Sustainable growth towards 2050

PwC Seafood Barometer 2017

Preface

The goal, 5 million tonnes of sustainable aquaculture production in 2050, is often repeated by the politicians in Norway - but how do we get there, and is this goal realistic?

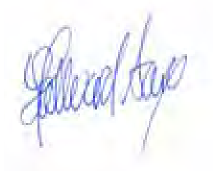
In this first edition of PwC's Seafood Barometer, we will explore some of the drivers for this increase. We will consider how realistic it is to reach 5 million tonnes by 2050, and discuss different challenges and solutions for achieving this goal. Our insights will be shared through PwC's Point of view, but the most important insights will come from the industry leaders, collected through our recently conducted CEO seafood survey.

Our purpose with the Seafood Barometer is to highlight different topics we believe will impact the seafood industry. In future issues we will also raise some new points of discussion, based on our knowledge about the industry.

The aquaculture industry is currently receiving a lot of attention, and expectations, in terms of future growth and its importance for Norway. However, there have been few realistic prognoses of how much the industry is able to grow.

We hope you will find this report interesting. If you would like to discuss any of the aspects of the report, feel free to contact us.

Best regards,



Hallvard Aarø
Partner, PwC

Executive summary

Government goal and the situation today

The Norwegian government's goal for the future is ambitious - becoming the world's leading seafood nation, with 5 million tonnes of sustainable aquaculture production in 2050. This is almost four times the level of the current production. However, the decade long rapid growth that has affected the aquaculture industry, has been put to a halt. The industry is now facing challenges like limited access to new areas, biological problems and decreased utilisation. Production volume has stagnated at 2012-levels, while production costs keep increasing. So, in order to reach the goal of 5 million tonnes by 2050, the industry have some challenges that needs to be addressed.

Two of the main challenges for increased production that the aquaculture industry needs to solve, are salmon lice and increased feed usage.

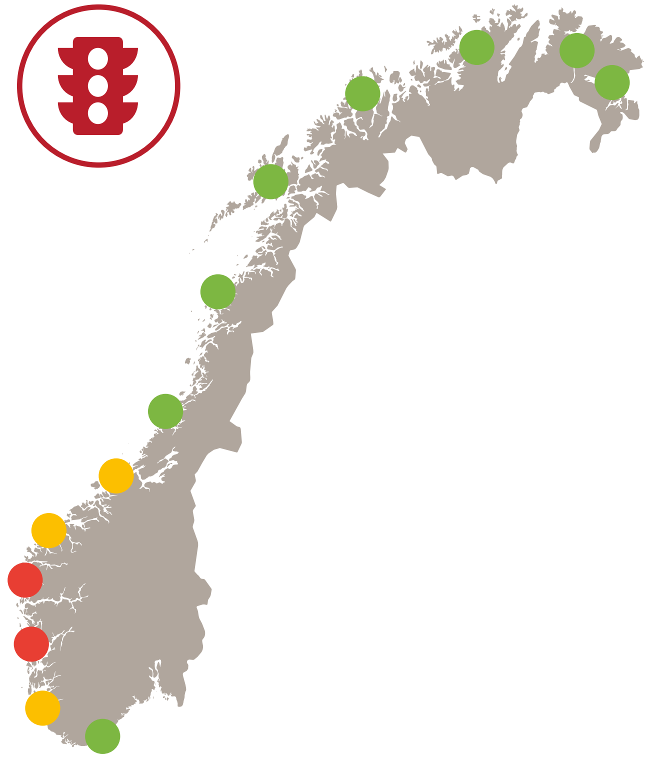
Government initiatives

The government has considerable influence on sustainable growth in the Norwegian aquaculture industry. Two government initiatives that will impact future growth potential are the Traffic Light System (TLS) and development licenses.

The ***Traffic Light System*** regulates sustainable growth, based on environmental indicators, where the growth-indicator (the current indicator is salmon lice) may change as challenges dominating the industry change.

Key success factors of the systems are ensuring transparency and predictability in determining the indicator and its risk levels. The price set for growth is much higher than expected and the majority of the growth volume offered are set to auction. We believe this will be in favour of the larger farmers and boost consolidation.

The ***Development licenses*** are used as incentives for innovative projects. Still, the evaluation method currently used run the risk of rewarding the projects with the highest investment costs and the most innovative solution. This as opposed to rewarding the solutions that may help solve the challenges in a more cost-effective way.



Megatrends

Many trends may impact the industry and growth potential. ***Climate changes and future government demands related to sustainability*** may challenge the industry. If government enforce regulations that are costly and biologically problematic. However, if the industry acts proactively it may seize opportunities.

Further, the industry needs to adapt to ***social and demographic changes*** that impact the industry, through changes in e.g. demand, export markets and access to manpower.

Also, ***new technology*** is becoming more commercially viable, as costs and time to market is falling rapidly. Accelerating technological development will enable the aquaculture industry to use Artificial Intelligence and Big Data models as grounds for decision-making and optimisation of the production. Further, increased automation, combined with machine learning and Artificial Intelligence, will reduce the need for local on-site manpower - which is considered to be a challenge in times of increased urbanisation.

New Technologies
Considering growth potential, we have looked more closely at four production technologies: the traditional Open Net Pens (ONP), but also new solutions with Closed and Semi Closed Systems (CCS), Offshore aquaculture and Recirculation Aquaculture Systems (RAS).

There is a lot of uncertainty regarding cost levels of the new technologies, which are in a R&D stage and involve high investments. Today, ONP farming is the most cost-efficient, both when it comes to operating costs and investment costs. Currently it is the preferred solution of the four concepts and the only commercially proven method.

Still, the new technologies offer new possibilities. Offshore aquaculture opens up a plethora of new farming locations. CCS and RAS provide potential solutions to salmon escapes, lice and nutrient discharge. Also, RAS production can be performed anywhere, and is not in need of access to public space. Fish can be produced near end markets, which eliminate air freight, but it may also remove the competitive advantage of production in Norwegian fjords.

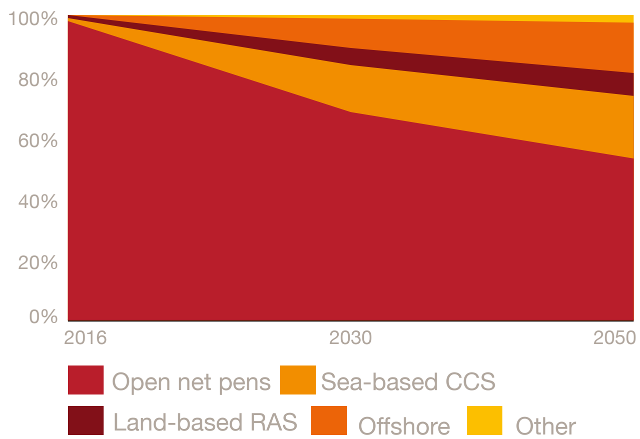
Though ONP is more cost efficient today, the gap has been closing in recent years. The problem with lice has lead to increased operating costs while RAS has experienced a cost decrease in terms of lower CAPEX.

Driver	ONP	CCS	Offshore	RAS
Salemon lice/fish health	☹	☺	○	☺
Regulations and tech. req	○	○	☹	○
Commodity prices	○	○	○	○
Scarcity of resources	☺	☹	☹	☹
Environmenttal focus	☹	☺	○	☺
Licence to farm	☹	○	☺	☺
PwC view on outlook	-	+	+/-	++

If we include air freight, RAS seems even more favorable for end-markets in the US and Asia, though most Norwegian export goes to the EU where transport cost is low.

PwC expect tomorrow's cost drivers to favor closed solutions, leading to converging costs of production for the different methods. In 2050 we expect both RAS and CCS to be competitive, eliminating the current super-profit in open net farming. A reduced super-profit in ONP salmon farming is likely inevitable in the long run, but this will primarily affect the license valuation in ONP, and not make fjord-based farming obsolete.

Nowegian aquaculture 2050



Scenario analysis

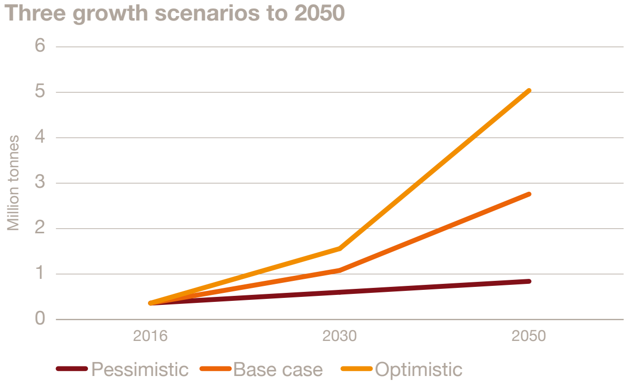
Keeping in mind the situation and challenges that the aquaculture industry faces – what are the possibilities for the future? Is the goal of 5 million tonnes in 2050 realistic? Only one third of the leaders in the industry believe so.

