Ministry of Foreign Affairs

Blue Bio Economy in Norway

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Blue Bio Economy in Norway

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1. Introduction

"Close international cooperation on sustainable ocean management is more important than ever. We must ensure better protection of the oceans so that we can increase production of nutritious food […]. If we fail to protect the oceans, it will not be possible to achieve sustainable global development by 2030", said the Norwegian Prime Minister Erna Solberg in December 2020, at the *High Level Panel of the Sustainable Ocean Economy*. Here, a set of recommendations[1] for creating a healthy ocean that provides solutions to global challenges were presented.

Dutch and Norwegian ambitions are high when it comes to reaching the Sustainable Development Goals (SDGs) and climate change. In both countries enthusiastic entrepreneurs and scientists are working on discovering the true potential and possibilities of the blue bio economy. The governments are stimulating finding solutions to be used in climate and environmental policies, and enable a strong cooperation between the public sector, private sector and research institutions.

The 'seascape' of the blue bio economy sector is rapidly developing in both countries. A great deal of scientific work and (technological) innovation is taking place, pilot projects in algae growing, robotics and precision aquaculture using sensor technology. Innovation is also clearly visible in the organizational sphere, such as managing data for business operations and improving transparency in the food chain. Science and technology in aquaculture have the potential to improve water quality, strengthen producers' position in the food chain and make the use of raw materials more sustainable, thus contributing to sustainable and future-proof blue carbon production.

Aiming high at the SDGs and climate goals, the Netherlands seeks to connect and cooperate with like-minded countries such as Norway to optimize solutions and stimulate new developments. To be able to do so, there is a need for additional sector intelligence. This study can be used for further strategy developments, as market intelligence for the business community and potentially pave the way for further knowledge-to-knowledge collaboration between the Netherlands and Norway.

2. Scope of the market study

This report identifies some of the recent and emerging developments in the Norwegian blue bio economy, and provides a brief overview of the key ocean-related policy activities undertaken by the Norwegian government, the most important stakeholders and relevant sources of information. Given the scope of topics covered under the blue economy 'umbrella' and the diversity of activities and institutions involved, the report should be considered as a first introduction, outlining in broad strokes the key (policy) areas, developments and ocean actors in Norway. As a result, this report limits coverage to a selected number of key organizations and flagship policy areas – many policies, programs and institutions dealing with additional topics related to the ocean will not be covered, or only covered very briefly. This study therefore does not claim to give the whole picture of the market and all of its opportunities and should be seen as a snapshot.

Priority has been given to identifying the advantages and challenges in Norway, for instance in scaling up to a sustainable aquaculture and the areas of conflict in spatial planning and the use of areas. A general historical overview and the global trends for the future, the economic relevance and Norway's position as a leading ocean nation will also provide for insights and background information on the broader blue economy developments in Norway. Within the realm of the blue economy the focus is therefore on topics relating to organic matter or 'biomass from the ocean: the blue bio economy in Norway.

Use of definitions

Different words are being chosen to describe the efforts related to the ocean. In this report, the term ocean refers to the entire marine environment (unless stated otherwise). The term blue economy is in practice often used in discussions on any aspect of making the ocean economy sustainable – including energy, shipping, food security, conservation, spatial planning, technology, natural infrastructure, etc. In the *EU Report on Blue Economy*[2], the distinction is for instance made between established sectors as marine living resources, marine non-living resources, marine renewable energy, ports activities, shipbuilding and repair, maritime transport and coastal tourism; and emerging sectors as ocean energy, blue bio economy and biotechnology, marine minerals, desalination, maritime defense and submarine cables.

Related to this point of use of language, it is important to note that although in the Netherlands in policy work[3] a distinction is often being made between the ocean on the one hand (hereby referring to the high seas and beyond the continental shelf), and the seas and coasts on the other (notably the North Sea). In the international ocean community however and in the context of SDG 14 the term ocean makes no distinction between different 'marine environments', and thus the term *ocean* is implied to cover all marine environments from the high seas through to coastal zones, and shallow and deep seabed.

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This report is intended for general guidance and information purposes only. It is under no circumstances intended to be used or considered as a recommendation or as (policy and investment) advice. The material in the report is obtained from various sources and publicly available information per dating of the overview. The Embassy of the Kingdom of the Netherlands in Norway cannot guarantee their accuracy and is not liable in respect of any activities (commercial or other) undertaken using information from this overview.

3. General facts and figures

Before diving into the theme of this report, some basic facts of the Netherlands and Norway will be presented to get a better understanding of the differences and similarities of the countries. More extensive background information can be found in chapter 4.

Geography

Although the Netherlands and Norway are both coastal countries, they seem to be complete opposites when comparing their geography. The most striking is Norway's long coastline. With its 100.915 km, including the islands, it is the second longest coastline, only beaten by Canada. To compare: the Dutch coastline measures 451 km[4].

Even more important is the difference in *type* of coastline, which is of course of great impact on the type of blue bio economy which can flourish in a country. While the Netherlands has a flat sandy coastline with some shallow waters, Norway shows a coast of fjords, skerries and deep waters.

Figure 1: Typical Norwegian coastline with fjords and skerries. Source: Pixabay.

Climate

Western Norway has a marine climate, with comparatively cool summers, mild winters and nearly 2.250 mm of annual precipitation. Eastern Norway, sheltered by the mountains, has an inland climate with warm summers, cold winters, and less than 760 mm of annual precipitation. Along the 1.750 km stretch length of the country there are evidently differences, but the relatively warm golf stream tempers the worst cold and keeps harbors open (ice free) along the coast.

Economic key figures

Norway has an open and highly developed mixed economy. The key figures for the Norwegian economy show a very affluent society. With the 14th place Norway scores high on the GDP per capita ranking; while in comparison the Netherlands reaches the 21st place[5].

The Norwegian economic figures are often stipulated to be in regard to the 'mainland' economy, thus excluding the influence of North Sea oil and gas. However this influence is difficult not to take into account as the oil and gas exports (as well as seafood) fuel the economy and makes the Norwegian economy extremely efficient and stable.

Norway	
GDP per capita	€ 63.124
Average yearly earnings	€ 58.455
Yearly earnings in agriculture, forestry and in fisheries	€49.926
Yearly earnings in mining and prospecting	€ 89.198
Export x million (excl. oil and gas)	€ 77.421
Of which seafood x million	€ 10.143
Export crude oil and natural gas	€ 33.140
Import 2020 x million (excl. oil)	€ 75.015
Employment in seafood and processing (2018)	31.367 full time employees
Employment in the oil and gas industry (2018)	225.000 full time employees

Table 1: Key figures Norwegian Economy. Source: SSB. [6][7]

The Norwegian economy has proven to be robust over the years. Norway's substantial oil and gas revenues are managed to the benefit of the society as a whole. A large proportion of these revenues is channeled into Norway's sovereign wealth fund, the Government Pension Fund Global, better known simply as the Oil Fund.[8] Norges Bank Investment Management manages the assets of the Oil Fund. The Council of Ethics[9] evaluates whether or not the fund's investments is consistent with its Ethical guidelines. In 'expectation documents' the bank sets out the guidelines and framework how they expect companies to manage various environmental and social matters. The expectation document on ocean Sustainability[10] focuses on the effects of the degradation of the ocean, including seas and marine resources and how this may affect the long-term value of companies.

About 5% of the total employment in Norway is directly or indirectly related to the petroleum industry[11]. Salaries in the oil and gas industry tend to be higher than in other sectors, like fisheries and aquaculture. The challenge of attracting skilled employees may therefore cause a bottle neck for the development of several sectors, for instance new blue bio based economy companies.

Employment in the Norwegian seafood sector (including processing) accounted for 31.367 jobs in 2018. This represented an increase of 10% compared to 2008. Over the same period, the average value of production per employee increased by 38% in marine fisheries and increased by 51% in aquaculture.

In 2018, Norway produced 4 million tons of fish (including molluscs and crustaceans), with a total value of € 9.000 million. 77% of this value originated from aquaculture and 23% from fisheries. Between 2008 and 2018, the quantity produced increased by 17%, while its value increased by 104%.

