market in 2018.

Food that has been produced should primarily be used for human consumption. The grocery sector and food industry have estimated that about 360 000 tonnes of food is thrown away annually in Norway, which represents both a major environ-

mental impact and economic value[29]. It is estimated that it is ten times more climate-efficient to focus on and prevent food waste from occurring than to handle it in the most environmental and resource-efficient way through the production of biogas for energy purposes[30]. It is therefore a goal to prevent and reduce food waste across the entire food value chain from primary production to the consumer. This has been established both in the national waste strategy from 2013 and in the agreement of intent between five ministries and the food industry from 2015, followed up with a more binding negotiated agreement for optimal use of resources throughout the value chain.

The meat and poultry industry annually produces 220,000 tonnes of residual material which is used in other product flows and markets. It goes to food items, high value ingredients, health food products and for medicinal purposes, as well as products such as animal feed, bioenergy, fertiliser and bio-oils. The waste in the fruit and vegetable industry varies between product groups[31]. Some of the raw material is used for purposes such as aquavit, production of flavourings for the food industry etc. In addition, livestock manure, corn husks and straw are resources which can be included in the production of biogas. However, today's energy prices and subsidies make the production less profitable. An important prerequisite for increased use of residual materials for such purposes is sufficient market demand and profitability in the further use of the residual material.

Extensive closures in the pulp and paper industry have led to a situation where 40% of the timber that is harvested from forests annually is exported directly without any form of further processing. Furthermore, weak domestic demand for wood chips, which is a residual product of the woodworking industry, has led to profitability challenges for the sawmills. Branches, tops and bark constitute significant amounts of biomass in addition to the timber that is logged in Norwegian forests. These are mostly left behind in the forest. This means that there is a significant surplus of raw material from the forest, both in the form of untapped roundwood, but also in the form of residual material from the industry.

In 2015, more than 890,000 tonnes of residual material was produced by fisheries and aquaculture, of which approximately 75% was utilised. Close to 220,000 tonnes of residual material was identified, of which 163,000 tonnes of residual material from whitefish[32], which is not used because the fish is gutted or processed on board the boats and the residual products are not landed. This is partly due to capacity problems on board the vessels. Several new boats are being built with equipment for on-board ensiling[33] because it provides profitability. An increase in the degree of processing of salmon, pelagic fish and whitefish, including through automated filleting, will provide increased access to raw materials for the marine ingredient industry. Through the Norwegian Fishery and Aquaculture Industry Research Fund (FHF), the industry has now launched its own initiative to increase automation and thus the further processing of mackerel in Norway[34].

Sludge from aquaculture facilities is an untapped resource. Based on several factors, the amount of such sludge is expected to increase significantly in

29) Waste in primary production and the catering sector is not included in this figure.

30) Østfoldforskning AS (2009): "Food waste and packaging - what are the possible correlations."

31) Examples: carrots 26%, potatoes 15%, onions 13%. Ref. Identifying food waste in primary production, Nordic Council of Ministers, TemaNord 2013: 581.

32) In addition to blood from farmed fish, as well as shells from prawns and crabs.

33) Ensiling is a technology for the preservation of residual raw materials.

34) The Fishery Industry Research Fund has initiated a partnership between industry and policy instruments and established an initiative called Pelagic Lift to increase the processing of mackerel.

the future[35]. Approximately 9,000 tonnes of phosphorus is discharged annually into the sea from aquaculture pens located at sea. This corresponds approximately to the total amount of phosphorus currently used in mineral fertilisers in agriculture. Regulating the use of sludge from hatcheries on land occurs through fertiliser product regulations which are currently under revision and may have implications for the application in the form of possible stricter quality requirements on the fertiliser. With closed facilities at sea, production of large smolt on land and land-based fish production, opportunities are opening up for an increased degree of purification and collection of sludge from the production, but investment costs are considerable.

Waste prevention, material recovery, biological treatment and incineration of waste provide emissions reductions through the production and use of new raw materials and reduction in number of products, and through the energy in the waste replacing other energy production with greater climate gas emissions. In the waste strategy, food waste, construction waste, packaging waste, textiles and electrical and electronic waste (WEEE) are highlighted as areas with great potential for waste prevention. In order for greater portions of the organic waste to go to biological treatment and to play an important role in a future bioeconomy, this waste must be made available for biological treatment. Increased use of biogas for energy purposes and increased use of organic fertiliser and compost from biological treatment are relevant measures that will lead to reduced emissions. There are also opportunities for better use of available resources in the wastewater sector. Another measure that can contribute to climate gas reduction in the waste sector is to convert various types of biological and organic waste into biochar that can be utilised for soil conditioning. Biochar is quite resistant to biological decomposition, and thereby reduces the amount of carbon emitted from the terrestrial environment.

35) 1) a general growth in the industry provides more sludge from hatchery facilities, 2) the interest for the production of post-smolt up to 1 kg on land, 3) the development of closed facilities in the sea with the possibility of collecting sludge 4) regulatory changes have allowed for the charge-free permits for production of fish of salmon in land based fish farms.

Government policy

The government wants to ensure increased profitability in the bio-based value chains by increased use of all raw materials, side streams and residual products from manufacturing and use of biomass from products that can no longer be used for its original purpose. There is a need for development of technology which enables recovery and recycling of energy and material resources from a wide range of residual raw materials and waste. There is also a need for more knowledge about processing and handling of infective agents and environmental toxins, allowing more of the raw material to be used in the new cycle and for better paying markets. Hazardous chemicals and other extraneous matter can be persistent and will accumulate to undesirable levels if they are not removed from the cycle when the resources are recovered and circulated.

To promote increased use and reuse of renewable biological resources, the focus will be on:

- Developing a White Paper on waste policy and the circular economy
- Developing a strategy for landing and use of residual waste from the fisheries
- Stimulating increased use of life cycle analysis in relevant areas
- Ensuring increased knowledge and development of technology for the recycling of biomass in manufacturing, including the reduction of unwanted substances, such as extraneous matter, environmental toxins and infective agents
- Revising fertiliser regulations and ensuring increased use of organic fertilisers/sludge, including regulations for depositing, storage and spreading
- Increased use of residual materials to make profitable products
- Ongoing evaluation of relevant regulations to ensure efficient use of resources

6
Sustainable production and extraction of renewable biological resources

Photo top: Birch forest. Photo: Thinkstock.
Photo bottom: Algaes. Photo: Ragnar Våga Pedersen/Nibio.

Population growth and changes in eating habits towards more resource and energy-intensive diets in parts of the world are leading to a need for increased food production. Together with the increased use of renewable biological resources, including replacing fossil carbon, this will require access to significant amounts of biological resources worldwide. There will also be a need for a much more efficient and smart use of biological resources, including what is today considered as waste.

A lack of renewable biological resources will be a limiting factor for the emergence of the bioeconomy in large parts of the world. For Norway, however, access to significant biomass resources can be a decisive factor for being able to exploit the value creation potential within the bioeconomy. Norway also has the tradition, knowledge and expertise to utilise and manage our natural resources.

