Value created from productive oceans in 2050

A report prepared by a working group appointed by the Royal Norwegian Society of Sciences and Letters (DKNVS) and the Norwegian Academy of Technological Sciences (NTVA)

Preface

In 1999 the NTVA and DKNVS published the report called "*Norges muligheter for verdiskapning innen havbruk*" (Norwegian opportunities for growth in the aquaculture sector), and in 2006 the report "*Utnyttelse av biomarine ressurser - globale muligheter for norsk ekspertise"* (The exploitation of biomarine resources – global opportunities for Norwegian expertise). The reports focused on and described Norwegian opportunities for the development and exploitation of biomarine resources. They should both be regarded as bold statements aimed at generating public debate. This report represents a sequel to the two aforementioned reports, and outlines perspectives and opportunities which Norway now has, as one of the world's major nations in terms of its economic exploitation of the oceans, in the fields of the cultivation and harvesting of the ocean's biological resources.

The recommendations in this report have been prepared by a Working Group. The group has had four meetings, and SINTEF Fisheries and Aquaculture AS has acted as its Secretariat.

The NTVA and DKNVS take this opportunity to thank the authors, the Working Group, the Secretariat and the sponsors:

Authors

The main author is Trude Olafsen, assisted by co-authors Ulf Winther, Yngvar Olsen and Jorunn Skjermo.

The Working Group

- Karl A. Almås, President, SINTEF Fisheries and Aquaculture AS (Leader)
- Christina Abildgaard, Head of Department, Research Council of Norway
- Edel Elvevoll, Dean at the Faculty of Biosciences, Fisheries and Economics at the University of Tromsø
- Jørn Krog, Governor of Sør-Trøndelag county
- Leif Inge Nordhammer, formerly CEO at SalMar ASA
- Yngvar Olsen, Professor at the Department of Biology at the Norwegian University of Science and Technology (NTNU)
- Asgeir J. Sørensen, Professor at the Department of Marine Technology at NTNU.
- Kristian Overskaug, General Secretary of the DKNVS

Secretariat

SINTEF Fisheries and Aquaculture

Sponsors

- SINTEF Fisheries and Aquaculture
- The Norwegian Ministry of Fisheries and Coastal Affairs
- The Research Council of Norway

On behalf of the publisher

Kristian Fossheim President, DKNVS	Roy Helge Gabrielsen President, NTVA

Table of contents

1 Summary and recommendations

Background to the report

The earlier reports published by the DKNVS/NTVA (1999, 2006) both point out the potential of exploiting Norway's advantages linked to increased value generation based on biomarine resources. Twelve years since the publication of the first report, the issue has been made more relevant as a result of this report and other strategic projects, including HAV21 and a recent Government White Paper, which have been initiated to address how Norway is to maintain future economic growth by means above and beyond exploitation of its oil and gas resources.

In his recently published book "*Et kunnskapsbasert Norge"* (A knowledge-based Norway), Torgeir Reve states that the seafood sector is one of three industries which we can regard as a "global knowledge hub". The two others are the offshore-based commercial sector (supplier and service sector) and the maritime sector.

What has happened since the last analysis published in 1999?

In 1999 it was predicted that in 2010 the biomarine industry (or aquaculture as it was then known) would represent a total market value close to NOK 75 billion. The actual value turned out to be about NOK 80 billion. Both salmonid farming and the marine ingredients industry have experienced higher levels of growth than anticipated.

Key terms used in this study

Terms such the Marine business, sector and/or industry are used synonymously in this study and must here be understood to encompass all activities involving the sustainable exploitation of raw materials produced by living marine organisms. This includes companies within the aquaculture, fisheries, fish processing and export/wholesale sectors, as well as the suppliers of goods and services, research institutes and public sector bodies (used in the previous analysis). It also includes newer and more embryonic industries such as the marine ingredients industry, seaweed and microalgae farming, and others.

Global and domestic development trends important to the marine sector

In recent years the marine sector has enjoyed a higher status than previously within the Norwegian economy. The fish farming sector has become increasingly visible in coastal waters and many more commentators than before are expressing their opinions about the industry. The Norwegian marine sector is to an ever-increasing extent dependent on both global and domestic development trends in society as a whole. In this report, the Working Group has selected the global and domestic development trends which it believes will be the most important influences on the marine sector in the years to come (see Figure 1-1).

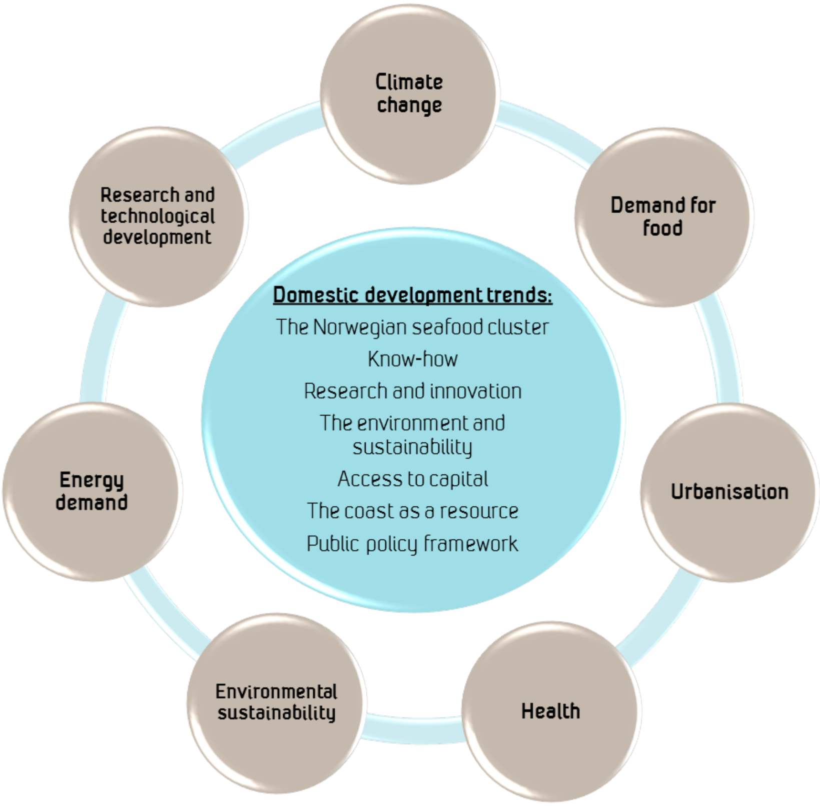


Figure 1-1 **Global and domestic trends which will be important for the development of the Norwegian marine sector.**

The most important global development trends influencing the marine sector is the rising demand for food resulting from overall population growth, combined with increased purchasing power among the middle class in particular. The demand for seafood and other marine products is set to increase, and Norway is one of the countries which will be able to meet these demands, given its natural advantages, expertise and an established industrial base. The second important development where marine products can make a difference is in relation to meeting global health challenges linked to unhealthy diet, obesity, and the demand for marine oils and other marine products.

On the one hand, the development trends outlined above represent opportunities for, and on the other also potential threats to, future growth in value generation in the marine sector. In fact, all these trends may represent threats if development continues in directions which are unfavourable to the marine-based industries.

Some threats may be difficult to influence such as:

- Climate changes which take a more dramatic course than anticipated to date
- A global economic recession with long-term consequences
- Stricter trade barriers resulting from a global economic recession
- A reduction in the quality of the marine environment due to factors such as pollution.

Conclusions and recommendations

The Working Group has made an assessment of the potential for value generation in 2050, which is divided into two main areas.

1) Progressive development of the seafood industry's core areas with which we are currently familiar

2) The development of embryonic and new industries

Within both of these main areas, separate value chains and areas of focus have been identified which are key to realising the value generation potential (see Figure 1-2). Some of these can be quantified, while others can not.

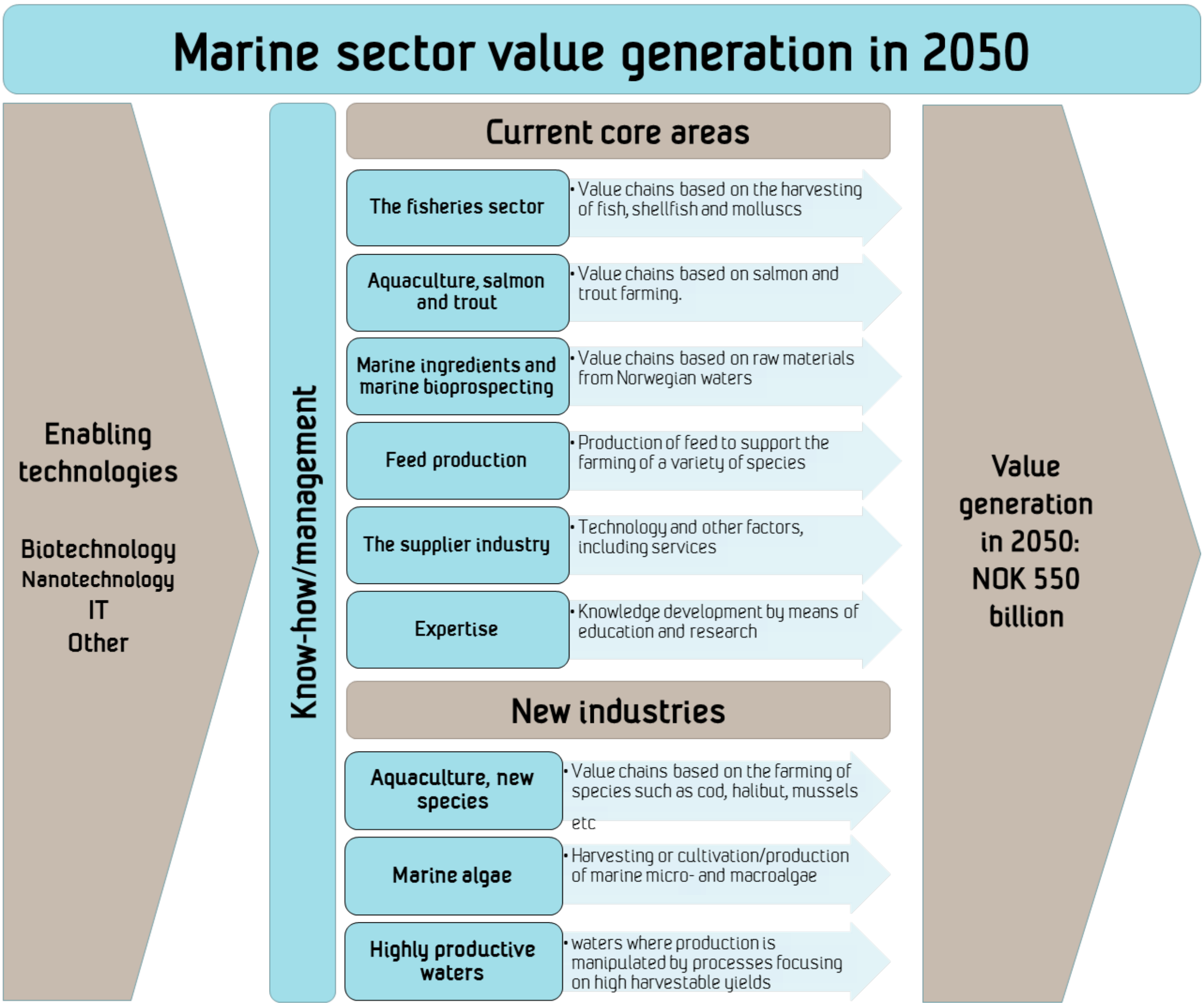


Figure 1-2 Marine sector value generation in 2050

In **Figure 1-3** we present our estimates of value generation potential in the different fields within the marine sector. The estimates have been made on the basis of how we believe development will progress within the fields in question. There are also some conditions in terms of what should take place if such potential is to be realised. The value of value generation in the marine sector in 2050 is estimated to be a little in excess of NOK 500 billion. In 1999 it was predicted that in 2030 value generation in the marine sector would be just less than NOK 250 billion. This means that the present study is adjusting this potential downwards somewhat in the period leading up to 2030. After 2030 and in the period leading up to 2050 the Working Group expects that global trends such as overall rising demand for food production, and increased demand for seafood in particular, will combine to promote a massive increase in value generation within the Norwegian marine sector and among Norwegian interests overseas. Other global issues such as climate change and economic instability will conspire to create uncertainty as to whether or not such potential can be realised. A pattern of developments as outlined here will also require for example that the aquaculture industry succeeds in addressing the environmental challenges it faces, thus opening the doors to increased levels of growth. One of the greatest challenges will be linked to obtaining the necessary raw materials for feedstuff production.

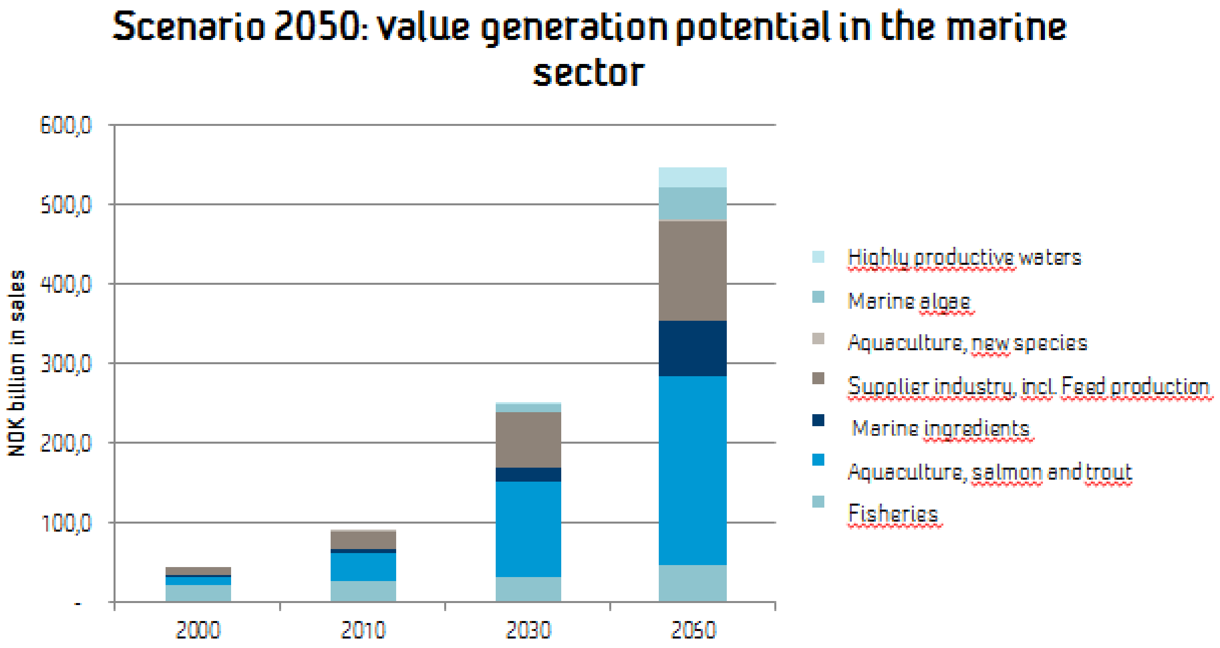


Figure 1-3 **Value generation potential in the marine sector**

Recommendations

The Norwegian Minister for Fisheries and Coastal Affairs has made it clear that it is Norway's aim to become the world's leading seafood producer. The Working Group fully supports this aim. However, it also wishes to point out the importance of expanding ambitions to the extent that efforts made at home should also incorporate affiliated industries such as the supplier sector and the marine ingredients industry, as well as industries based on marine biological resources which are currently seen as embryonic, including the service-based industries.

On the basis of the perspectives discussed in this report, the group here presents its recommendations in the form of "10 pieces of sound advice":

1) Prioritise businesses. Businesses enjoying comparative advantages must be supported to a greater extent than is currently the case. The marine-based industries must be assigned higher priority by Norwegian politicians.

2) Natural resource advantage. Compared with other nations, Norway's oceanic and coastal resources confer on the country unique natural advantages. These advantages mean that Norway must assume a particular responsibility for the production of food, feedstuffs for the fish faming industry, and other vital intermediate products based on marine biological resources. Because Norway enjoys a strong position within all the major marine-based industries, including marine resources, the maritime, oil and gas and marine renewable energy sectors, it is also in a unique position, and has an opportunity, to become a world leader in marine-related technology, expertise and value generation from the oceans. Norway shall be ambitious enough to become a leading global marine nation, and take the necessary steps to ensure that this comes to pass.

3) Management of the oceans and coastal areas. The future development of, and focus on, a knowledge-based coastal and ocean management system will be vital if Norway is to realise its value generation potential and, not least, make a contribution to economic growth in northern Norway. Management expertise is also in demand in other countries which want to consolidate their practices in this field. Norway should aim to become a world leader in the management of coastal and oceanic areas by investing in the systematic development of skills and expertise.

4) Policy framework for business activities. Future value generation based on marine biological resources will depend on the maintenance of robust value chains within the aquaculture and fisheries sectors which are currently large volume producers, thus generating major value. Both the traditional value chains and the new developing marine industries must be competitive in global markets. A stable policy framework is a key factor here.

    a. The current framework must be reviewed with a view to creating a policy regime which meets the industry's demands for predictability and permits a certain level of flexibility.

    b. The seafood industry is in competition with both the oil and gas and maritime sectors for manpower, capital investment and public attention, and all three sectors are regarded as global knowledge hubs. It is important that the seafood sector is able to compete on a more or less level playing field.

c. The work to secure access to markets for Norwegian products should be assigned high priority.

5) Embryonic and new industries. Embryonic and new industries based on marine biological resources have great potential, but will require other and more effective leverage than the current core industries, given the way in which they are described in this report. Suggested measures:

   a. The use of drawback funds in the same way as in industries such as the oil and gas sector.

   b. Access to seedcorn and venture capital

   c. Clear efforts in terms of policy implementations which can mitigate risk

   d. Simplification of the policy implementation regime

   e. Consolidate and develop large and small-scale testing facilities.

6) An industrial supercluster Establish a world-class supercluster or "Global Centre of Expertise" to exploit the expertise located at the interface between the three global knowledge hubs: the maritime, renewable energy/petroleum and seafood sectors.

7) Investment in R&D. Businesses within the sector must invest in R&D by employing personnel with R&D expertise, implementing self-financed R&D projects, and becoming demanding commissioners of research at domestic and international research institutes. Norway as a nation ought to direct more public funds towards research and development in the marine sector.

8) Attract talented personnel. In order to fulfil its great potential for value generation, as pointed out in this report, the industry must become attractive to the best talents to a greater extent than is currently the case. A trend towards larger business entities will make a positive contribution since larger businesses more commonly demand more personnel with higher educational qualifications and generate real career paths for their employees.

9) Demand-driven education system. The vocational education system directed towards the marine sector must be reviewed continuously and adapted to the sector's needs. The educational structure must be evaluated with a view to establishing the world's best marine-related education system. The education institutions and companies must develop a strategy to address the challenge of urbanisation.

10) Technology strategy. There currently exists no co-ordinated technology strategy in the field of the exploitation of marine resources. Such a strategy should be established. The export of marine

technology and expertise is a field with great potential. It should be possible to combine Norwegian aid efforts with initiatives designed to create opportunities for the Norwegian seafood sector (supply industry, skills and expertise).

2 Introduction

The earlier reports published by the DKNVS/NTVA point out the potential inherent in exploiting Norway's advantages in terms of increased value generation based on biomarine resources. Twelve years after publication of the initial report, this issue is now even more relevant. Global and domestic development trends and processes are combining to put this issue on the agenda.

Among the key political processes currently under way in Norway, which also address Norway's opportunities for future value generation based on biomarine resources, we wish to highlight the following:

- HAV21: HAV21 is a research-based strategic project initiated by the Government with the aim of promoting sustainable industrial development and sound management of the marine environment.

- A new Government White Paper addressing seafood issues which the Ministry of Fisheries and Coastal Affairs is in the process of preparing will be put before the Norwegian Parliament in 2012/2013.

At their heart, both this report and other strategic initiatives currently under way are addressing how Norway is to maintain future economic growth by means other than the production of oil and gas.

In his recently published book "*Et kunnskapsbasert Norge"* (A knowledge-based Norway), Torger Reve states that:

Norway has three, and only three, industrial sectors with the potential to become so-called "global knowledge hubs", which is Reve's criterion for a sector to achieve export-driven success in the long term. These are industries which can act as driving forces in terms of know-how, which have access to capital and which operate in a global market. The first of these is the offshore-based industry, primarily the supplier and service sectors. The second is the maritime sector, which is also linked to the offshore sector to a greater extent than in the past. The third is the seafood sector, which now of course also incorporates aquaculture in addition to the traditional fisheries industry. The Working Group believes that while Reve's approach is appropriate to an analysis of the established sectors, it is less well suited to an analysis of the new, less well-known industries.

The oil and gas boom was launched with discoveries in the North Sea in the 1960s. Since then, resolute politicians, industrial leaders and academics have all contributed towards making Norway one of the most important oil and gas nations in the world. This was a determined and strategic process characterised by the commitment and determination of key individuals. It is sufficient here to mention personalities such as Jens Evensen, Jens Kristian Hauge and Arve Johnsen.

The maritime sector is the second of the important future-oriented industries mentioned by Reve. This sector has long traditions in Norway and has grown slowly but surely over the years. Norwegian ships, the Norwegian maritime supply industry and Norwegian seamanship are and have been renowned across the globe. They are inseparably linked to the country's sense of national pride and honour as illustrated by a stanza from Bjørnstjerne Bjørnson's Norwegian Seafarer's song from 1868 "…*og vor ære og vor magt har hvide seil os bragt*." ("…white sails have conferred on us our honour and our power"). The maritime sector has always been skilled in attracting the attention of politicians and in obtaining policy frameworks which have enabled the industry to remain competitive in the global market.

The seafood industry with its fisheries traditions has “always” been with us, and the present fisheries industry has evolved through many centuries of tradition. In a global context, Norway is well-recognised as a fishing nation, and reputed for its sound management and efficient fisheries practices. However, the fisheries have neither had the need for, nor have they demanded, the same high levels of political resolution in decision-making as the oil and gas sector.

The aquaculture sector has grown and developed during the same period as the oil industry, but has not enjoyed the same powerful policy facilitation as the oil and gas sector. Fish farming has expanded tremendously along the coast and there are currently many groups holding entirely legitimate opinions about the development of the industry. Norway has gradually established a very strong position in Arctic waters, largely by virtue of the presence of its fisheries industry in these areas. Norway is also well-known in the rest of Europe as a major power in terms of its exploitation of marine resources.

In order to take the next steps involving further investment in education, research, large-scale infrastructure and logistics chains, we believe that now is the time that politicians in Norway, to a greater extent than in the past, and much as they did for the oil and gas industry, commit themselves to the development of future marine-based industries so that we can generate greater value from the resources to which we already have access. We are seeing only the start of what can actually be exploited from the oceans by means of value generating activities, and we need political will and determination if we are to grasp the opportunities before us.

In brief, this report addresses the following issues:

1) The events of the last 10-12 years regarding the exploitation of biomarine resources (including seafood)

2) The key global and domestic trends driving future development within the biomarine industries

3) Perspectives relating to future developments in selected fields leading up to 2050

4) Recommendations aimed at enabling realisation of the potential.

The study covers a long time span, and it must be assumed that much of what it will be possible for us to take from the oceans in terms of resources in 2050 is currently unknown. Our ability to extract future potential resources will depend to a great extent on ensuring a sound development culture and a capacity to acquire new knowledge.

3 Mandate

The Working Group appointed jointly by the DKNVS and NTVA was given the following mandate:

The Norwegian fisheries and aquaculture sectors have enjoyed consistent levels of growth during the last decade. New biomarine industries are being established and in many respects our supply industry is the most advanced in the world. Since the oceans must be exploited to a greater extent in terms of the production of food and energy, value generation in Norway, linked as it is to the knowledge-based exploitation of marine resources in the broadest sense of the term in the years leading up to 2050, has a significant growth potential.

The world population has now passed the 7 billion mark, and the increased purchasing power of this population generates major challenges linked to future production of food and energy. How will we be able to produce sufficient food and energy? How will we distribute the resources, and how will we be able to do this without over-exploiting the environment? Compared with agricultural land, exploitation of the oceans has so far been only minimal, and previous studies have pointed to the potential of the oceans, both in terms of harvesting and cultivation.

The Working Group will employ previous studies as its point of departure and then go on to discuss the key driving forces influencing the various biomarine industries in the years leading up to 2050. It will propose important scenarios and point out the domestic and global opportunities and challenges which Norway as a nation will encounter. The study will conclude with some recommendations.

4 Approach

The following approaches have been applied:

1) The acquisition and review of relevant statistics and literature.

2) Processes within the Working Group: A total of four meetings were held with the Working Group during which focus was directed at promoting fruitful discussions and contributions from the participants. The participants also gave presentations in their respective fields, and these were subsequently used during the writing of the report. External speakers were invited to give presentations during the meetings with the Working Group.

Commercial value and volume estimates

In each chapter an estimate of future production volumes and commercial values are presented for the fields under discussion, and reasons are given as to how these figures have been arrived at.

Terminology

Value generation is a term used in many contexts in everyday speech. In this study we have chosen to use the term synonymously with the value of commercial activities or sales revenues generated by the marine sector. An exception is made when in Chapter 7.1.5 we discuss the spin-off effects generated by the sector in other fields of industry.

It is important to be aware that the term "value generation" in the context of the National Accounts has an entirely unique definition in terms of contribution towards the GDP. In Table 4-1 below we have opted to give an account of the correct definitions of the two terms.

Table 4-1 Definition of key terms used in the Norwegian National Accounts (Statistics Norway)

Gross Domestic Product (GDP) (Norwegian National Accounts)	GDP is an indicator of a country's total value generation value and also provides an indication of gross revenues earned from domestic production activities. GDP is equivalent to the Norwegian abbreviation BNP (*Bruttonasjonalprodukt*). GDP is measured in market value, and can be defined and determined using three different methods: (I) the production method, (II) the expenditure method, and (III) the income approach.
Value of commercial activities (Norwegian National Accounts)	The value of commercial activities or sales revenues is defined as the sum of amounts earned from service industry activities carried out for customers, the sale of commodities, and gross revenues derived from other forms of business activity. The value of commercial activities includes revenues from leasing activities and commissions, but excludes public subsidies or gains resulting from the sale of fixed assets. Value added tax is not included in these figures.

The seafood sector. In its annual study of spin-off activities[1] SINTEF has defined the seafood sector as embracing both the aquaculture- and fisheries-based value chains, as well as the direct and indirect supply of goods and services (see Figure 4-1).