The number of people working within the blue bio based sector is still considered modest.[12] However, it is important to realize that in many coastal communities the ocean industries and more specifically the blue bio economy-based jobs are of high importance regarding their value creation. This is clearly shown in the Norwegian government's updated ocean strategy, *Blue Opportunities*:

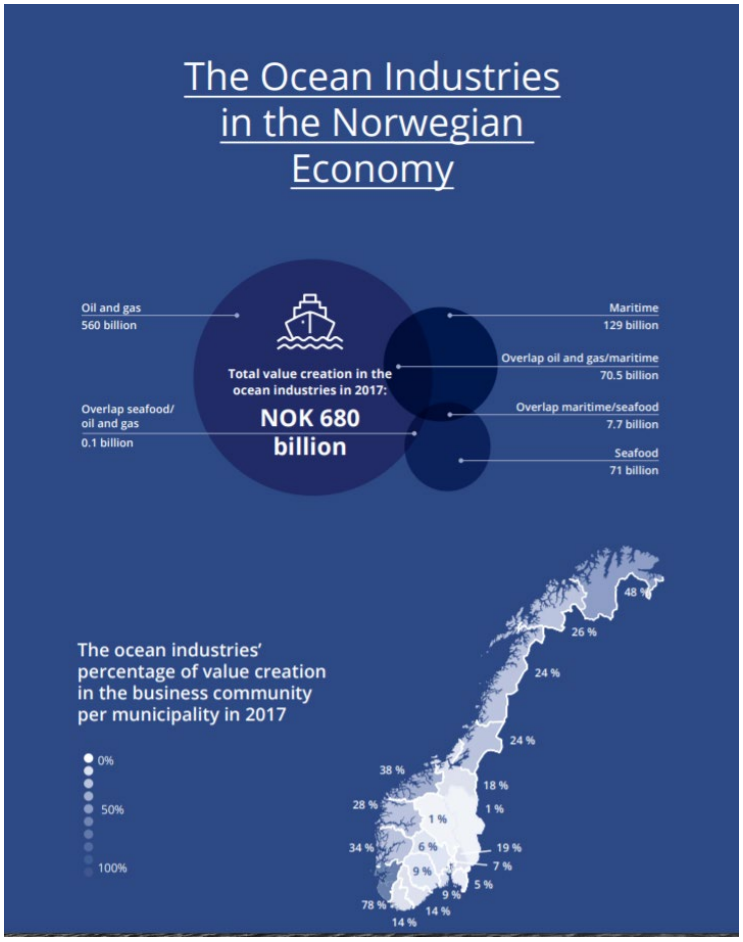

Figure 2: Ocean industries in the Norwegian economy. Source: Norwegian Ministries/ Menon Economics 2019. [13]

Population

The population density in Norway is very low compared to the Netherlands. While the Netherlands has a density of 512 persons per km^2, Norway has only 15 persons per km^2.

	Inhabitants	**Population density (people per km^2)**[14]	**Main cities and inhabitants**
Norway	5,4 million	15	Oslo: 600.000 Bergen: 280.000 Trondheim: 200.000
Netherlands	17 million	512	Amsterdam: 1,158 million Rotterdam: 1 million

Table 2: Population in the Netherlands and Norway. Source: CIA Factbook.

Large parts of the population live in the southern part of the country and especially in the area surrounding the capital city Oslo. At the same time the Norwegian government aims to spread the population over the whole country. This results in an active policy to stimulate the creation of jobs also in rural areas and the establishment of facilities to keep people stay in the more remote areas. Such as schools and cultural institutes, but also investments in infrastructure in all parts of the country.

History

Perhaps the most famous period in Norwegian history has been the Viking period. During this period people from Norway, Denmark and Sweden made a major impact on the coastal areas of Northern

Europe. Thanks to innovative seaworthy ships, they could travel further than before and next to the well-known plundering, they were also active traders. Traces of this period can still be found along the coasts of the lowlands.

Economically, the Hanseatic period in the late 13th and 14th century has been important. Although Bergen was not a Hanseatic member, the foreign post led to an increase in international trade. Again, the location of Norway (Bergen) with its long coastline made the exchange of goods an interesting one for international trade.

Between 1380 and 1905, Norway has been part of different political wars and alliances in Scandinavia. This led to Norway being under the control of both Sweden and Denmark at different points in time. During these times Norwegian shipping industry was limited, which led to many Norwegians working on Dutch sailboats. This in turn led to a new spring for Norwegian shipping. From the 1600s, the sector steadily increased and by the mid-1900, the Norwegian shipping was the world's fourth largest. This has strengthened the maritime industry in Norway, laying the foundation for other ocean activities.

In 1969, the discovery of oil changed the economy Norway completely. During the sixties, Norway had about the same BNP as Greece, while the country is now one of the richest in the world. The discovery of oil can therefore be seen as the beginning of a new era in Norwegian economic history. Again, the ocean had given Norway an economic advantage compared to surrounding countries. But also the way Norway has managed this resource has meant a lot for the economic growth of the past 50 years.[15]

The most recent 'happening' which defines Norway and has had impact on its economy is the rejection to become an EU member, in the referendums in 1972 and in 1994. The country is thus not a member of the European Union, but it is a member of the European Economic Area and the Schengen Agreement. This means that Norway is fully integrated in the European Single Market, and that goods, people and services can seamlessly cross the border. The EEA and various agreement between the EU and Norway allow for many rules and regulations to also apply to Norwegian trade and industry, and ensures compatibility and level playing field between the Netherlands and Norway in most areas.

The EEA between the EU and Norway provides free movement of goods, but with the exception of agricultural and fisheries products. Negotiations to reduce any type of trade barriers in these sectors are regularly undertaken.

Cultural differences

Norway and the Netherlands have close ties through trade, politics and international cooperation. Both countries are very like-minded and the cultures are considered to have many similarities. Nevertheless, minor differences do occur and are important to keep in mind when fostering collaboration and business relations.

Research conducted by Geert Hofstede[16] could provide for some insights regarding the cultural differences between Norway and the Netherlands, of which the following aspects are briefly highlighted in this report:

Power distance: "The extent to which the less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally". Both the Netherlands and Norway score low on the Power Distance, which means that in general hierarchy is perceived less important than in many other countries. As an example, in a business meeting in Norway one could observe that people address each other on first name basis and all participants will actively engage, no matter their role or position in the organization. Knowledge of the topic is considered to be key.

Another factor is the *Masculinity* of the country. Norway has a low score on this dimension (and is the second most Feminine society, after Sweden) which means that "the dominant values in society are caring for others and quality of life". This is for instance expressed in the way care for families is organized: maternity and parental leave are widely accepted and daycare is available and affordable. As a result more equal labor participation is enabled. Furthermore, like the Netherlands, Norway is considered an individualist society where personal opinions are expressed and there are clear lines between work and private life.

Perhaps the most significant cultural difference between the Netherlands and Norway concerns the dimension called *Long Term Orientation*: "How every society has to maintain some links with its own past while dealing with the challenges of the present and future". Norway has a relatively low score, indicating a normative society with great respect for traditions. On the other hand in the Netherlands, traditions seem to adapt more easily to changed conditions and there is more of a long-term view on things, for instance expressed by the time people use to plan ahead. In general in business culture the Dutch tend to plan ahead more in advance than Norwegians do.

4. Background of the blue economy

Historical overview over the blue economy in Norway

"The history of Norway is a history of the ocean."[17]

Today, Norway is one of the world's leading ocean nations. The ocean is the backbone of the Norwegian history and economy. The Norwegian ocean territories are the basis for a wide range of sectors and economic activities, both marine and maritime, both offshore and along the coast.

Norwegians have for centuries, even millennials, explored, utilized and lived off the resources the ocean has provided. The blue economy has secured settlement along the entire Norwegian coastline, from south to north, and has been a vital part of Norwegians' way of life and value creation. Norway's ocean territories are six times the size of its land areas and still today, 80% of the population lives less than 10 km from the shore.[18] Even the choice of name for Norway's carbon capture and storage (CCS) project, *Longship*[19], harkens back to the Vikings' ocean mastership and excellence in innovative technologies, such as in shipbuilding.

Norway has the world's second longest coastline, 100.915 km when including islands, only beaten by Canada. The Norwegian ocean territory is divided in three main areas, based on geography and wildlife: The Barents sea (Barentshavet) is in the High North, including Svalbard in the north and the Lofoten Islands in the south; the Norwegian sea (Norskehavet) stretches from the coastal areas of mid-Norway and all the way to Greenland and Iceland; and lastly there is the North Sea (Nordsjøen) and Skagerrak area in the South, bordering to Denmark, the Netherlands, Germany and the UK.