The potential for increased production and harvesting must be exploited within sustainable boundaries. Knowledge-based management must be built on realistic estimates related to how much can be harvested from the resources we have available and take into account the protection of biodiversity and functioning ecosystems, climate gas emissions in short and longer time scales and changes in natural carbon storages. Moreover, the impact on production from climate change must be considered. Climate change can affect species composition and habitats, both in the sea and on land. This can provide both opportunities and limitations with regard to species, volume and harvesting areas.

The government will promote sustainable production and extraction of renewable biological resources by facilitating:

A. Increased profitable and sustainable production and extraction
B. Appropriate framework for sustainable production and extraction

A. Increased profitable and sustainable production and extraction

Norway has the right of possession and proximity to major biomass resources. We have sea areas that make Norway the world's tenth largest country in area if one includes the sea areas. In a global context, the resources from land and forests represent somewhat limited volumes. However, the forest resources in Norway have a lower utilisation rate than most other countries to which it is naturally compared. The development of a modern bioeconomy will also create the need for adjustment of production towards new types of biomass, harvesting methods, processing and storage, etc.

Increased extraction of bioresources for new processes and new production

In a modern bioeconomy, the resource base is broader than the physical biomass that can be harvested and that arises from the processing and use of it. Developments in the enabling technologies (biotechnology, nanotechnology and ICT) allow us to use a far wider range of renewable biological resources as a basis for advanced products than we managed to do only a few years ago. Biological resources in the form of cell cultures, microorganisms, insects, etc., are available and attractive in a bioeconomy context. Already today, enzymes, drugs, nutrients, fine chemicals and more are produced using specially-designed organisms and processes. The natural biodiversity is in itself an essential resource for bioprospecting. It is assumed that there are about 55,000 species in Norway[36], and so far about 44,000 have been registered and named. Within these species, there is a large biochemical diversity in terms of genes and other biochemical substances with potential commercial applications. In some cases, the final product will be the result of sophisticated processing of biomass and require a continuous supply of raw material. In other cases, the final product is created artificially and completely independent of the original raw material using

36) Excluding bacteria and viruses.

chemicals and/or gene technology. Norway is also an international leader in the fields of livestock breeding, such as salmon, pigs and cattle. New gene technologies will be able to contribute to the development of new production organisms and better breeding for food production and security.

Blue-green interaction within genetics and breeding

Norway has a 30-year history of cooperation and technology transfer between the green and blue sectors. The firms Geno, Norsvin and AquaGen have developed competitive breeding material which is in demand in the international market. The firms have laid the foundation for progress in breeding and new and innovative biotechnology companies. Cryogenetics AS, which was established by Geno SA, develops effective freezing technologies for milk that enhances the reproduction of fish and preserve the fish genes. Cryogenetics had at the end of 2015 approximately 90 clients on four continents, from aquaculture companies such as Marine Harvest and Lerøy, breeding companies such as AquaGen and SalmoBreed, medical research groups such as Boston Children's Hospital, and public agencies like the Environment Agency and the Veterinary Institute. Cryogenetics manages the world's largest gene bank for cold water fish. Here more than 200 salmon stocks are stored from Norwegian rivers along the coast in the form of frozen milk. The freezing methods have been established through expertise transferred from Geno. SpermVital AS is another biotechnology company originating from the breeding community in Hamar. They have developed a technology that provides an extended time frame for the insemination of cattle by combining knowledge of cell biology and the use of alginate from kelp. The technology which was first introduced in 2010 already has patents in 40 countries.

Increased production and extraction from agriculture

There are limited exports of Norwegian agricultural products, and the production volume in agriculture is therefore determined mainly by the demand in the domestic market in addition to natural conditions. The government aims to increase production in Norwegian agriculture and in particular wants increased production where there is a shortfall of Norwegian goods. Most of the biomass production of cultivated land is well-utilised with current production volumes. In recent years, there has also been a slight reduction in total agricultural land. To reach the goal of increased sustainable production, it is important to limit the decline in cultivated land, while taking advantage of existing land as efficiently as possible. Norway also has favourable opportunities for better utilisation of pastures and meadows. Food production brings with it a number of valuable renewable resources which should be exploited to a greater extent for profitable products.

Precision agriculture

Precision agriculture through the use of such things as robotic weed removal, spraying and fertilisation reduces costs, reduces environmental impact and can provide higher returns. Precision agriculture is a strategic priority for both the research community and for suppliers of equipment for agriculture. Many farmers have adopted sensor technology to optimise the production process. This helps to reduce the cost of fertiliser and pesticides as well as higher returns and better quality. Fertilisation is made more precise in terms of quantity, where on the field nutrients need to be added, and the optimal time for fertilisation. In addition to optimised production, this technology is environmentally friendly because the plants are only fertilised with the amount they absorb and utilise. Climate gas emissions and pollution are thereby reduced.

Increased production and extraction from the forest

In a European context, Norway currently has a low rate of forest resource logging and a high proportion of unused forest biomass, with a total standing volume of about 900 million m^3 and an annual growth of approximately 25 million m^3. Only 35-40% of growth or around 10 million m^3 per year is logged for industrial purposes[37]. The forest is a renewable resource. Access to forest raw materials depends on investments in forestry production, natural conditions and the profitability in the forestry. Due to the fact that logging for a number of years has been significantly lower than growth, it is possible to increase logging within environmentally acceptable limits, where respect for biodiversity and other ecosystem services from forests are safeguarded. In addition to the timber, there are additional biomass fractions from forestry that are currently only utilised to a limited extent. Fertilisation of the forest is the measure that may lead to the fastest increase in production, while plant breeding, denser and faster planting after logging and planting of new areas will increase the production and availability of forest biomass in the long term.

Increased production and extraction from the sea

Norway is well-positioned in terms of production of food and other resources from the sea. The harvesting potential of the commercially important stocks in the sea is almost fully utilised. The possibilities for increased extraction are related to the harvesting of species at lower trophic levels, or other species that are currently not being properly utilised, increased aquaculture production including farming of new species, and increased access to the residual material. Organisms at lower trophic levels are in the mesopelagic zone of the oceans, which are the open water masses between 200 and 1,000 metres, and include crustaceans such as copepod and krill, mesopelagic fish such as lantern fish, squid, jellyfish and zooplankton. Crustaceans such as copepod are an attractive resource that should be considered for exploitation for commercial purposes within an ecologically sustainable framework[38]. More mesopelagic species may also have a potential as feed for farmed fish or as food products or other ingredients[39]. There are no complete estimates of how much "untapped" biomass is to be found in Norwegian waters, but the potential must be characterised as significant. An opportunity range is illustrated in Figure 2, where it appears, that for example the annual production of calanus species (including copepods) in the Norwegian Sea is almost double the world's total fisheries and aquaculture production. At the same time, a better understanding of the potential for and consequences of harvesting at lower trophic levels and harvesting of others, underutilised species still need to be established.