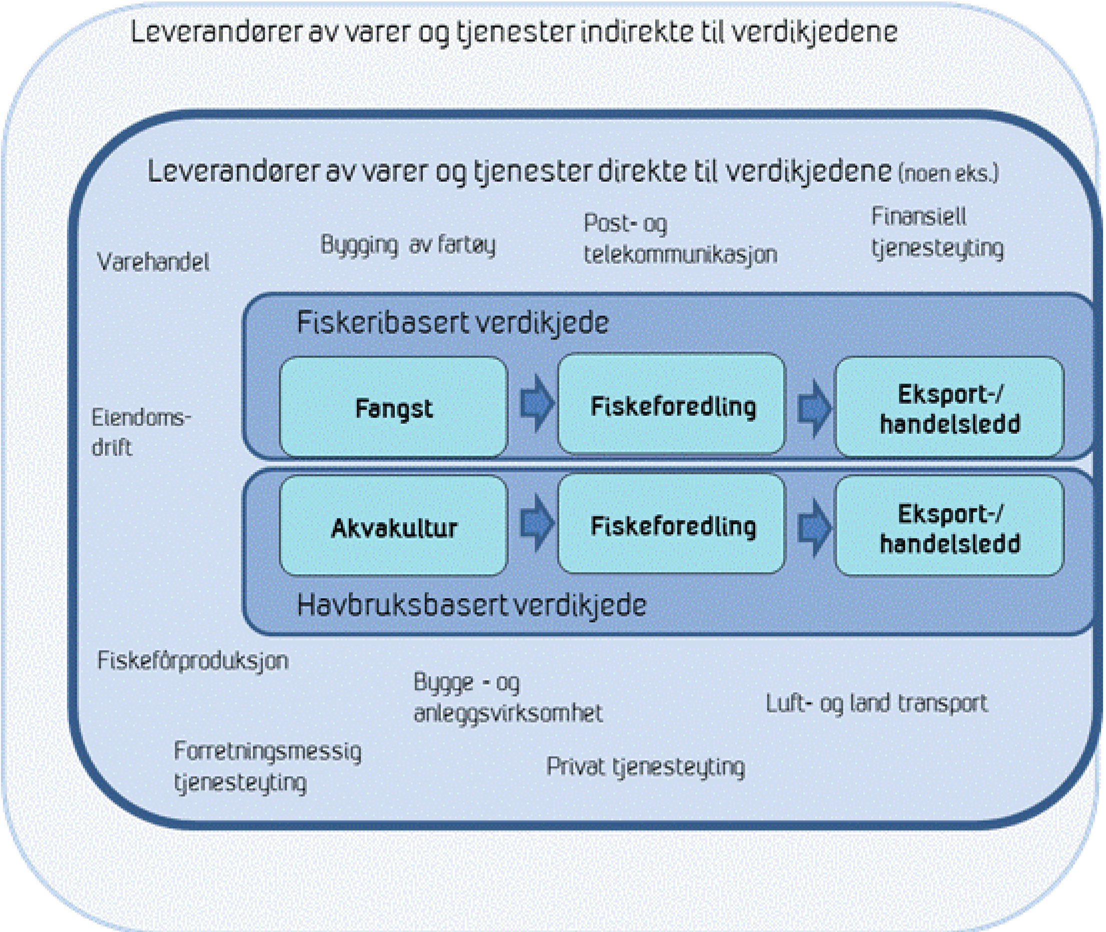


Figure 4-1 An illustration of the Norwegian seafood sector

Terms such as the **marine business, sector and/or industry** are used synonymously in this study and must here be understood to encompass all activities involving the sustainable exploitation of raw materials produced from living marine organisms. This includes companies within the aquaculture, fisheries, fish processing and export/wholesale sectors, as well as the suppliers of goods and services, research institutes and public sector bodies (used in the previous analysis). It also includes newer and more embryonic industries such as the marine ingredients industry, seaweed and microalgae farming, and others. The marine sector is considered a broader term than the seafood sector.

[1] Henriksen et al. (2012). *Verdiskaping og sysselsetting i norsk sjømatnæring 2010 – en ringvirkningsanalyse*. (Value generation and employment in the Norwegian seafood sector 2010 – a spin-off analysis). SINTEF Report A23089

Marine bioprospecting involves the exploration for interesting biomolecules from the marine environment. It concerns the discovery of genes and biologically active compounds found in living organisms for use in various applications linked to medicines, food or the processing industry. We refer otherwise to definitions presented in the relevant chapters.

5 Previous NTVA/DKNVS studies – what has happened since?

In this chapter we present summaries and conclusions from the previous two studies published by the NTVA and DKNVS:

- 1999: Norway's opportunities for value generation from aquaculture.
- 2006: The exploitation of biomarine resources: Global opportunities for Norwegian expertise

5.1 Norway's opportunities for value generation from aquaculture

The report's summary stated the following:

We aim to maintain our high standard of living, the social benefits we enjoy, the low levels of unemployment and the liberal domestic economy provided for us by the exploitation of North Sea oil and gas resources, even when these resources go into decline. The benefits we enjoy must be financed primarily from the surplus gained from our export of goods and services overseas. However: the global market will only purchase Norwegian if Norwegian is the best.

We can only become the best if we focus our human as well as our material resources on the few fields where we enjoy durable and comparative competitive advantages. Within the aquaculture sector[2] *Norway possesses a range of naturally-occurring advantages such as large tracts of unpolluted and ideally sheltered coastal waters, a healthy climate promoting the production of high quality seafood, and large areas available for the cultivation of marine plant biomass. Moreover, aquaculture exploits natural processes of self-renewal.*

Given the anticipated levels of population growth, the demand for high quality and sustainably produced protein sources will increase dramatically. However, the restricted availability of water and land fit for cultivation may limit production volumes from the landmasses. The production of healthy food from the oceans will thus provide a vital supplement, particularly in the long term. The Norwegian aquaculture sector is thus well qualified to compete in global markets when it comes to the supply of sustainably produced foods, energy and raw materials, even in a highly globalised world.

This present study reviews the value generation potential within the main Norwegian aquaculture industries which are: the traditional fisheries, salmon and salmonid farming, the farming of new species such as shellfish and marine algae; the development of biochemicals and energy carriers; the production of feedstuffs and the exploitation of highly productive ocean areas, as well as equipment manufacture, farming activities overseas, and skills and expertise.

---

[2] In 1999, the Norwegian term "*havbruk*" (aquaculture) referred "use of the oceans" in the same way as the term agriculture refers to "use of the land". In other words, the term was used to encompass all marine resource exploitation, not restricted only to aquaculture.

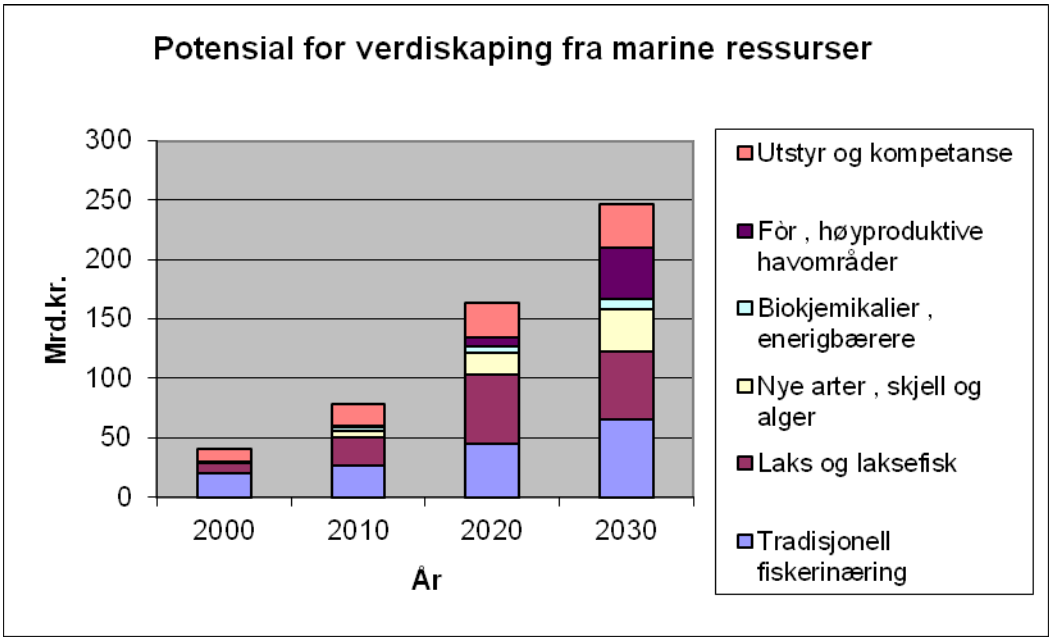


Figure 5-1 Value generation potential from marine resources as presented in 1999

A cautious assessment of the value generation potential of a wide-ranging Norwegian aquaculture sector demonstrates that it is of the same order of magnitude as that for the oil industry. Even if production of luxury seafood products will dominate the Norwegian industry in the short term, there is a potential demand to supply twice as many people as we do today without serious impact on the environment. This is the most persuasive argument for exploitation of the ocean's production potential, which will in turn reduce the pressures on land use in the long term. The wide-ranging exploitation of the value generation potential of the Norwegian aquaculture sector requires investment on a national scale of the same magnitude as has been made to facilitate the development of the country's oil and gas industry.

On this occasion too, the government must take the lead and devote major efforts at all levels on order to make it clear that Norway wishes to establish robust, and preferably Norwegian, corporate ownership structures to take on the roles as major global players involved in industries such as the production of healthy seafood and the provision of advanced maricultural services. Provided that these efforts on the part of Norway achieve the levels that the country dedicated to the oil industry, value generation in the aquaculture sector will be able fully to compensate for the decline in oil revenues.

Research and development will be a crucial success criterion, and we propose that Norway draws up a Framework Plan for the development of the Norwegian aquaculture sector based on a model taken from the EU's Framework Plans. This in turn will attract highly qualified researchers from the many coastal countries around the world to work on resolving our issues. As part of this programme, we should be prepared to spend up to NOK 1 billion annually over several 5-year periods in order to finance high quality Norwegian and foreign research.

5.2 The exploitation of biomarine resources. Global opportunities for Norwegian expertise

The 2006 report highlights areas of special interest with a view to boosting value generation based on the export of Norwegian expertise within the biomarine industry. The summary states the following:

The Working Group based its selection of areas of focus on two main principles:

1) The Norwegian team concept. *In selected fields Norway is already established as a key and leading global supplier of technology, skills and expertise.*

2) New markets with major potential. *The domestic Norwegian marine sector is well developed in a number of fields, but has so far made only limited attempts to penetrate, and has enjoyed only little success in, the global market. Global trends indicate that some of these fields have major global potential.*

The figure below illustrates the export potential of biomarine products and expertise. It must be emphasised that the Working Group believes that these are the most interesting areas of focus. The list of fields provided here does not aim to be comprehensive.

The current export value of marine expertise constitutes 10% of the total value of marine sector exports. There is a potential to increase this figure to 25% by 2025, to the extent that "expertise" will become a major contributor to value generation in combination with the traditional export of seafood products.

The figure shows that the export potential for Norwegian biomarine expertise is estimated to be NOK 25 billion by 2025. Ten billion will come from expertise within new markets and 15 billions from expertise that we currently regard as being held by "the Norwegian team". The Working Group sees this as a conservative estimate.

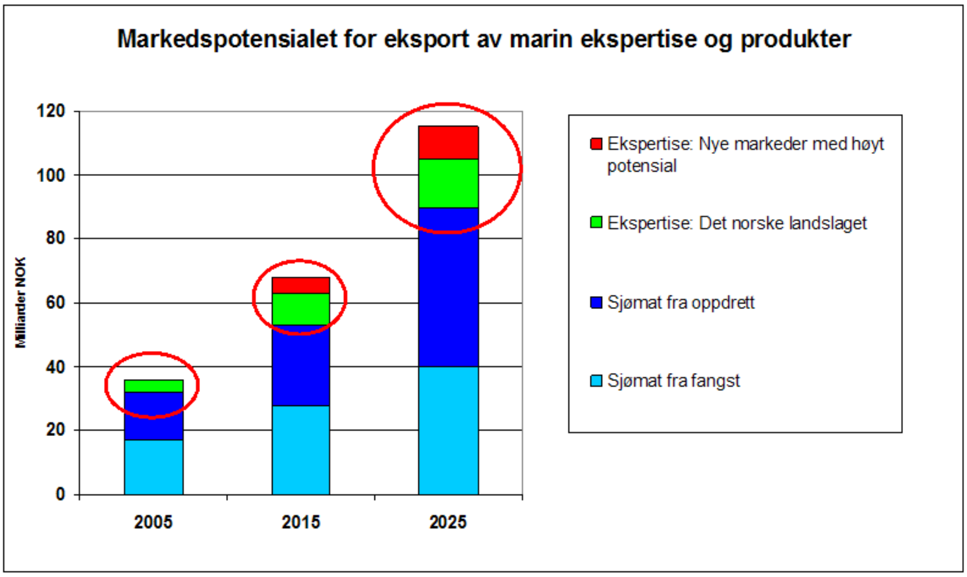


Figure 5-2 **The export potential for marine expertise and products (2005-2025), as presented in 2006**

Recommendations

In order to achieve the NOK 25 billion in marine expertise export potential it is vital that Norway continues to maintain its status as a leading technological player in terms of our own production (core activities), since *it is this which makes our expertise both interesting and saleable. The FAO is currently predicting a two- to three-fold increase in global production by 2030. The greater part of this increase is expected to come from the industrial marine sector, and it is in this field that Norway possesses its highest levels of expertise. These future perspectives constitute a major market potential for Norwegian marine sector expertise.*

The Working Group recommends that the Government, the biomarine industry (including the research institutes), and the public policy makers draw up a national strategy with the principal aim of boosting the export of Norwegian biomarine expertise. The Government must take a leading role in preparing this strategy.

An important part of this strategy work is to achieve acceptance of the idea that the export of expertise is equally as important as that of fish and fish-related products. Expertise must be regarded as of equal value as an export item.

In brief, the most important components of the strategy should be:

- *To develop strategies designed to protect intellectual property rights*
- *To make investments in human capital*
- *To establish strategic alliances at domestic and international level*
- *To become attractive to industrial and long-term capital investors*
- *To establish a policy regime tailored to support the export of marine expertise.*

A national strategy of this type should be developed with wide-ranging support, and must meet the needs and wishes of the industry.

The Working Group behind this new report can state categorically that few of the recommendations made in the two reports published in 1999 and 2006 were implemented.

5.3 What has happened since 1999?

In this chapter we have examined what has really happened since 1999 in the years leading up to 2010. Despite the fact that few of the recommendations made in the two reports published in 1999 and 2006 were implemented, how do the predictions made in 1999 match up to what has really happened in the marine sector since that time? The figure below provides schematic illustration of each field of interest described in the 1999 report (see Attachment A).

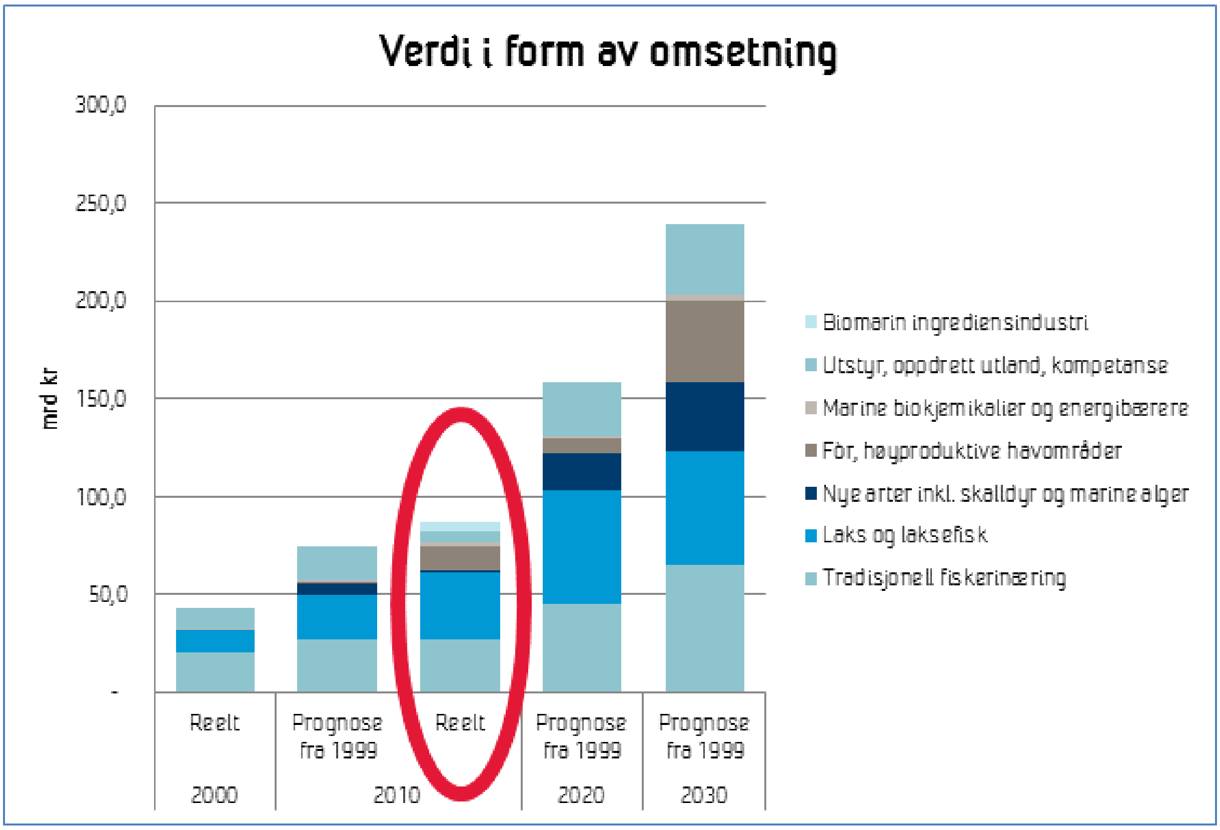


Figure 5-3 Prognoses made in 1999 compared with real data taken from 2010 (commercial value).

The traditional fisheries sector

In 1999 it was predicted that production volumes from the traditional fisheries sector in 2010 would be 2.7 million tonnes (the same as in 1999), amounting to a value of NOK 27 billion. The anticipated increase in economic value from 1999 to 2010 was NOK 7 billion.

Time shows that this prediction was very close to the mark, both in terms of production volumes and economic value. However, there are major variations from species to species. As regards the pelagic fisheries, large volumes of blue whiting and sand eels were fished in 1999, but the volumes of these two species declined dramatically in the 2010 figures. However, the volumes of herring, mackerel and capelin have increased rapidly in recent years. There have also been positive trends in the cod fisheries in recent years, and more cod is currently being landed than in 1999. Overall, catch volumes are approximately identical. The rise in economic value is linked primarily to a dramatic increase in the value of pelagic fish species. We also see some increases in value in the cod sector, but this is nothing compared to that observed in the pelagic sector.

Salmon and salmonids

In 1999 prognoses indicated that in 2010 the production of salmon and other salmonid species would amount to about 1 million tonnes. The actual figures for 2010 were just under those predicted. As regards the value of the fish, the actual value in 2010 was NOK 34.8 billion compared with a predicted NOK 23 billion. In other words, the prognosis proved to be a gross underestimate. It is worth recalling that many commentators were highly sceptical of the prognoses presented in the 1999 report, and insisted that the figures were entirely unrealistic. Key success criteria have been a continuous increase in market demand, and a regulatory regime which has provided opportunities to promote increases in production. This is now stagnating because many companies have begun to hit the production ceiling defined by maximum permitted biomass regulations (the so-called MTB). The increase in economic value recorded in 2010 can be ascribed to a very high average price. In 2000 the average price was NOK 21.65 per kg fish sold, whereas in 2010 it was NOK 31.43 (from the fish farm operators). It should be noted that production costs have also increased – from NOK 15.1 per kg in 2000 to NOK 20 in 2010 (Table 5-1). Feed and general operational costs (linked to lice treatment and other factors) are the major factors contributing to production cost increases. This indicates that the industry has failed to achieve improved production efficiency and that the high economic value generated by the salmonid farming sector in 2010 is for the most part the result of market-related factors.

Table 5-1 Average production costs (per kg) for salmon produced in 2000 and 2010 (round weight)

		2000	2010	% change
Smolt costs (per kg)	NOK	2.33	2.45	5%
Feed costs (per kg)	NOK	7.61	10.97	31%
Insurance costs (per kg)	NOK	0.25	0.15	-40%
Salary costs (per kg)	NOK	1.50	1.69	11%
Historical write-down (per kg)	NOK	0.73	1.16	37%
Other operational costs (per kg)	NOK	2.19	3.30	34%
Net financial costs (per kg)	NOK	0.49	0.29	-41%
Production costs (per kg)	**NOK**	**15.10**	**20.00**	**37%**
Slaughter costs (per kg)	NOK	2.33	2.84	18%
Total costs (per kg)	**NOK**	**17.42**	**22.84**	**24 %**

Source: Norwegian Directorate of Fisheries

New species including shellfish and algae

In our GAP analysis we have not considered the role of macroalgae in this category. The 1999 prognoses indicated that the production of new species would be approx. 300,000 tonnes, amounting to a value of NOK 6 billion. The industry failed to achieve these levels, and production in 2010 was 25,600 tonnes with an economic value of NOK 528 million. In particular, cod, halibut and mussels have failed to perform as anticipated. The reasons for this are many and complex. In spite of intensive support in terms of public policy, involving a variety of measures, the industry has failed to establish these species as “large volume species” in the same way as for salmon. The industry has had to face major production- and market-related challenges.

Feed, highly productive areas

In the 1999 report this topic was defined as follows:

- Fish feed production
- Highly productive waters
  - "Upwelling areas". These are areas of ocean characterised by especially high levels of production of plankton and fish as a result of large and naturally-occurring nutrient supplies from the deep ocean
  - Sea ranching – the release of fry and juvenile individuals in their natural habitats with the intention of harvesting them later as adults.

The 1999 report predicted that in 2010 the industry would not yet have started “cultivating” highly productive areas. However, estimates for feed production were about 0.2 million tonnes, valued at NOK 1 billion. At that time fish feed production was incorporated as a component in the estimates linked to the “salmon and salmonid” value chain and was not assigned its own economic value category. Norwegian fish feed production in 2010 amounted to about 1.3 billion tonnes and was valued at NOK 12.3 billion. The vast majority of fish feed produced in Norway is used in Norwegian aquaculture production. The prognoses were wide of the mark in terms of production volume, but the economic value figures were about right.

Fish feed production is currently dominated by the fact that the marine-derived components in the feed, represented in the main by fishmeal and fish oils, have during the last decade been in sharp decline and replaced by ingredients derived from plant material. As a result of intensified research and development, the feed sector now uses land-derived sources as replacement for those from the oceans. The challenge facing us today is that within a few years there will be a global shortage of fish oils, and the feed producers will have to find alternatives.

Marine biochemicals and energy carriers

In 1999, the term “marine biochemicals and energy carriers” referred to the following:

- Organic compounds and products (animal- or plant-derived) recovered from marine biomass sources. Typical examples are alginates, agar and carrageenans derived from a variety of macroalgae, as well as chitin and chitosan produced from crustacean shells.
- Energy carriers such as biogas and ethanol produced by the microbiological processing of seaweeds, and a range of raw materials used in the chemical industry, such as the lower alcohols, fatty acids and aldehydes, including those used as a replacement for substances derived from fossil carbon.
- Vaccines are also included in the estimates for this category.

It is impractical to assign production volume data to these categories. However, in 1999 the total economic value of these components was estimated to be NOK 0.5 billion. In 2010 the value prognosis for biochemicals and vaccines was NOK 0.82 billion. It is a challenging task to obtain figures for production levels for these categories in 2010. However, we have used figures supplied by the key industrial producers of alginate and vaccines (and other fish-derived health products).

FMC Biopolymer is by far the biggest producer of alginate and alginate-like products. In Norway, its production facility on Karmøy is based on harvested seaweeds. The company imports some of its raw materials, and in 2012 harvested approx. 150,000 tonnes of a total estimated seaweed production along the Norwegian coast amounting to about 50 million tonnes. In 2010, the company's turnover was NOK 1.12 billion.

Norwegian fish vaccine producers recorded a combined turnover in 2010 estimated at between NOK 700 to 800 million. There are a couple of companies in Norway currently manufacturing chitin and chitosan, although production levels are low. Chitinor, for example, recorded a turnover of NOK 5 million.

In Norway we observe a marked increase in interest, both in terms of research and industrial production, in the microbiological processing of seaweeds for the generation of biogas and ethanol. However, no commercial company has yet been established in this field, although there has been some success in the cultivation of seaweeds from germ plants.

Export of equipment and expertise

In 1999 the Norwegian equipment industry was defined as incorporating categories such as vessel manufacture and equipment and instrument production, including that linked to fish farming, process equipment, electronic equipment and software. Estimates of economic value were about NOK 20 billion, of which 10 billion were for export. This chapter also addressed economic value in terms of the production of know-how which took place within companies and the R&D institutes (research, consultant services, etc.).

In 2006 the NTVA and DKNVS carried out the study called "Exploitation of marine living resources – global opportunities for Norwegian expertise". Following a detailed review as part of this study, export potential figures were drastically reduced. In 2006 the total economic value was estimated at NOK 3.8 billion, of which industry suppliers accounted for the greater part. It is estimated that in 2010 this value could be as much as NOK 6 billion. It should be made clear that these suppliers are responsible for only a limited part of the total supply of goods and services to the seafood sector. Later in the report the authors have opted for another approach and have provided a broader definition of the supply industry. (see Chapter 7.1.5).

The biomarine ingredients industry

In the 1999 study, no special mention was made of the biomarine ingredients industry. Waste raw materials in the form of products for human consumption were incorporated in the export figures for the fisheries and aquaculture sectors, but the economic value of marine ingredients is not reflected in these statistics. The term "marine ingredients" is applied in the main to products derived from marine oils, proteins, the ensilage process, biochemicals, krill oil and krill meal. In 1999 the marine ingredients industry was of only marginal significance, but has now increased in status. In 2010 approximately 50 companies recorded a combined turnover of NOK 4.8 billion (Figure 5-5). Several of these companies import raw materials, such as oil from South America, as the basis for their production. NOK 2 billion of the NOK 4.8 billion turnover is based on Norwegian raw materials[3].