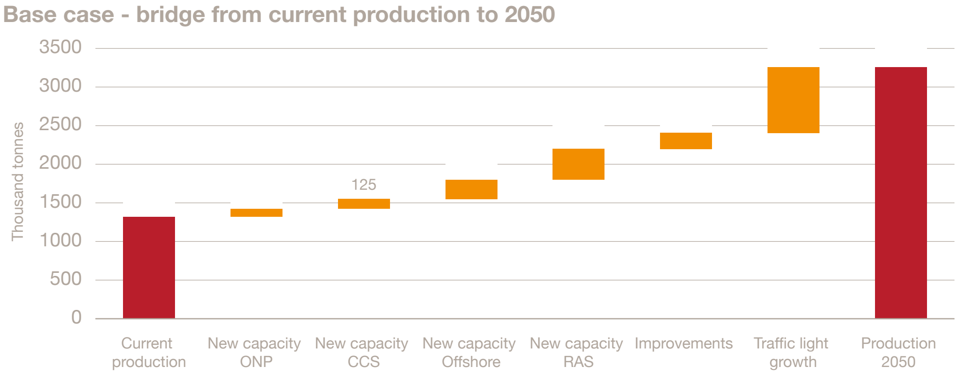
PwC has looked at possible production scenarios for the Norwegian aquaculture. One optimistic, one base case and one pessimistic analysis. PwC believes in significant volume growth towards 2050. However, our base case only suggest 3.3 million tonnes in 2050. In our most optimistic scenario, it is possible to reach 5.2 million tonnes. Also our pessimistic scenario indicates growth, but from 1.3 million tonnes to 1.7 million tonnes in 2050.

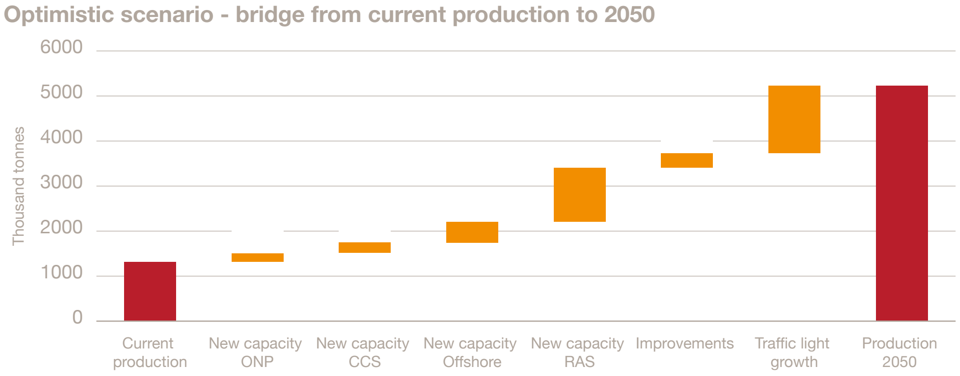
The uncertainty is high and growth depends on many variables. The success of new production technologies, like closed cages and offshore farming, will be crucial. As will cost efficiencies, government initiatives, and the development of current and rising challenges. Development in lice levels, hence future traffic light indicators, must be positive.

We believe that the traffic light system will provide growth on current licences. In addition, we expect new licences on land using RAS for post smolt, and in sea using new farming technology.

The base case scenario assumes main growth from the traffic light system, at approximately 50 % green lights. The optimistic scenario assumes that the main growth drivers are both the traffic light system, with almost 100% green lights, and RAS production of post smolt with average weight of 1 kg in 2050. Both scenarios assume growth from improved operations and new licences, mainly from offshore and closed sea-based systems, though at higher rates in the optimistic scenario. Also, both scenarios assume a shift towards the use of CCS as the main production method, both within new and current production capacity.







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The government has a vision of Norway becoming the world's leading seafood nation

Verdiskapning basert på produktive hav i 2050

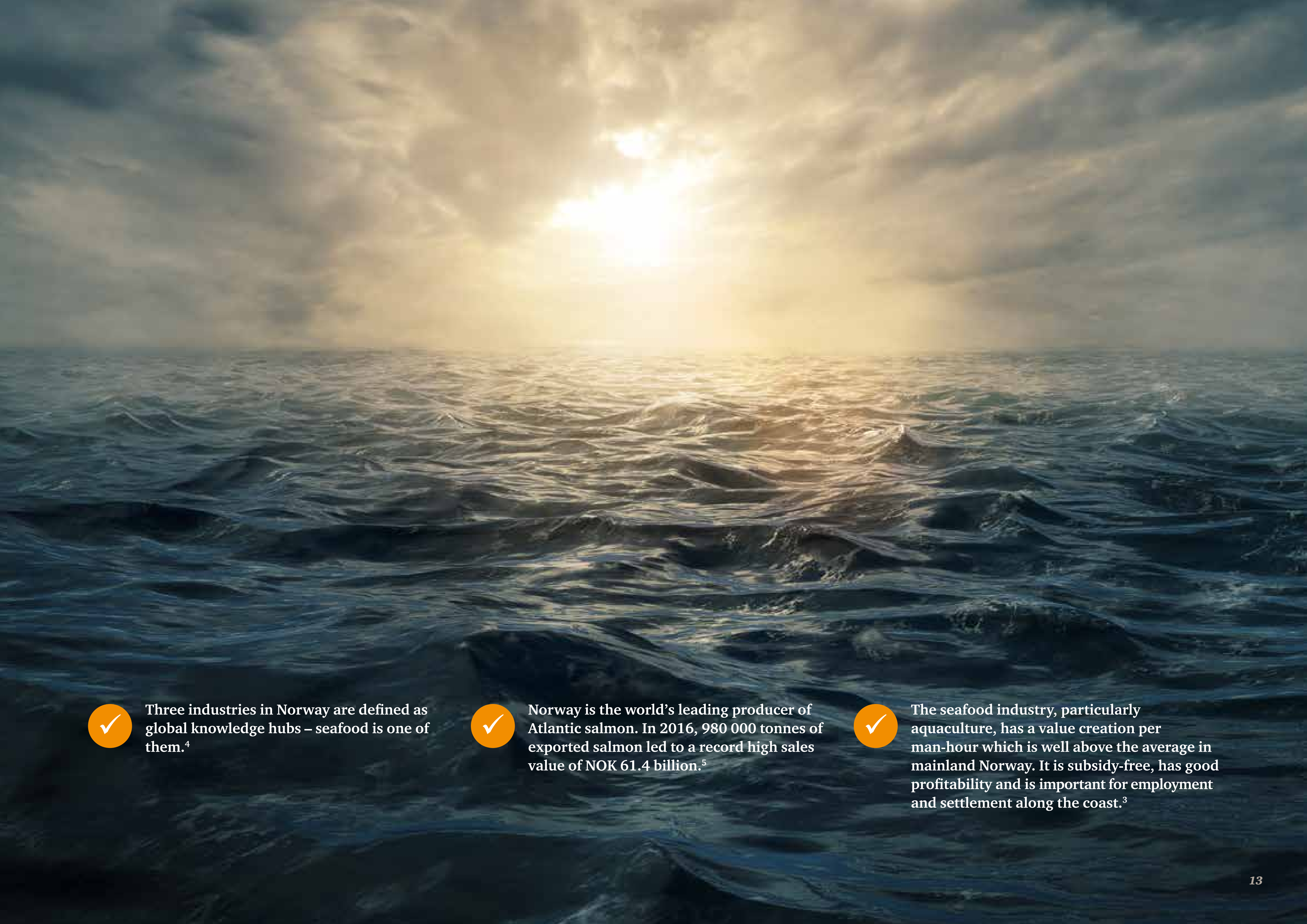
In 2012, notable scientists, researchers and opinion leaders published a report called "value creation based on productive oceans in 2050". They have estimated that it is possible to have a six-fold increase in sales value of Norwegian marine production, by 2050. This requires, among other things, **a production of salmon and trout of 5 million tonnes – almost a five-fold from today's level.**[1]

Verdens fremste sjømatnasjon

In 2013, the Norwegian Ministry of Fisheries and Coastal Affairs released parliament report no. 22 (Meld. St. 22),where the government's vision for Norway, as a seafood nation, is detailed. **The government wants Norway to be the world's leading seafood nation**, and adopts the view and vision that seafood production can be increased six-fold by 2050.[2]

Havbruksmeldingen

In 2014, the Norwegian Ministry of Fisheries and Coastal Affairs published parliament report no. 16 (Meld. St. 16), presenting their view on how vision 2050 can be reached. Global demand for salmon increases, but production growth has stagnated due to sustainability challenges. Historically, regulations and policies for growth, and changing governments, have shown nothing but predictability. The allocation of new licenses has been termed a "beauty contest" by the press. **The government, therefore, suggested a predictable system for sustainable growth based on environmental indicators**. This framework has been named «The Traffic Light System», where Norway is divided into 13 production areas and gives each area a green, yellow or red light. The new system came into effect in October 2017.[3]



- Three industries in Norway are defined as global knowledge hubs – seafood is one of them.[4]
- Norway is the world's leading producer of Atlantic salmon. In 2016, 980 000 tonnes of exported salmon led to a record high sales value of NOK 61.4 billion.[5]
- The seafood industry, particularly aquaculture, has a value creation per man-hour which is well above the average in mainland Norway. It is subsidy-free, has good profitability and is important for employment and settlement along the coast.[3]

Will the Norwegian seafood industry be able to capture future market demands?

Aquaculture growth receives broad political support, but meets public opposition on its way to 5 million tonnes – will the Norwegian seafood industry be able to capture future market demands?

Political willingness and support

According to the OECD, the global ocean economy will double its contribution to global value creation within 2030, and the Norwegian government expects that much of this growth will take place in industries where Norway already has important advantages.[6]

In their Ocean Strategy, launched in february 2017, the government emphasises that it «will facilitate predictable growth in the fish farming industry.»

Public opposition

The aquaculture industry frequently meets opposition and unfavourable coverage in media. Examples of critics are both local municipalities, who believe they are left with too small of a share of the value created within their jurisdiction[7], or the Fishermen's Association expressing their scepticism towards opening new areas for offshore farming.[8]

Also, unfavourable coverage of lice outbreaks on various locations, have put public pressure on politicians to pause the industry growth until the Political willingness and support problems have been solved.

69%

*We asked which **factors** leaders in the industry thought would **affect their industry the most.** Of the respondents, **69%** answered **technological breakthroughs** and **45%** answered **new market regulations and barriers!***

45%

One thing is for sure – the road towards 5 million tonnes will not be a walk in the park!