The Norwegian Sea is deep, 1.800m on average. The two others are more shallow, with the Barents sea averaging at 230m and the North Sea-Skagerrak at 90m. When referring to the different seas and coastline as a whole, including policies, blue industries and environmental issues, Norwegians talk about the *ocean* as one entity.

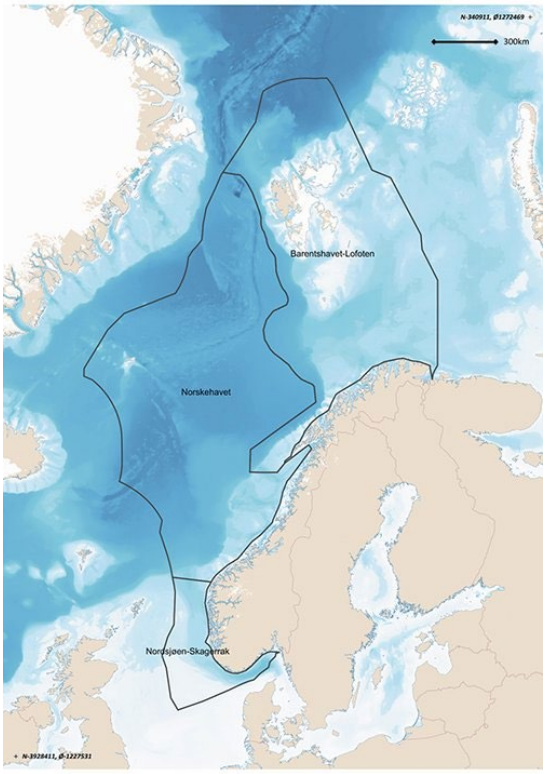

Figure 3: The three main areas of Norway's ocean territories. Source: Regjeringen.no

The warm North Atlantic Current[20], which extends the Gulf Stream from the Atlantic northeastward to the coast of Norway, brings with it a temperate climate to the coast of Norway, which makes the Northern parts more livable and ice-free than the latitude indicates. It is the basis for life on land and in the sea, and forms the foundation for blue economic activities in Norway. The stream also brings with it a range of nutrients and plankton, with is the foundation for marine species, living in and by the ocean.

The ocean itself, the seabed, the continental shelf and the coastline are a biological treasure chest and center for a wide range of economic activity.[21] They could also hold the key to solutions to some the most pressing challenges for the future.

Economic relevance

Norway's blue economy is inherently international by nature. It has been and will remain an important international sector. The oil and gas sector and the seafood sector, which are the two largest industries in Norway, are exporting almost everything that is produced. 70% of Norway's export value comes from the blue economy, and creates hundred thousands of jobs.

Norway is one of the world's biggest producers of oil and gas. This sector is the single most important sector in Norway, in terms of jobs, value creation and developing technology. The sector has created revenues that has safeguarded the future welfare for the people of Norway. Additionally, the oil and gas sector has had a ripple effect on several other technology and maritime businesses, and has created an innovative, internationally competitive supply sector with advanced technology for offshore industry. On the other side, the sector has drawn massively on the available workforce, thus raising the level of salaries and creating lack of workers in outer sectors with fewer possibilities to raise payments.

Fishing and aquaculture have also been sectors securing the welfare and job creation in Norway and is one of the world's biggest seafood industries. While fishing refers to offshore fishing and the catch of wild fish and seafood, aquaculture refers to the breeding, raising, and harvesting of fish and other seafood, either on-land or in the sea.

Seafaring and shipping has historically been an important sector in Norway, and Norway continues to be one of the world's biggest and most advanced shipping countries. Norway is currently the 4th largest shipping country in the world, measured by value. The offshore segment has the highest marked value of the shipping sector in Norway. Both the number of ships and tonnage has grown the last years.[22] The growth in the maritime traffic will continue to increase in the years to come, both along the Norwegian coast and deep sea shipping.

Building upon the success of these sectors, maritime innovation, businesses and research communities have developed in Norway. Appendix 1 provides a stakeholder overview of research and business communities in Norway. Other blue economy sectors are also developing, including seabed mining, renewable energy and tourism. These sectors also have strong international ties. These sectors are growing, both in Norway and internationally, and will continue to uphold the blue economy's importance in Norway for the foreseeable future, both for jobs, value creation and for the economy overall.[23]

Blue bio economy in Norway

Norway is the world's second biggest exporter of seafood. According to the Norwegian government, Norway is home to one of the world's most sustainable seafood industries.[24]

Norwegian waters are home to the world's largest stock of cod and herring, along with 250 other types of fish. Numerous species of seaweed, coral reefs and a large variations of molluscs and crustaceans live on the seabed. These species provide food for other animals, such as seabirds, seals and whales, in addition to humans.[25]

While fishing off the coast has long traditions and roots, the modern aquaculture and fish farming in Norway started in the early 1970s and is thus less than 50 years old. However, this sector has grown rapidly in both production volumes and in export value. While building upon the knowledge from offshore fisheries sector and ocean governance, along with new technology, it has developed into an industrialized and highly advanced sector.

Fish farming makes up 99,9% of all aquaculture in Norway. The aquaculture focuses mostly on salmon, which is the most sought-after and has the highest value, but also cod, halibut and other types of fish are bred. There is also a small production of mussels, scallops and oysters, in addition to seaweed and other types of algae. In 2018, the seaweed production was valued to be € 0,2 million.[26] [27]

In Europe, Norway produces 71% of all algae by volume, followed by Ireland and France. Total European production (EU28 + EEA) is approximately 0,2 million tons of wet weight. At the global level this is close to nothing. World production rounded 33 million tons in 2016, the European share would be around 0,6 %. Whereas most production in Asia is farmed, the bulk of the European production is harvested in the wild.

95% of Norwegian seafood is exported. Seafood is thus one of the most important export product of Norway, and is exported to over 100 countries. The export from aquaculture has been stable at around 1-1,2 million tons per year for the last decade, while export from offshore fishing (wild-caught fisheries) is stable at around 1,5 million tons. At the same time, the export value has doubled from approximately € 5,3 billion to more than € 10 billion in same time period.[28] Despite a challenging year, Norway exported 2,7 billion tons of seafood (aquaculture and wild-caught fisheries combined) of a value of more than € 10,5 billion in 2020. This was the second highest value ever, much helped by the weak Norwegian krone to other currencies.[29]

According to the Norwegian Seafood Council, Norwegian seafood companies are resilient, adapt well to crises, and answer many of the growing trends in consumer behavior, such as higher standards for health and sustainability.[30] Innovation, willingness in the industry and financing are key ingredients in order to adapt to changing situations. This will be increasingly important for the sector in the future, since Norwegian seafood's reputation as healthy and sustainable is key for its export market value. Norwegian seafood is highly sought-after, and a possible spillover effect to the algae sector could become likely.

From 2014, the Norwegian Directorate for Fisheries started to hand out licenses for production of seaweed. The number of licenses has increased rapidly the last years. From 60 in 2014 to over 700 in 2020.[31] Even though the production volumes are still relatively small, Norway is by far the largest producer of seaweed and algae in Europe.[32]

There are several scientific clusters researching the use of seaweed in Norway. There are also several associations and interest organizations within the industry itself that invest in the future of the blue bio economy sector. These are small, but growing, and have a strong international profile. Appendix 1 shows a stakeholder overview for more information on these organizations.

Potential for increased value creation and innovation

The OECD suggests that the growth in ocean economy worldwide will double by 2030, compared to 2010.[33] The Norwegian government and businesses across sectors also expect that the blue economy will continue to grow in the future.

Increased demand for sustainable food, natural resources and renewable energy will be the main drivers for further growth. This growth potential will also include other non-bio emerging sectors such as ocean wind and seabed minerals, in addition to new bio-based components for food and medicine.

Seaweed cultivation is one of the emerging industries which experienced a sharp increase in interests over the past five years. The Norwegian coastline is particularly suited for production of seaweed, with its long coast and cold, nutritious waters.

This industry is still relatively immature in Norway, and only takes up a few percentage of the total aquaculture industry in Norway. Most projects are still in the pilot phase, and heavily dependent on manual and labor intensive processes for harvesting. However, the industry has gained increased attention from both the public and investors, and is expected to have rapid growth and develop further with a higher degree of automation.