---

[3] Richardsen, R. & Olafsen, T. *Marin ingrediensindustri* (The Marine Ingredients Industry) 2007-2010. SINTEF Report A 178320

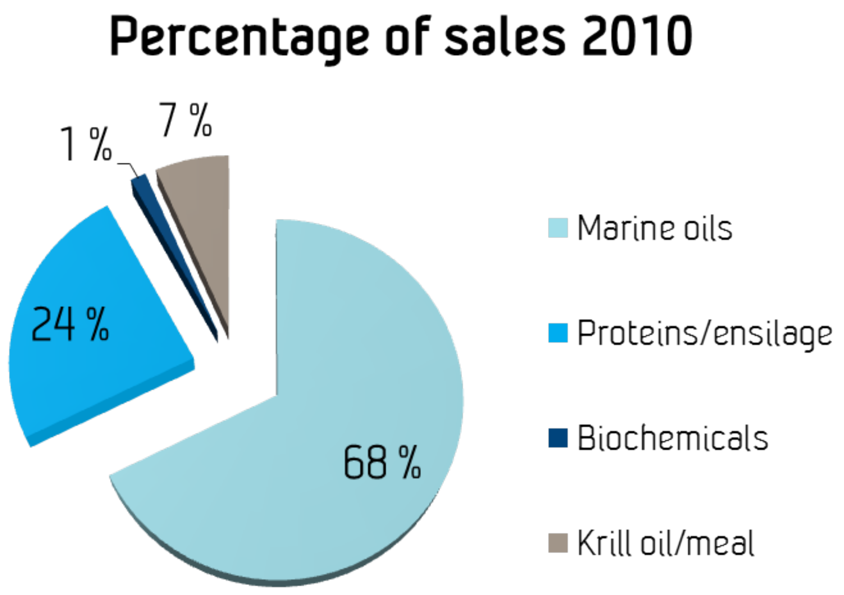


Figure 5-4 Economic value of product groups in the marine ingredients industry 2010

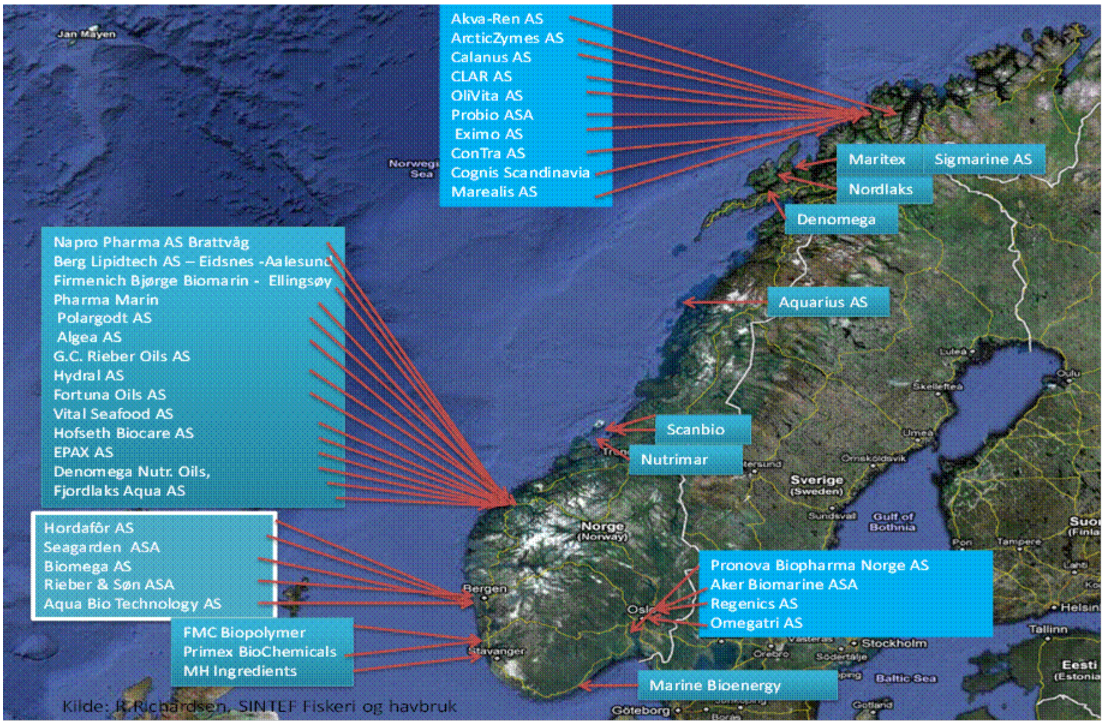
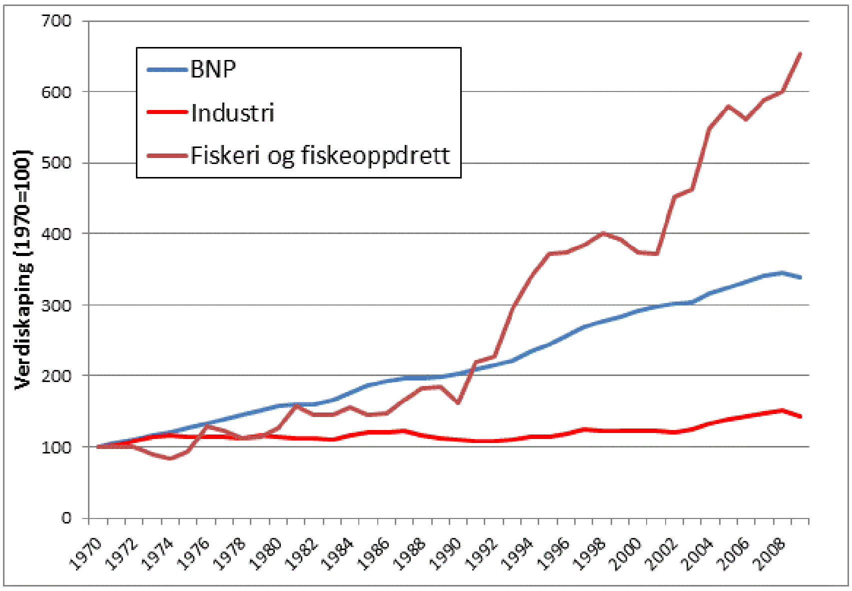


Figure 5-5 Companies engaged in the marine ingredients industry

The seafood sector – one of three Norwegian knowledge hubs

In the recently published book *"Et kunnskapsbasert Norge"* (A knowledge-based Norway) it is pointed out that the seafood sector is one of the three global knowledge hubs in Norway. Reference is made to the fact that in recent years the seafood sector has recorded runaway growth rates, measured in terms of value generation as a contributor to GDP.

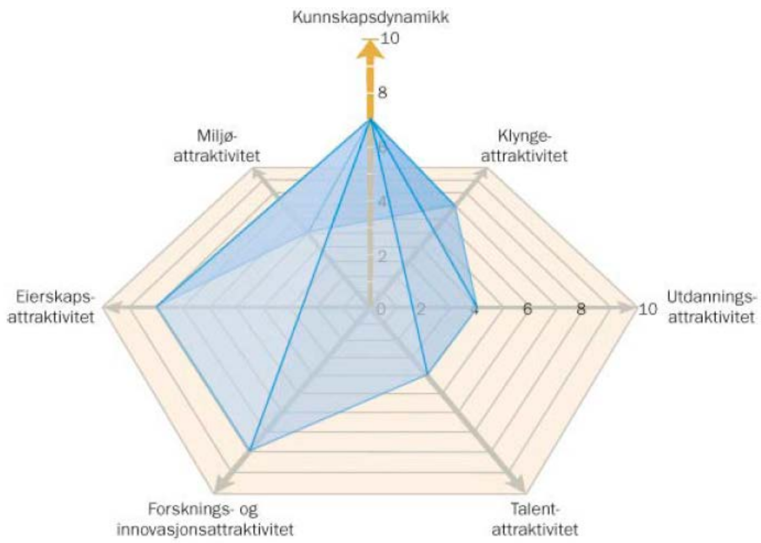
Figure 5-6 shows that the annual growth in GDP in Norway is 1.9%, whereas the fisheries and aquaculture sectors grew by 5.5% per year, and the remainder of the industrial sector by 1.5%.



Source: Statistics Norway

Figure 5-6 Total growth in value generation in Norway, in both the industrial sector in general and in the fisheries/aquaculture sector (from Reve and Sasson, 2012)

Reve's analysis develops a knowledge hub model in which different industrial sectors are awarded grades in relation to their scores on a set of attractiveness parameters. Figure 5-7 demonstrates that the seafood sector scores high in terms of attractiveness to investors, R&D attractiveness and cluster attractiveness. However, it scores less well in terms of environmental attractiveness, talent attractiveness and educational attractiveness.



Kilde: Reve og Sasson (2012). Et kunnskapsbasert Norge

Figure 5-7 The global knowledge hub model

6 Development trends of significance for the marine sector

6.1 Global trends

Since the Norwegian marine industry is, and will continue to be, an export sector which is reliant on the global market, global development trends will play a major role in determining the aspects of potential that can be realised. It is in the nature of some trends that they will be able to influence all activities on a global scale. Climate change and the demand for food will act as key determinants of this type. Many processes have been initiated with the aim of identifying the key challenges facing society, and the trends and driving forces which will influence future development. Examples include the UN's International Panel on Climate Change (IPCC)[4]; The Millennium Project[5], generated by the UN and other international institutes; the EU Grand Societal Challenges project, and Horizon 2020, which is the EU's new framework programme for research and innovation[6]. In the concluding statement from the Rio+20 UN Summit on Sustainable Development, the oceans are for the first time acknowledged as a vital resource for future food production. The statement points out that the fisheries and aquaculture sectors are vital if the world is to obtain adequate nutritionally healthy food for a growing population.

Figure 6.1 provides an overview of the most important domestic and global development trends considered to be relevant for the development of the marine sector in Norway. These will be described in the following.

---

[4] http://www.ipcc.ch/

[5] http://www.millennium-project.org/

[6] http://ec.europa.eu/research/horizon2020/

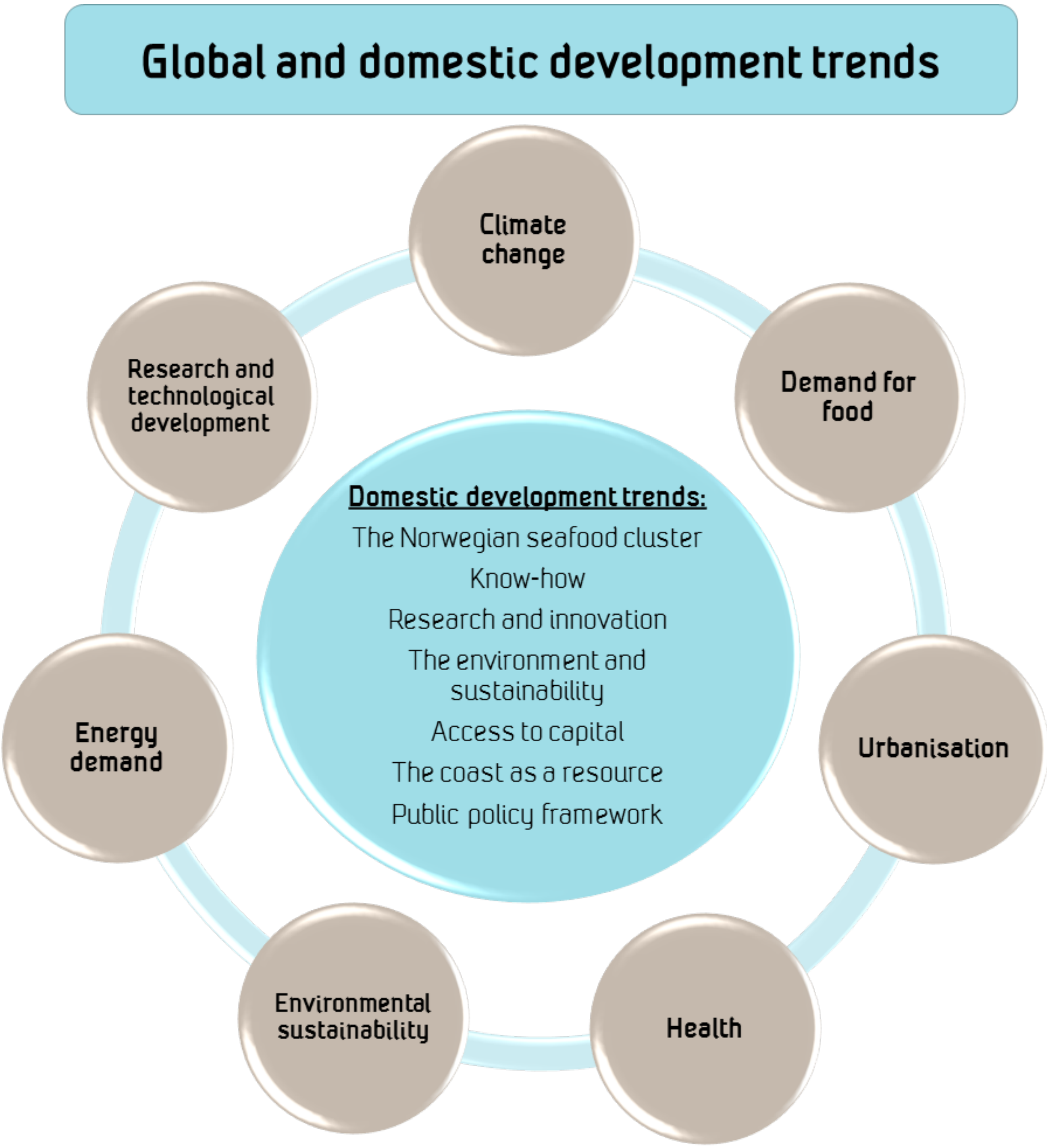


Figure 6-1. Global and domestic development trends influencing the development of the Norwegian marine sector.

Climate change

Waters under Norwegian sovereignty extend across several climatic regimes and ecosystems. It is anticipated that the ecosystems may change their character in response to future temperature increases resulting from climate change[7]. Naturally-occurring fluctuations in ocean temperatures will be able to mask changes caused by human activity in the short term, but ocean temperatures in Norwegian waters are expected to rise in the long term. It is highly likely that climate change will have an effect on existing and new marine industries, but the nature, direction and extent of these influences remains unclear.

[7] This paragraph is based in part on a presentation by Svein Sundby of the Norwegian Institute of Marine Research.

The Norwegian Institute of Marine Research considers it possible to increase production as a result of rising temperatures in the Norwegian Sea, Barents Sea and Arctic Ocean, but that it is uncertain as to whether total production will increase from the North Sea. If this comes to pass, the effect of temperature rises might be positive for the commercial fish species which Norway currently exploits. However, there is much uncertainty linked to these conclusions, especially when considering the situation in the period leading up to 2050. Among other things, there is a need for more knowledge about how changes in ocean temperatures and melting of the Arctic ice cap will influence organisms at lower trophic levels which constitute the basic food source for our commercial fish populations.

In the first instance, a rise in ocean temperatures along the Norwegian coast will result in a northward migration of the most optimal salmon production areas. This is due not only to changes linked to factors associated with optimal growth of the salmon itself, but also because temperature rise may in turn aggravate existing problems linked to parasites (including salmon lice) and pathogenic organisms. However, it should be possible to adapt operational practices and breeding strategies to changes taking place over time. This will enable the industry to reduce the impact of rises in ocean temperatures. Rising ocean temperatures may make it possible for the aquaculture sector to exploit greater numbers of thermophilic species.

There is a great need for more knowledge about climate change and its impact on the marine environment. It is currently not possible to draw clear conclusions about the consequences it will have on marine-based industries in Norway. Assessments of these consequences are for the most part model-based, and there is a need for more field data input to improve the quality of model computations. Any increased pollution of the oceans, which in turn may have a very serious impact on a number of organisms which currently represent the foundation of biomarine production, may also result in significant changes, the consequences of which it is not at present possible to predict.

Demand for food

In 2012 the world population reached the 7 billion mark, and is expected to be in excess of 9 billion in 2050. Almost the entire increase in population is anticipated to take place in cities in developing countries, where the numbers of people living in slum conditions is rising rapidly[8]. In 2010 there were almost 1 billion people suffering from malnutrition and in many countries 30-40% of agricultural production was lost. In order to keep pace with population increases and economic growth, which in turn increase the demand for food, overall food production must rise by 70% by 2050. Food from agricultural sources will most probably not be able to meet this need. Shortages of fresh water and the effects of climate change will reduce food production capacity in many regions.

[8] http://www.millennium-project.org/millennium/Global_Challenges/chall-03.html

Norway is currently responsible for the management of extensive tracts of highly productive ocean, and a coastline ideal for aquacultural production. For this reason, we have an ethical obligation to increase our exploitation of these areas in order to produce food, or products which themselves can be exploited for food production. In addition to traditional seafoods, new food products can be produced from lower trophic levels, provided that harvesting is carried out on a sustainable basis. It is now possible to manufacture feed for the aquaculture sector, and to cultivate organisms which capture phosphates which are rapidly becoming very scarce as a source of fertiliser for global food production. Harvesting from the marine food chain is currently carried out at very high trophic levels (between levels 3 and 4), at which stages the majority of primary production has been lost (Figure 6-1). There is major potential in the harvesting of resources at lower trophic levels.

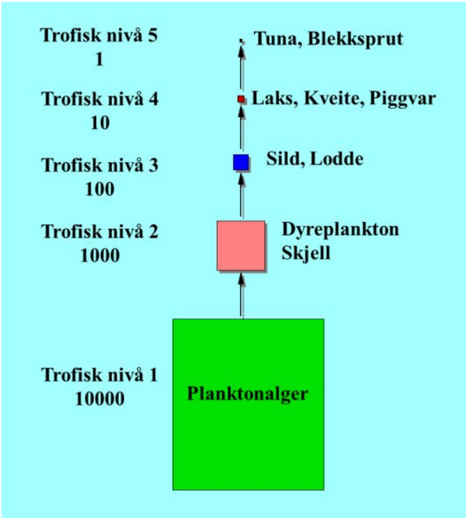


Figure 6-1 Schematic representation of the production potential at different trophic levels within the marine food chain.

Traditional Norwegian seafood will represent only a relatively insignificant option for the poor of the developing world. However, it will make a very important contribution towards overall global food production. In particular, Norwegian seafood will help meet the increasing demand for seafood among the growing middle classes in countries such as the so-called BRIC nations (Brazil, Russia, India and China).

Urbanisation

It has been a growing trend for some time that the majority of the world's population is moving into urban environments, and that most of future global population growth will take place in the cities. This means that an ever larger proportion of the population is abandoning areas where the natural environment is traditionally exploited for the production of food and other essential goods. The urban culture appears to be less aware of the necessity of exploiting natural resources, and this will create challenges in terms of gaining understanding and legitimacy for major increases in production in the marine sector, even if this occurs within sustainable limits.

Health

Seafood represents a very healthy food option offering a wide range of positive and preventive effects. We are advised to increase our consumption of seafood ahead of other foods. According to the WHO, lifestyle illnesses, including heart and circulation diseases and obesity, are the most common causes of early death and reduced quality of life in the industrialised world, and are expected to increase. The FAO and WHO recommend that people increase their consumption of fish in order to reduce the risk of heart and circulation diseases. They promote the benefits to pregnant women of eating fish in order to assist development of the foetus[9]. Recent research indicates that the consumption of whole fish results in better health outcomes than those achieved by consuming only the oils, and that omitting to eat seafood may constitute a health risk.

Access to marine oils (especially the fatty acids EPA and DHA) may become a challenge in the future in terms of the content of healthy marine oils in farmed fish as a result of limited production and high levels of competition for raw materials. The development of new production methods for marine oils will be crucial to ensuring adequate access. It is possible here that macro- and microalgae, together with crustaceans such as copepods and krill, will represent interesting new sources of marine oils.

Marine organisms may also have interesting applications as medicines, dietary supplements, cosmetics and in connection with research and industrial uses. Major efforts will be required to identify interesting substances (by means of bioprospecting), and highly demanding processes (in terms of skills and expertise, funding and time considerations) will be needed to develop finished products.

In the realm of medical, health and nutritional research, new and powerful biotechnological approaches, such as genomics, proteomics and metabolomics, are now being applied to generate fresh awareness of and new applications for genes, proteins and metabolites. An approach of this type generates future opportunities for the manufacture of individualised dietary and nutritional products, diagnostics and treatments (so-called “personalised medicine and health”).

Environmental sustainability

The harvesting of naturally-occurring species, as well as maricultural production, will have to be carried out in an environmentally responsible manner. The requirements for documentation and certification are on the increase. The requirements of the public authorities, transnational organisations, NGOs and the market, represented by the major food distribution and retail chains, are increasing in their stringency. The most important requirements include the documentation of climate-friendly food traceability and the certification of environmentally-responsible harvesting and marine production methods, such as those provided by the Marine Stewardship Council (MSC) and the Aquaculture Stewardship Council (ASC).

In some situations it will be possible to contravene demands for stricter environmental standards on the basis that there is an ethical obligation to produce more food. For the most part, better environmental practices will contribute towards an increase in exploitation in the long term, and in the development of a sharp increase in global awareness that better management of marine resources can result in the increased production of food and other key products, as well as greater value generation. Better, and increasingly ecosystem-based, global management practices may result in increases in the harvested volumes of fish species vital to the Norwegian fisheries sector, and in the exploitation of fish as a raw material for the aquaculture sector. Stricter requirements will be stipulated regarding the use of all parts of harvested fish.

[9] FAO/WHO. Expert Consultation on the Risks and Benefits of Fish Consumption, September 2011

New management regimes may be established to the extent that it will become mandatory to retain all fish caught on board vessels, as has been recommended by a research group[10].

The aquaculture sector will have to find new sources of feedstuffs, partly because parts of the fish currently used for feed will now be utilised in the production of food for human consumption. The marine raw materials used must be sourced from environmentally certified fisheries. The harvesting at lower trophic levels of planktonic crustaceans such as krill and copepods has the potential to create opportunities for new and as yet undeveloped industries within the aquaculture sector. Strict requirements regarding documentation will be stipulated to ensure that such harvesting practices entail no negative impact on other marine species and habitats.

Requirements that wild salmon populations shall not be subject to negative impact will be made more stringent. It is possible that the discharge of nutrient salts such as nitrogen and phosphate compounds, as well as organic material, will not represent a constraining factor on increases in salmon production in Norway. This is not due to the negative environmental impact in itself, but because such discharges provide opportunities for the cultivation of macroalgae and shellfish which can be exploited as food, ingredients, fuels and fertilisers. The production of macroalgae can also be exploited for the capture of CO_2.

Energy demands[11]

Global energy demand will continue to increase. The nuclear disaster in Japan, combined with the oil field blow-out in the Gulf of Mexico and the increasing awareness of climate change, continue to promote investment in renewable energy sources. Investment in alternative energy sources is on the increase. However, in the absence of a radical technological breakthrough, the majority of the world's energy in 2050 will continue to be sourced from fossil fuels. The IPCC's "best case scenario" estimates that renewable sources could meet 77% of global energy demand in 2050, and that the proportion sourced from biofuels could increase from its current 3% to 27% in 2050.

It is possible that the demand for renewable energy exploiting nutrient salts from aquaculture and CO_2, will provide major opportunities for the production of macroalgae along the Norwegian coast. This could take place in the form of free-standing algal production facilities or in so-called IMTAs (Integrated Multi-Trophic Aquaculture) facilities in which algae production is carried out in close proximity with aquaculture facilities.

Trade and economics

At present, 72% of fish exports measured in terms of economic value goes to Europe, and of this 57% goes to the EU[12]. In the short term, the current economic recession will dominate the economies of Europe, and the EU in particular. The USA and Japan will experience modest growth, while it will be countries outside the OECD which will make the dominant contribution to economic growth. To date, the Norwegian seafood sector has done very well out of the economic crisis taking place in key countries and markets importing Norwegian seafood. However, in the long term the recession could dampen these markets' motivation and

[10] Garcia, S.M. et al. (2012). Reconsidering the consequences of selective fisheries. Science, vol. 335, pp. 1045-1047.

[11] http://www.millennium-project.org/millennium/Global_Challenges/chall-13.html

[12] From a presentation by Chief Economist Øystein Dørum (DNB), during the General Meeting of the FHL (Norwegian Fishery and Aquaculture Research Fund), held in March 2012.

ability to pay for Norwegian products. This in turn could reduce the ability and motivation of Norwegian companies to invest in development of the marine sector.

Norwegian seafood has experienced a reduction in trade barriers in relation to major markets such as the EU and the USA, but the financial crisis may result in increased levels of protectionism. Political and administrative adjustments to major Norwegian seafood markets could impact on short-term export opportunities.

Research and technological development

Progress in terms of global research and development is accelerating in leaps and bounds and access to know-how is now generally universal. This provides opportunities for the development of the Norwegian marine sector at much greater rates than in the past. It also means that Norwegian research centres focusing on the marine sector are increasingly having to work within a global framework and establish strategic co-operative alliances. In order to keep pace with increased international competition in the development of new and innovative systems and technologies, it is vital to be aware of protecting intellectual property (IP). In a sector which is becoming increasingly technology- and knowledge-intensive, markets for such products will also expand rapidly on a global scale. Similar trends have also been observed within the maritime and oil and gas sectors, in which a supplier and service industry growing in a strong domestic market becomes globalised over time. An international expansion of suppliers into global markets can take place in parallel with manufacturers also trying to penetrate global markets.

Research activity is becoming increasingly multi-disciplinary and transsectorial. Biotechnology, information and communications technology (ICT) and nanotechnology are regarded as so-called “enabling technologies” which will contribute the know-how needed to boost other fields of research. Biotechnology has been extremely important to Norwegian aquaculture in terms of the development of vaccines, breeding methods and feed production. It is anticipated that biotechnology will also play an important role in the future development of marine industries in Norway in fields such as environmental monitoring and the exploitation of waste raw materials and algae. New materials may find applications in resolving environmental issues such as escapes.

6.2 Domestic and regional development trends

The Norwegian seafood cluster

The Norwegian seafood industry has been described in a study as Norway’s third strongest industrial cluster, hot on the heels of the oil and gas and maritime sectors, respectively. These three industrial sectors constitute the so-called global knowledge hubs which, among other things, attract knowledge-based enterprises, services and qualified personnel from all over the world[13] [14]. The seafood cluster is attractive in fields such as research and development, and to capital-intensive stakeholders. On the other hand, it is less attractive in areas such as the environmental, education and its ability to attract talented personnel. Overall, the Norwegian marine industries have an excellent foundation for achieving future growth and development.

---

[13] Torger Reve and Amir Sasson. (2012) *Et kunnskapsbasert Norge* (A knowledge-based Norway). Published by *Universitetsforlaget*.

[14] The seafood sector is defined by Reve as the value chain involving fisheries, aquaculture, the processing and export of seafood, as well as the suppliers of equipment and services to the various segments of this value chain.

Know-how

Norway boasts a highly-educated population. However, the seafood industry employs a lower percentage of personnel with higher education qualifications (approx. 10%) than the population at large (approx. 35%)[15]. Very few of those employed in the seafood sector hold a Master's degree or doctorate. A growing proportion of students who opt for higher education are of foreign extraction, and a significant proportion of those working in the fishing industry hail from overseas. However, we have seen a positive trend in recent years in the numbers of applicants for courses related to the marine sector both in upper secondary schools and in higher education.

Competing for talented personnel with the oil and gas sector, among others, represents one of the biggest challenges for future development within the marine industries because skills and expertise at all levels in the value chain represent a crucial success criterion for the future development of the sector. This applies in particular to new marine industries. Interesting jobs and high salary levels are attracting young people to the oil and gas sector.

In general we are seeing a migration from rural areas, especially among young and highly-qualified people. We also observe an urbanisation process converging on the oil industry centres, and in many cases away from locations where marine industry production is taking place. Many companies are small and are located at some distance from the attractive urban centres. This represents a particular challenge in terms of maintaining and raising levels of know-how within the companies in question.

Research and innovation

Research and innovation will be crucial to the successful development of the Norwegian marine sector. About NOK 1.3 billion (about 3.1% of Norway's total R&D expenditure) is dedicated to R&D linked to the aquaculture sector which currently represents the most R&D-intensive segment of the seafood sector[16].

In Norway, companies within the seafood sector are more innovative than those in other sectors as regards products, but lag behind somewhat when it comes to innovations in service provision[17]. In the future it will be important for the companies to have in-house research expertise so that they can implement essential and desirable research-based innovations.

If the value generation potential described in this report is to be realised, steps must be taken to facilitate the necessary research and development activity, as well as increased levels of innovation within the marine sector.