The industry will frequently have to overcome several bumps in the road, starting today with the biological and salmon lice challenges. Shortage of feed ingredients, available areas for expansion, technology-driven increase in investment costs, or increased competition from new, near-market producers may occur in later stages of growth.

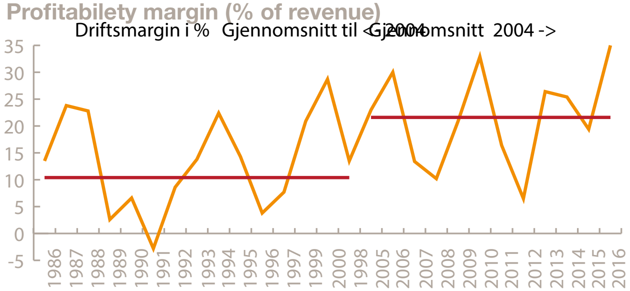
To achieve a production volume of 5 million tonnes, the industry must focus on technology and expertise. At the same time, they must maintain quality and keep market prices at sustainable levels without experiencing a severe cost increase. Simultaneously, trade authorities must focus on establishing and maintaining long-term relations with authorities in both new and existing markets. They must also co-operate with the industry to prevent and reduce trade restrictions that may create entry barriers for Norwegian seafood.

Access to markets is an important prerequisite as there may be considerable contributions to the supply side. The production capacity in Chile is estimated to grow steadily towards 618,000 tonnes in 2018.[9] Also, the super-profit amongst producers today opens up for new farming technologies, elaborated on later in this report. Maintaining the Norwegian industry's market access and position will be increasingly important, demanding attention from both producers and trade authorities.

Biological challenges, limited access to new areas and decreased utilisation have forced the aquaculture industry to pause its decade long high-growth adventure

Following nearly a decade of rapid and continuous growth in production volumes, the Norwegian aquaculture industry has experienced a stagnation between 2012 and now. Before 2012, the aquaculture production had seen an annual growth rate of 10% since 2005, despite the significant variation in the profitability of the producers illustrated below.

Profitabilety margin (% of revenue)

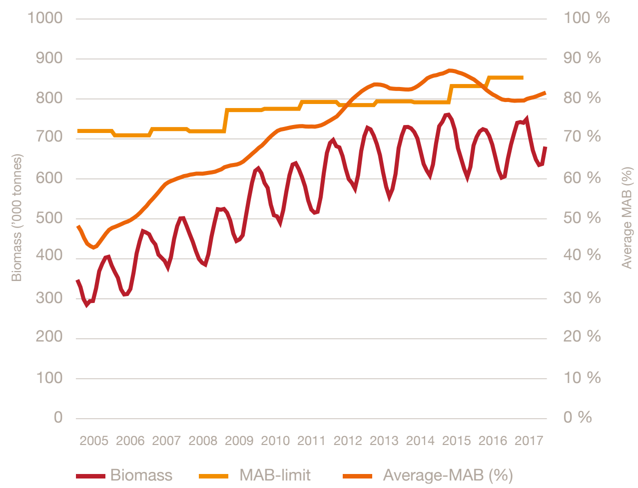


Source: The Norwegian Directorate of Fisheries, Proff Forvalt

The stagnation of the production volumes of salmon and trout comes as a natural effect of the biomass volume approaching the maximum allowed biomass (MAB) in Norwegian fjords. However it also comes as a result of higher mortality rates and several incidents of lice breakouts resulting in more frequent treatments, which have caused a decrease in the utilisation of existing licenses.

There seems to be a broad understanding within the industry that further production growth must be based on the premises of fish health and environment. The Norwegian Minister of Fisheries has repeatedly stated that no further growth will be allowed before the industry has handled its biological challenges.[10] The challenges are especially concerning salmon lice outbreaks in mid-Norway and Southwestern Norway, as well as the occurrences of viruses and diseases along the Norwegian coast line.

MAB utilization



Source: The Norwegian Directorate of Fisheries, PwC Analysis

New and ***more effective lice treatments*** *are considered as the* ***most important factor for future production growth*** *in Norway, according to leaders in the industry*

However, producers operating within the strict restrictions concerning lice levels and fish health have, for a test period spanning from 2017 through 2019, been allowed to exceed the MAB restrictions during the growth season in change for a NOK 1.5 million fee[11]. This is as long as the average annual biomass level is within today's limits. Also, the recent introduction of the Traffic Light System has opened for bi-annual growth in «green lighted areas» – areas operating within current lice limits and without significant disease outbreaks.

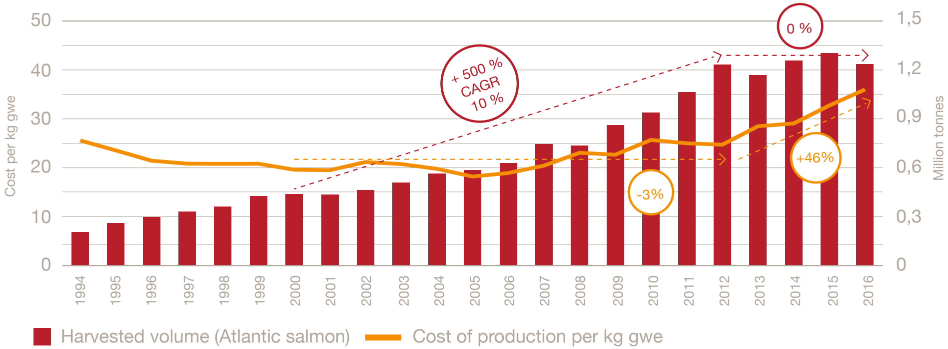
As shown in the illustration, there is still room for significant growth within existing licenses as they only utilise, on average, ~85% of their MAB.

Costs per kg HOG has increased steadily since 2005, while volume has stagnated since 2012 - is there a parallel to be drawn to the oil price hike some years ago?

Production volume has stagnated at 2012-levels, while production costs keep increasing

The Norwegian salmon farming industry has seen a continuous volume increase since its early days in the 70's up until 2012. Production cost remained stable from 1994 to 2012 while volume increased five-fold. The volume increase is tied to both consolidation in the industry and changes to political regulations (e.g. from feed quotas to MAB), but also in improved marked conditions, and better feed. We do, however, observe that from 2012 the volume has been quite stable at ~1.1 million tonnes HOG, which has driven the salmon prices to a record high ~80 NOK/kg[12] at the end of 2016. In the same period cost of production increased by 46 %. By October 2017 the price has dropped 30% to ~55 NOK/kg[12] which makes it relevant to ask, what happens if the salmon price drops significantly in the future as the price of oil did?

Historical cost vs volume growth



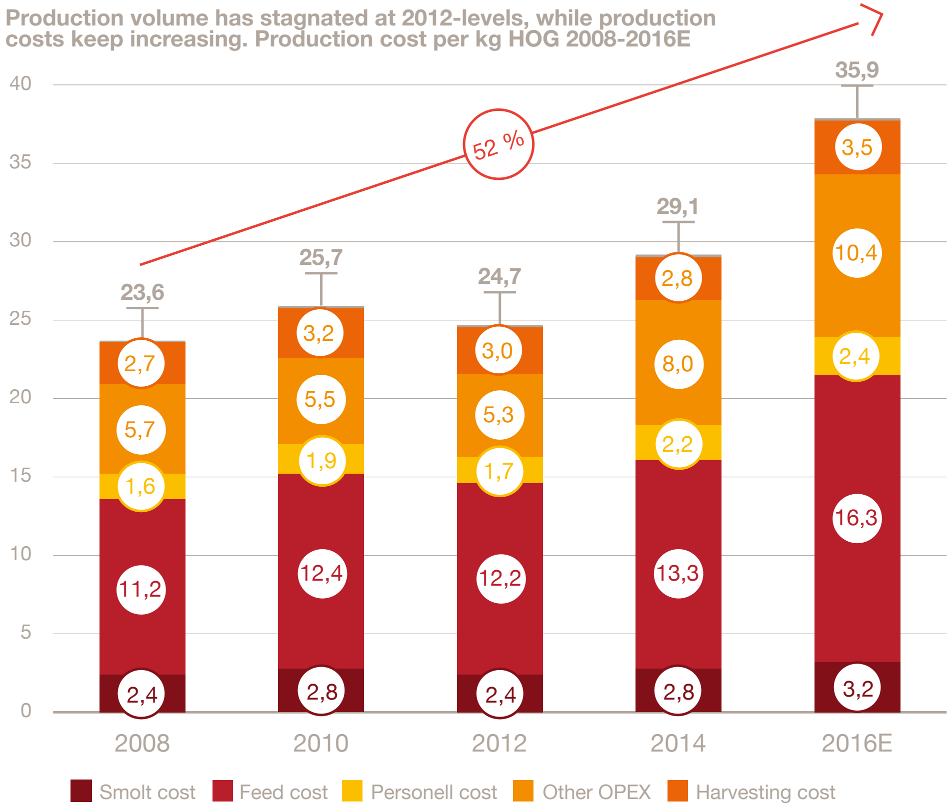
Source: Directorate of Fisheries, SSB, PwC analysis

PwCs point of view

PwC's view is that there are many similarities between the production costs and price hike of the oil industry and the salmon farming industry. The producers should keep this in mind to avoid being taken aback by a significant price reduction some time in the future, which could make their business unprofitable.