The production of seaweed was 145 tons in 2017.[34] Today, there are between 30-40 companies or projects growing and processing seaweed for around € 0,14 billion combined. The commercial success and value creation of the seaweed and other types of algae is thus currently moderate, and the focus has mostly been on research and development.[35]

According to an analysis by a task force appointed by two Norwegian science institutions, The Royal Norwegian Society of Sciences and Letters (DKNVS) and the Norwegian Academy of Technological Sciences (NTVA), and penned by the research institute SINTEF, the bio marine industry as a whole has a huge potential for future growth. The report from 2012 estimated a six fold increase by 2050, which would mean a value of € 55 billion.[36] In a previous estimate the bio marine industry would represent a total market value about € 7,5 billion in 2010. The real value proved to be about 8 billion, which means their calculations were quite accurate. The report also estimates that the production of micro and macro algae combined could be 20 million tons by 2050, with a production value up to € 4 billion.[37] That is almost half of the value of all seafood exported from Norway today.

Norwegian interest in algae, both micro and macro, is mostly focused on seaweed as a source of proteins in feed for other species. There is no tradition of producing or harvasting seaweed for human consumption, but this appears to be changing. The use of seaweed for consumption, dietary supplements and medicinal use is growing.[38] In particular, fatty acids and proteins from bio marine resources will see an increase in demand for the future. In addition, application of biomass from seaweed could also be used in cosmetics, bioenergy, fertilizers and bio chemicals.[39]

Besides seaweed there are also attempts to commercialize the sustainable production of urchins and sea cucumbers. Fishing for the invasive king crab and the harvesting of scallops has proven to be financially interesting for some time.[40]

Extraction from seabed minerals is also a growing industry. The underwater ridge between Greenland and Norway contains several minerals, as gold, silver, zinc, lead, cobalt and copper. These are resources in high demand for the European industry, including the production of batteries.

Norwegian sustainable ocean policies and international engagements

Increased economic activity in Norway will in most cases also contribute to increased emissions and pollution. The growth of these sectors will naturally also have an impact on the marine environment and the species living in and by the ocean. The growth of these sectors in Norway will therefore only be viable if they are developed with sustainability at its core. The Norwegian government recognizes this and puts sustainable ocean economy and ocean health as a top priority in its policies.

The government has also taken a lead in developing international policies for ocean economy. Reducing marine litter and plastics in the oceans has been one of the central challenges the Norwegian government has lifted on the international arena.

Close cooperation between businesses, the R&D sector, workers and governments has been central in the historical development of Norway's blue economy.[41] This will also be the case for future development of the blue bio economy and division of areas and extraction of resources.

In 2017, the government published its ocean strategy *New growth, proud history*[42], along with two white papers *The place of the oceans in Norway's foreign and development policy*[43] and *Update of the integrated management plan for the Norwegian Sea*[44]. In 2019, the ocean strategy was updated with *The Norwegian Government's Updated Ocean Strategy: Blue Opportunities*[45]. In 2020, the *Norway's integrated ocean management plans — Barents Sea-Lofoten area; the Norwegian Sea; and the North Sea and Skagerrak*[46] was published. It aims to balance the increased activity and continued value creation with environmental needs and sustainable use of the ocean.

The government published a Holistic National *Plan for Protection of important areas for Marine Nature*[47] in 2021. This plan aims towards protecting vulnerable areas, rebuilding ecosystems and mapping and protection of carbon rich areas to halt climate changes. A report on the significance of the ocean for Norway and the world was also published in 2021. This report, named *Blue Ocean, Green Future*[48], aims at mapping the importance of both the ocean and ocean related businesses, and gives an overview of the governments ocean policies for the last eight years. It also looks ahead to future challenges.

EU cooperation

Algae represent an untapped resource, according to the EU, and could be used produce food, feed, pharmaceuticals, bioplastics, fertilizers and biofuels, among others. In the *Food From the Oceans* report from 2017, the EU states that food from the lower trophic level will be the basis for future sustainable aquaculture and growing human intake of food from the ocean.[49]

Norway's and EU's views on sustainable aquaculture align, and the two share many of the same challenges. Therefore, EU policies will also be highly relevant in moving forward to a sustainable, internationally oriented blue economy.

EU policies can provide funding for algae projects and spur cross-country innovation in blue bio economy industries. Although not an EU member, Norway is fully integrated in the Single Market through the EEA-agreement, along with several other agreements with the EU that regulates the EU-Norway relations. Norway adopts relevant EU legislation on areas such as climate and environment, and is a fully integrated member of the EU programmers for research, innovation and education, such as Horizon Europe and Erasmus+.

The European Green Deal is the EUs strategy for sustainable growth and aims to fulfill the UNs SDGs. The EU acknowledges the important role of algae as a source of alternative protein for a sustainable food system and global food security. The European Commission includes European stakeholders in their work through the *Blue Bio economy Forum*: *Roadmap for the Blue Economy*.[50]

Various initiatives such as the *Farm to Fork* [51] and the *Bio Economy Strategy*[52] sets out to better utilize the potential of algae. In 2021, the EU published a new set of *Aquaculture Guidelines*[53], for a more sustainable and competitive EU aquaculture. These provides a vision for the further development of aquaculture and build on experience at EU and national strategic level. Further, the EU is planning to publish a *EU Algae Initiative*[54] in 2022, which will boost the blue bio economy sector by supporting research and innovation, collecting and mapping data and information, improving the regulatory and governance framework and supporting market developments.[55]

All of these initiatives will have an impact on the general development of blue bio economy, including the way forward for Norwegian algae industry.

International engagement

Norway wants to take a leading role in international ocean topics. The government has made ocean economy and health a priority in its international work. The Ocean Panel, initiated by Erna Solberg and the president of Palau in 2018, gathers 14 state leaders towards a sustainable ocean economy. [56] The foreign minister of Norway hosted the Our Ocean conference in Oslo in October 2019. Norway also joined the UK-led Global Ocean Alliance for protection of marine areas in 2021.[57]

Both the Norwegian government and the EU puts the Sustainable Development Goals at the heart of their policies at all levels of government. The 2030 Agenda for Sustainable Development[58] and its 17 SDGs seek to build on the Millennium Development Goals and complete what these did not achieve. It provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. The UN has also decided that 2021-2030 will be the international decade for ocean research.

Figure 3: The SDGs. Source: UN.

According to the Institute of Marine Research, only approximately 5% of Norway´s oceans are currently marine protected areas. About half of all ocean areas are protected in some degree by other area-based conservation measures in fisheries management.[59]

Norway supports a global goal of conserving 10% of coastal and ocean areas by 2020 as marine protected areas or other effective area-based conservation measures. Currently the parties to the Convention on Biological Diversity (CBD) are discussing an ambition to increase the target to 30% by 2030.[60]

5. Current developments and challenges

The main drivers behind the innovation and development of the blue bio economy in Norway are also some of the main challenges that the sector faces regarding the future: population growth, increased demand for natural resources, renewable energy and healthy food, shortages of land areas and increased transport. Overarching these challenges is climate change and the threat it causes to the marine ecosystems. Still, many of the solutions to climate change can be found in the ocean.

Norway's long coastline and ocean resources provide for obvious opportunities for development of the blue bio economy sector. Other advantages Norway has, are the scientific community, its highly developed maritime industry, and expertise in aquaculture. Some challenges to the sector are related to price level and financing, immature technologies and developing demand for innovative products.

Scaling up a sustainable aquaculture

The world's population is growing. Consequently, the demand for healthy and sustainable food production is rising. Aquaculture is the fastest growing food industry in the world and blue bio economy can therefore expected to play an important part in the future food security.

The ocean is also viewed as a solution to many of the climate and environmental challenges, such as being a natural carbon storage, providing renewable energy and providing possible sustainable food production.[61] More blue food sources will generally generate less emissions than other meat production on land.[62] Seaweed and algae can even mitigate climate changes and acidification of the ocean by containing CO^2, and purify the surrounding ocean areas by taking up nutrients from on land waste from industry, fish farming and farming.[63] Seaweed can be cultivated without the use of land, fertilizers, fresh water, pesticides or antibiotics, and is thus more sustainable than alternative biomass production on land.