The environment and sustainability

Both the fisheries and aquaculture sectors, together the new marine-based industries, will be subject to more stringent regulatory requirements in terms of operating within environmentally acceptable constraints. Conformance with such requirements will be a pre-condition for consent for continued growth. Public opinion, the politicians, the large food retailers and the public authorities will have to be convinced that the sector's operations are environmentally sustainable. Documentation and certification will become

---

[15] Reve and Sasson (2012).

[16] Reve and Sasson (2012).

[17] Reve and Sasson (2012).

more and more important, and the sector itself will have to adopt an aggressive approach to reducing its environmental footprint. At present, the spotlight is firmly fixed on the aquaculture sector in connection with the industry's possible impact on wild salmon populations resulting from escapes and salmon lice, and the use of marine-derived raw materials in feedstuffs. We can also expect strict requirements in terms of impact analyses and documentation if the industry moves in the direction of harvesting resources such as krill and copepods at lower trophic levels. In order to gain acceptance for larger-scale harvesting at lower trophic levels, it may also be necessary to adjust current views as to how ecosystems should be managed and exploited.

<u>Access to capital</u>

Development of the opportunities inherent within the marine industries will require major levels of capital investment. The aquaculture sector, the pelagic segment of the fisheries sector, and the biomarine sector are all currently experiencing that it is a relatively straightforward matter to finance expanded levels of production and capacity. On the other hand, other segments within the sector are finding it more difficult to raise necessary capital. In particular, it will be important to raise capital for the development of new industries which represent a greater risk and require long payback periods.

<u>Coastal waters seen as a resource</u>

Norwegian coastal waters represent a fundamental resource. It is essential to exploit these waters if the marine industries are to achieve major growth. Access to exploit the most suitable areas and to maintain them in a condition which does not reduce their suitability will be a crucial factor in determining whether their potential can be realised. At the same time is it likely that a major increase in value generation linked to coastal waters will require access to larger areas than are currently being exploited. There is a multitude of interested parties currently making use of the coastline and coastal waters and there is increasing competition for the most suitable areas. For instance, the coast-based tourist industry is enjoying rapid development.

Table 6-1 Examples of the utilisation of coastal waters

Utilisation of coastal waters	
Fisheries	Transport
Aquaculture	Oil and gas operations
Fishing tourism/recreation/hunting	Mineral production
Holiday cabins	Other commercial activities
Wild salmon, other wild salmonids	Military operations
Nature conservation/biodiversity	

The aquaculture industries are looking beyond their traditional areas and are seeking opportunities to carry out their activities further offshore. At the same time technology is being developed to produce facilities such as closed containment fish farms, which can be located further offshore. This may provide the aquaculture sector with opportunities to develop production strategies resulting in less competition in coastal waters and introducing the possibility of increased production without negative impact on the environment.

Along parts of the coast, such as in northern Norway where the oil and gas industry is experiencing growth, a process is underway to resolve potential conflicts between the marine industries and the oil and gas sector. The outcome will have a bearing on opportunities for future value generation in the areas in question. In order to grasp this opportunity for increased value generation from coastal waters it is essential that quality is not allowed to deteriorate.

Public policy framework

A key criterion for the realisation of value generation potential is a stable and harmonised public policy framework. In general, the marine industries are governed by high levels of public regulation. This applies in particular to the traditional fisheries and the aquaculture sector.

There is now an even greater need to adopt focused and stimulating policy initiatives aimed at achieving desired development goals. This is the case in the oil and gas sector where there exist excellent public financing arrangements designed to promote investment on the shelf, including separate financial stimulation packages to support the supply industry.

Proposals entailing that in the future the marine industries will have to pay for the utilisation of given areas, such as have been put forward for the aquaculture sector, must be assessed in the light of the impact they will have on future levels of activity and value generation in coastal waters.

6.3 Potential threats to future development

On the one hand, the development trends outlined above represent opportunities for, and on the other also potential threats to, future growth in value generation in the marine sector. In fact, all these trends may represent threats if development continues in directions which are unfavourable to the marine-based industries.

Some threats may be difficult to influence such as:

- Climate changes which take a more dramatic course than anticipated to date
- A global economic recession with long-term consequences
- Stricter trade barriers resulting from a global economic recession
- A reduction in the quality of the marine environment due to factors such as pollution.

7 Value generation in marine sector in 2050

In this chapter we aim to describe the levels of value generation which the marine sector may achieve in 2050 within selected industry segments. Value generation is represented by two principal areas of development:

1) A progressive development of the seafood sector's currently familiar core industries
2) The development of new industries

In order to realise potential within both the established (item 1) and the less-well known (item 2) sectors, we must rely on being able to utilise the so-called "enabling technologies", such as biotechnology, nanotechnology, information technology (IT), and others such as materials technology. This can be visualised using the figure below:

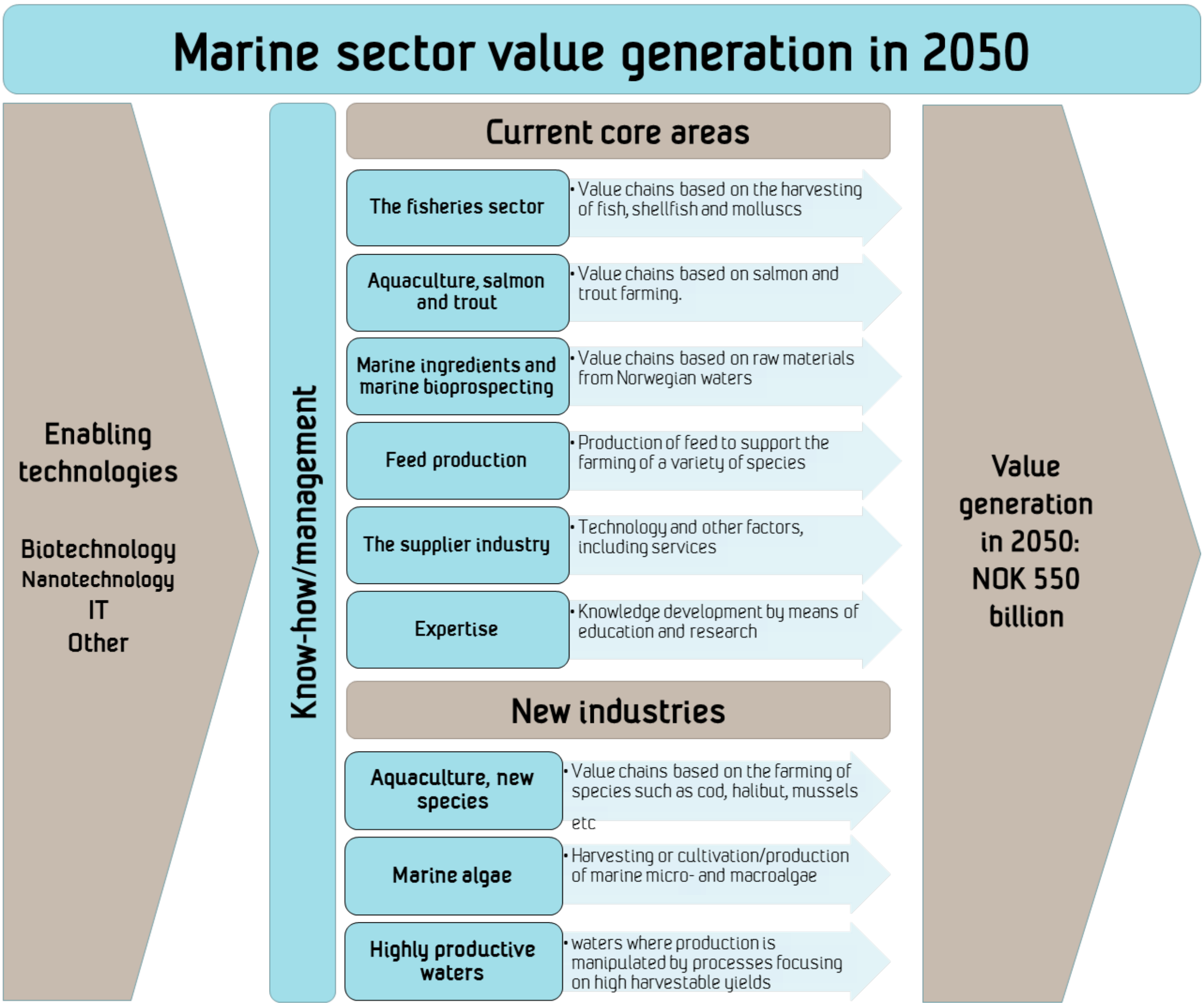


Figure 7-1 Marine sector value generation in 2050

1) **<u>A progressive development of the seafood sector's currently familiar core industries</u>**

- The fisheries sector: value chains based on the harvesting of pelagic species, cod varieties, and other species such as flatfish/benthic species, shellfish and other molluscs.
- Aquaculture, salmon and trout: value chains based on salmon and trout farming.
- Marine ingredients: value chains based on raw materials from Norwegian waters which contribute to the production of oils, proteins and biochemicals.
- Feed production: the production of feed to support the farming of a variety of species.
- The supply industry: technology and other advances required either to harvest or to produce marine-derived products. These include fishing vessels, equipment for the aquaculture sector, fish health products and such like.
- Expertise in the form of the collective experience and know-how that currently exists within the industry, the public authorities and the research communities.

2) **<u>The development of new industries</u>**

- Aquaculture, new species (fish, shellfish): value chains based on the farming of other species such as cod, halibut, Arctic charr, mussels, among others.
- Marine algae (macro- and microalgae, harvesting, production): The harvesting or cultivation/production of marine micro- and microalgae (seaweeds). Applications in the fields of energy, feedstuffs and food.
- Highly productive waters.

7.1 A progressive development of the seafood sector's currently familiar core industries

Subchapters are organised identically as follows:

1) A description of key development trends on which the selection of production volume and economic value figures for 2050 is based, including definitions
2) A highlighting of industries with particular potential
3) A calculation of production volumes and economic value based on selected criteria.

7.1.1 The fisheries sector

7.1.1.1 A description of key development trends

The term "fisheries sector" is understood to encompass value chains based on the harvesting of cod varieties, pelagic species, flatfish and benthic species, shellfish and other molluscs. These value chains include links incorporating harvesting, processing and sales/export activities. This is the fisheries sector we are familiar with today, and in 2050 these species and value chains will continue to make up the core activities within the traditional fisheries industry. We also anticipate that in 2050 the industry will have begun to harvest species at lower trophic levels in the food chain. We are already seeing glimpses of this today in the form of krill (*Euphausia superba*) fishing in the Antarctic Ocean, as well as attempts to harvest copepod species such as *Calanus finmarchicus* in our own waters. Fishing activities of this type must be carried out in a sustainable manner, and this will require a significant accumulation of know-how within the research communities, the industry and the public authorities. Moreover, other species not currently considered to be of commercial interest, including marine mammals, will be caught and processed.

The fisheries sector value chain is both intricate and highly complex. The pelagic value chain is characterised by a few vessel operators, a highly structured industrial link, and large production volumes of simple products passing through the system. The white fish sector operates with a complex fleet structure made up of many fleet groups, a filleting industry in which the market share in processing is in decline, and a conventional sector (dried fish, salted fish and stockfish) which is increasing its market shares. In recent years, shrimp and prawn harvesting has been in decline, and there are only a few processing factories left.

Resource base

There is a given probability that in 2050 the coastal and oceanic waters managed by Norway will continue to be highly productive. There are major uncertainties linked to these prognoses (see Chapter 6.1). However, there is a certain consensus among climate researchers that, compared with many other countries, our waters will be positively impacted by climate change[18]. Marine pollution will contribute towards complicating this scenario, and in the future it will be necessary to boost levels of research into issues such as climate and ocean acidification.

Norway is already a world leader as regards the management of our fisheries resources, and we are putting major efforts into building up our knowledge base with the aim of developing management systems which are as far as possible ecosystem-based. The principles governing ecosystem-based management are under

[18] Presentation given in 2012 by Svein Sundby of the Norwegian Institute of Marine Research.

continuous development and a recent publication [19] has pointed out that it is possible to manage our waters on the basis of principles other than those which we currently practice.

An example of this are the so-called “balanced harvesting” principles which involve distributing harvesting practices across many more species and size cohorts than is the case today – as they relate to their inherent growth and development within the ecosystem in question. In 2050 Norway continues to be a world leader in terms of the development of sound management systems. The fixing of quotas and the governance of other management practices takes the entire ecosystem into account to a much greater degree. For this reason the need continues to acquire more knowledge and generate better models to simulate resource management, population dynamics and function, and the structure of the marine ecosystem. In 2050 our fishermen’s know-how is applied in an entirely different way than is the case today. Fishermen and researchers contribute on an equal footing to our systematic accumulation of knowledge. Much of current time spent at sea will be saved by using technology dedicated to continuous and real time monitoring which is transmitted onshore. More efficient management practices mean that we will be able to harvest greater volumes than is the case today.

Fishing practices as before

Challenges facing harvesting practices will be linked to regulation of the catches and the quality of fish and shellfish aimed at ensuring that species are not overfished. The regulation of catches is a demanding and perpetual exercise. In the future this will be carried out as a joint effort between the research community, the industry and the authorities. New approaches and technologies will permit the continuous improvement of estimates and computations, provided that Norway, as a seagoing nation, prioritises public financing to maintain and boost the quality of research into its fish populations and the marine environment. In the future it is possible that we will also see population fluctuations. However, overall catch volumes will either remain stable or be somewhat greater.

The economic value of total harvested volumes from our recognised fisheries is estimated to increase in the years leading up to 2050. The reason for this is linked primarily to increased demand which is anticipated to come from a variety of different markets. Assuming that Norway successfully maintains its sound management practices, in addition to preventing accidents linked to its oil production from Arctic waters, seafood from Norwegian waters will continue to keep its excellent global reputation as unpolluted and healthy food. The sector achieves high prices for its products in 2050, thus providing an excellent foundation for increased value generation throughout the value chain. Increased value generation is also concerned with the development of a profitable fishing fleet, and in 2050 we anticipate that the fleet will have increased its profitability while at the same time adopting more energy-efficient and sensitive approaches to its fishing practices. Norway possesses a very sound knowledge base, both in the industry and its research institutes, within the fields of fisheries-related and vessel technology. Several of the most successful suppliers operate within all markets linked to marine activities. They are considered as members of the “supercluster”.

Processing – at home, abroad or onboard?

In recent years, much of the profitability linked to the “harvesting value chain” has been connected with fleet operations, while the processing sector onshore has struggled with prolonged periods of poor

[19] Garcia et al. (2012). Reconsidering the consequences of selective fisheries

profitability. It is reasonable to question whether Norway will have a land-based processing industry in 2050 or if such activities will be carried out in low-cost countries or onboard large factory vessels which harvest fish in Norwegian waters before proceeding directly to the markets which they serve. Or are we seeing a tendency towards vessels shuttling between the fishing grounds and their markets, while others spend their entire time on site (a Japanese model)? Overall, we can be certain that there will be value generation opportunities linked to the processing of fish in Norway. However, this will require a number of changes both from the industry and the policy makers if the sector is to become more profitable. The value of waste raw materials must be realised, and developments in both technology and expertise will be required both in the processing sector and among the suppliers. Logistics and traceability systems must be better developed.

Waste raw materials as the basis of consumer products and a new ingredients industry

We will also see an overall rise in commercial value within this sector in 2050 because all fish waste raw materials will be utilised. A directive has been in place for some time to conserve all waste raw materials, and efficient handling and logistical systems have been established even for the smallest vessels. This means that in all probability a land-based industry will be established in Norway. Heads, livers, roe, milt and stomachs are utilised directly either in consumer products or for the production of ingredients, and the relevant markets are well-established. Currently, 170,000 tonnes of waste raw materials are dumped by the coastal ands sea-going fleets. At an average price of NOK 5 per kilo, this is equivalent to a value a little short of NOK 1 billion. However, the major source of increases in economic value will be linked to the markets' willingness to purchase marine proteins and oils. Norway has the potential to assume a leading position in the global marine ingredients sector in 2050. However, this assumes that the Norwegian authorities support developments both in the industry and in expertise, both currently in their embryonic stages.

The consumer decides

In 2050 our knowledge of individual consumers' wishes and preferences will dominate the entire value chain, including the fisheries. Fish are seen as a health-promoting product and are in demand among an increasingly growing and aware middle class with a willingness to pay. The quality of both fresh and frozen products has increased significantly, and shelf life has been prolonged. The range of products has increased and several "combination products" are available which bring together a variety of seafood groups and other foods. The price range is also much wider than today and consumers pay very good prices for high quality products. The consumer is increasingly concerned with product labelling, and information is communicated using advanced traceability and IT systems.

7.1.1.2 Production volume and economic value estimates for the fisheries sector

Our criteria for achieving increases in catch volumes are linked to:

- Increased volumes of harvesting from lower trophic levels. Such activities will involve strict requirements in relation to documentation and sustainability.
- Many more species and sizes of fish and shellfish will be harvested than is the case today, and all will be brought onshore.
- Optimal management of current populations (ecosystem-based management)

Our criteria for achieving increases in economic value in 2050 (an increase in excess of the production volume increase) are linked to:

- Increased scarcity of food combined with an increased desirability and demand on the part of the consumer to eat healthy products
- Greater know-how built into the products
- Increased purchasing power among the middle class
- Increased profitability in the land-based industry due to increased levels of processing, automation, etc.
- Increased exploitation of, and higher prices received for, waste raw materials.

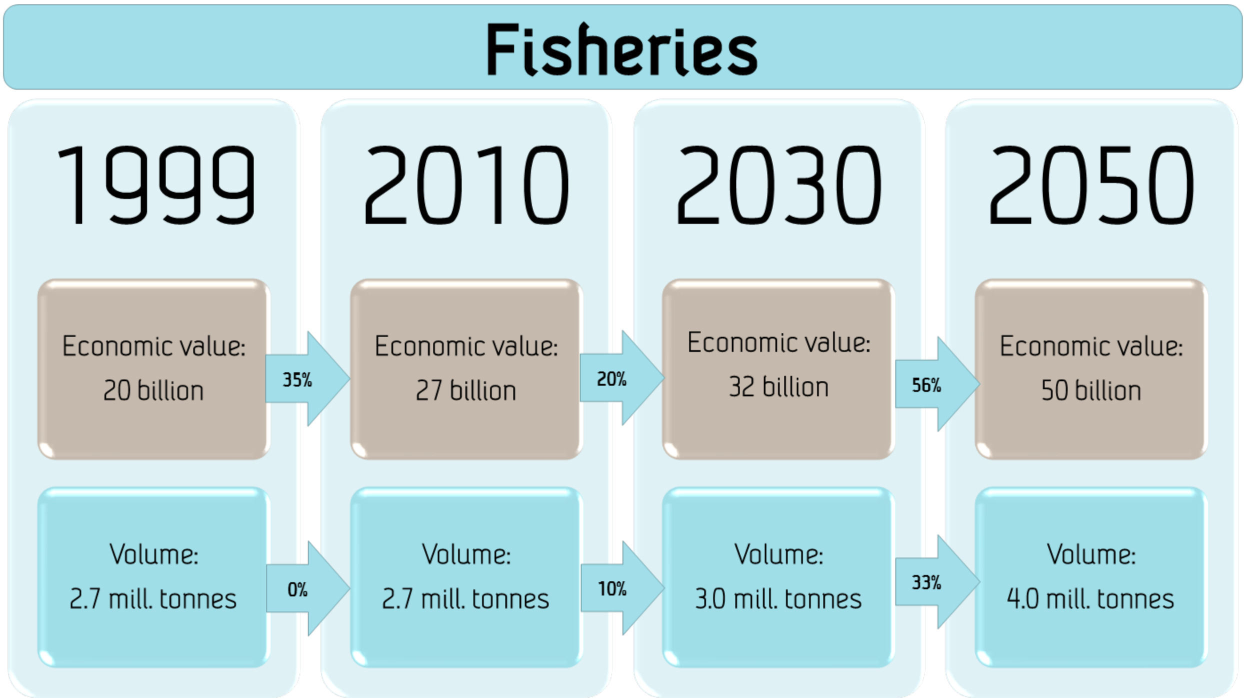


Figure 7-2 Economic value and production volumes in the fisheries sector

7.1.2 Aquaculture, salmon and trout

7.1.2.1 A description of key development trends

The term “salmon and trout farming value chain” is understood to refer to breeding and broodstock activities, smolt production, the production of marketable size fish for human consumption, slaughter, processing and export and sales activities. In this chapter we intend to focus of the principal value chain. Issues regarding the suppliers of various goods and services will be discussed in a separate chapter.

Salmon will continue to be the dominant farmed fish species in 2050. In recent years, trout production has stagnated somewhat, and more uncertainty is linked to the role that trout might play in future commercial fish farming activities.

Solving environmental challenges – a prerequisite for future economic growth

A prerequisite for salmon maintaining its position in 2050 as the dominant farmed fish species in Norway is that the industry and research communities find solutions to the environmental challenges set out in the Government’s sustainability strategy linked to the genetic impact on wild salmon of escapes, disease (including parasites), pollution and discharges, area use and feed resources. The industry and the research communities are working to find answers in all these fields, and this work will only be intensified in the years ahead. The Norwegian Board of Technology has very recently proposed that the Government’s criteria for a sustainable aquaculture industry must be implemented as soon as possible since it represents the most important means of establishing a focused and planned R&D strategy going forward[20] . This will be vital if we are to make plain the demands which will be required of the industry, and will at the same time provide clear signals as to how we should organise future efforts to promote innovation. This work is underway, although the Board of Technology recommends that it should be completed as soon as possible and provide clear and as far as possible quantifiable objectives.

In 2050 biotechnological and genetic methods have enabled the development of a sterile salmon with excellent growth properties and robust immune system. New net technologies have been developed and escapes of farmed fish have been eliminated. In 2050 we have achieved good control over the louse situation, as is the case in many locations today. In addition to a vaccine against the salmon louse, work is continuing to develop biological and technological solutions. Fewer and larger fish farming enterprises are making it easier successfully to achieve joint initiatives and strategies in certain fields.

Even though we have resolved many disease-related challenges by means of ever-improved vaccines, nutrition, and other preventive measures (less stress, sensitive handling and such like), there still remain disease-related issues within the fish farming industry, as is the case for other domestic animals.

The greatest challenge in 2050 in terms of resources will be linked to access to high quality feed resources and marine-derived resources in particular. Harvesting at lower trophic levels in the marine food chain has improved access to marine-derived feed resources, but here too there are constraints on what it is possible to extract. When it comes to land-derived feedstuffs, those produced with the help of GMOs are now

[20] *Fremtidens lakseoppdrett. Teknologirådet, nr 1. 2012* (The future of salmon farming. The Norwegian Board of Technology, no.1, 2012)

permitted, but issues remain linked to quality and access. The competition for feed resources has become tougher.

Organisational changes and the strategic application of R&D

Solutions to the environmental challenges have been the result of more intensive and committed joint collaboration between the aquaculture companies, the supply industry and the research communities. The aquaculture companies have declined in number and those remaining are larger. In 2050 they have become demanding commissioners of solutions from both the supply industry and the R&D centres. In many ways they conduct their operations similarly to the way Statoil does today. They are granted concessions to operate fish farming facilities and assume responsibility for the fish themselves, for product development, sales, marketing and customer relations. They have also made stakeholder acquisitions in large foreign customer enterprises. At the same time, the supply industry delivers goods and services linked to technology, feedstuffs, fish health and breeding products, as well as the establishment and operation of farming facilities. Many operations are highly specialised and require specific levels of expertise which it is inappropriate for the fish farming companies themselves to employ. Core expertise within the fish farming companies is linked to the feeding and care of the fish themselves.

Moreover, the fish farming companies have accumulated high levels of research expertise and are significant and reliable commissioners of research work.

Diversification into a variety of production fields and approaches

In the years ahead a diversification of production approaches will take place in the fish farming industry. These will include the production of larger fish in the hatcheries than is currently the case, closed systems deployed at sea, and the exploitation of new and more exposed sites for the location of fish farms. Developments will take place largely as a result of stipulated environmentally-based restrictions on growth which in turn appear to promote an “inventiveness” needed for the industry to be able to produce greater volumes.

Even if we anticipate that the fish farming industry will eventually be regulated according to principles other than those stipulating specific production volume requirements, technological developments and diversification within the industry will continue. The reason for this is that some of these production approaches appear to be profitable. Furthermore, the Norwegian supply industry is experiencing great interest from other parts of the world where there is an even greater need than in Norway to contain production within closed facilities and to exploit more exposed sites for the location of fish farming facilities.

In the future, the majority of salmon will be reared in coastal waters where conditions for profitable production are the most favourable.

Increased levels of processing and the exploitation of waste raw materials

In 2050 it is most likely that all fished farmed will be filleted in Norway. We will also see the production of larger volumes of more highly processed products. Transport is significantly more costly than today. Moreover, waste raw materials have become valuable components in the marine ingredients industry. Waste raw materials for human consumption such as belly flaps and heads fetch higher prices and make a major contribution to the processing industry’s bottom line. Oils derived from farmed fish are used both as feed for farmed fish and in other products. Levels of automation are high and production is driven mainly by process operators and robots.

7.1.2.2 Production volume and economic value estimates

In 2050, the most important criteria for increased production are linked to the following:

- Resolution of the environmental challenges set out in the Government's sustainability strategy
- Political will is a prerequisite
- Changes to the regulatory regime enabling the industry to experience a predictable strategic framework within which companies can make investments, and that these regulations do not restrict their opportunities to develop competitive businesses
- Continued rise in market demand for salmon
- New and important innovations in the fields of feedstuffs, fish health, breeding and technology.

The criteria for increases in economic value in 2050 are in many ways the same as those for the fisheries value chain, and are linked to the following:

- Increased scarcity of food combined with an increased desirability and demands on the part of the consumer to eat healthy products
- Greater know-how built into the products
- Increased purchasing power among the middle class
- Increased prices for waste raw materials
- Increasing levels of processing to produce fillets and other semi-manufactured products.

In the last two decades, the average annual growth in the production of salmon and trout has been just under 10%. It is unlikely that we will see the same levels of annual growth in the years leading up to 2050, and Figure 7-3 provides an illustration of how production trends may emerge in 2050 based on a range of different growth scenarios. In the case of a 3% annual increase, production will achieve levels of approx. 3.2 million tonnes in 2050. A 5% annual increase will result in approx. 7 million tonnes, and a 7% annual increase will result in more than 14 million tonnes.

Within the global aquaculture sector, annual growth in recent years has been 4% on average, and the FAO points out that real future demand will be about 5.6% annually[21] .

It is the opinion of the working group that provided the aforementioned criteria are met, it may be possible to achieve production levels for salmon and trout of 5 million tonnes in Norway in 2050. This figure is the basis for the NOK 240 billion estimate attached to the economic value of the salmon and trout farming industry in 2050.

---

[21] Presentation given by Arni Mathiesen of the FAO (AquaVision 2012).