The leaders in ***the industry do not believe in a price reduction for feed*** *any time soon, while an* ***effective treatment or method to prevent salmon lice*** *is seen as the* ***most probable cost reducing factor***

Production volume has stagnated at 2012-levels, while production costs keep increasing. Production cost per kg HOG 2008-2016E



Sources: Directorate of Fisheries and PwC analysis

A deep dive into the main cost drivers - the price of marine feed ingredients and the biological situation in the industry are mainly responsible for the cost hike

The total production costs of salmon are combined of many factors, which we have divided into the four categories listed below. Out of these four, feed costs and other OPEX have seen the most significant increase, which is due to a global price increase of marine feed ingredients and the biological situation in the industry.

Smolt production has over the last decade seen a significant technological boost through automation and RAS-technology, which has allowed increased production volume and made it possible to grow the smolt longer before transferring it to seawater pens.

Personnel costs has seen an increase of 22%[13] over the time period after discounting for a general pay rise in the industry. It is our view that this is mainly due to the the biological situation with increased treatments, reporting, monitoring, and control requirements. Administrative work associated with license applications also add up. Combined, they impose a higher workload with higher competency requirements.

Feed costs have historically represented about half of the production cost per kg[13], and has increased by 45.5% which is not far from the total production cost increase. This is mainly due to feed ingredients being imported and bought in USD, which has become more expensive as the USD/NOK exchange rate has increased ~40% from 2014 to 2016.

Marine feed ingredients have seen an overall price increase over the last decade, as there is a limited supply of ingredients such as fish oil at ~1 000 000 tonnes annully[14]. Consequently, feed producers are using more vegetable oil instead of fish oil. This is not ideal as it doesn't contain marin omega-3, EPA and DPA, and vegetable oil has also increased in price. Feed producers have therefore, among other things, started the development of marine oil production from algae.

PwCs point of view

It is our view that the increased smolt growth before transfer to seawater is the main reason for the cost increase related to smolt, and as such, the price increase is only a small reallocation of cost from the other categories to smolt costs.

The transition to other feed ingredients such as algae is a necessary development if there is to be a sustainable feed cost, enabling a total production of 5 million tonnes of fish in Norway by 2050. This view is backed by our survey, where 56% of the leaders in the industry believe algae is going to be the main fish feed ingredient in the future.

It is difficult to predict whether a solution to the salmon lice challenge is going to be found in the near future, but it is our belief that the industry will find better ways to mitigate the effect of salmon lice in the short term, while more permanent solutions are being developed.

70%

of the leaders in the aquaculture industry believe that ***new and more effective salmon lice treatments*** *will result in the largest* ***volume increase***

Other OPEX have seen the largest price increase out of the four categories, which totals 82%[13] over the time period. Insurance, depreciation and net finance costs are part of this category, but only accounts for ~20% increase in Other OPEX according to PwC estimates. The remaining increase is associated with other costs, which significantly jumped from 2013 to 2016E.

The main cost driver in other OPEX, according to the PwC analysis, is the biological situation in the industry. Lice weaken the salmon's immune system, which results in higher mortality and lowers the economic feed conversion rate. There are also significant negative effects associated with salmon lice treatment, such as increased mortality due to stress. Many treatments also require the salmon to be starved prior to the start of the treatment, which require increased use of high energy fish feed, leading to increased feed costs. An overall effect is reduced harvest weight, resulting in increased cost per kg HOG in all cost categories.

Medical treatments and chemicals have been used on a large scale by many producers, due to its effectiveness. The use has now been reduced, as the salmon lice have started to form immunity to the treatments, according to the Norwegian Institute of Public Health[15]. This requires that producers invest in new equipment, to use combinations of different treatment methods, which results in increased finance, depreciation and insurance costs.

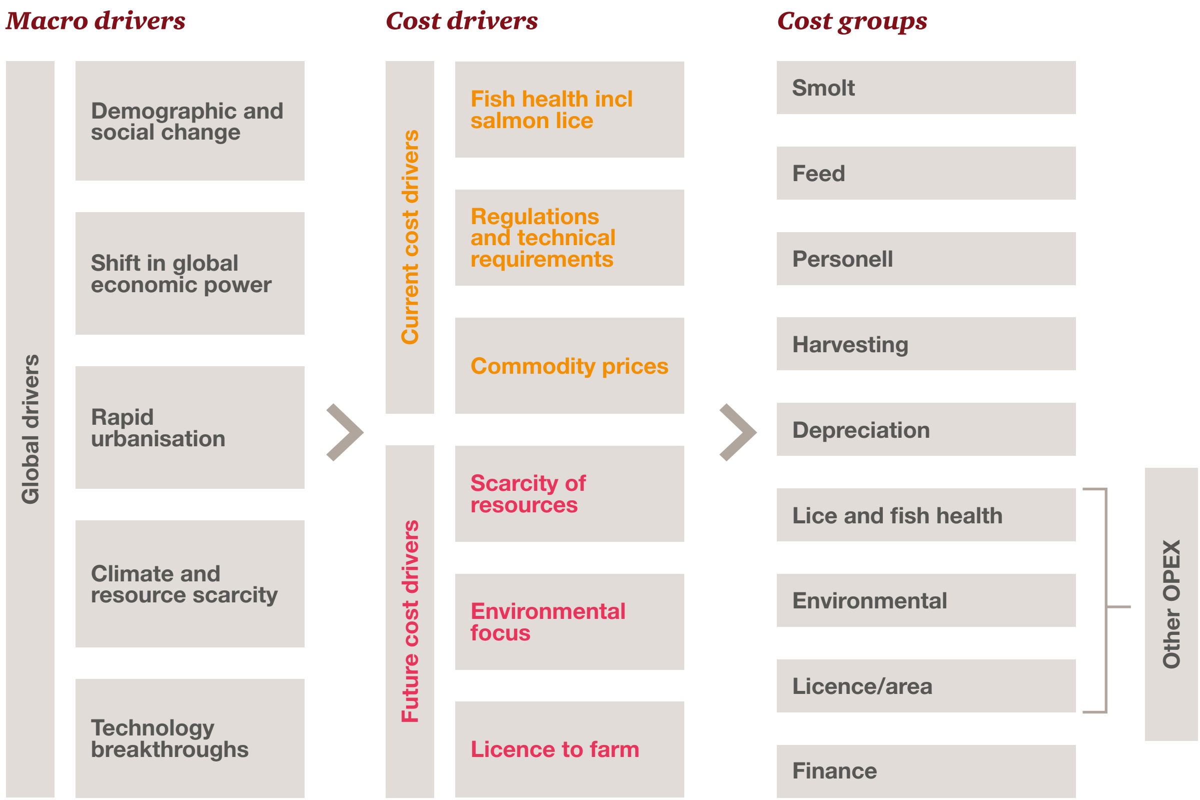
According to a study from Nofima, the direct and indirect costs related to salmon lice amounted to 5 NOK/kg in 2015[16], whereas the cost in 2010 was only 1.5 NOK/kg, according to a report from Pareto[17]. This highlights the significant cost increase associated with salmon lice, which from 2010 to 2015 has been a staggering 233%. It is our view that costs associated with salmon lice are closer to 6 NOK/kg in 2016, as a result of producers transitioning from medical treatment to a combination of cleaner fish and mechanical treatment.

We believe the current, global macro drivers will result in new cost drivers for aquaculture in 2050

When estimating the future growth for different technologies we also need to consider the future cost of production for the different concepts. Apart from the traditional open net pens, reliable cost data is limited, and forecasting to 2050 near impossible.

To provide a basis for our analysis we have defined three key drivers for the current increase in production cost, and derived another three future drivers based on our analysis of the global megatrends. The drivers are not exhaustive, but provides a useful framework for discussing the potential development in CoP between the different farming technologies, that we will utilize when estimating the future growth later in the report.

These cost drivers again impact both the traditional cost groups that we recently discussed, and may also create new cost groups for costs traditionally included in “other OPEX”.



Commodity prices
Limited supply of both marine feed resources and other feed resources has increased the feed price in recent years. This is likely to continue until we are able to replace current marine ingredients with new feed ingredients. This mainly drives the feed cost.

Salmon lice
High costs related to treatment and prevention of salmon lice has been an important driver for the recent cost increase. Direct costs, like lice skirts and cleaner fish, mainly affect other OPEX, while indirect costs, such as mortality from treatment, affect all cost groups by reducing volume.

Regulations and technical requirements
Increasing and more complex regulations, reporting requirements, and standards like Global GAP and ASC, contribute to higher personnel costs and other OPEX. New technical requirements such as NYTEK also drives CAPEX, affecting both depreciation cost, finance cost and other OPEX (through maintenance)

Environmental costs
In a zero emission community, we believe all environmental footprints will have a cost side. Where the impact on wild salmon is a key driver today, cost of CO_2-emissions, nutrient discharge, and other effects on the local and global ecosystems, may be more important in the future.

Scarcity of resources
While the limited supply of marine feed ingredients is a key driver today, we believe scarcity of other resources will be more important in the future. Although feed is likely to be the largest cost component also in 2050, scarcity of construction materials and other resources may become more important. How would a potential ban of non-degradable plastics affect aquaculture?

Licence to farm
In a world with increasing differences, the importance of legitimacy and contribution to the local community will become more important, especially when farming on public land or sea. To achieve this, we believe politicians will use the licence and tax system to ensure that a fair amount is paid to the public. This might be solved using either a production/area fee, licence fees, other taxes or a “licence reversion model” as known from the electric power industry.

In order to produce 5 million tonnes by 2050, we need to increase production capacity and utilize existing production capacity even better

Today, the Norwegian production of Atlantic salmon and trout has reached 1.3 million tonnes. For the production of salmon and trout to reach the desired growth, the whole value chain needs to be upscaled. We need increased production in existing cages in the Norwegian fjords, and we need increased production in offshore facilities and production in new technologies, such as closed sea based or closed land based facilities.