37) In addition, there is an extraction of 2-3 million m^3 annually with logging and other forest biomass for private use, so that the total extraction is about 50% of the growth.

38) Harvesting of copepods has occurred in a limited way in Norway for decades. Since 2003, copepod fishing has been carried out under a trial license granted to the firm Calanus AS which annually has been able to harvest up to 1,000 tonnes of copepods.

39) Currently almost no direct fishing for mesopelagic species is carried out, but individual shipping companies have shown interest in trying. Knowledge about the harvesting of mesopelagic species is limited and it would thus be appropriate to have a gradual approach that balances the need for increased knowledge while some fishing is allowed.

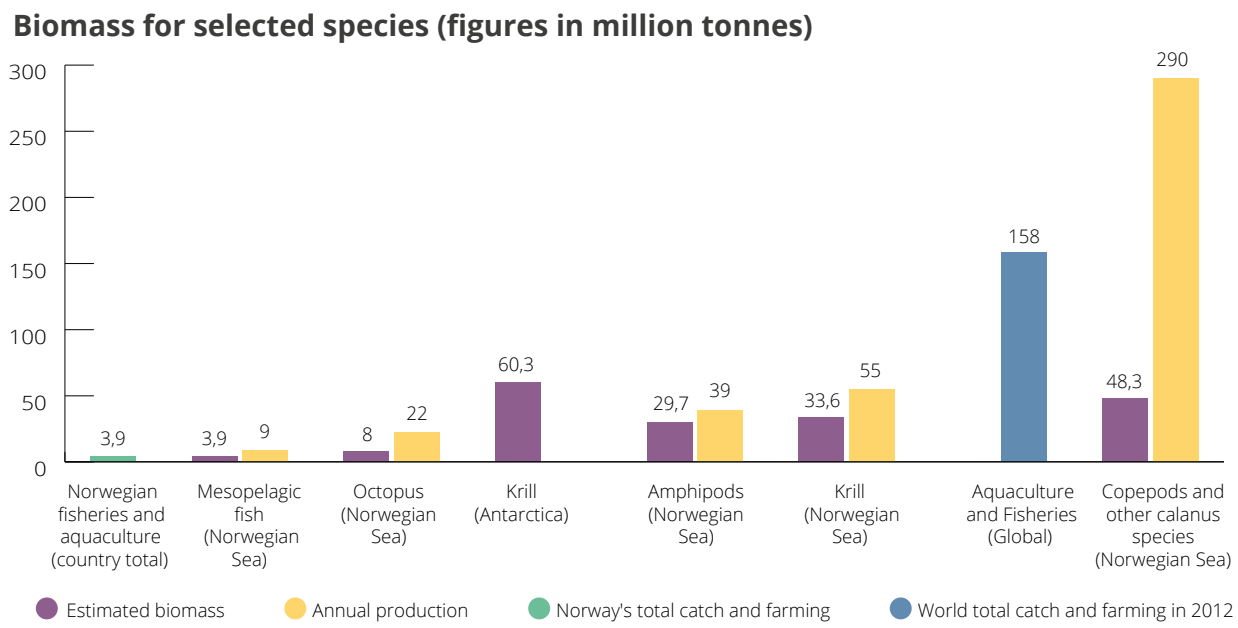


Figure 2: Overview of biomass estimates for selected species/areas. Source: Directorate of Fisheries (2016), Institute of Marine Research (2016), FAO (2014), Skjoldal HR (2004).

Seaweed Energy Solutions AS

Seaweed Energy Solutions (SES) is among the key players in aquaculture of kelp and has been assigned two localities of 320 and 330 decares (Frøya). Originally, the company was cultivating kelp for biofuel production and has completed major technology projects aimed at bioenergy, including together with Statoil. In recent years, there has been a huge increase in interest in kelp as a raw material in a variety of high value markets, and the company now sees opportunities for commercialisation in the short term in applications such as food (kelp contains the fifth flavour, umami), feed, fertiliser and for use in pharmaceuticals and cosmetics.

The company is developing an industrial method for cultivation of kelp which is compatible with the Norwegian cost level. The cycle means that seedlings of kelp are produced on land in the autumn, and placed out in large networks that are arranged vertically in the sea in winter, and harvested after five, six months. In 2015, the company harvested its first major crop at its plant outside Frøya of around 100 tonnes and is working on processing and product development in markets such as food and salmon feed. SES currently has seven employees who primarily work on research and development. SES both carries out and participates in research and innovation projects co-financed by the Research Council, Innovation Norway and the European Union (Eurostar) in collaboration with researchers from, among others, SINTEF, NTNU and NMBU. The company also has a partnership with the aquaculture industry. When kelp is grown near aquaculture facilities, the kelp can utilise the nutrient salts and faeces from fish as fertiliser which will in turn both solve a pollution problem and increase profitability in the production of kelp.

The greatest resource challenge for further growth in the aquaculture industry will likely be associated with access to feed resources, particularly marine resources. Norway has a large feed industry, but much of the raw materials (soy, corn, vegetable oils, fish meal and fish oils) are imported. The supply of marine oils is currently limited and may be a challenge for increasing salmon production and maintaining high quality salmon. It will therefore be important to develop new feed ingredients and sources of omega-3 for salmon feed, such as by harvesting from low trophic marine species, cultivation of macro- and microalgae, fermentation of cellulose sugar, methane or CO_2. In multitrophic aquaculture, different species are produced adjacent to each other with the purpose of the species achieving mutual benefits. A current example for Norway will be the production of salmon in conjunction with the production of mussels and kelp. In such a system, the discharge of nutrients and organic matter from fish farming will be nutrition for mussels and kelp. The potential for growth in the cultivation of macroalgae is regarded as significant[40], with applications such as food, feed, nutrients, chemicals and energy. The Gulf Stream brings nutrient salts which lead to a sizeable production capability of seaweed and kelp in Norwegian waters. As of 2015, 26 licenses for aquaculture of seaweed have been granted which can potentially provide an output of approximately 10,000 tonnes. Meanwhile increased utilisation of seaweed and kelp creates increased needs for knowledge, including related to food safety.

Government policy

Future value creation based on renewable biological resources from land and sea will require proper resource management.

Norway has large forest resources and there is considerable potential to increase logging and access to raw materials for the industry within environmentally acceptable boundaries. The government wants to facilitate increased logging of forests within sustainable boundaries. Improvements of infrastructure for forest management and efficient transport of timber to industry contribute to increased profitability in the industry. Other key areas to strengthen the industry's competitiveness are research and development, better organisation and planning and a more rational ownership structure. Likewise, measures to increase production in forestry could provide greater growth and a greater resource base in the long term.

The government is planning to intensify forestry where increased logging etc. is combined with strengthened protection of environmental considerations.

The government has presented its policy in this area in a separate white paper on the forest and timber industry. The report has a value chain perspective, and assumes that the forest and timber industry can play an important role in the future bioeconomy.