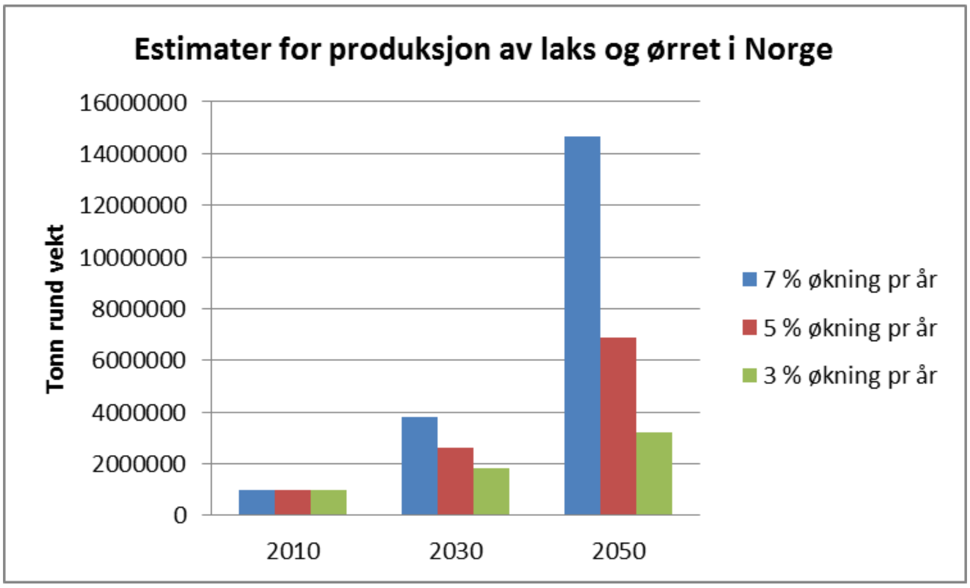


Figure 7-3 Production prognoses for salmon and trout in Norway for the period 2010-2050

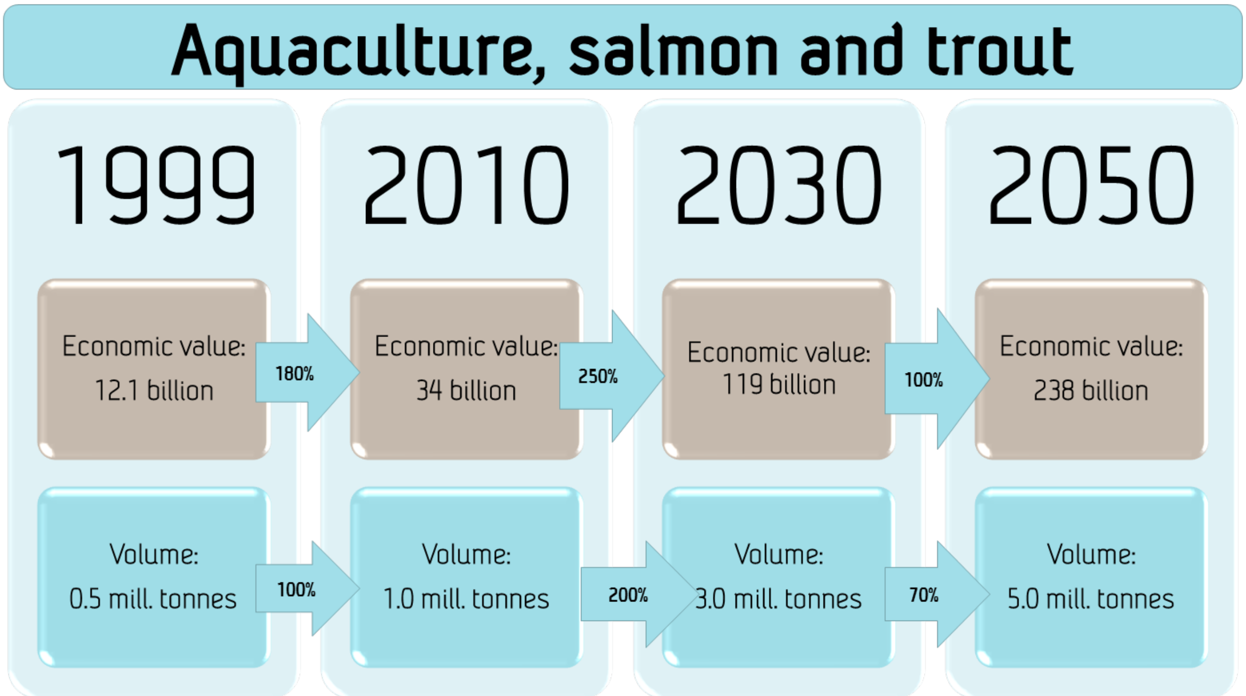


Figure 7-4 Economic value and production volumes in the aquaculture sector[22]

[22] The term "economic value" is here understood to refer to the equivalent of export value + domestic trading value (price x the volume of the various products). The term "volume" refers to salmon and trout production measured in round weight.

7.1.3 Marine ingredients and marine bioprospecting

7.1.3.1 A description of key development trends

The term "marine ingredients" is understood to refer to value chains based on raw materials derived from Norwegian waters which contribute to the production of oils, proteins and biochemicals. In principle, there are three relevant raw materials sources which can in turn be assigned to two categories:

1) Ingredients based on the harvesting and processing of a given volume of biomass:
   - Waste raw materials from the seafood industry
   - Seaweed production and harvesting (see Chapter 7.2.2)
2) Ingredients produced by specific organisms and identified by marine bioprospecting.

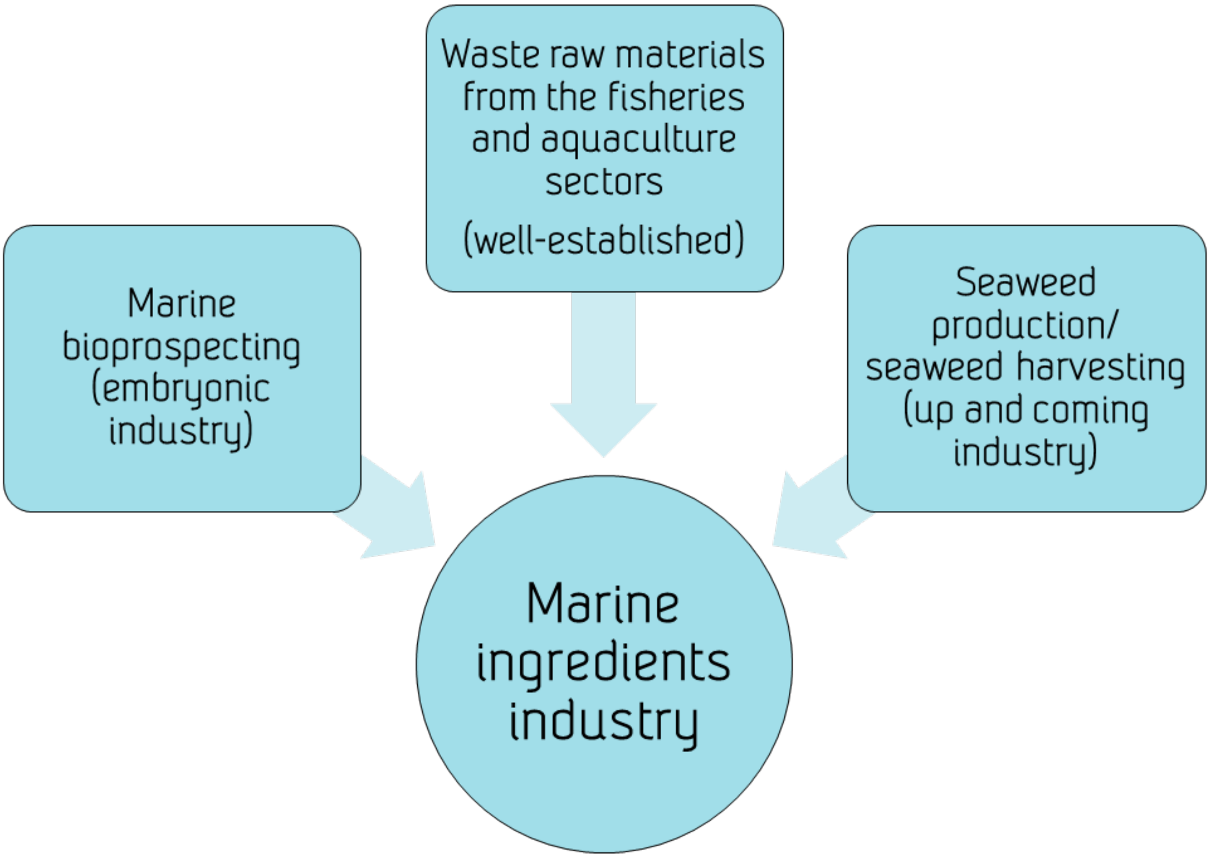


Figure 7-5 Potential sources of raw materials for the marine ingredients industry

Industrial processes make use of both established process technologies more closely related to the foodstuffs industry, combined with more biotechnological processes, including marine bioprospecting.

Waste raw materials from the seafood industry

The most important sources of marine ingredients in Norway today are the waste raw materials derived from the traditional fisheries and aquaculture industries. In 2011 waste raw materials amounted to 820,000

tonnes, of which 624,000 tonnes were utilised[23] .
Approximately 170,000 tonnes were used in the manufacture of consumables and specialised products, while the remainder was used as feed in the form of fish meal, ensilage concentrates and feed for the fur industry. Approximately 180,000 tonnes of waste raw materials derived from the fishing fleets are not exploited at all.

<u>Waste raw materials volumes on the increase</u>

If catch volumes and production from aquaculture increase in the future, together with the levels of fillet production (see Chapter 7.1.2), we will also see a major rise in the volumes of waste raw materials. In 2050 we anticipate that the waste raw materials currently dumped at sea in 2012 will be conserved for other uses. This will require a combination of regulatory changes and innovations within the traditional fisheries industry.

<u>Use as feed and for human consumption</u>

In the future, the greater volume of waste raw materials will enter the recognised feed markets, and be used directly for the manufacture of products for human consumption. In 2050 products such as heads, belly flaps, livers, roe and milt will be regarded as part of the main product and will not be referred to as waste raw materials, by-products and such like. The terminology will change and in doing so will contribute towards raising the status of these products and the markets' willingness to purchase them.

In 2050 there is an even greater focus than today on obtaining raw materials for the production of feedstuffs, and waste raw materials will be regarded as an even more valuable source of marine raw materials (such as proteins, oils and special ingredients) for the production of feed for various fish and domestic animal species. Research and innovation has contributed towards a clear identification of the challenges we face linked to infectious diseases to the extent that regulations are now tailored to incorporate the exploitation of waste raw materials within new ”cycles” – free of the risk of the spread of infectious disease carriers.

Marine bioprospecting

<u>Marine bioprospecting</u> involves the exploration for interesting biomolecules in the marine environment. The great biological and biochemical diversity which we encounter in marine plants, animals and micro-organisms provides great opportunities for the discovery of unique genetic materials and active chemical substances and molecules with a multitude of potential applications. Little research has been carried out on organisms which are adapted to cold water conditions. This makes it even more interesting to carry out exploration in Arctic waters, such as offshore northern Norway and Svalbard, where biodiversity is especially rich. Arctic species survive under extreme conditions of variations in daylight, salt concentration and temperature, and have adapted themselves over millions of years by developing unique survival strategies based on the utilisation of certain chemical compounds – the so-called secondary metabolites.

This potential formed the basis for the Government's statement that marine bioprospecting should constitute a special area of focus. The strategy document "*Marin bioprospektering – en kilde til ny og bærekraftig verdiskaping*" (Marine bioprospecting – a source of new and sustainable value generation)[24]

---

[23] Source: *Varestrømanalysen* (Goods flow analysis) 2011. The RUBIN Foundation.
[24] Norwegian Ministry of Fisheries and Coastal Affairs et al. (2009)

describes this as follows: “The potential in terms of knowledge development and value generation makes marine bioprospecting a vital area of focus as part of the Government’s Arctic strategy, and is described in particular in “*Nye byggesteiner i nord”* (New building blocks in the Arctic). Norway has a long tradition of harvesting from the oceans, and has developed high levels of expertise within the marine sector and in the field of marine biotechnology. This gives us an advantage as regards the acquisition and description of a wide diversity of marine organisms. Our proximity and access to the Arctic regions means that Norway, by focusing on marine bioprospecting, has the opportunity to become a global leader in this field. The strategy document states the following:

“The Government regards marine bioprospecting as a source of new and sustainable value generation. The potential levels of value generation are great and Norway is well positioned to take the lead in the face of international competition. The Government believes that Norway’s extended coastline and open waters provide us with major opportunities in terms of access to resources and biological diversity. Norway possesses an infrastructure and research institutes which enable us to acquire and describe a wide diversity of marine organisms. In combination with our domestic expertise already established within the marine sector and in the field of biotechnology, this provides Norway with an excellent launch pad for investment in marine bioprospecting. During autumn 2009, the Government published its own national strategy document which presented a range of initiatives with the aim of promoting research and industrial development related to bioprospecting. Our ambition is to trigger realisation of the wide range of value generation potential by means of a focused and co-ordinated national effort. The Arctic regions lie at the heart of this strategy, and priority will be given to the collection of marine organisms from Arctic waters.

Norway is responsible for the management of extensive and relatively unexplored waters. Some of the marine organisms survive under extreme conditions, in Arctic oceans typified by low temperatures and shifting daylight conditions, or in oil reservoirs under high pressures and temperatures, while others inhabit the coasts and fjords in high species concentrations. There is good reason to believe that many of these marine organisms have characteristics which can be exploited for the manufacture of products and development of processes within a large number of industrial fields.”

Future growth of the marine ingredients industry

In 2050 Norway enjoys a strong position within the global marine ingredients industry and is manufacturing products for the foodstuffs, functional food, health food and pharmaceutical markets. These are global markets enjoying high levels of growth as they attempt to meet the health-related challenges linked to obesity and defective lifestyles. Global trends and a popular focus on health matters have made it possible to develop a leading and dynamic industry on the basis of marine-derived oils. This trend has made possible the growth of an industry which exploits proteins or protein molecule fragments such as peptides and amino acids in the manufacture of products which can function as antioxidants and as blood pressure and body weight regulators. For example, developments in genetics have opened up new markets for specialised enzymes derived from marine biomass. In parallel with the very early development of the marine bioprospecting, a significant level of industrial expertise has gradually been accumulated. During the last decade, the global economic value of marine ingredients has enjoyed steady growth from NOK 1 billion in 2001 to almost NOK 5 billion in 2010[25]. Levels of profitability vary greatly. However, many companies are doing good business by exploiting materials once regarded as waste.

Global estimates put the market value of marine ingredients at between NOK 22 and 23 billion, accompanied by an annual growth rate of between 4 and 5 per cent[26]. This is a cautious annual growth estimate in that less conservative estimates are in the region of between 10 and 12 per cent. Norwegian companies account for about 20% of turnover in the global market. The economic value of the Norwegian marine ingredients industry in 2010 is reported to be NOK 4.8 billion[27].

Naturally, it is difficult to predict how large the Norwegian marine ingredients industry will become since it is not directly linked to the harvesting and fish farming segments of the value chain in the same way as the traditional seafood sector. One of the reasons that the industry is located in Norway is the result of proximity to its raw materials in the form of marine resources. It is also difficult to predict whether Norway will become a primary producer of products such as oils and proteins, and whether or not “higher levels” of processing to manufacture more advanced products yielding better returns will take place overseas. If Norway is to grasp the present opportunity and assume a strong position across the entire marine ingredients value chain, major efforts will be required in a number of fields, including facilitation on the part of the policy makers and investment in R&D.

In 2050, waste raw materials derived from the Norwegian fisheries sector and aquacultural production will be vital raw materials for the Norwegian marine ingredients industry. To a much greater extent than is the case today, this industry is based on other sources of raw materials such as seaweeds and chemicals and other substances extracted from the marine environment with the aid of bioprospecting and other biotechnological methods.

Ownership – a mix of Norwegian and foreign interests

The marine ingredients industry is currently made up of small companies with limited resources. In recent years, several of these companies have been acquired by foreign interests and larger Norwegian enterprises which contribute with capital investment and expertise. It is anticipated that restructuring will continue, resulting in fewer and larger companies, and that interest from foreign investors will increase. Our aim must be to make it sufficiently attractive to run these companies from Norway so that foreign companies will opt to establish their operational bases here.

It remains to be seen how the traditional seafood sector will exercise active ownership within the marine ingredients industry. At present they are principally involved in the production of fresh oils, protein hydrolysate and other products which are then used in the manufacture of more “finished products”.

Research and education – a key factor

It will be a challenge for Norway to keep hold of the more profitable industries and avoid being left simply as a supplier of raw materials. Access to highly educated personnel and competent research and

---

25 Marine Board & European Science Foundation. Position Paper 15 “Marine Biotechnology; A new vision and strategy for Europe”. September 2010.

26 UNU-IAS Report. “Bioprospecting in the Arctic”. United Nations University, Institute of Advanced Studies (2008).

27 Richardsen, R. (2011). *Norsk marin ingrediensindustri*. *Struktur og lønnsomhet 2007 -2010*. (The Norwegian marine ingredients industry - structure and profitability 2007-2010). SINTEF Report A21511.

educational institutions will represent one of the key factors contributing to keeping vital and profitable industrial activity in Norway. The factors of talent and educational attractiveness will also be important in this regard.

7.1.3.2 Production volume and economic value estimates

The most important criteria for the maintenance of a robust marine ingredients industry in Norway in 2050 are linked to the following:

- An increase in status and economic value of waste raw materials in the feed and consumer markets
- Strong growth in profitable feedstuffs, foodstuffs, functional food, health food and pharmaceutical markets
- An intense focus on research and innovation within both the private and public sectors
- A robust source of raw materials from within the traditional seafood sector
- New raw materials sources such as marine bacteria, and micro- and macroalgae.

It will be possible to link some production volume estimates to raw materials sources such as waste raw materials derived from the fisheries and aquaculture industries, and possibly also from seaweed production (see Chapter 7.2.2). It is very difficult to assess the opportunities available in what we term microbial production since this activity is little related to production volumes. We have opted to provide some estimates of what emerges in terms of the production volumes of waste raw materials, on the assumption that our growth estimates for the seafood sector hold good (Chapter 7.1.1 and 7.1.2).

The criteria at the basis of our computations are found in Figure 7-6:

- Approx. 4% annual growth within the aquaculture sector
- The filleting of 50% of the raw materials derived from the aquaculture sector in 2030 and 100% in 2050
- Roughly speaking, the identical product range within the fisheries sector as is the case today.

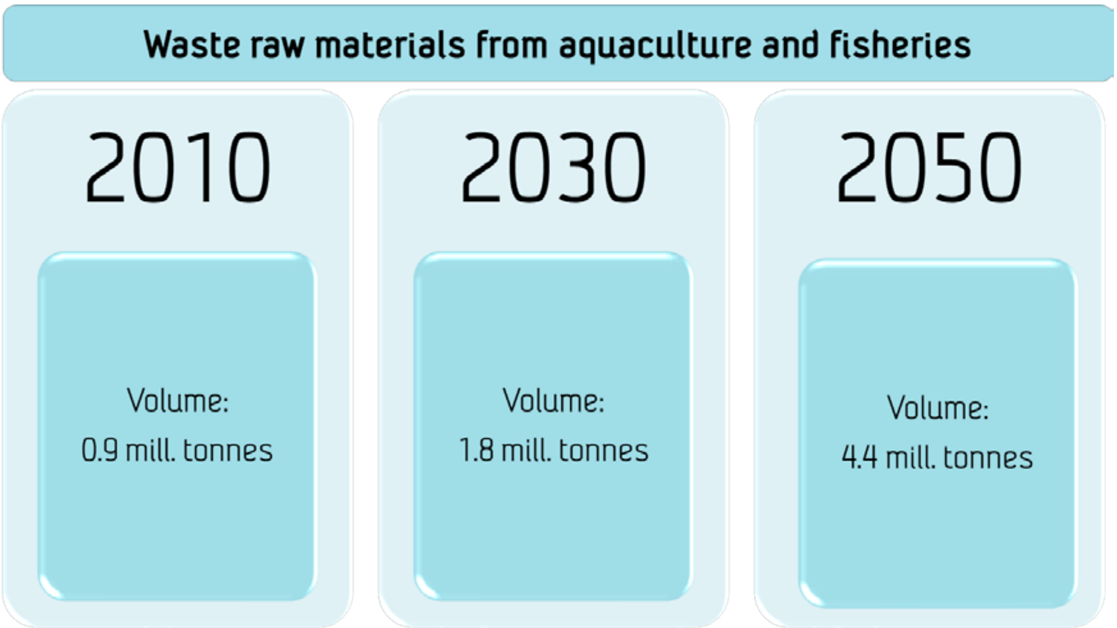


Figure 7-6 Estimates of the volumes of waste raw materials derived from the aquaculture and fisheries industries

The economic value estimates presented for a future Norwegian marine ingredients industry are contingent on current industry activity achieving the same conservative levels of growth as predicted for the global industry (7% annual increase in the period leading up to 2050). It should be emphasised that the volumes of waste raw materials presented in Figure 7-6 represent a measure of one of several potential sources of raw materials for the marine ingredients industry ("input value" in terms of volume), whereas Figure 7-7 is a measure of the economic value within the industry based on the raw material in question ("output value").

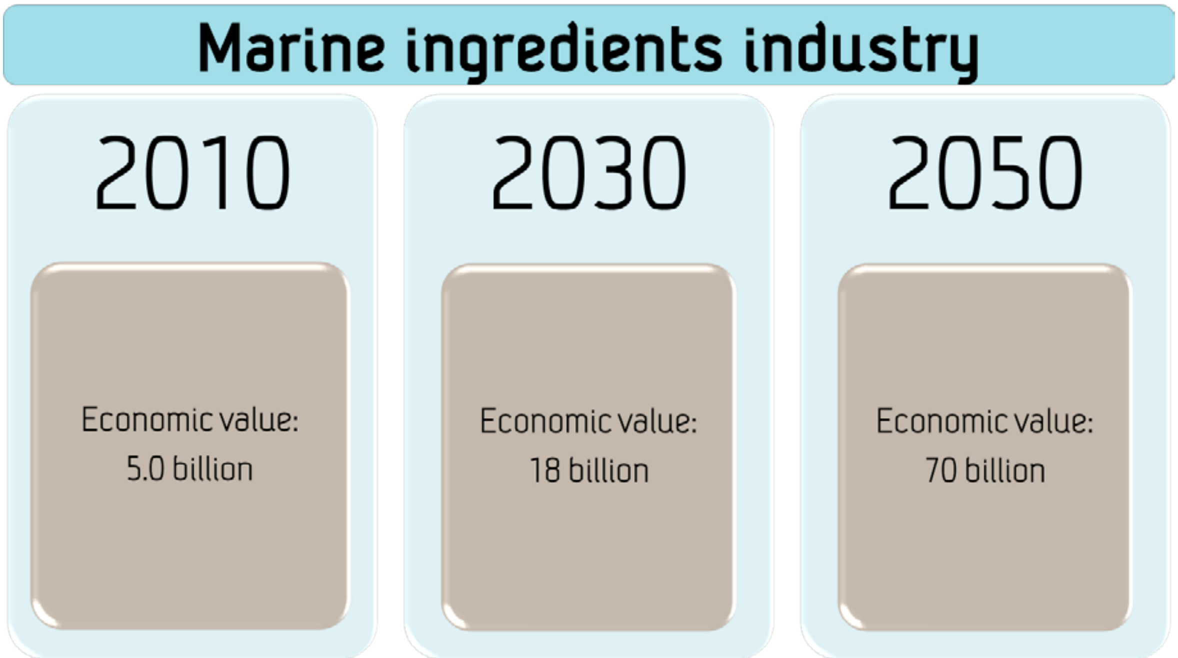


Figure 7-7 Estimates of economic value within the marine ingredients industry

7.1.4 Feed production

7.1.4.1 A description of key development trends

The term "feed production" refers to the process of obtaining biologically-derived resources from domestic and global markets and the manufacture of effective and usable feedstuffs for salmonids and other species.

On the basis of comparable global primary production both onshore and offshore, the human race obtains about two per cent of its food from the fisheries and aquaculture sectors. The proportion is higher for protein (about 15%) because most marine production involves animals. Primary production sources in the oceans (planktonic algae) are generally more accessible as food for fish and other aquatic organisms than primary sources are on land. However, the production potential is lost within extended food chains. The human food chain involving seafood is about two trophic levels longer than that for food derived from agricultural sources (Figure 7-8). In theory, this results in an additional loss of up to 99% within in the seafood chain. Potential linked to the traditional food chain where aquaculture is involved, incorporating the use of fishmeal and oil from harvested resources, will always be constrained by this natural law.

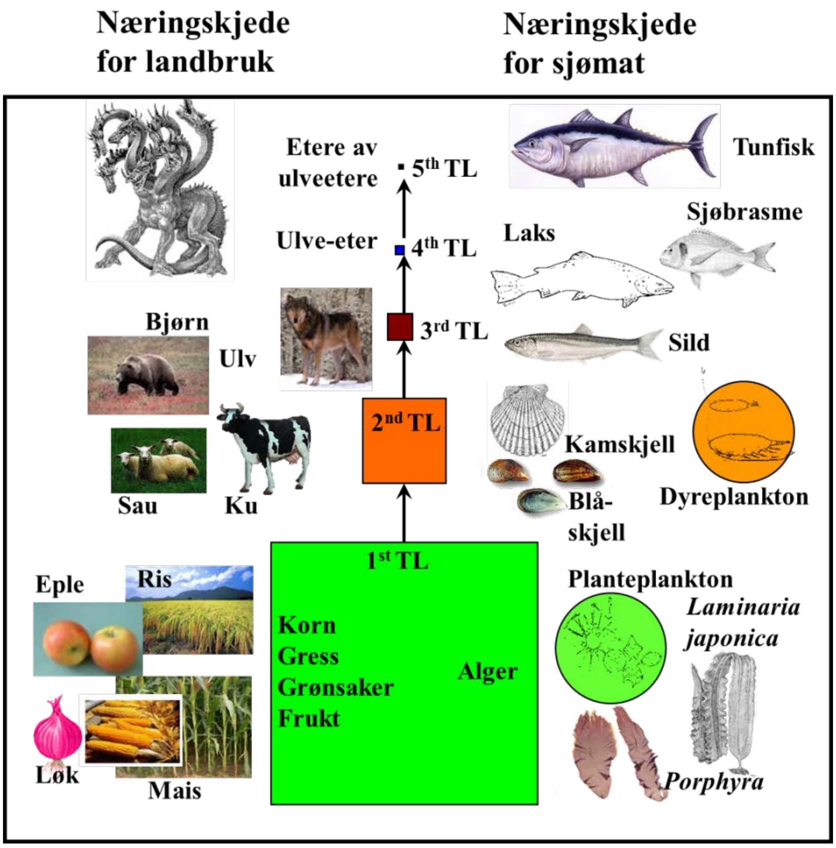


Figure 7-8 Agricultural and seafood-based food chains (modified after Duarte et al., 2009. "Will the Oceans Help Feed Humanity?" BioScience, 59(11), pp. 967-976)

Marine-based feed resources contain long-chain n-3 fatty acids such as DHA, and obtaining new sources of this fatty acid is becoming particularly demanding. In contrast to the agriculture industry, a significant proportion of feed resources for animals reared in aquaculture is still harvested directly from nature. If all the waste materials from the fisheries industry (estimated to be 20 million tonnes annually), combined with waste derived from different forms of processing (estimated to be a maximum of 30 million tonnes annually), could be utilised as feed in the aquaculture sector, this would result in a two-fold increase in available marine-derived feed resources and a potential two-fold rise in production. If it is our aim to increase protein production from the aquaculture sector to the same levels as in the agricultural sector, we will require a greater than five-fold increase in protein production from the oceans. If the intention is to maintain food production at current levels, this must be increased by in excess of 50-fold in the oceans. In recent decades, developments in the salmon farming sector have to a great extent been reliant on an increase in the use of plant-derived resources, moving the salmon one step down in the food chain from level 4 to level 3.