A main challenge for the aquaculture sector in Norway is the balance between increased production volumes, the potential for increases in demand, and sustainability and environmental concerns. More advanced equipment, feeding technology and surveillance could develop the fish farming sector further to become more sustainable, with lower emissions and lower impact on the local environment.[64]

Increased use and interest in seaweed and biomass from the sea as food thus attracts attention to the safety aspects of consumption, and the need for risk assessments. A challenge for the seafood sector in general is that some fish also contain toxic concentrations of heavy metals, persistent organic pollutants, and plastic, bringing potential harm to humans. This is the result from on land human activities. Mercury levels in fish have been a problem for the industry in Norway, caused mainly by pollution from industry on land. Safety challenges could be thought to be transferred to other emerging sectors within the blue bio economy. For example, the Norwegian Institute of Marine Research has penned a *Report on Macroalgae Food and Feed Safety*[65] in Norway in 2020. It found that some macro algae may contain elevated levels of iodine, cadmium and inorganic arsenic, making them potentially unsafe for human consumption. The development of the emerging blue bio industries must have sustainability at its core, focusing on environmental effects in the whole value chain.

Technology, innovation and research

As previously mentioned, the seaweed and algae sector is relatively small in Norway (compared to the fisheries sector). Therefore, many of the challenges for the emerging industries are tied to getting the production up and running, and creating a business case and attracting investors. These challenges include attracting investments, developing a stable demand side, a sustainable value chain, adapting to new regulations and policies.

Innovation, research and new technology could be a solution to develop a sustainable aquaculture for the future. Having updated, scientific knowledge about the life in the oceans is key, in order to create sustainable business models based on ocean resources. For example, the challenge of lice in fish farms has been an headache for the sector for decades. Several projects have demonstrated solutions by the use of new technologies, innovation and research. The same goes for escapes from fish farms, which have environmental effects on wild salmon, fish health and welfare for the rest of the ocean ecosystem.

To be able to harvest more from the ocean without adding to the pollution, new technology must be developed. New technology could reduce the pollution and emission from ocean activities, and even remove pollution, e.g. by develop new solutions to find and remove marine litter. New technology is needed to use every part of the harvest, reducing waste and creating new products.

Additionally, the high Norwegian price on labor[66] means that the industry will need a high degree of standardization and automation of the growth and harvest, in order to be able to compete with other countries with cheaper manual labor. New and advanced technology and having scientific knowledge underline the need for the right skills.

Two megatrends that will affect the blue bio economy in the future are digitalization and green transition, which are both inherently international. More research in these fields are needed to utilize the full potential of these trends. While the scientific communities in Norway are highly advanced in research on algae and its properties and applications, a concern is that these communities are very small and fragmented. International cooperation and development of robust communities will be important, in particular in bio based marine industries and environmental impact.[67] International cooperation will also be key when developing safety and production standards and regulations for the bio marine industry.

In order to develop new emerging industries, a high level of innovation will be needed. This area will benefit from international cooperation with R&D actors and businesses across Europe.

Spatial planning and use of areas

Despite large ocean territories, only some areas are suitable for aquaculture and other blue economy activities. Growing interest in blue bio economy, the need for increased production volumes, new and emerging industries and priorities with regard to biodiversity and sustainability can be a source of disputes when it concerns the use of areas. The coastal areas are also a popular areas for recreation, and most people live and work close to coastal areas. This means that infrastructure, industry and wastewater also put a pressure on these areas. Conflicting or diverging interests could thus be a potential challenge for the growth of the blue bio economy sector in the future.

Some activities could have consequences for the existing wildlife and impact the local environment negatively. Per today, it is hard to see the full environmental consequences of seaweed growth and harvesting, since the knowledge and research is currently very limited, even on an international

level. However, growing seaweed has benefits to local environment in comparison to fish farms, since seaweed requires no fertilization and is a carbon storage and filters nutrients from the ocean.[68]

On the other side, some species of seaweed will require large areas for growth and sunlight. Seaweed could thus block out sunlight from other existing species in the area. While providing shelter and grazing areas for a range of other species, seaweed could also contribute to suppressing natural species and be a stepping stone for invasive species to establish themselves and spread in unwanted areas.[69] The increased production could also lead to more maritime litter from equipment used at the farms.[70] The production and scaling up of seaweed must therefore ensure sustainability for the ecosystem as a whole.

The use of areas up to one nautical mile off the coast is regulated by the Planning and Building Act.[71] It is the responsibility of each municipality to implement and manage the national and regional regulations via their plans, and good governance is thus key to ensure a well-managed ocean space use that covers the needs of different actors. New establishments are also subjected to an impact assessment. Outside of the near-coast areas, the state is responsible for the area planning. The government has developed roadmaps and tools for the municipalities to navigate these regulations. Additionally, the *Nature Diversity Act*[72] also applies to all areas concerning biological diversity.

The previously mentioned report *Norway's integrated ocean management*[73] from 2020, is one example of how the government aims to balance the increased activity and with environmental concerns. Such regulation plans are important to fulfill the UN SDG 14 according to the government.[74]

As previously stated, approximately 5% of Norway´s oceans are marine protected areas, while about half of all ocean areas are protected in some degree by other area-based conservation measures.[75] With increased pressure from new and existing activities and increased focus on protecting ocean areas from both the UN, EU and the government, the percentage of protected areas is expected to increase. This will probably not go without discussions and weighing different needs against each other, as accessible, economic valuable areas in near-coast areas have been one of the advantages on Norwegian seafood industry so far.

Challenges related to spatial planning and use of areas are on the political agenda. Still, the seaweed industry is developing fast, and regulations are needed when new industries are entering the market. It is essential to have plans and regulations for handling potential conflicts before they arise. A report from Norwegian Institute for Water Research (NIVA) points to regional and local authorities must take an holistic approach through common, updated plans for coastal areas. The plans should also be flexible enough to take into consideration the future needs. The report points out the need for more knowledge on both growing seaweed and on future technical solutions.[76]

The development and use of digital tools and new technology could help solve these types of challenges, in addition to the more industry related challenges mentioned above. On one hand, new technology could enable some businesses to move away from the most pressed areas into new and undisputed areas. On the other hand, digital surveillance and governing tools could help adjust or optimize the use of pressed areas, and avoid damage to vulnerable nature and species by mapping their activities.

International governance and regulations

As this report maps out, a main challenge, which is not limited to Norway, is the sustainable development of a new sector. A good governance model where both industry, the scientific community and public authorities are involved, is key. Both the international community and national policy makers must be ahead of the development, enabling sustainable innovation and excluding non-sustainable ways of making use of the ocean resources. The high level of trust and existing level of cooperation between the government and the business sector in Norway are important factors going forward.

For the industry to overcome many of the initial challenges, clear framework regulation of the industry and incentives from the government will be important. This includes funding for research and innovation. Likewise, ocean governance, principles of sustainability from the international community as well as the national government will be key.

The demand side is of course also vital for the industry's success. A growing number of consumers, in particular the Netherlands and Norway, are choosing food based on health and sustainability markers. Transparency of the sector will contribute to further familiarize the general public with its products, enable well-informed consumers and will therefore be crucial to build up a consistent consumer basis that accepts algae products and their nutritional value.

Some global developments may be difficult to influence, both for national and international governmental bodies. Such challenges might be economic recession followed by stricter trade barriers, causing dwindling demand for seafood. It might also be a reduced marine quality and changes to the marine ecosystems caused by climate change.

6. Main takeaways

As became clear in the previous chapters, Norway's relation with the oceans has been historically shaped and is strongly embedded in its culture. The Norwegian lengthy, yet complex, coastline extends over 100.000 kilometers and is characterized by fjords, islands and skerries. Blue economy activities dominate the Norwegian economy and are crucial for employment and growth. Considering the extensive scope of topics that relate to this sector, the focus in this report has been narrowed down and provides a brief overview of the key ocean-related policy activities undertaken by the Norwegian government and some of the recent and emerging developments in the Norwegian blue bio economy.

Norwegian fisheries is a very mature industry and it is also no surprise that aquaculture and to a much lesser extend the harvesting of kelp and macro algae stand out. Aquaculture in Norway mainly consists of fish farms, and the algae sector is relatively small. Still, the algae sector in Norway is big compared to other European countries. The cold temperate waters of the Northeast Atlantic are home to more than 400 species of brown, red and green seaweeds, many of which have recognized commercial value for a variety of products (feed and food additives, cosmetics, bioenergy, fertilizers and bio chemicals). The coming years Norway will attribute priority to further scaling up sustainable aquaculture and the harvesting and cultivation of macro algae. The previously mentioned report penned by SINTEF, predicts a production of 20 million tons of macro algae in Norway in 2050, which accounts for almost half of the value of all seafood exported today.