In this report we will discuss important growth issues and consider growth potential through new farming technology. We will also reflect upon how realistic we believe the growth target is. To guide you through the report we have designed a net pen with different layers to make it easy to follow the different topics throughout the report.

We start by looking at the big picture, by exploring how global megatrends might impact Norwegian aquaculture. From there we will discuss important challenges that needs to be solved in order to reach 5 million tonnes. We then focus on government initiatives implemented to achieve sustainable growth.

Before we start discussing new farming technologies, we will consider possibilities within improved utilisation of existing farming solutions. The farming solutions we will explore are:

1. New solutions for farming in open cages
2. New technology for farming in closed systems
3. Offshore farming - both open and closed
4. RAS systems - both land and sea-based

We then finish off by summarising our views and findings, and by comparing them to those of the industry leaders in our survey.

Sustainable growth - 5 million tonnes

Global megatrends will influence the growth target

Challenges

Government initiatives

The Traffic Light System - Sustainable growth in the Norwegian salmon industry
New regulations of the MAB-volume per production area - growth is controlled by a predefined indicator (the traffic light) which is currently based on the risk of wild salmon being harmed by salmon lice.

Development licences - Innovation and new salmon farming technology
Licences granted for projects with significant innovation and investments - may help solve one or more of the environmental challenges, and the lack of available production areas, faced by the industry.

Improved operations

Improved utilisation
Growth potential with lower losses due to treatment of diseases and salmon lice, better MAB utilisation, and better feed and feeding.

New farming technologies

New solutions for farming in open cages
New solutions like submersible cages may represent a new concept of open-cage farming

New technology for farming in closed systems
Closed and semiclosed systems in the sea combine aspects from both open-net and land-based farming

Offshore farming - both open and closed
Offshore farming, ships and installations, offer a new and exciting growth potential in the future

RAS systems - both land and sea-based
RAS systems, on land and at sea, offer a controlled environment with a lower CAPEX than before

Other farming technologies
In 30 years from now we may see other concepts not yet imagined

Potential growth

Global megatrends will influence the growth target

Megatrends will have a notable impact on Norwegian aquaculture, and disrupt the industry

Demographic and social changes will have a great impact on the aquaculture industry through increased food demand and emphasis on food trust.

The world population is projected to increase by more than 2 billion, equalling a staggering 9.8 billion in 2050[19]. People are living longer and having fewer children, and the fastest growing segment are those over 65 years old.[20,21]

An aging population will change the dynamics of labour. Women and the young and elderly, must take a greater part in the workforce. Currently, women only represent 20% of the workforce directly employed in the Norwegian aquaculture sector.[22] Young people, on the other hand, are eager to get "their foot in the door" - applicants for fisheries and aquaculture studies have grown threefold since 2013.[23]

With an ever growing population, we'll also see an increased need for food.[24] Aquaculture production is estimated to grow by 30 million tonnes towards 2030, equalling 62% of the global seafood supply.[25] Currently, the global omega-3 consumption is too low to prevent cardiovascular and cognitive health issues in most parts of the world, partly due to processed food.[26] Still, today's consumers have high expectations for the food industry, and are becoming more concerned about convenience, choice and transparency.[27]

PwC's Point of View

Even if production of Norwegian salmon reaches 5 million tonnes, it will not be the solution to the increased global food demand, and will therefore continue to be a middle-class product. We believe it will be of utmost importance to meet consumers' expectations with traceability throughout the value chain and a variety of product choices focusing on convenience and health.

The shift in global economic power from advanced economies to emerging economies will continue in the coming decades.

As the global economic power shifts, China and India have the potential to become important export markets for Norwegian salmon and trout. China is the world's largest seafood market with high seafood consumption and increasing purchasing power,[28] but the market access for salmon and trout is constrained.[29] Even if market access is fully solved, there will be uncertainty related to its stability. In India, seafood consumption is increasing due to higher purchasing power. However, the main challenge with the Indian market is tariffs.[30]

Europe is the largest market for Norwegian salmon and trout. Lately, high salmon prices have affected the export to many markets within Europe.[31,32] As the Gross Domestic Product (GDP) is expected to fall in the EU, a shift to new markets with a higher purchasing power is expected.[33]

The US and Great Britain are important markets for the Norwegian aquaculture industry, but negotiations of trade agreements[34,35] and uncertainty about their economic growth, make market growth uncertain [36,37] According to PwC's global CEO survey, leaders are increasingly focusing on established, rather than developing economies, for growth. However, developing economies have the potential to become growth markets for global businesses.[38]

PwC's Point of View

It is important to closely view which markets hold the greatest growth potential in the short and long term. With today's uncertain market growth, the industry should consider spreading risk across economies with different characteristics in order to manage potential volatility.

Rapid urbanisation can lead to a brain drain (human capital flight) in Norwegian aquaculture

By 2050, 70% of the world population is predicted to live in cities.[39,40] Norwegian cities, and municipalities near regional centers, are predicted to grow considerably the next ten years. Other municipalities will experience a decline, especially in the north.[41]

The first permanent Norwegian aquaculture act stipulated that the industry should be located in the districts to maintain employment and settlement. The framework later favoured profitability and competitiveness. Value creation along the coast is still important, but the emphasis is not as strong. As a consequence, production units have grown, local ownership is reduced, and many administrative functions are centralised.[42] That being said, 88% of companies, producing grower salmon commercially, are locally owned and not listed on the stock exchange. However, listed companies, including Cermaq, own 58% of the grower licenses and the biomass (MAB) in Norway.* In our survey, leaders in the industry believe that strong private ownership will continue towards 2030. Nine out of ten do not agree to the statement that listed companies will account for 90% of the future turnover.

If attracting the right people is a challenge today, it certainly will be in the future. Both SINTEF and NHO state that aquaculture requests more formal qualifications, and that there is an unmet need for competent labour.[43,44]

PwC's Point of View:

Listed companies tend to locate their headquarters in urban areas. Still, most companies and farm sites are located along the coast. If they do not apply measures to attract and keep competent labour, or to join hubs together, they will face a serious brain drain in the future.

The cost of new technology and time from breakthrough to mass market is falling rapidly, making new technology more viable and widely used in a variety of industries

Blockchain

Blockchain is a technology that provides an overview and verifies transaction between equal participants through a decentralised ledger, or list, of all transactions in a network. Blockchain is a digital infrastructure (database) where multiple participants transfer elements of value to each other without the need for any third-party validator or reconciliation.

PwC's Point of View:

An important shift in the food industry will be the use of blockchain technology to gather information throughout the value chain and to make it easy for the consumer to access. This is an important part of building food trust. How does this apply to aquaculture? Consumers can verify every fish feed ingredient and trace it back to fish consumption. They can also receive information about the harvesting plants and their impact on the environment, plus detailed information about transport, and more.

Internet of Things (IoT)

IoT is a network of objects, hardware and software with sensor connectivity, that has a capability to collect and exchange data over the internet. IoT can help companies achieve enhanced process optimisation and efficiency by collecting and reporting data from the business environment. More and more businesses are adding sensors to people, places, processes and products to gather and analyse information. This can lead to better decision-making and increase transparency.

PwC's Point of View:

For the aquaculture industry, wearable technology can provide a hands-free way for employees to engage with real-time, context-specific business information. For example, companies can provide tailored, in-the-moment onboarding and training to workers equipped with smart badges or wearable displays. Wearables can be a low-cost way for the industry to learn about their employees and operations - and then be used to improve engagement, sales, productivity, safety, and much more.

75%

of the leaders in the aquaculture industry ***believe technology breakthroughs will change the industry*** *within the next 5 years.*


BILA

Automation of aquaculture production is increasingly more relevant as rapid urbanisation and technology development reduce the need for, and availability of, manpower

Drones
Air- and water-based devices and vehicles, that fly or move without an on-board human pilot. They can be remotely controlled or autonomously guided based on navigation, machine learning and AI.

Unmanned aerial vehicles (UAV), commonly known as «drone», and unmanned underwater vehicles (UUV), known as underwater drone or ROV, are especially interesting for the aquaculture industry.

PwC's Point of View:
We believe the aquaculture industry will benefit from the use of UAV (drones) and UUV (ROVs). Drones may perform overall surveillance of the facility. Autonomous ROVs may analyse biomass, detect lice and perform safer, faster and cheaper net surveillance and maintenance. These are examples of the possibilities that future technologies provide.

PwC sincerely believe that increased automation is a key factor in the future of aquaculture operations. Combined with machine learning and Artificial Intelligence, fully automated vehicles will reduce the need for local on-site manpower which is considered to be a challenge in times of increased urbanisation. However, we believe the real benefits of automated operations are more likely to appear in forms of indirect savings, as cleaner and better maintained net pens may improve fish health and the surrounding environment, as well as improved safety for the employees.

In the survey of the recently launched PwC publication "The Digital Transformation of Shipping," the vast majority of companies were convinced that automation and digitisation in shipping will grow at an extremely swift rate over the next few years. We expect that this will impact the aquaculture industry in the years to come.

About **50%** *of the leaders in the industry believe they will achieve **reduced costs** by increasing **automation of the production** within the next **5 years.***

Robotics
Robotics is about integrating sensors, computation and machine systems to manipulate matter of any scale. Robotics are electro-mechanical machines, or virtual agents, that automate, augment, or assist human activities, autonomously or according to a set of instructions - often a computer program (Robotic Process Automation - RPA).

PwC's Point of View:
Robotics will eliminate jobs in the aquaculture industry with repetitive and less complex tasks. However, viewing robotics only in terms of direct job losses misses the point of how robotics can create new jobs and opportunities for workers and companies.