If the period leading up to 2050 results in increasing levels of conflict over the planet's food resources, increases in the use of feed products from agricultural sources will become the subject of critical discussion in many countries. For this reason, we should establish long-term targets to find new feed resources for the aquaculture sector containing high levels of quality marine fats, and which are not solely taken from the human food chain. This represents a formidable challenge for the research communities, the industry and society as a whole.

7.1.4.2 Future feed resources

It is important that almost all fish and shrimp-related species which are intensively farmed using formulated feed in the form of pellets, both in fresh and salt water, are fed with fishmeal as part of their feed, even if the proportions vary (1-35% fishmeal as a proportion of dry feed[1]). Salmonids, marine fish and shrimps, but not carp species, are also fed fish oil (1-20% oil as a proportion of dry feed[28]). Current and potential future feed resources can be categorised as follows:

Current sources:

- *Harvested resources from the fisheries industry* (industrial fish 30-35 million tonnes annually)
- *Discard from the fisheries vessels and losses during processing* (no more than 50 million tonnes annually)
- *Agricultural products and waste* (large volumes)

Potential future sources:

- *Zooplankton* (large herbivorous species such as krill and copepods)
- *Macroalgae*
- *Unicellular biomass*
    - *Microalgae* (not as a bulk resource, but possibly as a source of DHA)
    - *Bacteria, yeast and genetically-modified organisms*
    - *Thraustochytrids* (unicellular organisms, a possible source of DHA)
- *Agricultural waste* from both plants and animals
- *Genetically-modified higher terrestrial plants* (sources of DHA and EPA).

Current development and production costs for potential future feed resources are relatively high, but much can change in the course of a few decades.

7.1.4.3 Feed demand scenario 2050

In 2050 Norway continues to be a global leader in salmon farming. Production volumes have increased steadily at about the same rate as in the years prior to 2010. There is a demand for 6 million tonnes of feed pellets, an increase of 4.8 million tonnes compared with 2010. It will be possible to produce almost 1.2 million tonnes of new feed from marine-derived sources, released by the cessation of discard by the fisheries and the full utilisation of waste derived from the processing sector. From 2030, any further increases must be based in addition on new sources and increased optimisation of resource exploitation. New demands during the period from 2030 to 2050 amount to 2.4 million tonnes. We anticipate that regardless of other circumstances almost half of this volume must be derived from new resources. An increase in production on this scale represents a five-fold increase compared with 2010, and the access to high-quality protein from the fisheries and aquaculture sectors will converge on that derived from

[28] Tacon and Metian (2008), compiled by Olsen (2011).

agriculture. A further increase in production must in all probability be based on new resources, and the opportunities created will be crucial in the period from 2030 to 2040, and an essential prerequisite after 2050. If it becomes difficult to find new feedstuffs from known sources, including the fisheries and processing industries, groups of farmed organisms which do not require feed, such as molluscs and seaweeds, will become increasingly dominant within the global market, and the growth in fish and shrimp farming will be permitted to decline. It is important to note that salmonids appear to be metabolically flexible and exhibit more moderate requirements in terms of marine fats than many other fish species.

Norway is also a major player in the fish feed industry in 2050. A comprehensive European research effort into feed resources leading up to 2050 has expanded the feed companies' range of activities. They are now much more involved themselves in the processes of obtaining and manufacturing the resources needed for feed production. A fermentation industry has enjoyed consolidated development, driven by factors such as the demand for feed resources, and has gradually become part of the core activities of some groups of feed companies. In 2010, Norway boasted an array of strong companies within the feed sector, but no established enterprise cluster in the fields of biotechnology and fermentation. Research and development related to new feed resources in the years leading up to 2040 will take place mainly in Asia and Europe. The Norwegian food industry, together with some of the major industrial feed enterprises, is enjoying success as major and dominant player in the feed manufacture sector as a result of joint collaborations and acquisitions. Norway is experiencing a prolonged period of growth in fish feed exports, and this position is consolidated starting in 2040 as a result of access to new resources which may make aquaculture increasingly independent of catch volumes.

In our estimate of production volumes we have not taken the volume and economic value estimates linked to the export of fish feed into account because we expect that the greater part will be utilised in domestic aquaculture production. Another factor which will not be considered in more detail here is the activities in which Norwegian feed companies are engaged in other parts of the world and which, as long as these are Norwegian-owned, return economic value back to Norway. Such activity is currently highly significant and will probably be even more so in the future.

In our economic value estimates we have employed a feed price of NOK 10 per kilo. This price is included in the figures linked to Chapter 7.1.5 which deals with the supplier industry.

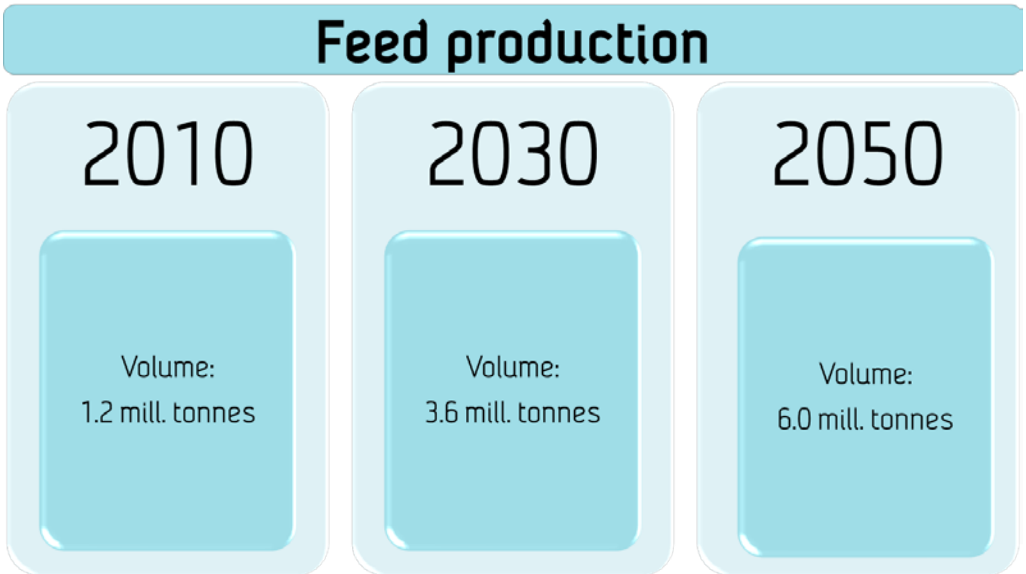


Figure 7-17 Estimates of the volumes of feed produced in Norway and used in the Norwegian aquaculture sector

7.1.5 The supplier industry

7.1.5.1 A description of key development trends

The term "supplier industry" refers to components in the form of goods and services which are essential either to the harvesting or manufacture of marine products. These goods and services represent a vital component of the Norwegian seafood sector. The most important components in terms of fishing activities are linked to vessels and vessel technologies, monitoring and control technologies, fishing gear, fuel, legal and business-related services, and such like. The most important components in terms of fish farming include feed, fish health products and services, transport services, technology in the form of equipment and buildings (sea cages, floats, onshore facilities, and such like), and legal and business-related services. The processing of all fish species, inclusive of salmonids, cod varieties and pelagic species, has need of the same components. Areas of particular importance are processing technology (slaughtering, filleting and advanced processing lines), packaging and transport.

The supplier sector also generates essential value

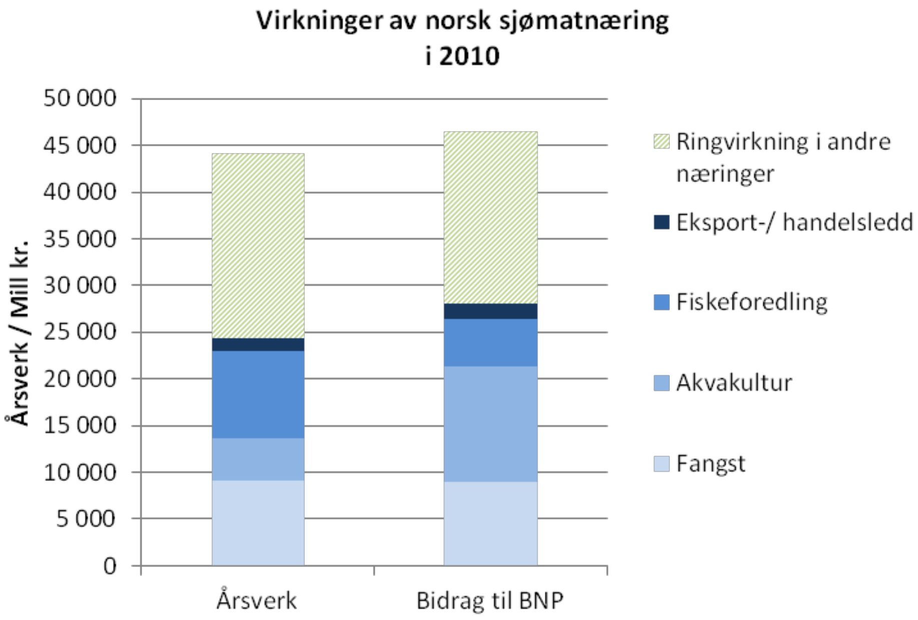
In this chapter we will utilise figures taken from the annual spin-off studies[29] which describe the influence of the seafood sector on employment and value generation in terms of its contributions to GDP and the economic value of production. The study describes the value generated by suppliers to and subcontractors working for the seafood sector's core companies (see Figure 4-1) – the so-called spin-offs.

In 2010, spin-offs constituted in excess of NOK 18 billion in terms of their contribution to the GDP (see Figure 7-9)[30], compared with NOK 28 billion in the core enterprises themselves. Employment in the supplier and subcontractor companies represented almost 20,000 man-years, and the value of production was approximately NOK 46 billion. The term "spin-offs" is understood to include all purchases of goods and services ranging from financial services, trade in goods, postal and telecom services linked to feed production, transport and construction and facilities-related activities. Some of these companies can be regarded as traditional suppliers to the seafood industry, whereas others supply goods and services to a wide range of commercial interests.

---

[29] Henriksen et al. (2012). *Verdiskaping og sysselsetting i norsk sjømatnæring 2010 – en ringvirkningsanalyse*. (Value generation and employment in the Norwegian seafood sector 2010 – a spin-off analysis). SINTEF Report A23089.

[30] Henriksen et al. (2012). *Verdiskaping og sysselsetting i norsk sjømatnæring 2010 – en ringvirkningsanalyse*. (Value generation and employment in the Norwegian seafood sector 2010 – a spin-off analysis). SINTEF Report A23089.



Kilde: SINTEF

Figure 7-9 **Value generation and employment statistics in the Norwegian seafood sector 2010**

In 2009, investment in the fisheries and aquaculture sectors totalled NOK 3.8 billion[31]. This investment reflects only a fraction of the deliverables made by suppliers to the industry since factors such as feed purchases are not entered in the accounts as investment.

In Chapters 7.1.1 and 7.1.2 we make the case for increases in both volumes and economic values generated by core activities within the seafood sector. Achieving such increases will be contingent on the innovative force which the supplier sector represents and delivers. At the same time, increased levels of activity within the core enterprises will be focused on the further development of the supplier sector. Assuming an increase in the industry's core activities, we anticipate significant growth in the supplier sector.

Value generation from exports

In addition to the supply of goods and services to the Norwegian seafood sector, technology and other commodities, including both fisheries and aquaculture-related technologies, are exported to several other countries. We anticipate increased levels of export activity from suppliers to the seafood sector, in much the same way as the oil sector's supply industry exports equipment and expertise to the rest of the world. On the whole, Norwegian technology and expertise enjoys a good reputation overseas[32], although they are seen as expensive and specifically tailored to the industrial fisheries and aquaculture sectors. Norwegian companies also lag behind in terms of their cultural awareness and language skills. Moreover, the structure of the supplier sector is such that we have only limited capital and other resources available to develop markets in other countries.

---

[31] Olafsen, et al. (2011). *Betydningen av fiskeri- og havbruksnæringen for Norge* (The significance to Norway of the fisheries and aquaculture sectors), SINTEF report A 23089.

[32] Burson and Marsteller (2010). *Omdømmeanalyse av norske leverandører til akvakultursektoren* (Reputation analysis of Norwegian suppliers to the aquaculture sector). Carried out for akvARENA.

Greater professionalism and standardisation

An industry which exploits public areas for its production and harvesting activities, and which over time has expanded to occupy large areas along the coastline, must expect that society will impose greater demands on its activities. In order for aquaculture companies to be granted public consent for further growth and development, a gradual improvement in professionalism must take place throughout the sector – both within the core businesses and among affiliated industries. In line with all other industries, increasing demands from the market and the authorities will be met with greater levels of professionalism and standardisation. We anticipate that in future, in parallel with developments in the oil industry, the supplier sector will assume greater levels of responsibility for the operation of facilities such as fish farms.

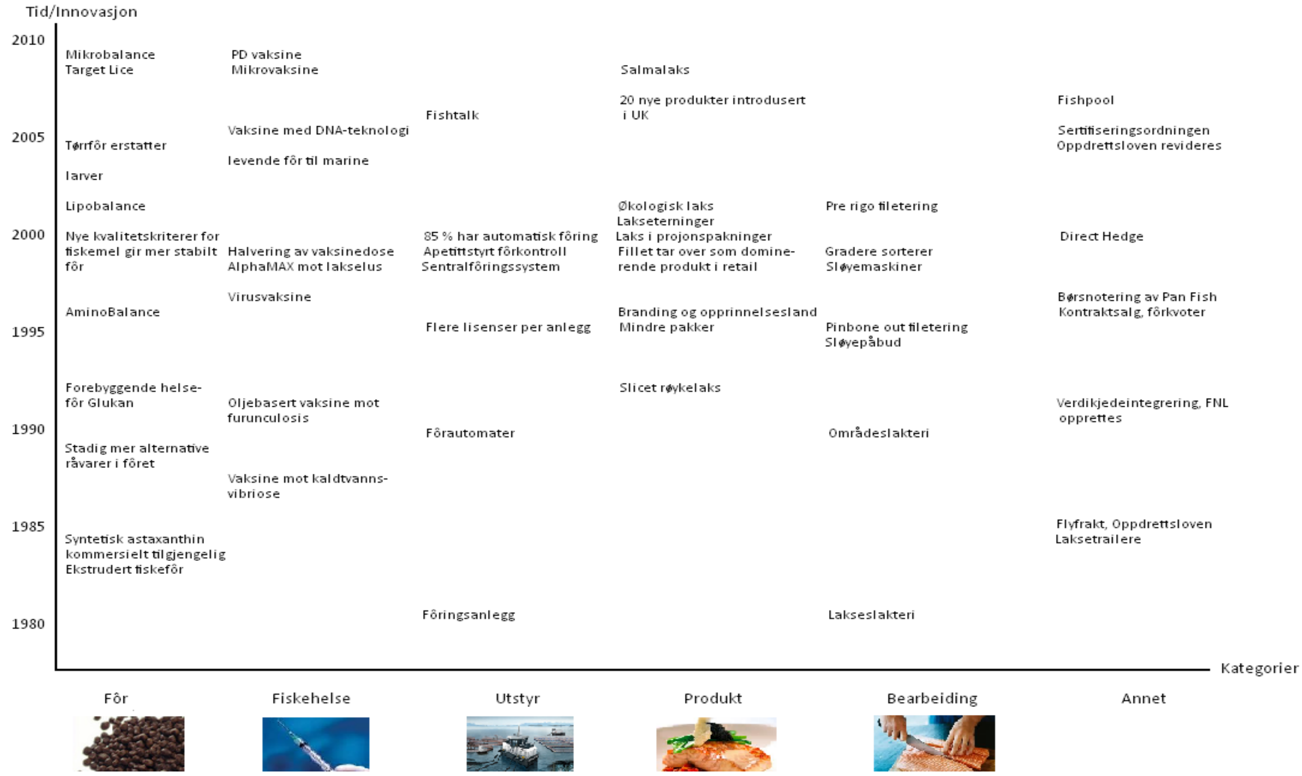
New ways of working together

For the most part, the supplier sector is made up of small companies[33] (with the exception of the feed companies and certain equipment suppliers) which aim to sell their products and services to what are in the main large customers. This is especially true within the aquaculture sector. There are a variety of issues linked to this type of “mismatch” in size between clients and their suppliers. In order to meet customers’ increasing needs it is anticipated that the smaller suppliers will organise themselves and work together in new ways, and that a general restructuring will take place within the supplier sector. In order to be competitive in global markets, suppliers will have to find new ways of working together.

The suppliers represent much of the innovative force

In the future, and as has been the case in the past (see Figure 7.11), the suppliers represent the core of the industry’s innovative drive. This is also true for the traditional fisheries sector. The interplay between the manufacturer and the supplier represents a special source of innovation. It is vital that as time goes by policy makers develop clear and assertive strategies focused directly on the supplier sector, in the same way as has happened within the oil industry. At present, however, policy makers are slow to support the supplier sector and mitigate its risks. In the future, the marine sector’s supply industry will have to deal with allied supplier sectors serving the maritime and offshore sectors to a much greater degree than they do currently.

[33] Olsen et al. (2011). *Vekst, lønnsomhet og organisering av leverandørene til havbruksnæringen*. (Growth, profitability and organisation of suppliers to the aquaculture sector). Notification of Issues to akvARENA prepared by INAQ Management.



Source: Reve and Sasson (2012)

Figure 7-10 Innovations in the salmon farming sector

In the future, the supply industry will systematically employ R&D as part of its development work in much the same way as the sector's core companies do, but to a greater extent. Some segments of the supplier sector are already knowledge-based and carry on their own R&D. These include the feed industry, fish health-related manufacturers, breeding companies and vessel manufacturers. Moreover, other segments within the supplier sector are intending to establish their own R&D centres, and in so doing will become more professional and more demanding commissioners of work from the R&D institutes.

The supplier sector's relations with new industries

In 2050 we anticipate that new industries based on marine resources will have been established in Norway (see Chapter 7.2). This means new markets for the supplier sector accompanied by new innovation challenges. If Norway as a nation, by means of its policy makers, intends to promote and assist the emergence of new marine-related industries, such as the cultivation of seaweeds, the supply industry must be included. The value generation which the supplier sector can then achieve thus becomes equally as valuable as the core activities such as cultivation, harvesting, processing and sales.

7.1.5.2 Economic value estimates

The most important criteria for the maintenance of a strong supplier sector in Norway in 2050 are linked to the following:

- Increased activity and production within the core industries (fisheries, aquaculture, etc.)
- Increased overseas demand for Norwegian aquaculture technology and expertise
- Certain restructuring within the supplier sector

- That the various enterprises find new ways of working even closer together to deliver integrated solutions
- Policy makers must assign priority to strategies for the supplier sector facilitating the mitigation of risk linked to investment in new technologies
- The supplier sector must obtain even greater levels of input and know-how from affiliated industries.

The basis of our economic value estimates (there is little point in presenting volume estimates here) for direct and indirect commercial activity within the supplier sector is obtained from the spin-off studies. This means that value estimates linked to feed production are included in these figures. We have used the value of production which the spin-offs represent (NOK 46 million in 2010) which in simple terms is almost equal to the turnover for a single company. From the entire range of spin-offs listed we wish to remove those services not linked to activities which we regard as traditional suppliers to the sector. For this reason we have opted to cut the value of production in 2010 by half.

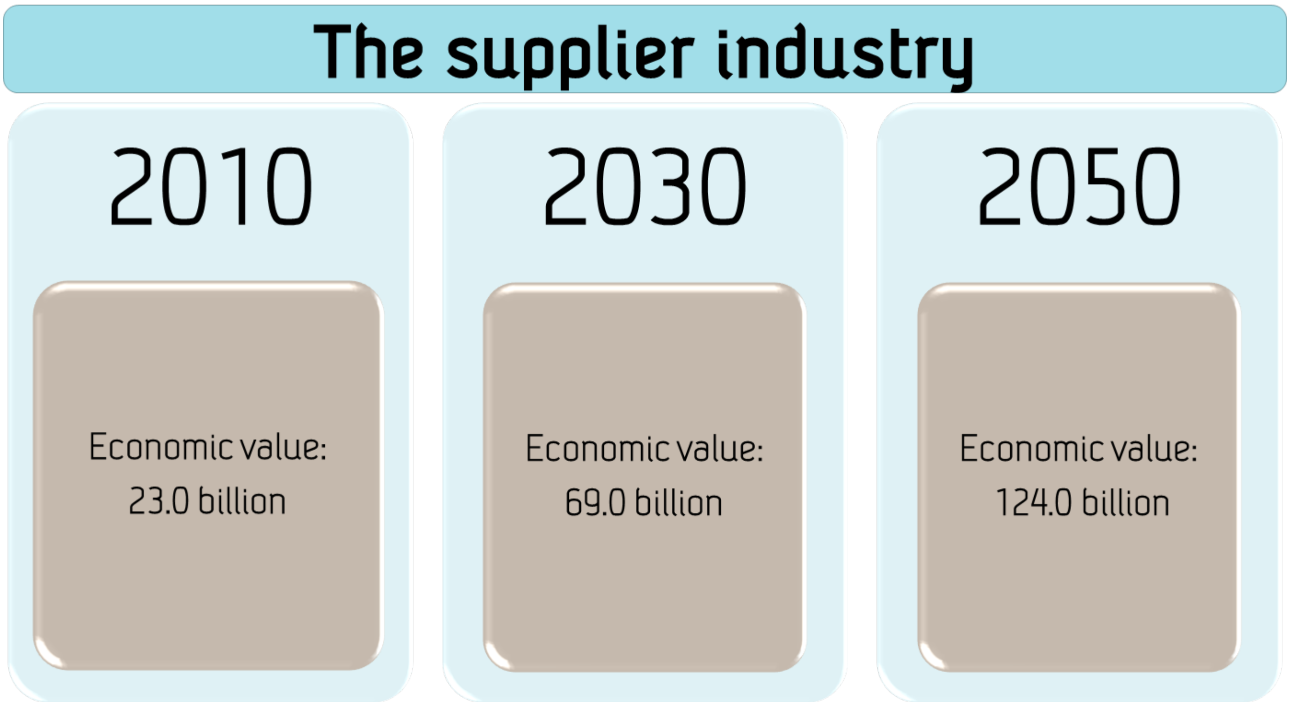


Figure 7-11 Economic value generated by the supplier sector

Exports

In a report published in 2006[34] the export of expertise in the form of know-how and goods and services was stipulated to be 25 billion in 2025. Our point of departure is that the 2030 value has risen to 30 billion and has doubled by 2050, in other words to 60 billion. In this report the results from export activity among

---

[34] Olafsen et al. (2006). *Utnyttelse av biomarine ressurser: Globale muligheter for norsk ekspertise.* (The exploitation of biomarine resources: global opportunities for Norwegian expertise). Report published by the NTVA/DKNVS.

the supplier companies will be included in the economic value figures for the supplier sector, illustrated in Figure 7-11.

7.1.6 Expertise

7.1.6.1 A description of key development trends

The term “expertise” is understood here to refer to the collective experience and know-how that exists in the industry, and within the public authorities and research communities. In this chapter we aim to focus on the accumulation of knowledge which takes place by means of the education system and within the research communities.

Norway is one of the few countries in the world with a well-established education system dedicated to the marine sector. It is possible to take an apprenticeship certificate at upper secondary school in a variety of marine-related subjects, in addition to higher education courses leading to Bachelor degrees and doctorates. Qualified personnel are employed in the industry and research communities, and with the public authorities.

The marine sector must improve its educational and talent attractiveness

According to Reve’s analysis, the seafood sector scores low on the scales of educational and talent attractiveness. However, applications for some marine sector-related courses are on the increase. If Norway is to achieve the growth outlined in 7.1.1 and 7.1.2 and thus become a global knowledge hub, the education system for subjects linked to the marine sector must become better adapted to the real world and more attractive to people with “wise heads and nimble fingers”.

However, the most important driving force has to do with the sector’s ability to look to employ qualified personnel. Higher levels of project specialisation within companies will promote the need to employ qualified personnel, as indeed will an increase in emphasis among the companies on the contribution which R&D can make. We anticipate that companies both within the core and affiliated industries will be larger, and this will promote the employment of more people with better qualifications.

High levels of competition with other sectors

In general terms, the level of applications for science-based courses is poor, and competition to employ those who qualify is great. Many are offered big salaries and favourable employment contracts to work in the oil industry. The seafood sector faces a major challenge in the future in terms of competition with other industries to employ qualified personnel. This contest will only become more intense in the years ahead, and it will be important to develop strategies to determine how the sector will approach this issue.

Resources for research

Norway is recognised for its research within a variety of marine-related disciplines. In 2009, funding for marine-related R&D amounted to NOK 2.8 billion[35]. During the last decade, resource provision for marine-related R&D has increased by an average of 7% (measured in fixed prices). Almost 60 per cent of marine-related research in Norway was carried out in research institutes, 23% in companies, and 18% in universities and colleges (HE sector).

---

[35] Sarpebakken, B., (2011). *Ressursinnsatsen til marin FoU og havbruksforskning i 2009* (Resource funding for marine-related R&D in 2009). NIFU report no. 10.

Almost NOK 1.8 billion (or 63%) of the resources allocated to marine-related R&D came from public funds. About 50% was provided directly from government ministries in the form standard budgetary allocations and grants, while about a third of public financing during 2009 was channelled through the Research Council of Norway.

The commercial sector provided just under NOK 800 million, which accounted for well over a quarter of the total funding dedicated to research within the marine sector. In the case of the aquaculture sector, the proportion of private sector funding was 40%. Five per cent came from overseas sources. In the future it is anticipated that a greater proportion of research will be both carried on and funded by the industry itself. We also anticipate that more public funds will be allocated to marine research.

Marine research creates many new jobs

In 2009 about 2250 researchers took part in marine-related R&D and aquaculture-related research in Norway. One third of these researchers were women. About 1100 researchers were employed in the research institutes, 650 in educational institutes, and about 500 in industrial enterprises. More than two thirds of the researchers in the institute sector had qualifications in the natural sciences. More than 1000 researchers in the HE and institute sectors, or three quarters of all those employed in marine-related R&D activities and aquaculture-related research (excluding new recruits) held doctorates.

In the years ahead competition to employ those who choose an academic career, especially within the natural sciences, will become harder. A tendency towards a decline in applications for new recruit researchers in marine-related disciplines has already been recorded. Levels of applications for posts for more experienced researchers are considered to be lower than in the past. The research communities must concentrate more and more on creating attractive jobs with well-defined career paths.