Besides biomass production in and from the ocean, also production on land is being performed more and more. Fish, urchins, algae, both macro and micro will to a larger extend and with increasing success be produced in closed land based systems.

Although the production levels of shellfish and molluscs in Norway are relatively low and have yet to reach commercial viability, research[77] shows that shellfish score well in terms of CO^2 footprint[78], circular production and health aspects. By focusing more on the sustainability and health aspects towards the consumer, the positioning of shellfish as a valued food could be improved. This could also enable and validate the business models of growers and other subsectors that are part of this value chain in Norway.

The Pacific oyster for instance has established populations in Scandinavian coastal waters.[79] The species is considered alien and invasive and dense populations may cause changes in benthic habitats. It is, however, one of the world's most important aquaculture species, and there is a growing interest in using the Scandinavian populations as a new marine resource. To release the commercial potential, there is urgent need for a better understanding of the oyster's effect on the ecosystem and a clarification of legal matters, as well as establishment of management practices for harvesting and marketing these oysters.

The Nordic cuisine which is in general to be considered very natural, based on local foods and ways to prepare food, is well-established and has a steady audience in Norway. Even though culinary delicacies concern a niche market, (top) restaurants are always looking for new resources and seafood like urchins, sea cucumber and the different varieties of seaweed and kelp have been a welcome addition. In the Netherlands attempts are also being made to bring the shellfish culture on shore[80]. Although outside of the scope of this report, given the right technology and starting material, this may also be feasible for the Norwegian industry and eventual technological developments in this region could be of interest for a follow-up research.

The throughout the report mentioned new developments and growth goals will naturally lead to potential new conflicts and challenges in spatial planning and the use of areas. Although on the other hand, combining certain ocean related activities may very well create added value, for example wind energy projects at sea combined with seaweed production.

With limited space in fjords and near-coast areas in Norway, the development of a new sector will conflict with other interests, such as transport, tourism, fisheries and natural protection.[81] The challenge is how one can better draw use of the full potential of an area and contribute to effective and cost-value extraction of marine bio resources. More knowledge and research into these challenges can show how to optimize production, harvesting, and the use of land areas

Policies enabling the balancing act between protection and production will constantly have to be updated in Norway's approach and ocean strategies, as it concerns a main source of food, income and welfare. Staying behind in development and innovation is not an option as the same skills and digitalization contributing to value creation along the entire coastline, are also required to enable climate change mitigation and contribute to sustainable growth.

Steps are being taken and for instance with its world class maritime industry, Norway is increasingly committed to more environmentally friendly technology and alternative fuel for vessels. In addition to which increased interaction between the different ocean industries is being stimulated. Norway also invests in implementing the regulations necessary for a secure long-term sustainability when it comes to the harvested stocks and the unavoidable environmental footprint, but the stakes are high and it remains very difficult to simultaneously maintain the structure, functioning, productivity and diversity of marine ecosystems. A strong Norwegian ocean-related cluster and more integrated blue bio economy ecosystem thinking would further enhance future-oriented ocean industries, education, the labor market, international cooperation and ocean diplomacy.

Norway and the Netherlands are likeminded when it concerns ocean policy measures and strategy. The international networks on science and collaboration are well established and interconnected. Both countries have high climate ambitions, are committed to the SDGs and therefore Ocean conferences and 'built back better' initiatives can count on joint Norwegian and Dutch support.

Zooming in to the blue bio economy business community, it occurs that the Dutch start-up scene has developed differently from that in Norway. The launch of new blue bio economy start-ups in Norway seems most often to be derived from established economic activities in the aquaculture sector and/or has a strong scientific connection. Furthermore, the number of actors and activities in the Netherlands with regard to the North Sea appear to have a much higher density compared to the typical ocean-scape in Norway. As result, growth possibilities in the Netherlands might be more constrained due to competition, while Norwegian challenges for expansion lie in the relatively smaller and less diverse home market and its rough climate conditions. Innovative solutions and new technology that further build on interdisciplinary and entrepreneurial thinking and offer an integral or cross sectoral approach could provide for new leads into the Norwegian market.

This report steers clear of making a comparison between the Netherlands and Norway, as the various sectors in both countries differ so greatly and there is no 'one size fits all' approach when it concerns entering one of the numerous blue bio economy market segments. Matching potential business and collaboration opportunities in Norway with the current developments in the Netherlands is therefore left at the discretion of the reader of the report.

In order to get a better understanding of the state of play of Dutch entrepreneurs and knowledge institutions with regard to seaweed cultivation in relation to the blue bio economy and its international opportunities for development and collaboration, it is good to keep an eye out for upcoming research to be published by Wageningen University in August 2021. In line with the international food systems transition and as input for the UN Food Systems Summit this coming fall, a report is to be foreseen with Dutch innovative solutions on 'boosting nature positive production' and will elaborate on the usage of algae in food, feed and as bio stimulant.

Appendix 1: Stakeholder overview

Governmental organizations

Actor	Information	Website
Ministry of Trade, Industry and Fisheries		https://www.regjeringen.no/en/dep/nfd/about-the-ministry/id714/
Directorate of Fisheries	The Ministry's advisory and executive body. The main tasks involve regulation, guidance, supervision, resource management and quality control.	https://www.fiskeridir.no/English
Faglig Forum for Norske Havområder	Cooperation of several governmental organizations to develop the maintenance plans of the Norwegian sea areas.	
Institute of Marine Research	Advisory body to the Ministry and performs key tasks in the investigation and monitoring of fish stocks and marine mammals, the marine and coastal environment and activities related to aquaculture and sea ranching One of the biggest marine research institutes in Europe.	https://www.hi.no/en
Norwegian Coastal Administration (Kystverket)	National agency for coastal management, maritime safety and preparedness against acute pollution. Part of the Ministry of Transport and Communications.	https://kystverket.no/en
The Norwegian Environment Agency (Miljødirektoratet)	Primary task is to reduce greenhouse gas emissions, manage Norwegian nature and prevent pollution.	https://www.environmentagency.no
Norwegian Maritime Authority	The authority has jurisdiction over ships registered in Norway and foreign ships arriving Norwegian ports.	www.sjofartsdir.no/en
Innovation Norway	Contributes to sustainable growth and exports for Norwegian businesses through capital and expertise.	https://www.innovasjonnorge.no/en/start-page/

Research and education institutes

Actor	Information	Website
Arctic University of Norway (UiT)		https://en.uit.no/forskning
Institute of Marine Research	Advisory body to the Ministry and performs key tasks in the investigation and monitoring of fish stocks and marine mammals, the marine and coastal environment and activities related to aquaculture and sea ranching. One of the biggest marine research institutes in Europe.	https://www.hi.no/en
Institute for Rural and Regional Research (Ruralis)	Knowledge on the interaction between people places, values and resources.	https://ruralis.no/en/
NOFIMA	An industry-oriented research group that conducts research and development for aquaculture, fisheries and food industry.	www.nofima.no/en/
NORD University		https://www.nord.no/en
Norsk Institutt for Bioøkonomi (NIBIO)	Contributes to food security and safety , sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other bio based industries.	https://www.nibio.no/en

Norwegian Institute for Water Research (NIVA)	Institute for fundamental and applied research on marine and freshwaters. Their research comprises a wide array of environmental, climatic and resource-related fields. They combine research, monitoring, evaluation, problem-solving and advisory services at international, national and local levels.	https://www.niva.no/en
Norwegian Seafood Research Fund (FHF)	Part of the Ministry of Trade, industry and fisheries. The goal is to create added value to the seafood industry through industry based R&D.	https://www.fhf.no/fhf/about-fhf-english/
Norwegian Seaweed Biorefinery Platform	The platform consists of the seaweed research groups of NTNU and Sintef with Nofima and Møreforskning as partners. The mail goal is to become a platform for research, knowledge, methods and stakeholders within the development of an economically and environmentally sustainable biorefinery of seaweeds (macroalgea).	https://www.sintef.no/en/latest-news/2019/kick-off-for-the-norwegian-seaweed-biorefinery-platform/
Norwegian Seaweed Technology Center	At SINTEF the Norwegian Seaweed Technology Center is a knowledge platform for technology development within industrial cultivation, harvesting, processing and application of seaweed. The center of competence constitutes SINTEF Fisheries and Aquaculture, SINTEF Materials and Chemistry, NTNU Department of Biology and NTNU Department of Biotechnology. The center has a broad network of national and international collaboration partners and aims to support the Norwegian industry and public sector in enabling a new economy based on seaweed cultivation and processing.	https://www.sintef.no/en/ocean/initiatives/norwegian-seaweed-technology-center/
Norwegian University of Life Science (NBMU)		https://www.nmbu.no/en/research
Norwegian University of Science and Technology (NTNU)		https://www.ntnu.edu/research
Norwegian Veterinary Institute	National biomedical institute delivering research based knowledge and contingency support in the fields of animal health, fish health and food safety.	
Research Council of Norway (Forskningsrådet)	Promotes and subsidizes wide variety of research projects.	https://www.forskningsradet.no/en/
SINTEF	One of Europe's largest independent research organizations.	www.sintef.no