At PwC, we have experienced how automation of administrative processes through robotic process automation (RPA) has sharpened the management's focus by allowing them to spend more time on value added activities instead of support tasks. With moderate investment costs, RPA may provide a quick-fix for repetitive and descriptive administrative tasks spanning across one or several different software programs. Examples of tasks that may be automated are periodical invoice generation, payroll, generating periodic management and authority reports, and many other repetitive, rule-governed tasks.

RPA often result in immediate effects of freed administrative capacity, or reducing the need for periodic hiring. But it just as often results in significant quality improvements as the standardised tasks are performed in the same manner each time, without the human errors that we all know are likely to occur when executing repetitive work.

85%

*of the leaders in the aquaculture industry **consider it likely or very likely** that they will **invest in new technology** to increase efficiency within the next 5 years.*

Accelerating technological development enables the aquaculture industry to use Artificial Intelligence and Big Data models as grounds for decision-making and optimisation of the production

Big data

Big data is about applying math to huge quantities of data to infer probabilities; the core of big data is predictions. Big data enable organisations to extract new value from data, providing important business insights leading to enhanced decision-making. The potential of using Big Data is huge, and currently only a small percent of data worldwide are analysed.

PwC's Point of View:

The aquaculture industry produces a huge amount of data every day, but the value of this data has to be extracted using analytics and visualisation to make the data valuable. By utilising the potential of increasingly more complex and detailed sources of information, we believe that application of Big Data analysis will play a key role in the future of sustainable aquaculture production.

As several companies operate within the same fjords and ecosystems, the output from Big Data models should not be considered a competitive advantage for each company, but an advantage for the industry as a whole. Today, the information and technology to develop the right models exist, but it is crucial for the industry that research facilities coordinate their development to avoid reinventing the wheel.

The industry must co-invest in technology development and aspire to achieve complete transparency outside the boundaries of sensitivity to exploit the true potential of Big Data.

Not quite Big Data, but nonetheless a helpful tool

Based on sophisticated mathematical modelling of both lice hatching data and predictions of underwater streams, the Institute of Marine Research launched their lice surveillance model earlier in 2017, providing the industry with a tool for surveilling lice levels throughout the Norwegian coastline.

63%

*of the leaders in the aquaculture industry are **likely** or **very likely** to **invest in Big Data** technology!*

Artificial Intelligence (AI)

AI is about developing intelligence to manipulate information. It's about dealing with the creation of machines that behave in ways we would call intelligent if humans performed the same action. AI may exceed human intelligence in many dimensions. Robotics and AI my take 50% of human jobs in 30 years.[45]

AquaCloud - by NCE Seafood Innovation Cluster

In co-operation with several of industry leaders in aquaculture farming, the cluster has designed a pilot project to develop the big data model "AquaCloud."

By collecting current and historical production data from their project partners, the primary objective for AquaCloud is to calculate the numbers of lice per fish on a daily basis and predict the same level two weeks ahead. Being able to estimate the number of lice per fish two weeks in advance, IBM's Watson AI engine, also embedded in the project, should in the future be able to recommend the most suitable lice treatment method at any given time.

AquaCloud incorporates the Watson AI engine to move from traditional business intelligence models to a model that, based on its calculations, will create insight into the future, and in time maybe even foresee future events.

PwC's Point of View:

We believe that AI will significantly change the way feeding to appetite and behavioral feeding are performed. Fish feed is by far the most important cost component in open net pens (ONP). Behavioral based feeding will reduce the amount of fish feed needed since behavioral based feeding will learn when the fish has received the exact amount of feed needed for optimal growth.

Climate change and sustainability can make or break Norwegian aquaculture

We believe the planet is unable to support current models of production and consumption. Average temperatures are predicted to increase by more than two degrees Celsius, and pressures on resources will increase. A growing global population is expected to demand 70% more food between 2009 and 2050,[46] and the type of food demanded as populations' incomes rise – vegetable oils, dairy, meat, fish and sugar – will have a high impact on energy and water.[47]

What	*Opportunity*	*Threat*
Efficient livestock	Farmed salmon is a climate and resource winner - it is the most efficient livestock as it has the lowest feed conversion ratio, the highest energy and protein retention and edible yield compared to chicken, pork, beef and lamb.[48] The opportunity lies in better communication of this to consumers.	Still, global production of livestock such as chicken, pigs, cattle and sheep exceed that of farmed salmon. To compare, pig production has a global production of 113 million tonnes.[48] FA and OECD predict that growth rates for most commodity groups, including fish, will be cut by around half between 2017 and 2026.[55]
Warmer sea temperatures	Warmer temperatures may open the Northeast and Northwest passages, but due to low bunker fuel prices, a short sailing season and treacherous ice even in summer, it may not be commercially viable until 2040 to ship seafood via the Northeast passage.[49] Southern Norway may be able to farm new species due to warmer sea temperatures.[50]	Warmer sea temperatures will also lead to a series of challenges for salmon, including bacteria and viral diseases, more salmon lice and less oxygen in the water. Salmon also eat less when it's warmer. This may lead to farms being moved offshore or further north to areas such as Finnmark and Troms,[56,57] possibly leading to scarcity in production areas.
Acidification	The ocean absorbs around 25% of CO2 emissions, causing it to become more acidic. Most studies have found negative effects of marine acidification, but research shows that some algae get better conditions [51,52] - an opportunity for multi-trophic aquaculture.	During the past 200 years, the average ocean acidity has increased by 26% worldwide, and the Arctic is particularly vulnerable. The consequences are uncertain and there is a great need for more knowledge.[51]

UN's sustainability goals, which can be related to aquaculture.

What	Opportunity	Threat
Greenhouse gas emissions	Farmed salmon produce less carbon footprint per kg edible part (2.9) compared to beef (30) and pork (5.9).[48] Still, a shift from motor truck cargo to sea freight, such as robot containers (SEAtrue)[53] and self-driving electric ships, could reduce emissions even further.[54]	Comparably, chicken produce less CO2 (2.7).[48] As seafood is transported across large distances, major greenhouse gas emissions are released.[12] It would be more environmentally friendly to consume the salmon in Europe, or at least, process it in Norway.
Plastics and microplastics	The World Economic Forum says there will be more plastic than fish in the ocean by 2050.[58] As a point-of-difference, farmers could invent ways of collecting plastic, reuse it for own products, or use biodegradable packaging.	The research program MAREANO has found 40-50 particles of microplastics per kg marine sediment in Møre og Romsdal. Fish eat plastic - it has been found in the stomach, tissues and meat, and it can end up on our dinner table.[64] Studies also indicate that microplastics develop a slimy biofilm with a diverse community of microbes which may spread dangerous pathogens.[65]
Alien species	There are 2,320 proven alien species in Norwegian waters, and many of them are harmless.[59] As they don't belong here, and should be harvested, it could be useful to investigate their potential use as a raw material in fish feed, or for other purposes.	217 alien species pose a threat to Norwegian ocean diversity. The shipping industry, through ballast water discharge and biofouling, is a contributor. Micro-algal blooms have caused great losses for aquaculture.[59]
Resource scarcity	Finite resources force feed suppliers to use alternative ingredients. In our seafood survey, 55% of the CEOs believed algae will be the most important future raw material. Just look at Ocean Forest and CO2Bio in Mongstad.	Heavy reliance on fishmeal and fish oil makes the industry vulnerable to shortages and increased feed costs when supply is low.[66] Decreasing the reliance means less omega-3 in farmed salmon, which can be negative for consumers.
Circular economy	Companies, even countries, are embracing the circular economy: creating more value and less waste out of resources used.[60] There are opportunities in utilising fish mortality and waste as a valuable resource.	Critics believe trade globalization makes the circular economy difficult to enforce as materials and products circle the world.[67] This especially applies to Norwegian farmed salmon, which are exported all over the globe.
Sustainability reporting & political agenda	The UN has agreed upon 17 sustainable development goals towards 2030. Many companies are now including these in their reporting.[61] The ASC-standard [62] and the Global Salmon Initiative (GSI) [63] are other ways of committing to CSR and the environment.	In Skretting's recent report about aquaculture's reputation, CEOs admit having a short-term mindset regarding the environment.[68] The result is that our government's regulations become baseline, such as the 2015 parliament report no. 16 (Meld. St. 16)[3] and the new Traffic Light System. Instead, companies could set the agenda by proactively implementing sustainability measures ahead of government intervention.

FARMED RESPONSIBLY asc CERTIFIED ASC-AQUA.ORG

PwC's Point of View:

Sustainability is not just a trend, it is a movement. And it can make or break aquaculture.

It can break the industry by enforcing impossible government regulations, which are both costly and biologically problematic.

However, it can make the industry if companies take it seriously and see the opportunities that come with it, preferably before strict government interference.

Improvements are most effective when clear goals are set, and they can be aligned with the UN's sustainable development goals. They can also differentiate your company, brands and industry as role models.

Challenges

Solving the lice issue is the first challenge in reaching 5 million tonnes

Increased volume

More salmon lice

More lice treatment

Wild salmon

Lice have led to an estimated annual ***loss of 50,000 adult, wild salmon*** to rivers between 2010-2014. This equals ***10% of wild salmon*** on a national level.[69]

Resistance

Increasing resistance to medical treatments has led to ***higher dosages, use of cocktails*** and controversial drugs like ***chitin inhibitors***. Have we created a ***super louse?***

Mortality

In 2016, ***19% of farmed salmon died***, mostly due to non-medical lice treatments. This equals a total loss of ***NOK 10 billion*** in potential export value.[70]

Escapes

In 2016, ***190,000 farmed salmon & trout escapes*** were reported.[71] This equals ***a loss of about NOK 38 million***. Escapes are partly due to increased lice treatments.