The government aims to increase production from Norwegian agriculture and will pursue an agricultural policy that encourages sustainable production across the country. The past two years, the government has implemented a number of simplifications and changes in grant schemes to help increase and streamline production. The government has also changed the concession limits so that producers can better exploit the farm's resources. Efforts to increase production efficiency in agriculture will continue in the next agricultural negotiations and will form the basis for the forthcoming white paper on the agricultural industry. Research and development on the genetic potential of plants and animals through processing and breeding efforts can help increase food production, lower emissions and better resource utilisation.

In the same way as legislation and administration gave us ownership of oil resources in the North Sea in the 1960's and 1970's, proper national and local administration of our renewable natural resources in the sea will be a prerequisite for future value creation to be beneficial to everyone. Both public administration and industry applying for permits for extraction, harvesting and other related measures are in need of knowledge and competence, and those needs will increase as a result of the cultivation and harvesting of several species. Continuous efforts are made to adapt legislation making it easier for new participants to invest in and develop new fisheries. The government will

40) A report from DKNVS/NTVA estimates that four million tonnes will be able to be cultivated in 2030 with an area requirement of 2,500 km2. By cultivating macroalgae in the same area as salmon farming today (800 km2) it will be possible to produce 470,000 tonnes of bioethanol.

maintain the activity requirement, but will maintain the activity requirement exemption that facilitates an appropriate development of new biomarine activity[41].

Available productive areas in the coastal zone are and have been one of Norway's most important competitive advantages as an aquaculture nation. Access to good aquaculture locations has however become a scarcity factor for sustainable development of the aquaculture industry, while it is a prerequisite for further growth in the industry. Over the long term and within sustainable boundaries, it is therefore necessary to allocate more area for aquaculture, and optimise the use of already allocated areas. New installations for farming at sea can also help ensure that new areas are appropriate for aquaculture activities. The municipalities through their planning allocate space for aquaculture activities in coastal areas within the framework of national guidelines on local government and regional planning[42]. Further development of the locality structure of the aquaculture industry will be a long term effort that requires both increased acquisition of knowledge and an increased degree of area planning across municipal and county boundaries.

The Nature Diversity Act and the Marine Resources Act provide the ability to regulate extractions for bioprospecting. It is important to facilitate the ability of research and industry to extract biological material from Norwegian nature in connection with bioprospecting, while ensuring that this takes place within sustainable boundaries.

To promote increased profitable production and extraction of renewable biological resources, the focus will be on:

- Exploiting the potential for increased profitability and more efficient production and extraction of renewable biomass from agriculture, forestry, fisheries and aquaculture within sustainable boundaries
- Knowledge-based restructuring of production towards new types of biomass, harvesting methods, processing, storage etc.
- Following up forestry measures in the climate agreement to increase the forest carbon storage and the availability of environmentally friendly raw materials and construction materials
- Working to ensure that forest resources are safeguarded and developed through active silviculture and plant breeding
- Further developing the forest road network through targeted use of grants and the Forestry Fund, while safeguarding biodiversity and recreation in the outdoors
- Increased use of Norwegian ingredients in the production of feed and other intermediate goods when it is profitable and environmentally sustainable
- Further developing the regulatory and administrative regime and strengthening the knowledge base, cultivation, harvesting and exploitation of macroalgae
- Developing a bioprospecting regulation which facilitates the ability of research and business to extract biological material from Norwegian nature within sustainable boundaries
- Increased knowledge acquisition and planning of area use across municipal and county boundaries for further development of the locality structure within aquaculture
- Increased utilisation of marine species, through facilitating multitrophic aquaculture, establishing a management plan for copepods, and considering a licensing scheme for mesopelagic fish

41) The Participation Act § 6 requires that one must have operated commercial fishing or catching on or with a Norwegian vessel for at least three of the last five years, and continue to be connected to the fishing profession, to get a commercial permit and thus own a vessel to be used for commercial fishing or catching. This is referred to as the activity requirement. There is an exemption from the activity requirement for vessels under 15 meters. The ministry may also in special cases, in light of commercial and regional considerations, make exceptions to this activity requirement by individual decision.

42) White paper no. 22 (2015-2016) Newly elected regions - role, structure and tasks.

B. Appropriate framework for sustainable production and extraction

A continued growth in production and extraction of renewable biological resources will have to be within sustainable boundaries where consideration of environmental values, as well as social and economic sustainability, are assessed and addressed. At the same time, all production and extraction have environmental consequences. Production and extraction of renewable biological resources must be done within the framework of the national climate change goals. For biodiversity, this entails that ecosystems must be in good condition and deliver ecosystem services, and that endangered nature is safeguarded. This requires prudent and long-term management of the resources at our disposal, and enhanced knowledge of negative environmental impacts and how these can be kept within sustainable boundaries. It is also important that sustainability be sufficiently incorporated in the development of technology and new solutions.

Sustainable framework for the production and extraction from agriculture

To ensure that the population today and in future generations have access to enough healthy and safe food, agriculture must have a long-term commitment to conservation and sustainable use of land and resources. Through methods of sustainable production, agriculture shall help to reduce pollution and climate gas emissions, facilitate increased binding of climate gas emissions and ensure adjustment of production to the changing climate conditions. The main strategies for reducing climate gas emissions from the agricultural sector will be linked to changes in consumption and composition of food consumption, and reduction in emissions within the same production volume through optimised production[43]. In addition, efforts must be made to reduce CO_2 emissions from soil and fossil energy in agriculture. The climate challenges in the agricultural sector are complex and there is evidence of significant knowledge needs. Use of new knowledge and technology will be key to reducing the climate impact from agriculture.

Sustainable framework for the production and extraction from the forest

Forestry is production and harvesting of a renewable resource. Measures should always be undertaken to ensure that new forest grows after harvesting so that the forest' production capability can be exploited over the long term. Nearly half of the endangered plant species live exclusively or partially in forests. In areas where forestry is operated, ecosystems and biodiversity are affected, and sustainability is a fundamental prerequisite both in the Forestry Act and the Nature Diversity Act. The regulations set the framework for forestry activities in all areas where forestry is allowed. Based on the Forestry Act and associated sustainability regulations and the forestry environmental certification through Norwegian PEFC Forest Standard, a comprehensive system of environmental considerations in forestry is established. The system includes resource and environmental monitoring, forestry planning with environmental registrations, regulations on sustainable forestry, regulations on road construction and the regeneration obligation, subsidies for environmental measures in the forestry, updated resource and environmental data for forestry planning and research on forest resources and environmental considerations. Effective trade-offs between industry initiatives and environmental concerns are important, and any increased activity in the forestry must be combined with stronger environmental considerations through the active use of the measures in the Nature Diversity Act and the forestry's own measures.

43) Ref. the climate report 'Agriculture and climate change ", which was delivered on 19 February 2016.