Other stakeholders

Actor	Information	Website
Action for Ocean	Action network for the youth to promote the knowledge and care of the ocean environment.	https://www.actionforocean.com/
Algenett	Network of companies involved in production of marine algae.	https://algenett.no/hjem
BarentsWatch	Collects, develops and shares information about the Norwegian coastal and marine areas.	https://www.barentswatch.no/en/about/
Centre for the Ocean and the Arctic (Havarktis)	Works towards a sustainable value creation from the ocean. Also facilitates partnerships for building sustainable blue businesses.	https://www.havarktis.no/en/
GRID Arendal	Non-profit environnemental communications centre. They transform environmental data into science-based information products and provide capacity-building services. They collaborate with the United Nations Environment Programme and other partners around the world.	https://www.grida.no/
Mareano	Maps depth and topography, sediment composition, biodiversity as well as pollution in the seabed of the Norwegian offshore areas.	https://mareano.no/en
NCE Blue Legasea	NCE Blue Legasea is to be a catalyst for intersectorial cooperation, to promote higher value of products and competitiveness for member companies and the fishery nation Norway	https://www.legasea.no/legasea/the-cluster1/
NCE Seafood Innovation	NCE Seafood Innovation is a cross-sectoral cluster that aims to contribute to sustainable seafood growth, by focusing on innovation.	https://seafoodinnovation.no/
Norwegian Blue Forests Network	Networking organization.	https://nbfn.no/
Norwegian Innovation Clusters	The Norwegian clusters promote cooperation and economic growth in a sustainable way.	https://www.innovasjonnorge.no/no/subsites/forside/english/
Norwegian Seafood Council (NCS)	Cooperation with fisheries and aquaculture industry to develop markets for Norwegian seafood.	https://en.seafood.no/
Norwegian Seafood Federation (Sjømat Norge)	Representing the seafood industry.	https://sjomatnorge.no/norwegian-seafood-federation/
Norwegian Seaweed Biorefinery Platform	NTNU, SINTEF, Møreforskning, NMBU, Nofima, The Research Council of Norway	Seaweed Platform: ocean@sintef.no Newsletter.
Norwegian Seaweed farmers	Association of seaweed farmers.	https://www.norwegianseaweedfarms.com/
Ocean Panel	The high level panel for sustainable ocean economy is an initiative of 14 serving world leaders working towards a sustainable ocean economy, where effective protection, sustainable production and equitable prosperity.	https://oceanpanel.org/
Promac	Energy efficient PROcessing of MACroalgae in blue-green value chains	http://promac.no/about-the-project/
REV Ocean	Not-for-profit company created with one overarching purpose and ambition: to make the ocean healthy again. Any profit generated will be reinvested. The company was established in 2017 and funded by Norwegian business man Kjell Inge Røkke.	https://www.revocean.org/
Rogaland Havsbrukpark	Startup Ocean Lab for 'aquapreneurs'.	https://www.roghav.no/home

SIG Seaweed	The Special Interest Group SIG Seaweed is a Norwegian cross-sectorial and multidisciplinary meeting place gathering businesses that cultivates and uses macro algae as raw material for various products, in addition to providers of technology, equipment and R&D in these areas	Coordinated by Jorunn Skjermo (jorunn.skjermo@sintef.no) at SINTEF Ocean
Stiim	Stiim aquacluster represents an ecosystem for aquaculture innovation, located on the south-western coast.	https://stiimaquacluster.no/english/

Commercial players in Norway

Please be aware that this list is not exhaustive.

Actor	Information	Website
Actic Seaweed	Cultivate, process and distribute seaweed.	https://aseaweed.com/
Akvahub	Network for research, development and innovation	https://akvahub.no/
Algea	Collects and processes the algae Ascophyllum nodosum to make seaweed extracts and phyto complexes for use in agriculture.	https://www.algea.com/
Algenior ASA	Developed a technology for total utilization of seaweeds to be integrated in a multifunctional biorefinery for seaweeds. With a focus on the kelp Laminaria hyperborea.	https://alginor.no/
Biomega	Biorefinery for human and animal nutrition.	https://biomegagroup.com/
Blue Lice	Finds the lice on the way to farmed salmon by combining light, smell and movement to attract salmon lice in the copepodid phase.	https://www.bluelice.no/english
Eukaryo ABC	Develops cultivars for macroalgae cultivation.	http://eukaryo.no/english/
King scallops	Collecting scallops by hand.	
Lerøy/ Ocean Forest	Core business is production of trout and salmon, white fish but also produces crustaceans, molluscs and seaweed.	https://www.leroyseafood.com/
Lofoten Blue Harvest	Seaweed farmer.	https://www.lofotenblueharvest.com/en/
MicroA	Biotechnology company, focusing on sustainable production of natural ingredients from microalgae.	https://microa.no/
Niri	Innovator in production technology for land based fish farming.	http://niri.com/
Norway Seaweed	Various seaweed products.	https://norwayseaweed.no/
Norwegian Lobster Farm	Produces plate sized lobsters.	https://www.norwegian-lobster-farm.com/en/
Rensefiskgruppen	Environmentally friendly method of removing salmon lice.	https://www.rensefiskgruppen.no/
Satpos	Tracking, sensing and monitoring solutions.	https://www.satpos.com/
Seas of Norway	Seaweed farming technology	https://www.seasofnorway.com/
Seaweed from Norway	Various seaweed products.	https://www.seaweedfromnorway.no/
Seaweed Solutions	Production and innovation of seaweed.	https://seaweedsolutions.com/
Skretting	Providing innovative and sustainable nutritional solutions for aquaculture industry.	
Smart Farm AS	Solutions for cost effective and environmentally friendly farming of bi-valves.	https://www.smartfarm.no/
SoftSeaweed	Seaweed software	https://softseaweed.com/
Tango Seaweed	Seaweed farmer.	https://www.tangoseaweed.no/

Tarelaks AS	Consultancy integrating seaweed and salmon farming.	
Tekslo Seaweed	Seaweed farmer.	https://teksloseaweed.no/en/
Urchinomics	Removing sea urchins from overgrazing the seafloor and deliver premium sea urchins to the food service sector.	https://www.urchinomics.com/

Events

Name event	Information	Website
Havexpo	A new fish farming- and fisheries expo. May 10.-11th, 2022 in Bergen, Norway	https://havexpo.no/en/
The North Atlantic Seafood Forum Conference	Annual conference. Industry only executive meeting place for seafood industry.	https://nor-seafood.com/
NTNU Ocean Week	Ocean Week is the annual conference hosted by NTNU Oceans, one of NTNU's four strategic research areas. The purpose of Ocean Week is to lay foundations for interdisciplinary ocean research.	https://www.ntnu.edu/ocean-week
Norwegian algae conference	In Norwegian, taking place on 14-10-21. A conference on development and innovation in the Norwegian algae industry.	https://www.tekna.no/kurs/norsk-algekonferanse-2021-41095/
Norwegian Blue forest week	Annual week of lectures and debates in Norwegian on the blue forest ecosystem and it's management.	https://nbfn.no/news/
Umami Arena	Once every three years. Most important meeting place for Norwegian Horeca and retail branch on food and non-food.	https://umamiarena.no/?-mc_cid=73d2f586f2&-mc_eid=bfbed2c084
Seagriculture	The European seaweed conference Seagriculture 2021 was to take place in Bodø, which is why we mention it here. It is however now organized virtually on 15-16 September 2021. All know-how within seaweed for feed, food, offshore cultivation, bio refinery of seaweed and more.	https://seagriculture.eu/
Passion for Oceans Festivals	A public celebration and knowledge spreading on all subjects 'Ocean', with festivals, summer camps and more. The festivals are in the harbors along the coast and focuses on a younger audience.	https://www.passionforoceanfestivalen.no/