Increased feed usage

Nutrient discharge

Only 5% of total nutrients along the coast derive from aquaculture discharge.[72] However, the risk of eutrophication will increase with higher biomass, and it also represents a lost resource.

Alternative feed ingredients

Supply from traditional fish oil and meal has been ***static for decades***,[73] and increased volume will require new and alternative feed ingredients, preferably with a high marine content and omega-3s.

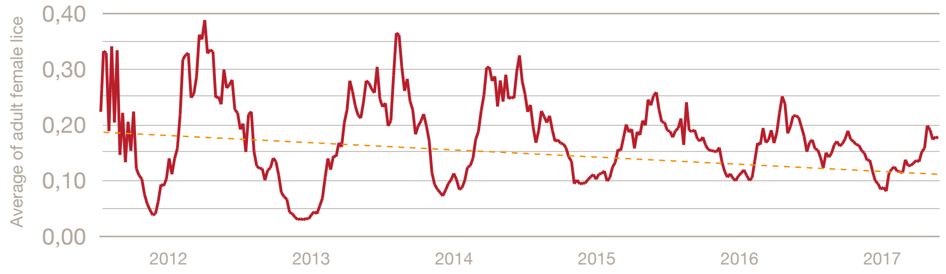
Unless solved, all of these negative consequences may contribute to a less positive reputation and reduced growth opportunities.

**The above overview is not exhaustive, and refers to challenges depicted in parliament report no. 16 (Meld. St. 16)*

Biological treatment, or treatment through feed, seems to be the sustainable solution

Despite large seasonal variations, the average number of adult salmon lice is slightly declining

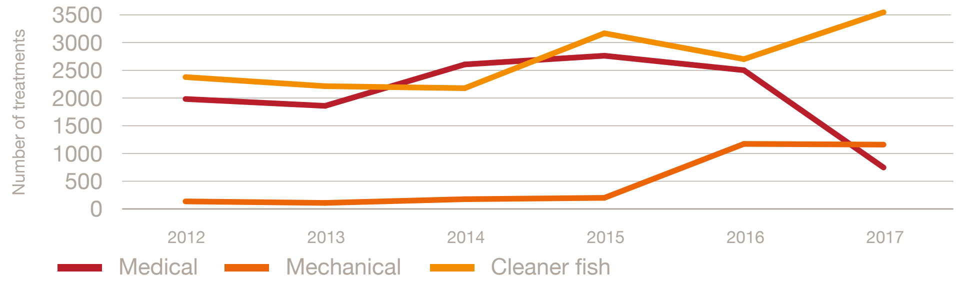
Avrage number of adult female salmon lice



Source: Barentswatch Fish health

Resistance against medical treatment has led to increased use of cleaner fish

Salmon lice treatments



Source: Barentswatch Fish health

Salmon lice is a natural parasite from long before salmon farming started in Norway. When the number of salmon hosts increase, so does the number of lice. It is clear that the total number of lice hosts increase in line with growth in production. A high number of salmon lice threatens the fish welfare of both farmed fish and wild salmon. To keep total lice count constant, the average number of lice per salmon needs to be reduced. But treatments drive resistance. Critics argue that some treatments also have a negative effect on shellfish and crustaceans living in the nearby aquatic environment.

The lice rapidly become resistant to new medical treatments. Today, these are the most commonly used non-medical alternatives:

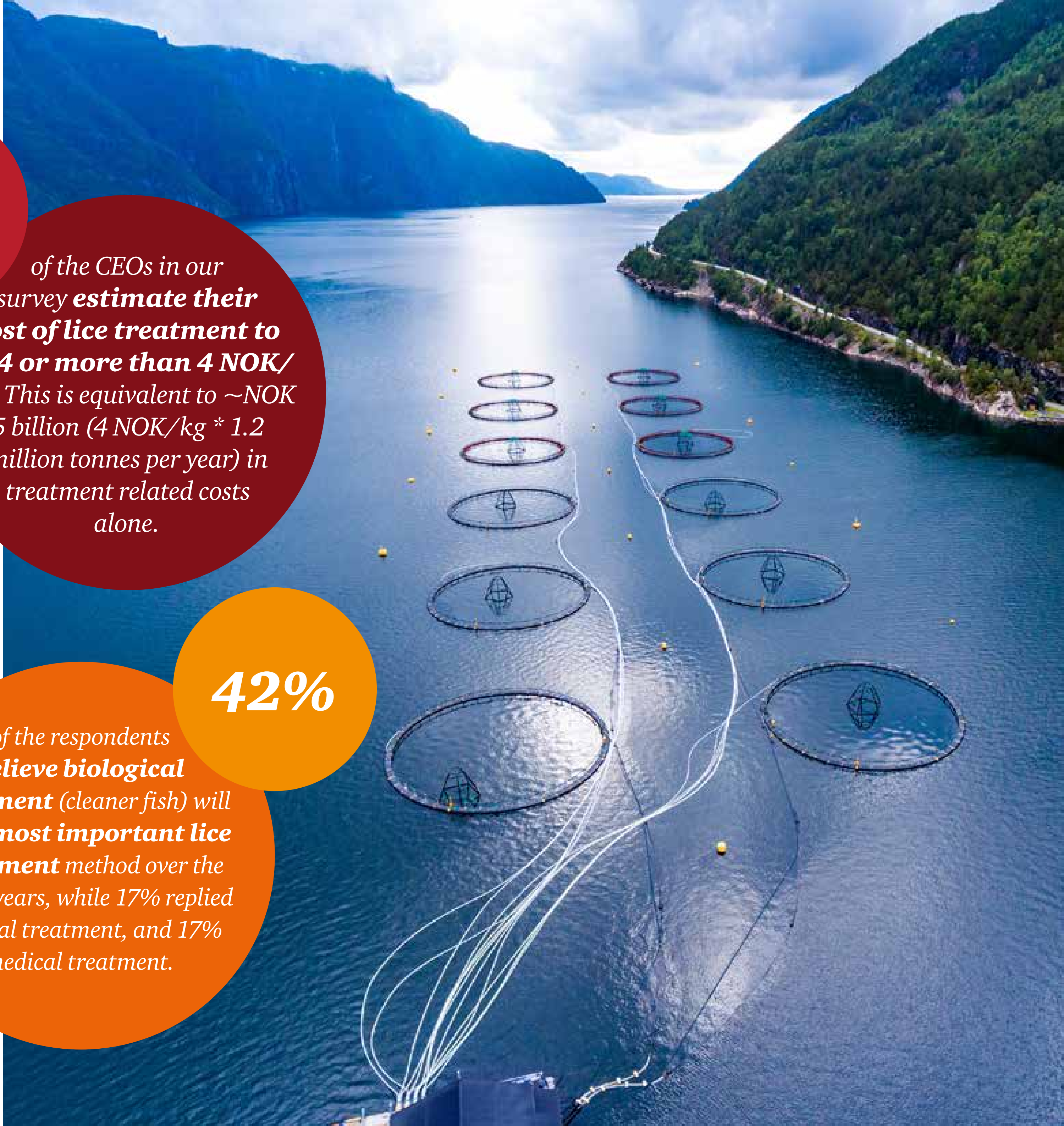
- Biological (cleaner fish, breeding and genetics)
- Mechanical/physical (flushing, hot water, freshwater)
- Prevention (post smolt, RAS/CCS, lice skirts)

Recently, scientists have found that salmon lice may also develop resistance against non-medical treatments such as fresh water (salinity) and thermal treatment (hot water).

PwC's Point of View:
The lice challenge has a negative impact on the reputation of the industry. For the government to allow further growth, reputation and public acceptance are crucial. To reach the desired production volume of 5 million tonnes in 2050, it will therefore be critical to solve the lice challenge.

In the short term, everything points towards use of larger smolt combined with cleaner fish. Larger smolt reduce the production time at sea, while cleaner fish help keep the number of adult lice low.

In the long term, however, one will probably find the solution through genetics or by using closed systems.



50%

of the CEOs in our survey ***estimate their cost of lice treatment to be 4 or more than 4 NOK/kg****. This is equivalent to ~NOK 5 billion (4 NOK/kg * 1.2 million tonnes per year) in treatment related costs alone.*

42%

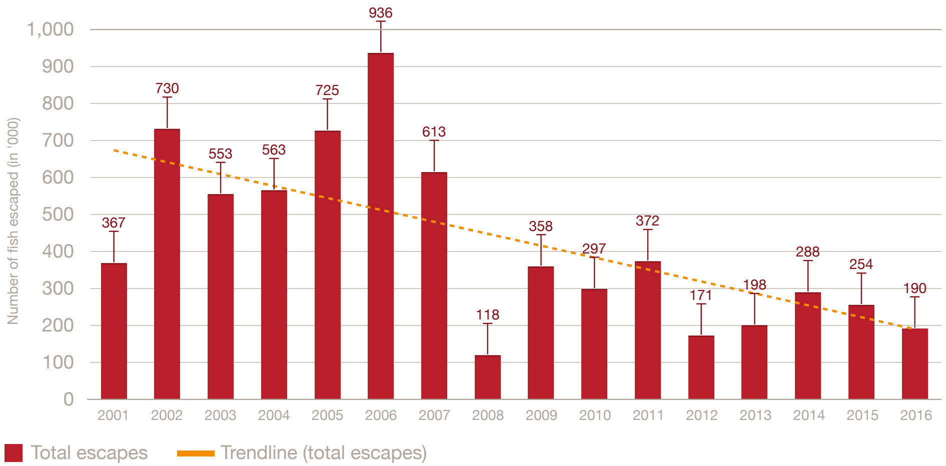
of the respondents ***believe biological treatment*** *(cleaner fish) will be the* ***most important lice treatment*** *method over the next 5 years, while 17% replied thermal treatment, and 17% medical treatment.*

A high share of the escape incidents, and the mortality rate, are caused by rough lice treatments

Although the number of escaped fish is greatly reduced, escapes are still a challenge. In 2016, the number of salmon and trout escaped was about 190,000 salmon.[71]

Escaped fish pose a problem as they may breed with wild salmon, interfering genetically, but they also lead to lost production and profit for the farmer. It is necessary to develop technology, operating procedures and control systems that prevent fish from escaping, especially when treating for salmon lice.