Sustainable framework for production and extraction from the sea

Norwegian coastal and sea areas constitute an important production area for healthy and safe food. Both globally and domestically, it is therefore essential to ensure clean and productive seas. The government wants to facilitate further growth of aquaculture. An important prerequisite for growth in aquaculture is a solution for the current challenges related to environmental effects and disease. The government believes that environmental sustainability should be the main prerequisite for government-regulated growth in the aquaculture industry in line with the Storting's consideration of Meld. St. 16 (2014-2015) - Predictable and environmentally sustainable growth in Norwegian salmon and trout farming. Development of new technology for closed facilities in the sea will be able to help reduce the environmental impact of aquaculture (escapes, sea lice), but will also lead to increased energy consumption. Meanwhile closed facilities in sea create opportunities for collecting and utilising sludge from the production. When it comes to cultivation of new species such as macroalgae, it is important to have an effective system for the identification and management of potential area-use conflicts with established aquaculture, fisheries, maritime and outdoor activities. There is also a need for increased knowledge about how large-scale cultivation of macroalgae could affect the marine ecosystems.

Government policy

Production and extraction of biological resources are regulated under the Pollution Control Act, Planning and Building Act, Genetic Resource Act and sectoral regulations such as the Land Act, the Forestry Act, the Wildlife Act, Aquaculture Act and the Marine Resources Act in conjunction with the Nature Diversity Act. The weight of provisions will vary according to how much nature is affected, how valuable this nature is, and what other social considerations the nature shall be weighed against etc. A challenge for Norwegian environmental management is that, except for the ecosystems in coastal and freshwater areas and to some extent the oceans, there are no specific and agreed upon objectives for which condition is to be achieved in the ecosystems. This leads to different perceptions of the need for action and how various considerations should be weighed against each other. The Climate and Environment Ministry will therefore clarify what is meant by "good ecological condition" based on scientific and verifiable criteria. The government will then by the end of 2017 set objectives for the condition to be maintained or achieved in Norwegian ecosystems. The aim is to have a management based on defined objectives for the ecological condition in place by 2020.

Agriculture, forestry, fisheries and aquaculture can affect environmental values. Therefore, the government has placed great emphasis on developing solutions and systems that counteract negative impacts on important environmental values, and a number of measures have already been implemented. Proper mapping of biodiversity and other environmental values is a prerequisite for effective management which is particularly important for a more intensive exploitation of forest and marine resources.

To promote a good framework for sustainable production and extraction, efforts will be directed towards:

- Developing knowledge on how environmental impacts of increased production and extraction of bioresources can be kept within sustainable boundaries
- Appropriate management of potential area conflicts between the cultivation of new species and established aquaculture, fisheries, marine and outdoor activities
- Expertise enhancement in industries with respect to efficient, climate-smart and sustainable production and extraction
- Developing the interaction between public instruments and private environmental considerations, with the aim of increased knowledge and strengthened environmental considerations in sustainable forestry
- Mapping the location of old forests to ensure sound management, and together with the forest industry investigate the most appropriate measures for increased protection of key biotopes, cf. the Government White Paper No. 6 (2016–17) - Values in growth

7
Implementation and follow-up

The bioeconomy includes several industries and application areas. A strengthened national effort within the bioeconomy shall both promote sustainable adjustment and competitiveness in established bioindustries, and promote the development of entirely new commercial activities by exploiting synergies across established structures and patterns of interaction. This must also be reflected in the development strategies of the various players within the bioeconomy.

The government's strategy provides guidelines for public efforts to promote development within the bioeconomy. Several of the current instruments that are relevant to the bioeconomy are oriented towards the needs within individual industries and individual segments of the value chains. In line with the guidelines in this strategy, the overall instrument portfolio should as far as possible encourage synergies across established sectors, industries and disciplines, and have a holistic approach to different stages in the value chain.

As a follow-up and specification of the strategy's overall guidelines, the Research Council of Norway, Innovation Norway and Siva shall prepare a joint action plan. The plan shall (i) include proposals for better structuring and coordination between relevant instruments within and across the agencies, (ii) ensure an appropriate balance in instruments for R&D, demonstration, pilot and scale-up, market orientation and internationalisation, (iii) provide the basis for knowledge transfer and cross-learning, and (iv) provide a platform for effective implementation and joint dialogue with industry and research. The plan is to be implemented within the existing budgetary frames.

The higher education institutions shall train a competent and in-demand workforce to meet the needs of Norwegian industry. It is therefore important that the academic studies are sufficiently oriented towards the future and designed in a way that reflects the importance of the bioeconomy. At the same time, they are, along with other players in the public sector and the institute sector, responsible for the long-term development of basic knowledge of relevance to the bioeconomy. The research institutes perform much of the applied research and constitute an important link between the basic knowledge communities, industry and the public sector. Industry involvement is crucial for the realisation of the strategy's objectives. The public support agencies shall be important facilitators, but the companies themselves are responsible for ensuring their own innovation and profitability. All those involved in the development of the bioeconomy have a responsibility to contribute to a responsible development in the area, including an effective societal dialogue.

The strategy's timeframe is ten years, with a revision assessment after five years.

Appendix 1: Status of the Norwegian bioeconomy

Primary Industries

Agriculture

In Norway, there are about 42,000 agricultural holdings which total 45,900 full-time equivalents. Only 3% of the Norwegian land mass is farmland and in 2015, the total area in operation was 9.85 million decares.

The global food situation must be applied when future food production in Norway is assessed. Statistics Norway estimates that the number of inhabitants in Norway will increase by 20% over the next 20 years. In the government's announced white paper on the agricultural industry, a plan will be presented with targets for increased food production based on Norwegian resources. At present, the self-sufficiency rate in Norway is approximately 50% measured in energy[44]. There must be boundaries for food production that contributes to climate gas emissions.

Internationally, the main trend has been increased efficiency and returns through industrialised farming methods. In Norway, a goal of nationwide agriculture and the topographical and geographical conditions have lead to a somewhat different use structure. At the same time, technological developments in agriculture have resulted in a substantial growth in volume and productivity. Moreover, Norwegian agriculture has focused on animal welfare, and animal and plant health through balanced breeding goals.

Norway imports large amount of agricultural products, and in 2015, the import value was NOK 59.1 billion. Imports consist largely of goods for which the conditions do not exist to produce in Norway, and are therefore largely imported duty free. In 2015, a full 79% of imports were duty-free. Although goods produced in Norway are relatively protected, there has also been a significant increase in imports of such goods, such as fish feed, cheese, cereal and pastries, as well as processed foods.

Companies that produce processed products such as yogurt, chocolate, baked goods, etc., are exposed to greater competition from imports. The reason is that tariff protection is only granted for the agricultural raw materials used in these finished goods, while they face full competition in the processing or industrial stage. Exports have increased in recent years and are at over NOK 9 billion. The EU is Norway's most important trading partner for agricultural goods.

The advantages in Norwegian agriculture are good quality, good plant and animal health, restrictive use of pesticides and low consumption of antibiotics. This is important for cost-effective and sustainable food production, and for the food industry to process the raw materials into high quality foods. The challenges in agriculture are to maintain and strengthen the current advantages, and to increase production. In addition to input factors such as climate-adapted plant material, soil improvement and new feed ingredients, developments in knowledge and technology will be central to ensuring sustainable and efficient production in agriculture.