Appendix 2: More interesting reading

Facts and figures

Name	Information	Website
Statistics Norway	The Norwegian Central Bureau of Statistics	https://www.ssb.no/en/
Central Bureau of Statistics	The Netherlands Central Bureau of Statistics	https://cbs.nl
Directorate of Fisheries	Economic and biological key figures concerning Norwegian fisheries and aquaculture	https://www.fiskeridir.no/English/Fisheries/Statistics/Economic-and-biological-key-figures
OECD	Short reports on fisheries and aquaculture, in this case: The Netherlands	https://www.oecd.org/agriculture/topics/fisheries-and-aquaculture/documents/report_cn_fish_nld.pdf
Stichting Nederland Maritiem Land	An annual overview of the Netherlands Maritime Cluster (2020)	https://maritiemehavenenbinnenhavenmonitor.nl/DocumentManagement/Documents/Document:26/Toolbar/Download/Download/Maritieme%20Monitor%202020.pdf
OECD	Short reports on fisheries and aquaculture, in this case: Norway	https://www.oecd.org/agriculture/topics/fisheries-and-aquaculture/documents/report_cn_fish_nor.pdf
EU	2020 Blue Economy Report: Blue sectors contribute to the recovery and pave way for EU Green Deal.	https://ec.europa.eu/commission/presscorner/detail/en/IP_20_986
SINTEF	A report accessing the added value of seafood for the Norwegian society. (in Norwegian)	https://www.sintef.no/globalassets/nasjonal-verdiskapning-sintef-2004-2019.pdf
IMR	Database with contaminants and nutrients in seafood, incl. shellfish and seaweed	https://sjomatdata.hi.no/#search/
Norwegian Botanical Association	A botanical list of Norwegian Marina Macro Algae 2021 (in Norwegian)	https://botaniskforening.no/marine-alger

White Papers and other governmental reports

Ministry of Trade, Industry and Fisheries	Norwegian Strategy for bio economy “Known resources, unknown possibilities” 2016 (No)	https://www.regjeringen.no/no/dokumenter/regjeringens-biookonomistrategi-kjente-ressurser--uante-muligheter/id2521997/
Ministry of Trade, Industry and Fisheries, Ministry of Petroleum and Energy	New growth, proud history - The Norwegian Ocean strategy 2017 (No)	https://www.regjeringen.no/contentassets/1ed01965de3249f689f1938ad3c0b672/nfd_havstrategi_webfil.pdf
Ministry of Trade, Industry and Fisheries	Blue opportunities - The Norwegian Government's Updated Ocean Strategy 2019	https://www.regjeringen.no/en/dokumenter/the-norwegian-overnments-updated-ocean-strategy/id2653026/
Ministry of Climate and Environment	Strategy for Ocean biodiversity protection 2021 (No)	https://www.regjeringen.no/no/dokumenter/meld.-st.-29-20202021/id2843433/
Menon Economics for the Ministry of Fisheries	Evaluation of developments and permits for the aquaculture in Norway in order to solve environment and special planning issues. 2021 (No)	https://www.regjeringen.no/contentassets/243bb973c8dc454dbb9e0a418ce0b15d/evaluering-av-utviklingstillatelser-for-havbruksnaringen-og-vurdering-av-alternative-ordninger-for-fremtiden.pdf
Ministry of Climate and Environment	Norway’s integrated ocean management plans — Barents Sea–Lofoten area; the Norwegian Sea; and the North Sea and Skagerrak	https://www.regjeringen.no/en/dokumenter/meld.-st.-20-20192020/id2699370/?ch=1

Other reports

Actor	Information	Website
SINTEF	Value created from productive oceans in 2050 (2012)	https://www.sintef.no/en/latest-news/2012/value-created-from-productive-oceans-in-2050/
Nordic Council	Nordic blue forests store CO^2 emissions from 700,000 Danish cars each year (2021)	https://www.norden.org/en/news/did-you-know-nordic-blue-forests-store-co2e-emissions-700000-danish-cars-each-year
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Examples of new species in fisheries and aquaculture

King Scallops[82]

The decorative King Scallops are harvested by hand and therefore show small production numbers. They are in high demand in high-end restaurants in Norway itself as well as in the south of Europe.

King Crab[83]

In the 1960s, Soviet biologists started to release these crabs into the Murmansk Fjord. The crabs thrived here, and as early as in 1977 the first king crab was caught in the Norwegian waters, just west of the border. The potentially damaging invasive species has been turned into an asset as there is a solid worldwide culinary demand. A fleet consisting of small fishing vessels operates along the coast of Finnmark County in northern Norway. The crabs are caught in pots and transported alive to tank facilities, where they are checked and sorted according to quality and size.

Sea urchins[84]

Sea urchins, in Norwegian cutely called *kråkeboller*, are vegetarians. They live on *Rhodophyta* and saltwater plants like brown algae, also called kelp. When their numbers get too high the impact on kelp fields can be devastating, as their 'grazing' can destroy entire kelp forests.

Natural predators like sea otters are not present in sufficient numbers to keep the urchin population growth on a sustainable level. Therefore, harvesting urchins for consumption could lead to a win-win-win situation for the continued existence of blue forests, for consumers and for the entrepreneur.

Harvested urchins are not straight away ready-to-market, as the roe has to be of a certain size. That's why the sea urchins are brought to a recirculation aquatic system (RAS) on shore to be grown to maturity with specially developed feed.

Sea cucumbers[85]

In Norway the sea cucumber is called 'sea sausage', but in fact it is neither a cucumber, nor sausage. Sea cucumbers are echinoderms . Sea cucumbers are found on sea beds worldwide and are related to the urchin and starfish. In Norway the brown and red variety are found.

Sea cucumbers are popular in Asia, both fresh and in a dried form and they have a high market value. The large demand and limited supply could offer opportunities for Norway. The red variety has not yet been introduced on a large scale in Asia.

The project HOLOSUSTAIN[86] is a North Atlantic cooperation with the Canadians looking at the commercial potential of the red sea cucumber, *Cuumaria frondosa*.

Micro algae

The commercial production of various micro algae for food, feed, medicine and more, is still considered to be relatively new, although over time it has already been extensively researched at all the mayor scientific clusters and universities.[87]

In the aquaculture industry, microalgae are an important food source and feed additive in the commercial rearing of all stages of marine molluscs and larval stages of several marine fish species. With the increase in aquaculture of marine species, there is a raised demand for suitable microalgae.

Macro algae

The same applies for the larger algae. The largest quantities are processed for feed, food additives or the use in supplements. Some of the species are used for human consumption and specifically

positioned and branded as delicacies in the Nordic cuisine. This sector is still emerging and exploring options for expanding its market value.

The seaweed production in Norway is mostly based on harvesting, although on a small scale also cultivation occurs. Wild harvesting is done by hand or machine and requires a permit. In the year 2020 703 licenses have been issued, of which 166 specifically regarding cultivation (owned by a total of 17 companies)[88].

The total seaweed production in 2020 in Norway sums up to an estimated 117 tons cultivated wet weight. Seaweed cultivation is an emerging industry and takes place mainly onshore and in sheltered areas. The main species suitable for cultivation are Sea Belt *(Saccharina latissimi),* Tangle *(Laminaria hyperborean)* , Babberlocks *(Alaria esculenta)* and Dulse (*Palmaria palmata*). The vast majority of Norwegian seaweed production is intended for the food market.

The harvested seaweed in Norway is mainly used for hydrocolloid extraction by the American company FMC biopolymer, which had a revenue of EUR 0,15 billion in 2016.[89] The main species used in this production are brown algae like *Laminaria hyperborea,* but also some *Ascophyllum nodosum* is harvested.

This seaweed company markets the seaweed as follows:

- High Nutrition Foods
- Health & Wellbeing
- Animal Health
- Pharmaceuticals
- Bio Growth Stimulants
- Sustainable Materials
- Renewable Energy
- Carbon Sequestration

Norway currently outweighs the Netherlands in its number of active companies and volumes. On the other hand, the Netherlands has more diversity in its production and a bigger focus on micro algae. For further details on the algae production in the Netherlands, there is a study on the existing market for seaweed food applications compiled by the North Sea Farmers.[90]

https://www.noordzeeboerderij.nl/public/documents/Valgorize-D4.1.1A_Study-on-the-existing-market-for-seaweed-food-applications.pdf

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