A multicultural sector

The seafood sector has long traditions in utilising foreign manpower for jobs which require little education and which over time have suffered a bad name among Norwegian workers. In general terms, Norwegians are unwilling to work in jobs which are physically strenuous and thus less attractive. Within the HE sector, and in the sciences in particular, marine-related disciplines are experiencing great interest from foreign students seeking an education and employment in Norway. We anticipate that this trend will continue and that in the future the marine sector, perhaps to a greater extent than other industrial sectors in Norway, will become multicultural – with all the opportunities and challenges this entails.

The education system – the key to closer ties between the industry and research

Reve (2011) concludes that the links between the industry and the universities and research communities within the seafood sector are often inadequately developed. This can be explained by deficiencies in expertise within the industry and the high levels of public funding. A consolidation of the education system will help to alleviate this problem. However, at the same time, the system must adapt itself more to the needs of the industry than is currently the case.

The marine industries are competing with other sectors for the best people. It is essential to put efforts into making marine-related studies at the various educational institutions more attractive, and the industry itself has a major role to play in achieving this. Levels of in-house expertise within the industry are currently unsatisfactory, and highly qualified and expert personnel must be employed if the companies are to reap the benefit for value generation of the rapid advances in know-how taking place in the world outside, in the R&D communities and in the supplier industry. For this reason the industry should find different ways of establishing closer ties with the educational institutions, such as becoming more involved in Master's degree courses and doctorate studies.

The research system – we need a holistic approach

The challenges facing the marine sector and the authorities have become more complex, making it essential to adopt a holistic approach on these issues. There is a need for a more multidisciplinary and transsectorial approach by which closer ties are established between the basic public and private sector research centres. The need for a major investment in resources both in terms of the use of costly infrastructure and research capacity will result in the development of larger and more integrated projects.

Domestic and international research collaboration is vital

Norway is a small country with limited resources. It must therefore put every effort into establishing better organisation and collaboration between the Norwegian research communities, while at the same time consolidating its collaborative efforts in the international arena. Know-how developed on the world stage will be become increasingly important to the development of the marine sector. For this reason, Norway has taken the initiative to establish a joint European marine research programme called JPI Oceans. This joint research effort will provide know-how on environmental issues, marine resources, value generation and commercial options related to the oceans managed by European nations.

Advances within other European and international collaborative projects demand that efforts on the domestic front are well co-ordinated and dovetailed with the international projects. Norway is recognised as a global player in terms of marine research, and an attractive partner with influence over research projects carried out under the auspices of the EU. At the same time, we must consider whether there are some areas which are more suited to international collaboration than others.

More international focus on the sustainable exploitation of marine resources for value generation – Norway's contribution

The path leading to increased levels of value generation from productive oceans must be based on the responsible exploitation of biological resources and a profound ecosystem-based awareness. Sustainability must remain the cornerstone for economic development, combined with an awareness of ecological cycles and the need for the full exploitation of harvested raw materials and waste. This takes place by means of harvesting and the production of both traditional and new products. Technology development is the key factor here. These are also the most important factors influencing the so-called "bio-economy" of the future. This term has developed globally in response to the "Grand Challenges" facing the human race. Both the EU and the OECD define bio-economy as the sustainable production and conversion of biomass to food, health and fibre products, industrial processes and products, and energy. This also defines the concept behind such terms as "blue growth" and the "blue economy" which are becoming more popular globally.

Expectations of major levels of value generation, accompanied by better strategies for sustainable and environmentally sound exploitation of marine resources, are attracting increasing attention in international fora such as the World Bank. It is within these fields that the Norwegian contribution can be greatest in a global context. Norway is a major player when it comes to the transfer of know-how which contributes to global food security. Norway is regarded as a world leader in terms of management of its fisheries industry and marine resources. This is sought-after expertise and Norway is currently already exporting such know-how to several countries all over the world.

Some examples of research challenges

The aims behind addressing challenges linked to research include the ambition to achieve sound management of the oceans together with an environmentally sound and sustainable seafood sector including new marine industries which have no unacceptable impact on their surroundings. This creates a need for various types of research in a variety of disciplines.

There is a need for research into the environment and pollution issues, including the escape of farmed salmon, raw material production and harvesting methods, genetics and breeding, disease and fish health, feed raw materials, product and process development, consumer awareness, safe and healthy food, labelling and traceability, equipment technology, distribution and the markets. Research into the marine processing industry and automation must be intensified so that we can compete with low-cost countries. Processes for the exploitation of raw materials and waste must become fully automated. In order to maintain food security and justify sustainability, it is vital that harvested marine raw materials are exploited to the full. Waste raw materials may have a variety of applications, such as food, feed, health products and in other industries.

A “blue-green” approach based on marine and land-based research may provide exciting new products leading to greater value generation. A well-known example is the role of the transfer of expertise from the agricultural sector which was essential to the development of the fish farming industry. The expertise currently established within the aquaculture sector can be combined with that from other sectors (such as offshore and maritime), and may result in innovations arising from intensified research efforts. The farming of more species and cultivation of the oceans using new methods could be vital to addressing future food security and health, climate-related issues and energy production (algae as sources of bioenergy and CO_2 capture). Expertise in other fields such as marine biotechnology and bioprospecting may create the basis for an entirely new resource-based industry. A long term focus on research and investment is essential if we are to meet the many challenges linked to the identification, isolation, manufacture and commercialisation of the interesting properties linked to as yet undiscovered species inhabiting Norwegian waters, with a view to future value generation.

There is also a need for knowledge regarding the impact of climate change on marine life. Relevant issues include marine pollution, changes in temperature and current regimes and their impact on fish population distributions, fish physiology and health. A better understanding of the impact of increasingly extreme weather events is vital if the marine sector is to adapt accordingly. This will entail the development of new technologies and harvesting methods which in turn also provide opportunities for value generation.

Any decline in the productivity of our oceans represents a threat to future value generation. The oceans are under significant stress in the form of increased competition for territory and resource exploitation. These factors serve to exacerbate the potentially negative impact of climate change. Acute marine environmental issues such as the loss of biological diversity, the increased spread of alien species, and the discharge of environmental toxins and biogenic substances (organic substances and nutrient salts), call for research which can contribute to finding domestic and global solutions. Research must include, among other things, studies into the usages of coastal and open waters, including territorial conflicts, new methods and technologies for population estimation and the analysis of biological processes, taxonomy, methods for and know-how in the use of remote sensing, and the biological impact of harvesting at lower trophic levels. Recent European environmental legislation will provide guidelines as to the research efforts needed to address environmental issues.

Challenges must be addressed by means of better collaboration and greater research efforts

Marine research is funded via the Research Council of Norway, Innovation Norway, the Regional Research Funds, by means of direct grants to given institutions, via the Fisheries and Aquaculture Research Fund, and by other private sector sources. It is important to develop functional collaborative approaches between policy makers and industry, and to build on these with a view to establishing better "Collaboration, Work Allocation and Concentration" (Norwegian acronym SAK). Organisations must pull in the same direction. Great expectations are attached to "Hav21", a strategic project initiated by the Norwegian Government which sets out a road map by means of a wide-ranging and integrated strategy for marine research and development. We must pursue this strategy if we are to succeed in becoming a major marine nation and achieve greater value generation from productive oceans.

7.2 The development of new marine industries

We have opted to subdivide our description of new species exploitation in such a way that the cultivation of algae is dealt with in a separate chapter. Integrated Multi-trophic Aquaculture (IMTA) is the approach by which microalgae and mussels are cultivated in close proximity to existing salmon and rainbow trout farming facilities, and represents a bridge between the cultivation of algae and other aquacultural activities. IMTA is discussed in the chapters dealing with new species and marine algae.

7.2.1 Aquaculture, new species

In this chapter we will consider the potential linked to the farming of fish and shellfish species (excluding salmon and rainbow trout), the production of shellfish by means of IMTA, and the production of cleaning fish for the salmon farming industry.

7.2.1.1 A description of key development trends

Cod and halibut farming – a lot of know-how, but obstacles to be overcome

Major efforts have been invested in cod and halibut farming in Norway, and considerable know-how has been accumulated. In spite of this, the cod farming sector is in decline (15,000 tonnes produced in 2011), while halibut farming remains at a low, but stable, level (3,000 tonnes produced in 2011). One of the reasons for this is that we have not succeeded in solving important production-related issues such as early sexual maturity, the reliable production of high quality fry, and high levels of wastage. Norway possesses excellent natural prerequisites for the farming of both cod and halibut, and is a world leader in terms of know-how regarding the farming of these species. Expertise exists both within the industry and the research institutes. Norway possesses the only cod breeding programme in existence. The production of competing whitefish species such as *Tilapia* and *Pangasius* has enjoyed a dramatic boost, and in some markets these species are regarded as major competitors to Norwegian whitefish. Moreover, the natural populations of whitefish in our waters remain large, and this represents major competition to farmed cod.

Farming of other fish species and shellfish – a peripheral industry in Norway

In Norway there is very little farming of species such as Arctic charr, wolffish and turbot. In 2011 a total of about 500 tonnes of these species were harvested. Challenges include production issues and relatively small markets.

The farming of mussels, scallops and oysters is also carried out to a very limited extent. The potential market is large, but the industry faces major challenges in the form of the quality of the shellfish (mussels), the presence of toxins which prevent harvesting (mussels) and high production costs. Small numbers of lobsters are also farmed in Norway, and both wild king crabs and sea urchins are reared in captivity.

Integrated Multi-trophic Aquaculture (IMTA) – providing new opportunities

The discharge of nutrient salts and organic material from salmon and rainbow trout facilities may represent an environmental problem, but can also be viewed as a resource forming the basis for the cultivation of macroalgae and the farming of mussels and possibly other species such as scallops. We can envisage a situation in which fish, mussels and seaweeds might be integrated within the same facility. Alternatively it may be possible to site mussel and seaweed production at some distance from the fish farming facility depending on where previous modelling studies have shown the most favourable locations to be. Both seaweed and mussel facilities can be located in areas which are not in direct competition with sites suitable for salmon farming.

There may be significant potential in the farming of mussels fed on the organic waste discharged from fish farms, as well as the cultivation of microalgae, also fed on the nutrient salts discharged from similar facilities.

Studies of pilot projects in Canada, and a doctorate thesis completed in Norway, have demonstrated higher population densities of shellfish reared in close proximity to fish farms. It was shown that the shellfish fed on particulate matter discharged from the salmon farm. The majority of mussel farming facilities in Chile (a country enjoying significant levels of mussel production) are located close to salmon farms with the aim of promoting the best possible growing conditions. However, we may encounter problems related to the spread of fish diseases arising from the close proximity of facilities containing different species. The large scale production of mussels in this way may generate by-products with other applications such as feed raw materials.

Cleaning fish – a natural approach to combating salmon lice

The salmon louse represents a significant challenge to the modern salmon farming industry. Cleaning fish such as gold finny and ballan wrasse have been employed to reduce lice levels for many years and lumpfish are now also used for this purpose. The use of cleaning fish is increasing and it is becoming necessary to farm them in order to meet the demand and avoid the overfishing of natural populations. If, as this report anticipates, salmon production increases in the period leading up to 2050, and salmon lice continue to be a problem, the demand for cleaning fish may increase dramatically.

7.2.1.2 Production volume and economic value estimates

The important criteria for achieving economic growth linked to new species for human consumption are as follows:

- We must resolve key issues linked to cod production in order to reduce production costs to levels that enable the industry to become profitable. At the same time, farmed cod must be harvested during periods of the year when they provide a supplement to, and do not compete with, wild cod.
- If industries linked to other fish species and shellfish are to achieve growth, significant levels of public funding must be allocated to support R&D and the commercialisation of existing expertise, to the build-up of biomass and marketing. Moreover, the industry must obtain significant amounts of private sector capital.

Based on current status, previous experience and an assessment of future potential, we predict cautious growth in the production volumes of farmed fish and shellfish in the period leading up to 2050.

Key criteria for growth within the IMTA mussel farming sector are as follows:

- We must seek out a demand and a market for Norwegian mussels – either in the form of an export market for human consumption, or a market for the by-products of mussels such as for feed or other products
- We must find aquaculture operators with the capital and appropriate expertise needed to establish facilities and build up biomass
- Know-how must be accumulated in a number of disciplines, such as growth potential
- Veterinary restrictions linked to the distance between mussels and salmon farms must be liberalised.

We predict moderate levels of growth for mussels farmed using IMTA in the period leading up to 2050.

Key criteria for growth within the cleaning fish farming industry are as follows:

- Cleaning fish continue to be regarded as an important method for combating salmon lice
- The industry is successful in the cost-effective farming of cleaning fish and in employing such fish in a responsible manner in terms of animal welfare.

We predict that there will be a significant increase in the demand for cleaning fish for use in the salmon and trout farming industries leading up to 2025.

The production volume estimates which form the basis for commercial value estimates are as follows:

Table 7-1 Species production volume estimates

	2010	2030	2050
Cod and halibut	22,600 tonnes	30,000 tonnes	50,000 tonnes
Other fish species for human consumption	500 tonnes	2,000 tonnes	5,000 tonnes
Shellfish, incl. mussels for human consumption	2,000 tonnes	3,000 tonnes	5,000 tonnes
Mussels farmed using IMTA	0 tonnes	2,000 tonnes	20,000 tonnes
Cleaning fish	12 mill. fish	36 mill. fish	60 mill. fish

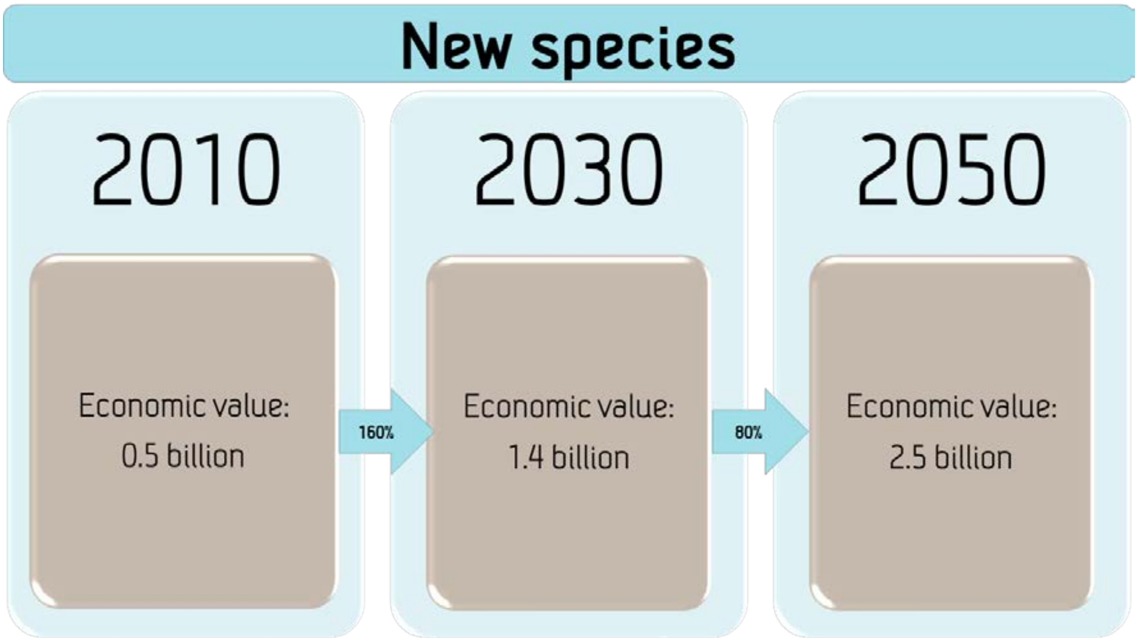


Figure 7-12 Economic value of new species production

7.2.2 Marine algae

The term marine algae encompasses both micro-and macroalgae. Algae obtain energy from sunlight, fix carbon from CO_2 dissolved in seawater and absorb nutrient salts. Algae represent the foundation of the marine food chain.

- Microalgae are unicellular organisms found growing in the oceans' photic zone all over the world
- Macroalgae are the multicellular plants we know as seaweeds.

Since micro- and macroalgae are so dissimilar, the principles for their cultivation and exploitation are also fundamentally different. For this reason they are dealt with separately in this chapter.

7.2.2.1 Microalgae

High levels of diversity and production potential

Microalgae are the most productive organisms on Earth and are able to increase their biomass two-fold in the space of 24 hours. It is estimated that there are between 200,000 and 800,000 different species of microalgae, of which only 35,000 are described. They exhibit a wide range of properties which make them attractive for exploitation. Because of their size, it is difficult to harvest them from naturally-occurring populations, but many species can be harvested from cultures grown on land. The exploitation of microalgal biomass on an industrial scale will require the selection of species which exhibit rapid growth and a high content of the useful components. By regulating the conditions of cultivation, it is possible to stimulate growth rates and biomass production, as well as the content of bioactive molecules.

Microalgae open the door to many opportunities

The omega-3 and -6 fatty acids obtained from fish are originally produced by microalgae. In terms if their industrial applications, algae can be used in the production of biomass, bioactive molecules and particular marine lipids, both for human consumption and for fish and animal feedstuffs. The protein fractions have both industrial and medical applications since they contain cold-active enzymes and bioactive peptides (used to reduce blood pressure and in immune modulation). The metabolite fraction has important potential medical applications. Pigments can be used as colouring agents and for sun protection. Thus the extraction of valuable components from algae provides major potential opportunities. In Europe, the cosmetics and pharmaceutical sectors are among the most active industries involved in bioprospecting for and research into microalgae. The demand for natural ingredients as replacements for manufactured chemicals is on the increase.

The entire microalgal biomass can also be used in food, so-called “functional foods” and feedstuffs. There are many products manufactured for human consumption and marketed as healthy on the basis of their containing microalgae. Perhaps of particular interest in a Norwegian context are studies which show that salmon feed mixtures containing up to 9% microalgae have a positive effect on health and growth rates. Cultivated microalgae can thus make an important contribution to sustainable fish feed production.

Microalgae contain invaluable oil

The high oil content in some species of microalgae makes them interesting as raw materials in the production of bioenergy sources such as biodiesel. In the future, biodiesel derived from microalgae will be able to replace fossil fuels. However, this will require massive efforts in terms of the optimisation of species selection and cultivation methods, as well as the development of technologies to promote biomass cultivation and the manipulation of individual algal compositions. It is difficult to estimate when production technologies will be sufficiently advanced and the demand for biodiesel so great that microalgae will emerge as relevant raw materials for commercial biodiesel production. However, it is likely that it will be some time before we are filling our tanks with Omega-3 oil. The market value of energy-related products derived from microalgae currently remains at NOK 1,000 per tonne, while the market value of high-cost products derived from microalgae can be in the region of NOK 10,000 per gramme. It is unlikely that production of this type will be profitable in Norway by 2050. In the meantime species are being tailored, and cultivation systems developed, to produce high-quality oils with major application potential in both foods and feedstuffs.

Cultivation of microalgae in Norway

Many different types of facilities exist for the cultivation of microalgae. Open ponds and channel systems are inexpensive to operate. However, such facilities make it difficult to control growth rates and contamination. Enclosed photobioreactors in which the algal culture is pumped round in pipes enable increased levels of control and the efficient exploitation of sunlight. In Norway, it will only be possible to cultivate microalgae in indoor facilities, preferably in greenhouse complexes exploiting a combination of sunlight and artificial lighting. It will be particularly advantageous if production can be linked to existing industrial facilities which generate surplus heat and CO_2.

As a result of long-term basic research efforts and a focus on so-called “Marine bioprospecting”, the production of algae will be able to provide access to biomass with an enormous potential as components in the fields of health, food, cosmetics and special ingredients for feedstuffs such as the essential omega-3 fatty acid DHA. Norway has both the expertise and infrastructure needed to develop a microalgae-based industry. However, there are currently very few industrial companies in the country equipped to promote such development. In the absence of strong and determined corporate interests supported by public subsidy, the development in Norway of a profitable industry based on the cultivation of microalgae will take many years.

7.2.2.2 Macroalgae

Norway is ideally placed for the production of macroalgae

Many species of seaweed are found growing naturally along the Norwegian coast, and many have been exploited as food for humans and their domestic animals for centuries. We have established traditions in research into and exploitation of these resources, and the alginate and seaweed meal industries are based on an annual harvest of brown kelp and bladder wrack amounting to about 200,000 tonnes.

A total of 15.8 million tonnes of macroalgae are cultivated globally, and in 2011 1.1 million tonnes were harvested and exploited for food, feedstuffs, chemicals, medicines, health foods, cosmetics and fertilisers. China, together with the Philippines, Korea and Japan, account for 90% of this production. Norway possesses both the naturally-occurring conditions and technologies needed to produce much greater volumes than we do today. The country also possesses high levels of biological expertise as it applies to macroalgae, and is a world leader in the development and operation of aquaculture facilities. In collaboration with other European centres of expertise in macroalgae, we are capable of developing efficient cultivation technologies which can provide us with biomass containing tailored properties which in turn can be exploited as a basis for a wide range of products, both for domestic use and export. Our biotechnological expertise enables us to develop processing technologies which will ensure the optimal application of all essential components contained in the raw material.

A raw material with a multitude of applications

Food

In Asia the majority of cultivated macroalgae is used as food. There is very little tradition in Norway and the rest of Europe for eating seaweeds. However, the rapid rise in the popularity of sushi is a sign that we are in the process of changing our eating habits, and it is now possible to buy imported macroalgal products in our food stores.

Some restaurants are starting to experiment with Norwegian macroalgae, and our interest in seaweeds as an original recipe ingredient will increase rapidly in the period leading up to 2050.

Seaweeds contain high concentrations of carbohydrates, vitamins B and C, antioxidants and minerals. Some species contain up to 40% protein. Moreover, there is a major variation in shape, colour, thickness, texture and taste. These properties can make seaweeds very attractive as foods.

The most relevant food species in Norway are sugar kelp (*Saccharina latissima*), winged kelp (*Alaria esculenta*), red and purple laver (*Porphyra spp*.) and the red sea lettuce (*Palmaria palmata*). These are similar to species cultivated on a large scale in East Asia and which thus have well-established fields of application and export opportunities. Species such as the green sea lettuce (*Ulva lactuca*) and the so-called carrageen moss (*Chondrus crispus*) are also potential food sources in Norway.

Feedstuffs

Some macroalgae have a relatively high protein content making them potential raw materials for feed production. For example, species such as winged kelp, red and purple laver and green sea lettuce have protein contents of 20, 37 and 25 per cent respectively, and contain a wide range of vitamins and minerals. Brown seaweeds represent a source of several immune-stimulant components such as laminaran (β-1.3

glucan) and high-M alginate (mannuronic acid). Admixtures of macroalgae and macroalgal extracts in fish feed promote digestive health and increased resistance against salmon lice and infectious diseases. Furthermore, the high carbohydrate content in seaweeds is of interest as a substrate for the microbial production of single-cell protein, which in turn can be used in feedstuffs. Thus macroalgae represent a very interesting raw material for feedstuffs both for farmed fish and domestic farm animals – as a source of protein, "functional food" and as the basis of single-cell proteins. They may make a major contribution to future sustainable feed production based on biomass sourced from primary producers. High iodine concentrations may be a cause for concern when using whole seaweeds for the production of feedstuffs, and the biomass must be processed in order to reduce iodine content.

Chemicals and bioactive compounds

The hydrocolloids alginate, carrageenan and agar are used as stabilisers, thickening and binding agents, and are the most important chemicals which can be extracted from seaweeds. Alginate is extracted from certain harvested brown seaweeds, whereas carrageenan and agar are derived from red algae cultivated in the tropics. This is a well-established industry involving major companies and significant production volumes. In Norway, any sustainable growth in this industry will have to be based on cultivated biomass.

Macroalgae contain many proven (and some less-well proven) health-promoting substances which are relevant to applications such as pesticides, medicines, health foods and cosmetics. Norway possesses high levels of expertise in the fields of biotechnology and bioprospecting. It thus has a major opportunity to develop products and new value chains based on seaweed species found in Norway. In the case of the industrial production of special compounds, cultivation will be a prerequisite for providing reliable quality and supply stability. A high price for such products is an important prerequisite for making biomass cultivation profitable. It also creates opportunities to use waste fractions in applications such as the processing required to manufacture low-cost products such as various types of bioenergy and fertilisers.

Energy

In spite of the fact that biofuels are probably among the least profitable products that can be sourced from seaweeds, it is just this application which is currently arousing most interest in the west, and to which most research funding is being dedicated around the world. This activity is driven by the demand for biomass for use in the sustainable manufacture of biofuels, especially in the transport sector. There really is major potential in the exploitation of the larger seaweed species for the production of bioenergy. Seaweeds can contain up to 60% carbohydrates of which 80% can be fermented to produce ethanol[36] . Potential products include other biofuels such as butanol and methane gas.

Sugar kelp is among the world's fastest growing plants – and the most efficient at fixing CO_2. It can be cultivated without the use of soils, fresh water, pesticides or fertilisers. The fact that macroalgae can be cultivated without the use of artificial fertilisers may prove to be a crucial factor in terms of establishing seaweeds as a vital source of bioenergy. This is because land-based plant biomass sources depend on the use of phosphorous to promote maximum crop yields, but the planet's established sources of phosphorus are beginning to run out. In this context it may also be of interest to regard the cultivation of macroalgae as

---

[36] Wargacki, A. J., Leonard, E., Win, M. N., Regitsky, D. D., Santos, C. N., Kim, P. B., Cooper, S. R., Raisner, R. M., Herman, A., Sivitz, A. B., Lakshmanaswamy, A., Kashiyama, Y., Baker, D. and Yoshikuni, Y. (2012). An Engineered Microbial Platform for Direct Biofuel Production from Brown Macroalgae, Science 335/6066, pp. 308-313

a means of capturing phosphates from the oceans for use in other applications, such as agricultural fertilisers.

Large areas exist which are suitable for industrial cultivation. Norway enjoys sovereignty over an economic zone comprising 90,000 km^2. This area contains many nutrient-rich and thus highly productive “upwelling” areas and estuaries which make the country a natural location for seaweed-based biomass production. Norway also exhibits excellent potential for the cultivation of seaweeds using IMTA (Integrated Multi-trophic Aquaculture) methods in close proximity to salmon farms. It has been demonstrated that seaweeds are able to exploit, and develop faster in the presence of, the nutrient salts contained in the waste discharged from fish farming facilities[37].

A value chain based on seaweeds as a source of biofuels will include both the cultivation of the biomass and the downstream processing needed to manufacture the fuels. At present, no commercial value chain exists, and many centres within the industry and the research communities are working to resolve issues related to biology, cultivation facilities and processing. They anticipate the launch of commercial activity by 2020. The key to profitability lies in cultivation on an industrial scale involving the extensive use of mechanised and automated systems combined with a cultivation strategy which exploits the genetic potential inherent in seaweeds rapidly to produce high-carbohydrate biomass. The full exploitation of all harvested biomass is also a prerequisite

Norway as a supplier of technology

Even though other countries are way ahead of Norway in terms of seaweed cultivation expertise, our skills and experience in aquacultural methods may enable us to become a major supplier of technology to the global cultivation industry. During the last four years several successful cultivation trials have been conducted in Norway using sugar and winged kelps and the sugar kelp life-cycle is well understood. Seaweed cultivation is an up-and-coming industry, although only a few companies are involved at present. Opportunities for success in the macroalgae industry may lie in species and product differentiation. In the near future, applications in fields such as energy, feedstuffs and food will most probably represent the main driving forces behind technological advances. For this reason, the potential inherent in the various species must be realised, and cultivation technologies developed and adapted in order fully to exploit Norway’s natural advantages.