Forestry

Norway has considerable forest resources. Forest and other wooded area amounts to about 14 million hectares or about 43% of the land mass. In the past 100 years, the rate of forest growth increased by about 150%, from just over 10 million m^3 per year to over 25 million m^3 in 2015. In the same period, existing volume increased from 300 million m^3 to 900 million m^3. Meanwhile, the total annual logging in Norway for industrial purposes, for home use and wood have been around 8 to 11 million m^3 of timber since the 1920's. In

44) The self-sufficiency rate is consistently high for animal products, close to 100% of meat (when we disregard that some of the feed is imported), eggs and milk, but clearly lower and falling for plant products. From 2005 to 2013, this was reduced from 52 to 47%, mainly due to reduced food grain production.

recent years, the logging has increased. Forest owners sold a total of 10.2 million m^3 of timber for industrial purposes in 2015. In addition, there has been an extraction of 2-3 million m^3 annually of timber and wood for private use, so that the extraction in 2015 amounted to about 50% of the growth. As a result of the logging during the entire period being lower than the growth, forests have grown older and the amount of biomass in Norwegian forests has tripled during the same period.

The Norwegian forest industry is fully exposed to international competition and the global market consequently establishes the basis for the entire forestry sector from the primary stage to the final product. The main objectives of raw material production will be sufficient volume of the right quality at a competitive price.

Sustainable forestry provides the basis for wealth creation based on renewable resources. Meanwhile, the forest is a habitat for a large biodiversity and a source of outdoor recreation, enjoyment of nature and economic activity based on natural assets and resources. In today's forestry, extraction of resources must always be followed by the renewal of the forest. It should always be ensured that new forest is planted after harvesting so that the forest's production capability can be exploited over the long-term. Virtually all forest operations in Norway is subject to environmental certification.

More than half of the timber felled in Norway goes to the Norwegian woodworking and wood processing industry. In recent years, the closure of a number of pulp and paper mills in Southern Norway has led to reduced demand for pulpwood and by-products from the woodworking industry. This is a challenge for profitability throughout the value chain. Norway has quickly gone from importing large volumes of wood for its own national wood processing industry to becoming a net exporter of wood. About 40% of all logging is exported, mostly to Sweden and Germany.

Fisheries and aquaculture

The Norwegian fishing industry is one of the world's most modern, with a well-developed management regime, advanced technology and expertise. The fishing fleet is composed of a coastal fleet and sea fishing fleet with a large range of fishing methods and delivery options for various marine species. Overall, more than 1,330,000 tonnes of pelagic fish, more than 780,000 tonnes of cod fish/demersal , and more than 35 000 tonnes of prawns, crabs and shellfish, was caught in 2015. In addition, close to 150,000 tonnes of seaweed was harvested[45].

The aquaculture industry is technology- and expertise-driven. Innovations in feed technology, breeding and vaccines have led to a strong increase in production, and in total over 1.4 million tonnes of farmed fish was produced in 2015[46]. Very little antibiotics is used in Norwegian aquaculture production. Production is relatively steady throughout the year. This provides good marketization and a predictable basis for investment in processing. The aquaculture industry has undergone a period of consolidation which has resulted in several companies that are also significant in an international context. The catch-based land industry is however more fragmented, especially with regard to whitefish.

The Norwegian seafood industry exports over 95% of all its production with a turnover value of NOK 74.5 billion in 2015[47], making Norway the world's second largest fish exporter after China. That is 8.4% more than the year before. The companies' exposure to international markets reinforces the need for innovation and attention to client demands.

45) Norwegian Directorate of Fisheries' key figures for 2015 (figures for 2015 not yet confirmed).

46) Sintef report 27704, analysis of marine raw materials, 2015.

47) Exports of salmon and trout account for NOK 47.7 billion, while cod fish, dried cod, mackerel, herring, prawns, crustaceans and molluscs make up the rest.

The ocean space must be part of the solution to the world's need for more food. Today, a relatively small portion of the ocean's potential is exploited. The global market demands an ever greater diversity of seafood products, giving the Norwegian seafood industry opportunities for commercial exploitation of previously unexploited species. Examples include the capture of snow crab, sea urchin, algae and species at lower trophic levels such as krill and zooplankton. This development will also result in new side streams and potentially new business areas. In a sustainability context, it is an upside that farmed salmon has an efficient feed utilisation.

The processing industry

The food industry

The Norwegian food industry is one of the largest mainland industries and includes more than 2,100 companies and employs approximately 48,000 people. In the food industry, products from agriculture, fisheries and aquaculture are processed for food, beverages and animal feed. The food industry is complex and consists of very different operators, from large listed companies and cooperative companies with several thousand employees to sole proprietorships with home production. The food industry accounts for approximately 24% of all industrial turnover and for 19% of all industrial gross value creation in Norway. The food industry in Norway had a production value of over NOK 177 billion in 2013. The largest segments of the food industry are the fish product industry which accounted for 24% of the production value, the meat industry with 22%, feed 14% and dairy products with 12% of the production value in 2013[48].

The food industry has in recent years shown a positive trend, with an increase in several key economic indicators, such as number of employees, companies, production value, gross investments and value creation. The value creation in the food industry has been stronger than in other industries in recent years, and especially after the financial crisis in 2008. This can be explained by the food industry being less vulnerable to economic fluctuations.

At the same time, the Norwegian food industry is experiencing increasing international competition in the domestic market. While the food industry's domestic market share was 88.2% in 2003, this is now at about 80%.

In Norway, there has been a great deal of innovation and product development in the food industry in recent years. There is also a growing market for local food, specially adapted food or food with special characteristics, adapted for example to athletes, the elderly, different patient groups or allergies. In general, the Norwegian seafood industry has been characterised by raw materials and semi-finished products with few products that are ready for consumption, as well as modest resources allocated to product development and marketing. The trend is positive in terms of increased product development and rate of processing, primarily aimed at the Norwegian and Nordic market.

The ingredient industry

In the Norwegian context, the ingredient industry is an important processing industry. The marine ingredient industry has developed as a result of the utilisation of residual materials from the marine industries, particularly from the Norwegian aquaculture industry. Also, the harvesting and processing of new resources such as copepods (calanus) and krill and harvesting and production of macroalgae for feed or nutrients have been incorporated into the marine ingredients industry[49]. Much of the raw material is imported.

48) NIBIO 2015): Food and Industry 2015.

49) Within the marine ingredient industry, marine oils in 2011 accounted for more than 44% of turnover, while seaweeds made up more than 17%, krill products 7% and Norwegian residual raw material more than 33%.

Feed ingredients are probably the largest area. Main products are protein in the form of fish meal and marine oils. The rate of processing can vary depending on the application. While protein for animal and salmon feed are manufactured through simple processes such as heat treatment or acid hydrolysis, the use in sports drinks or health foods require advanced biotechnological methods, as illustrated by companies such as Biomega, Hofseth and Nutrimar.

Nortura's subsidiary, Norilia, is an example of a company working to increase the use of residual materials from agriculture. Through the use of modern process technology and "tools" from nature (enzymes, yeast, fungus, bacteria) new products are created that can be used in feed, food items and health products. Fatland slaughterhouses are in the same market and also sell skins, intestines and other so-called "plus products" both domestically and for export. Biovotec, HOFF Norske Potetindustrier and Tine are examples of companies using new technology for the development of health-related high value crops. Orkla Foods Ingredients is another company that has a strong position in ingredients for the food industry.

Algipharma, Pharmaq and Biotec Pharmacon are examples of companies that are involved in the development of drugs based on marine raw materials.

The woodworking industry

The forestry and wood industries in 2014 had a turnover of NOK 35 billion. The woodworking industry currently accounts for around 70% of timber revenue for forest owners and is fundamental to the profitability of forest production. The building sector contributes significantly to logging being financially attractive. In certain areas, such as laminated wood in long spans used in bridges and large halls, Norway is currently at the forefront internationally. In recent years, there has been a significant development in efforts to industrialise wood building elements. If the market demands more use of wood in construction, it will be a huge potential for the development of the woodworking industry in Norway. The woodworking industry has solid basic conditions to compete both domestically and in Europe, given that operations are cost-effective. Efficient utilisation of by-products from the woodworking industry will improve the profitability of the entire value chain.

The wood processing industry

In recent times, the largest market for the timber that is not used in the building sector and by-products from the woodworking industry has been the pulp and paper industry. Printing paper is in decline, but there will still be a large global market for cellulose in the future. Tissue paper and packaging are expected to increase. Over the longer term, there is great potential for the processing of forest biomass through biorefining for bio-based materials, chemicals and biofuels. Although the portion of timber that goes to refining currently makes up a smaller volume in the overall picture, profitability can be high. The wood processing company Borregaard is a good example of an integrated biorefinery, which produces lignin, specialty cellulose, vanillin and bioethanol for a number of applications such as food, cosmetics, paint, car batteries, concrete, fuel, etc.

Bioenergy

Biofuels for the aviation industry (jet fuel) is expected to increase substantially in the coming decades. Norway has a potential advantage through the transfer of expertise from the petroleum sector. Bioenergy production in the form of woodchips serves mostly local markets. This market has a low ability to pay for forest raw material and little or no growth is expected. Biochar can, however, become relatively important over the course of a few years, and can contribute to reduced use of fossil coal in European coal power plants and in the Norwegian and international metallurgical industry.

Chemicals and materials

Carbon-based chemicals are contained in most products that surround us in everyday life such as paint, cars, clothing, toys, packaging, building materials, etc. These are based on a small number (20-30) of so-called platform chemicals, which are distillation and intermediate products from crude oil. In the bioeconomy, the platform chemicals will typically be replaced by degradation products from biological polymers such as cellulose, lignin, starch, fatty acids/oils and natural rubber. The establishment of new areas of biorefining is experiencing rapid growth. A particularly exciting growth is seen in plastic composites and in the use of micro- and nanocellulose. Integration of processes can stimulate the development of new business models and co-location of businesses. There are several initiatives to stimulate the production of bioplastics, including the Forum for Bioplastics and the expertise community around Norner in Grenland.

Microbial production

Biotechnology is an important technological driver for the bioeconomy, including through providing the basis for microbial production (fermentation). Traditional examples include the brewing industry, cheese, salami and yogurt. However, an increasing number of examples are seen on how the value chains in the bioeconomy are interwoven. Fermentation is the basis for the production of biological medicines, such as vaccines for aquaculture (Pharmaq). A potentially large emerging industry is related to the microbial production of feed ingredients. For example, proteins can be produced using yeast fermentation of cellulose sugar or with bacterial fermentation of natural gas.

Microalgae are primary producers of omega-3 fatty acids and astaxanthin and may prove crucial for the future growth of the salmon industry. So far, a pilot plant for the cultivation of microalgae has been established that utilises CO_2 from other industries, respectively, from the oil refinery at Mongstad and the smelter in Finnfjord.

Biorefineries such as Borregaard, Biomega and Norilia require robust industrial enzymes with improved properties and which can withstand greater variation in pH, temperature and salinity. Articzymes is developing new enzymes based on the Norwegian initiative on marine bioprospecting, but currently only Biosentrum in Stavanger has the infrastructure for the commercial production of such enzymes in Norway.

Biogas is another field in which Norway has the technology for both small and large-scale plants. Anaerobic fermentation will be able to produce methane from all types of organic waste such as waste/side streams from agriculture, the food industry, aquaculture industry and household waste. Within agriculture, the growing interest is in producing biogas from manure.

Cambi is a leader in anaerobic fermentation of various types of biodegradable waste on a larger scale, such as regional facilities for the processing of household waste, and they have established facilities in many European countries. There are a number of initiatives for the production of biogas from municipal waste plants and Biokraft in Skogn is building a large plant that could provide fuel for buses in the Trondheim area. Biogas production is currently primarily aimed at energy production, but both the gas and residue fraction can be processed both chemically and microbially.

The knowledge base

Key knowledge centres

The value creation can be increased through research, development and use of knowledge and technology. The development of a sustainable bio-economy will require expertise in many areas, both in depth and width, including the capability of interdisciplinary co-operation. Norway has great expertise in many areas that are key to the bioeconomy. Campus Ås, which is the common location of the Norwegian University of Life Sciences (NMBU), Norwegian Institute for Bioeconomy Research (NIBIO), NOFIMA and from 2019 also the National Veterinary Institute (VI), will be a power-

house for teaching, research and innovation. These communities are accustomed to working with each another, with various industry players, with public administration and with other societal actors. The new life science initiative originating from the University of Oslo (UiO), with emphasis on improving coordination between the traditional disciplines, will also play an important role for the development of the bioeconomy.

Campus Gløshaugen in Trondheim with the co-located Norway's University of Science and Technology (NTNU), SINTEF and Paper and Fiber Institute (PFI) is another powerhouse. SINTEF's departments (Energy, Materials and Chemistry, ICT, Fisheries and Aquaculture) together have a large interdisciplinary potential. NTNU also covers many relevant areas, such as biotechnology, sustainability and other environmental research. All these communities will be key to the interaction between biological and technological research for the development of new, profitable and efficient products and solutions as an alternative to those we know today. All the universities in general conduct basic research that may be relevant to the development of the bioeconomy. The public instruments and the participants themselves must encourage interdisciplinary cooperation between the various campuses.

Norway has a strong and clear position internationally in marine research, and has world-leading research communities in several disciplines in resource management, aquaculture and marine bioprospecting, such as at NOFIMA, SINTEF Fisheries and Aquaculture, IMR, NMBU, NTNU, University of Tromsø (UiB) and the University Bergen (UiB). Norwegian experts are listened to and play a crucial role in international knowledge development and management.