7.2.2.3 Production volume and economic value estimates

Important criteria for economic growth in the microalgae cultivation sector are as follows:

- In the future, the cultivation of microalgae will not necessarily take place in Norway, but rather in countries blessed with more favourable natural advantages such as sunlight, renewable energy sources and nutrient salts. The cultivation companies may very well be Norwegian-owned if the expertise and technologies established in order to achieve cost-effective production have been developed in Norway or as a result of Norwegian funding.

- The generation and commercialisation of know-how in the fields of production technology and cost-efficiency.

---

[37] Handå A., Forbord S., Wang X., Broch O.J., Dahle S.W., Størseth T.R., Reitan K.I., Olsen Y. and Skjermo J. (2012). Seasonal- and depth-dependent growth of cultivated kelp (Saccharina latissima) in close proximity to salmon (Salmo salar) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. Submitted to Aquaculture.

Important criteria for economic growth in the macroalgae cultivation sector are as follows:

- The exploitation of macroalgae for applications requiring high production volumes, such as bioenergy and feedstuffs, must be maximised.
- Universal acceptance of a further expansion of the areas of coastal waters occupied by mobile facilities and the development of space-efficient cultivation technologies.
- Know-how and technology are developed which enable the full exploitation of harvested biomass (the bio-refinery concept).

The production volume estimates which form the basis for economic value estimates are as follows:

Table 7-2 Macro- and microalgae production estimates

	2010	2030	2050
Microalgae	0 tonnes	10,000 tonnes	500,000 tonnes
Macroalgae	0.2 mill. tonnes*	4 mill. tonnes	20 mill. tonnes

*Harvesting of naturally-occurring populations

Price estimates:

- Macroalgae in 2030: NOK 2 per kilo results in NOK 8 billion
- Macroalgae in 2050: NOK 2 per kilo results in NOK 40 billion
- A price of NOK 2 per kilo assumes that a significant part of the volume produced is used for biofuels/bioethanol, but not all – the remainder being more profitable.

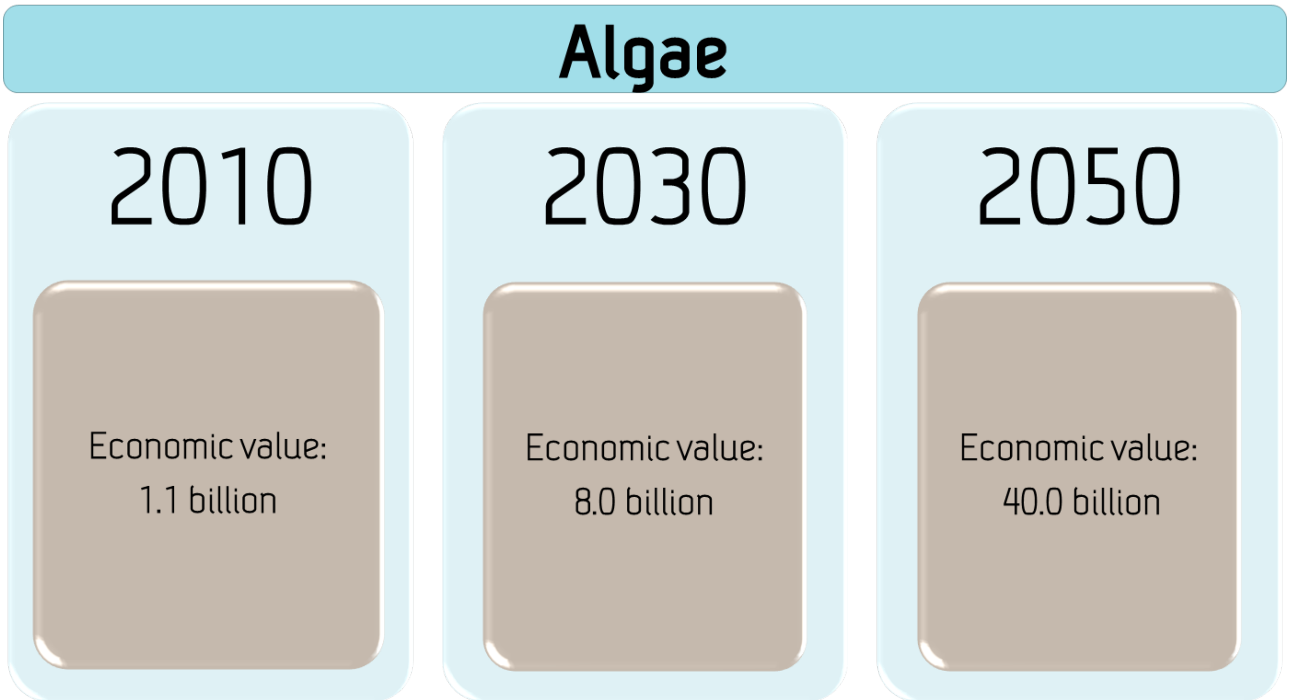


Figure 7-13 Economic value of macro-and microalgae

7.2.3 Highly productive waters

The term “highly productive waters” is understood to refer to waters in which biological production by means of natural processes or a variety of human interventions can be managed to result in high harvestable yields of commercially attractive plant and animal species.

The world’s oceans vary considerably in their potential for harvestable production. Large areas of the open oceans can be regarded as oceanic deserts, whereas coastal waters are often much more productive. Harvestable production is particularly large in the world’s so-called coastal “upwelling areas” where large volumes of water containing plant-derived nutrient substances such as nitrates and phosphates rise from deep to shallow levels and form the basis for high levels of production throughout the food chain. In the classic article written by John Ryther[38] the author has estimated that up to 50% of harvestable marine production is to be found in upwelling areas, and that the remainder occurs primarily in coastal waters at depths of less than 200 metres. The reason for this is the degree of natural nutrient input, but is primarily the result of the fact that trophic chains are much shorter in upwelling areas (2 to 3 levels) and coastal waters (3 to 4 levels) than in the open ocean (5 to 6 levels) (see Figure 6-1). This illustrates the potential to increase production in coastal waters by means of aquaculture, since one level down in the trophic chain can represent an eight to ten fold increase in harvestable production.

Japan, China and other Asiatic countries have been exploiting the potential of the oceans for several decades. This is especially true of Japan, where the coastline is cultivated systematically by local communities with harvesting rights. In China, large companies have been awarded time-limited concessions to cultivate the oceans. The Chinese company Zhangzidao Group is currently cultivating a shallow area of ocean located east of Dalian (equivalent to the size of the Norwegian municipality Oppdal) involving the extensive release of young scallops, sea cucumbers and sea urchins. When the organisms have reached marketable size, harvesting is carried out by divers and re-catch rates are satisfactory (>30%).

Norway has extensive shallow waters which can be exploited in the same way using species such as lobster, scallops and other highly-prized benthic organisms suited to sea-ranching of this type. We have legislation which in principle permits sea ranching, but we have yet to test biological and legislative feasibility by means of specific projects. Since maricultural harvesting requires no feed input, it may become very important if we fail to succeed in developing new feed resources for the aquaculture sector. It will be possible to carry on such activities in areas allocated either to aquaculture and seaweed cultivation or to other commercial activities taking place in coastal waters.

The following initiatives may contribute towards an increase in the harvestable production of desired species:

- Artificial generation of upwelling of deep water, possibly in combination with energy production
- Habitat restoration measures such as artificial reefs generally increase production
- Advances in breeding technology for relevant species such as lobsters and large scallops
- Methods for the release and consolidation of desired species and predator control
- Better know-how related to marine production factors with a view to the management of production in shallow oceanic areas

---

[38] Ryther (1966). Photosynthesis and fish production in the sea. *Science* **166,** 72-76.

- ROV (Remotely Operated Vehicle) technologies to enable the monitoring and harvesting of ranched and cultivated organisms in shallow waters.

Research and development work, followed by the launch of commercial maricultural harvesting, must be developed as part of joint international efforts by which Norway can learn from the Asian countries. It is difficult to estimate the value generation potential hidden in the expansion of exploitation from highly productive waters, but it is likely that in 2050 we will be seeing significant and ever-increasing levels of activity. This is because conditions in our coastal waters are highly favourable. We also have some suitable organisms which fetch high prices in the market, combined with a massive interest in the further expansion of our seafood sector. It is possible that this will become the most important method of producing seafood in the years after 2050? We estimate that the harvested species (lobsters and scallops) will have a commercial value of NOK 50 per kilo.

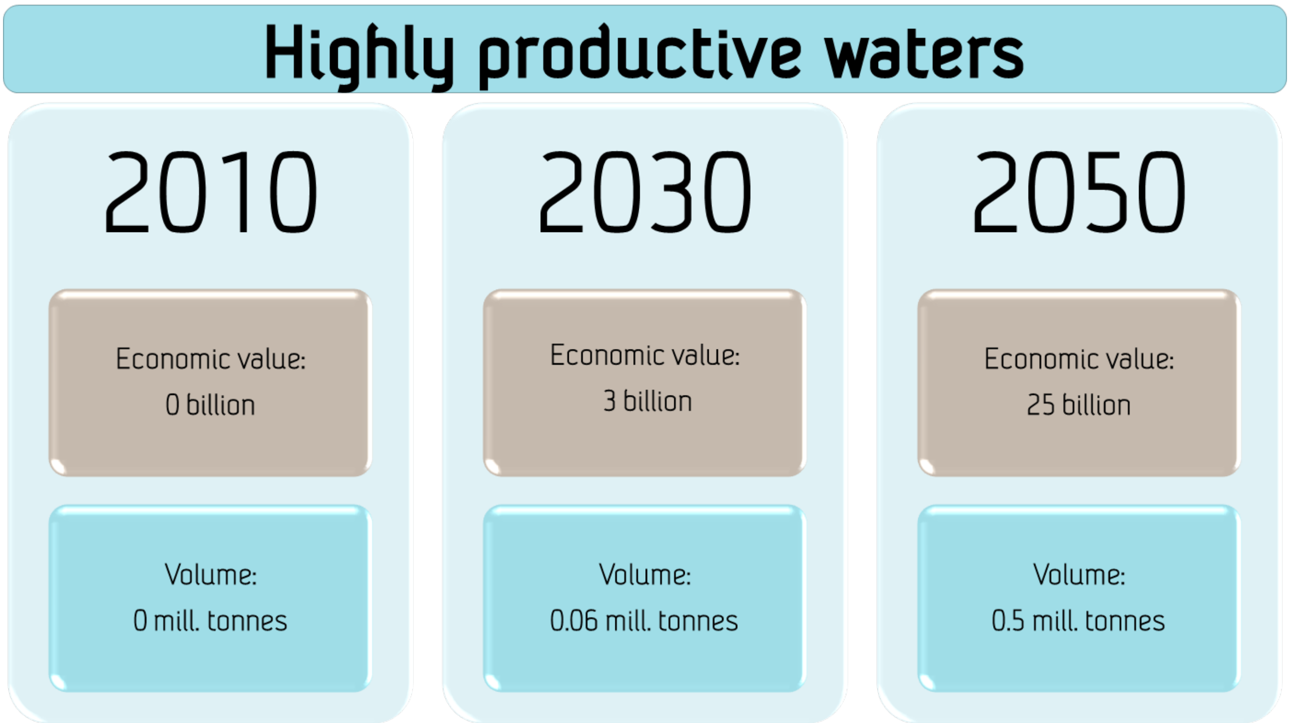


Figure 7-14 Economic value of the highly productive waters

7.3 Global opportunities

This analysis has concentrated for the most part on marine-related value generation in Norway. However, since the sector always has and will continue to operate in a global market, we will devote this chapter to brief comments on various opportunities linked to global activities in general and overseas investment in particular.

The most important export-focused activities are currently linked to the following:

- Seafood exports. 90% of our products are sold into markets outside of Norway. Norwegian seafood companies enjoy close relations with many of the seafood markets in which they operate.

- Export of fisheries and aquaculture technologies. Norway is recognised for its fisheries and aquaculture-related technologies, and exports these to several countries. The term “technology” is used here in its broadest sense, and includes also feed production, vaccines and livestock breeding products.

- Export of management expertise. Norway is recognised for its management expertise and assists many countries in the establishment of new management systems. Norway's expertise in management methods also has a crucial role in relation to the governance of Arctic waters.

- Export of know-how. Research is by its very nature a global activity, and Norwegian research institutes work together with researchers from other countries across a broad front. As well as the research institutes, there is export of know-how linked to organisations such as consultancies in the form of foreign aid projects, even if these are relatively modest by comparison.

- Establishment of commercial businesses in other countries. Norwegian companies make investments in other countries by means of establishing and acquiring aquaculture and fisheries interests, and this can generate value for the companies concerned.

We have not previously described the establishment of businesses in other countries in any detail. This is an activity which has been taking place for many years, at varying levels of intensity. Norwegian fisheries interests have involved themselves both in fleet and land-based activities in other parts of the world for many years. In recent years, Norwegian aquaculture companies’ investments in other salmon-producing countries have made this issue more relevant. Such companies have made investments in countries such as Scotland, Canada, the USA and Chile. Profits made by these companies, given that they are organised as subsidiaries, are ploughed back into the Norwegian parent companies, while taxes and other duties are paid to the authorities in the countries where they are established. In this way such activities boost value generation in Norway.

Perhaps more important than the plough-back of direct financial value is the supply of know-how which international commitments confer on a company which invests overseas, and which in turn helps to strengthen its innovative capabilities. Of course this also applies to other expertise organisations which have contacts overseas. International activity also opens doors for the development of Norwegian talent, and increases the attractiveness of companies if they can offer potential employees overseas assignments.

Future perspectives

How will the situation develop in the years leading up to 2050? It is highly likely that Norwegian companies will increase their levels of international involvement during the next 40 years. In the aquaculture sector, levels of business establishment in other countries will be highly contingent on the tax and operating regimes “offered” in the countries in question. The major companies will establish businesses in the countries which, in addition to possessing favourable naturally-occurring production conditions and a given level of expertise, also offer attractive tax and operating regimes in the opinion of the companies in question.

It is likely that the supply industry will to a great extent follow in the footsteps of the major aquaculture companies. However, they will also focus on export to a number of countries which farm species other than salmon and trout. Many opportunities present themselves in this scenario. However intensive efforts will be required on the part of both the public and private sectors. There will also have to be a restructuring within the supplier sector.

7.4 Summary

In Figure 7-15 below, we present a summary of the potential for marine sector value generation within the various industries. The scale of value generation in the marine sector in 2050 is estimated to be of the order of NOK 550 billion.

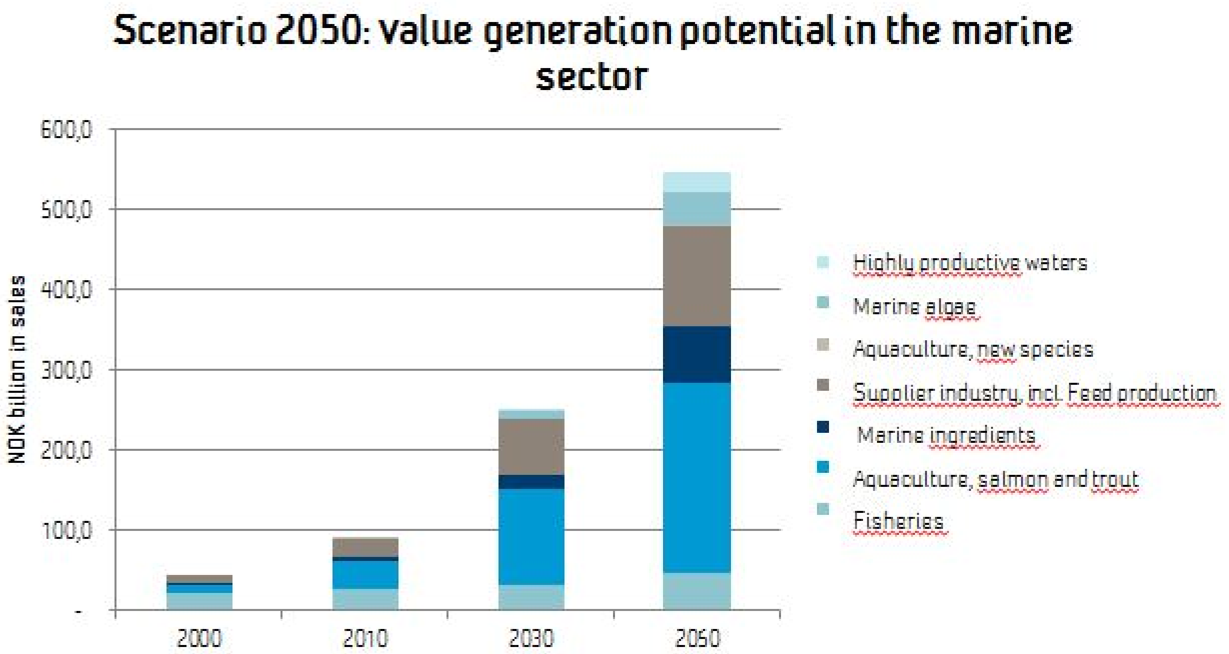


Figure 7-15 **Potential for value generation in the marine sector in 2050**

7.5

8 Sources

Burson & Marsteller (2010). Reputation analysis of Norwegian suppliers to the aquaculture sector. Carried out for "*Teknologi akvARENA*"

FAO/WHO. Expert Consultation on the Risks and Benefits of Fish Consumption, September 2011.

Norwegian Ministry of Fisheries and Coastal Affairs et al. (2009). Marine bioprospecting – a source of new and sustainable value generation. National Strategy 2009.

Norwegian Directorate of Fisheries (2012). Statistics in the public domain.

Fremtidens lakseoppdrett (The future of salmon farming). *Teknologirådet, nr 1. 2012*. The Norwegian Board of Technology, no. 1, 2012)

Garcia, S.M. et.al. (2012). Reconsidering the consequences of selective fisheries. Science, vol. 335, pp. 1045-1047.

Handå A., Forbord S., Wang X., Broch O.J., Dahle S.W., Størseth T.R., Reitan K.I., Olsen Y. and Skjermo J. (2012). Seasonal- and depth-dependent growth of cultivated kelp (Saccharina latissima) in close proximity to salmon (Salmo salar) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. Submitted to Aquaculture.

Henriksen, K., Sandberg M.G., Olafsen, T., Bull-Berg, H., Johansen, U. and Stokka, A. (2012). *Verdiskaping og sysselsetting i norsk sjømatnæring 2010 – en ringvirkningsanalyse, SINTEF Rapport A23089* (Value generation and employment statistics in the Norwegian seafood sector 2010 – a spin-off analysis.) SINTEF Report A23089.

http://ec.europa.eu/research/horizon2020/

http://www.ipcc.ch/

http://www.millennium-project.org/

http://www.millennium-project.org/millennium/Global_Challenges/chall-03.html

http://www.millennium-project.org/millennium/Global_Challenges/chall-03.html

http://www.purehelp.no

Marine Board & European Science Foundation. Position Paper 15 "Marine Biotechnology; A New vision and strategy for Europe". September 2010.

Mathiesen, A.M. (2012). Aquaculture towards 2030: Policies for sustainable development. FAO. Presentation given at AquaVision 2012.

Olafsen et al. (2006). *Utnyttelse av biomarine ressurser*: *Globale muligheter for norsk ekspertise* (The exploitation of biomarine resources: Global opportunities for Norwegian expertise). Report published by the NTVA/DKNVS.

Olafsen, T., Sandberg, M.G., Henriksen, K., Bull-Berg, H., Johansen, U. and Stokka, A. (2010). *Betydningen av fiskeri og havbruksnæringen for Norge - en ringvirkningsanalyse* (The importance to

Norway of the fisheries and aquaculture sector – a spin-off analysis). SINTEF Report A19673

Olsen, O.C, Krogstad, N.O., Blakstad, F. og Pedersen, J. (2011). *Vekst, lønnsomhet og organisering av leverandørene til havbruksnæringen* (Growth, profitability and organisation among suppliers to the aquaculture sector). Notification of Issues to “*Teknologi akvARENA*” prepared by INAQ Management

From a presentation by Chief Economist Øystein Dørum (DNB), during the General Meeting of the FHL (Norwegian Fishery and Aquaculture Research Fund), held in March 2012.

Richardsen, R. & Olafsen, T. (2011). *Marin ingrediensindustri 2007-2010* (The marine ingredients industry 2007-2010). SINTEF Report A 178320.

Richardsen, R. (2011). *Norsk marin ingrediensindustri. Struktur og lønnsomhet 2007 -2010*. (The Norwegian marine ingredients industry. Structure and profitability 2007-2010). SINTEF Report A21511.

Ryther (1966). Photosynthesis and fish production in the sea. Science 166, 72-76.

Sarpebakken, B. (2011). *Ressursinnsatsen til marin FoU og havbruksforskning i 2009* (Resource funding for marine-related R&D in 2009). NIFU report no. 10.

Sundby, S. (2012). *Effekter av klimaendringer på norske kyst- og havområder*. (The effects of climate change on Norwegian coastal waters and oceans). Norwegian Institute of Marine Research. Presentation given in February 2012.

Tacon and Metian (2008). Compiled by Olsen (2011)

Reve, T. and Sasson, A. (2012). *Et kunnskapsbasert Norge* (A knowledge-based Norway): Published by *Universitetsforlaget*.

UNU-IAS Report «Bioprospecting in the Arctic». United Nations University, Institute of Advanced Studies (2008).

Varestrømanalysen 2011 (Goods flow analysis 2011), The RUBIN Foundation.

Wargacki, A. J., Leonard, E., Win, M. N., Regitsky, D. D., Santos, C. N., Kim, P. B., Cooper, S. R., Raisner, R. M., Herman, A., Sivitz, A. B., Lakshmanaswamy, A., Kashiyama, Y., Baker, D. and Yoshikuni, Y. (2012). An Engineered Microbial Platform for Direct Biofuel Production from Brown Macroalgae, Science 335/6066, pp. 308-313.

Attachments Tables

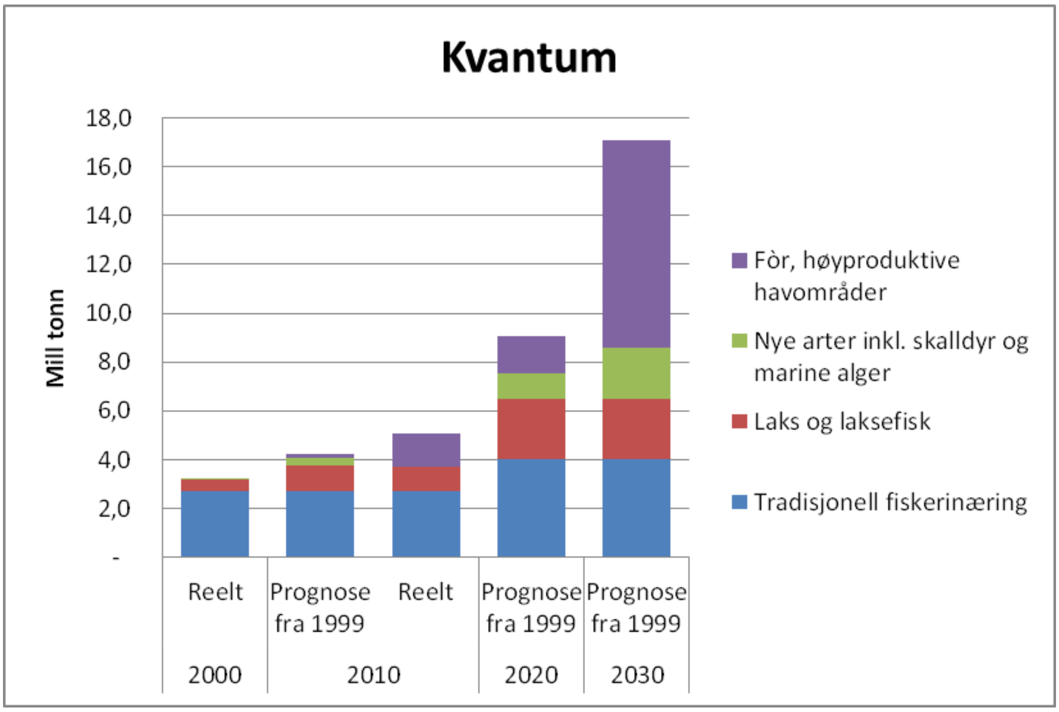


Figure Prognoses made in 1999 compared with real data from 2010 (volume)

Table Prognoses made in 1999 compared with real data from 2010 (volume)

	2000	**2010**		**2020**	**2030**	**Source/remarks**
Figures in mill. tonnes	**Actual**	**Prognosis 1999**	**Actual**	**Prognosis 1999**	**Prognosis 1999**	
Traditional fisheries	2.7	2.7	2.7	4.0	4.0	Volume landed for first hand sale. (Directorate of Fisheries)
Salmon and salmonoids	0.5	1.1	1.0	2.5	2.5	Sold volume salmon, round weight after starvation and bleeding. (Directorate of Fisheries)
New species incl. shellfish and marine algae	0.0052	0.3000	0.0256	1.0400	2.0800	Sold volume marine fish after starvation and bleeding. (Directorate of Fisheries)
Feed/highly productive waters	-	0.2	1.4	1.5	8.5	Fish feed production in Norway. (Directorate of Fisheries)
Marine biochemicals and energy carriers			0.15			Figures here irrelevant, with exception of seaweed (approx. 150,000 tonnes annually)
Equipment, aquaculture overseas, expertise						Figures here are irrelevant

Table Prognoses made in 1999 compared with real data from 2010 (economic value)

Figures in NOK billion	**2000**	**2010**		**202C**	**2030**	Source/remarks
	Actual	**Prognosis 1999**	**Actual**	**Prognosis 1999**	**Prognosis 1999**	
Traditional fisheries	20.0	27.0	26.7	45.0	65.0	Export value + domestic value. Source: Norwegian Seafood Council
Salmon and salmonids	12.1	23.0	34.8	58.0	58.0	Export value + domestic value. Source: Norwegian Seafood Council
New species incl. Shellfish and marine algae		6.0	0.5	19.0	35.0	Export value + domestic value estimate. Source: Norwegian Seafood Council
Feed/highly productive waters	·	1.0	12.3	7.5	42.5	Estimated average price for fish feed
Marine biochemicals and energy carriers	0.5	0.8	1.8	1.7	2.4	Harvesting of seaweeds and alginate production. Source: "*Norsk marin ingrediensindustri. Struktur og lønnsomhet»* (Norwegian Marine Ingredients Industry. Structure and Profitability). SINTEF report no.A21 511. www.purehelp.no
Equipment, aquaculture overseas, expertise	11.0	17.0	6.0	27.0	36.0	Source: Previous NTVA report + estimate (uncertain)
Biomarine ingredients industry			4.8			Source: "*Norsk marin ingrediensindustri. Struktur og lønnsomhet»* (Norwegian Marine Ingredients Industry. Structure and Profitability). SINTEF report no.A21 511.