Within biotechnology, Norway has amongst other areas world-leading institutions in enzyme technology (NMBU, UiT), alginate research (NTNU), and vaccines (UiT, UiB). Within genome research, Norwegian institutions (for example the University of Oslo) have helped sequence the genome of important fish and plant species (salmon, cod, wheat, strawberries). SINTEF and NMBU's research on fermentation and development of microbial production organisms is also internationally prominent.

Both the higher education and institute sectors provide specific technological expertise and infrastructure of relevance for biorefining. Certain firms, such as Borregaard, have their own R&D departments which are substantial in size and scope. Norway also conducts outstanding research in animal breeding, animal health and welfare and plant health, with Arena Heidner as a significant industry cluster in Hamar.

The environmental research institutes will also be important contributors to the development of a sustainable bioeconomy. Within the environment and climate field, Norway has many strong institute communities, such as the Norwegian Institute for Nature Research (NINA), Norwegian Institute for Water Research (NIVA), Norwegian Polar Institute, Marine Research and Cicero.

International cooperation

As most of the world's knowledge development occurs in other countries, international cooperation will therefore be important looking ahead. Norwegian research groups succeed well in those parts of the EU research and innovation programme that are relevant to the bioeconomy. This applies in particular to marine research and the field of bio-based industry, but also to such topics as agriculture, food, climate and environment. It is important to maintain, or preferably increase, this international orientation in order to be prepared for the future bioeconomy.

Challenges ahead

Although Norway has research in many relevant areas, it is a challenge that many research groups are small and fragmented, and thus not very robust. The focus on increased, sustainable production and extraction of renewable biological resources will require the development of more robust communities in several disciplines.

In order to achieve effective and holistic solutions, it will be a challenge to achieve real integrated interdisciplinary collaboration. Such cooperation will require that businesses, government, societal actors and others actively participate in the building of knowledge. Increased interaction between biological and technological communities will be essential in the future. It will be a challenge to create appropriate meeting places where various research groups can meet with each other across disciplines and sectors, and where academia can meet industry. Achieving this will be a criterion for success for the sake of genuine cooperation and cross-interaction.

Transfer and further development of the solid technological expertise built up in the petroleum industry will be very useful for the development of the bioeconomy.

Relevant education

Bio-based industry needs a competent and innovative workforce in order to compete and develop, both domestically and internationally. It is therefore important that universities and colleges help train graduates with high levels of scientific knowledge and competence. Several institutions have bachelor and master's programmes that are geared towards the key areas within bioeconomy, such as the University of Bergen (UiB), Norwegian University of Life Sciences (NMBU) and the Norwegian Business School (BI). At the same time, there are many education programmes where subjects related to bioeconomy are included as a minor part of the curriculum.

The universities and colleges determine which educational programmes they will provide and the academic content of the programmes. It is important that educational institutions have proper contact with the relevant stakeholders so that the academic content and design constantly take into account the needs in the workplace. At the same time, educational programmes must be closely linked to domestic and international high-quality research in this area. Business gets its largest contribution to research-based knowledge and innovation precisely through the flow of graduates with expertise based on updated research.

Appendix 2: Input to the strategy

There has been a great emphasis on gathering input and establishing a good dialogue with stakeholders involved in the strategy work. A national input conference, six regional input meetings and an international workshop, among others, was organised, in addition to individual meetings with relevant stakeholders. A significant number of written submissions from a wide range of actors were also received.

National input conference

A national input conference was held in Oslo on 18 June 2015, which was opened by the Minister of Trade and Industry, Monica Mæland, the then Minister of Fisheries Elisabeth Aspaker and the then Minister of Agriculture and Food Sylvi Listhaug. The conference had about 200 participants from business, knowledge institutions, organisations, support agencies and regional authorities. The conference was structured according to the following four thematic sections:

1. A competitive green industry
2. More renewable carbon for energy, materials and chemicals
3. Safe and healthy food with less environmental and climate impact
4. A holistic competence platform for a knowledge-based bioeconomy

The conference had 15 main presentations in addition to 40 pre-announced 3-minute presentations from conference participants. A video recording of the conference in its entirety and the main speakers' presentations is available on regjeringen.no.

Regional input meetings

In collaboration with Innovation Norway's regional offices six regional input meetings were held in August-September 2015 with participation from industry, knowledge communities and regional authorities from all of the country's counties. The meetings took place in Ås (Oslo, Akershus, Østfold, Vestfold), Hamar (Hedmark, Oppland), Trondheim (Nord-Trøndelag, Sør-Trøndelag, Møre og Romsdal), Tromsø (Nordland, Troms, Finnmark), Bergen (Rogaland, Hordaland, Sogn- og Fjordane) and Skien (Aust-Agder, Vest-Agder and Telemark).

Written minutes of these meetings are available on regjeringen.no.

Seminar with international experts

In September 2015, a seminar with the participation of the following four internationally recognised bioeconomy experts was organised:

- Adrian Higson, NNFCC (consultancy), UK
- Michael Carus, Nova-Institute, GE
- Jim Philp, OECD
- Johan Sanders, Wageningen University, NL

Presentations from the above-mentioned experts are available on regjeringen.no.

Written input

Affected parties were invited to submit written input to the strategy. A total of 43 written submissions were received from the following stakeholders: Barents Biocentre AS, Nordic Innovation, Follo Council, Norwegian Society for the Conservation of Nature, Norwegian Association of Pharmaceutical Manufacturers (LMI), Norwegian Seafood Federation, Green Gas AS, Norwegian Forestry Society, Food for the Future, Agricultural cooperatives in Norway, IRIS, Wood Industry, Forest and Wood Value Chain, Elkem, NTNU, Tønsberg, Sandefjord, Larvik and Horten industry associations, LO, Borregaard, SINTEF, Forest industry in Coastal Norway, Pharmaq, University of Oslo, Zero, Norwegian Waste Management and Recycling Association, Animalia, Norwegian Bioenergy Association, Statskog, Norskog and Norwegian Forest Owners Association, Hedmark and Oppland county councils and county governors, NHO Food and Drink, University of Bergen, Confederation of Norwegian Enterprise, Norwegian Farmers Union, WWF Norway and SABIMA, NMBU, NIBIO, Østfold County Council, SusWalueWaste/NIFU, Akershus County Council, OREEC, Statkraft and Biokraft. All the written submissions are available on regjeringen.no.

Reports from Innovation Norway, the Research Council of Norway and the Norwegian Environment Agency

On behalf of the ministries, Innovation Norway, the Research Council of Norway and the Norwegian Environment Agency have prepared separate knowledge base documents in connection with the strategy work. These reports provide a description of the status of the Norwegian bioeconomy and include the agencies' assessments and recommendations for a national effort in this area. The reports constitute an important part of the knowledge base for the bioeconomy strategy.

External report from Vista Analyse AS

As a basis for the work on the bioeconomy strategy, an external commissioned study was carried out in spring 2015 by Vista Analyse AS, related to the mapping of the framework conditions and barriers to developments within the bioeconomy (Vista Analyse (2015/07): Framework conditions for the bioeconomy in Norway).

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Production plants for biogas: www.cambi.com.
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