Escapes of Atlantic salmon and trout

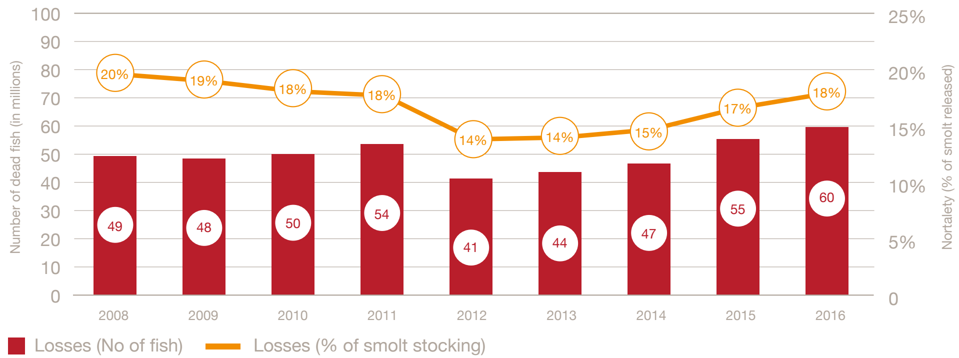


Source: Directorate of Fisheries

Fish welfare is important for growth, production and the economy of the industry, but fish welfare must primarily be preserved based on ethics and general principles for animal welfare. A loss of up to 20% of the Norwegian production corresponds to the loss of approximately one billion salmon meals per year.* However, this does not necessarily imply bad fish welfare as wild fish have a very high mortality rate as well.

How high can the mortality rate be, before it becomes an animal welfare issue? The answer depends on the cause of mortality, and the assumed welfare of the remaining population in the pen.

Mortality



Source: Directorate of Fisheries

**20% of a annual production of 1.2 million tonnes equals 240 thousand tonnes. Assuming approx. 200 g per meal, this corresponds to ~1 billion meals lost.*

PwC's Point of View:

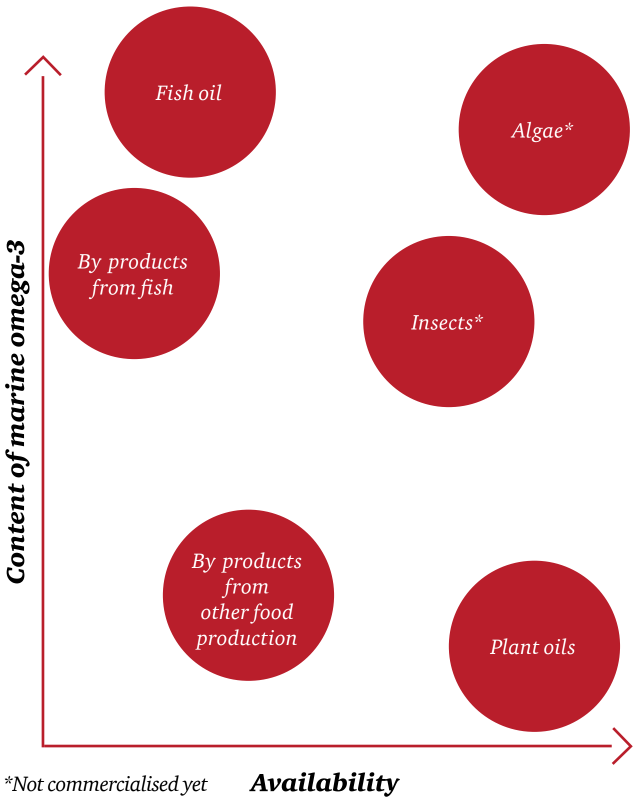
In our view, addressing the escapes and the treatment related mortality is important for two reasons:

The first reason is to ensure public acceptance and maintain a good reputation. Regardless of whether you care about the wild salmon or not, it does not look good to have thousands of confused escapees in the fjords, nor is it good business. The same goes for mortality. In the eyes of the beholder it seems clear that neither escapes, high lice levels, or rough mechanical treatment is ideal fish welfare. Without public acceptance, the industry will not be allowed to grow.

The second reason is that we all have a moral obligation to ensure good animal welfare, and to maintain the diversity of wild species and ecosystems. In the long run this will also be good for business and for global food production.

Lack of available feed ingredients will be an important challenge in the long run

The availability of marine feed ingredients will be a critical issue only a couple of years from now. The availability of traditional fish meal and oil does not increase, while global aquaculture continues to grow.



*Not commercialised yet

The global supply of ***fish meal and oil*** has been static for decades,[74] and the share used for fish feed has increased rapidly. Finding new sources is urgent to ensure a high share of marine omega-3 in the future.

Using by-products is good from a sustainability perspective. ***Fish by-products*** is particularly positive as it supplements the marine content in the feed. 340,000 tonnes of whitefish by-products are thrown overboard annually in Norway.[75] Still, the availability will not be sufficient in the long run as it is a scarce resources.

Shifting from fish oil to ***plant oil*** has been the answer so far. Salmon now eat feed with a high share of plant based ingredients - plants which are produced on land which otherwise could have been used for for human consumption. In addition, the marine omega-3 content is low.

Insects are often mentioned as a future source of proteins for both humans and animals. If produced in a commercial scale, the availability will probably be good, and the price low. Insects may also be a potential source of omega-3.[76]

Algae, specifically microalgae, may be able to offer the best from both the animal and plant world. The algae may grow fast, and can be produced commercially on a large scale, and may also offer the desired marine oils the salmon is known and appreciated for.

55.6%

PwC's Point of View:
After solving the short term issues regarding lice and lice treatment, the next big challenge to overcome is where and how to find sustainable feed ingredients with the right nutritional content for salmon.

We believe that the salmon feed in 2050 will still have a high share of plant based ingredients, but with a significant share of algae and a small share of by-products. The share of traditional fish oil and meal will continue to fall.

Salmon lice are the reason why aquaculture growth in Norway has stagnated, and should be taken seriously

The industry's most critical challenge is the salmon louse. Why? Because there is a correlation between the amount of farmed salmon in the ocean and their level of salmon lice, and the impact of lice on wild stocks. If production is reduced or increased, and this has an effect on the environment, there is a correlation.[77] If we are to reach 5 million tonnes in 2050, environmental pressures will increase and the government will introduce new criteria to the traffic light system.

	Criteria	*Escapes*	*Fish health*
More salmon lice	Lice	Salmon lice are the reason why aquaculture growth in Norway has stagnated. The Norwegian Scientific Advisory Committee for Atlantic Salmon has identified salmon lice as the second largest threat to wild Norwegian salmon. The annual loss of wild salmon, due to lice, was estimated to 50,000 adult salmon between 2010-2014, equalling 10% on a national level.[69]	As lice become resistant, a variety of new delousing methods have been, and will be, introduced. Unfortunately, they can negatively impact fish health and lead to escapes. According to professor Horsberg at NMBU, the lice will never be eradicated. An Integrated Pest Management System should be used to avoid the development of a "super louse." Closed cages may be the solution.[79].
	Escapes	The above-mentioned committee has identified escaped farmed salmon as the greatest threat to Norwegian wild salmon due to genetic introgression. Introgression can result in reduced production and survival, thus less adults returning to rivers.[69] The government sees this as a serious challenge and has enforced a regulation and binding agreement with the industry, that ensures financing and measures, to reduce escapes.[77]	If it is still hard to trace where escapes originate from, farmers in a given area have little incentives to change their routines. Still, if production increases, escapes may increase. Closed containment may be a solution, unless extreme weather, which is predicted to become more fierce in the future, lead to accidents.[80] Sterile salmon may also be a solution. Recent data indicate higher mortality of triploids compared to diploids, especially for the fall season salmon.[81]
	Fish health	Fish health is of high priority. Norway is free of most internationally listed diseases and effective vaccines have made bacterial problems rare. PD is the most common viral disease. Bad smolt quality and infections cause fish mortality.[77] In 2016, 53 million salmon died, or 19% of salmon in net pens, mostly due to non-medical lice treatments. This equals NOK 10 billion in treatment costs.[78]	Mortality will most likely continue to be a challenge in the future as production increases and new lice treatments and technology are tested. Alien species and microplastics may disperse new diseases to Norway, and it takes about 10 years to develop a new vaccine.[82] EU has recently allowed DNA-vaccines, and Norway may be next.[83] Still, it is in the interest of the farmer to avoid mortality and new, better ways of monitoring fish health will become available.

PwC's Point of View:

When the industry solves the first challenge, which is the salmon lice and its potential impact on wild salmon, new challenges will arise. This will change the indicators in the Traffic Light System.

Relevant candidates in the future may be the genetic impact that escapes have on wild salmon and fish health indicators, like mortality.

Fish oil scarcity may lead to a boom in commercial algae production towards 2050

	Criteria	Escapes	Fish health
Increased feeding	Nutrient discharge	The government does not see this as a big problem in the short term. Aquaculture discharge only represents 5% of the total amount of nutrients along the coast. Environmental monitoring confirms this view.[77] Still, if production is to grow fivefold by 2050, discharge will follow.	If the lice challenge is solved, and production grows, discharge will also grow. Unless captured and reused as a resource, more pressure from NGOs and the government will likely follow as a consequence. With the new development licenses, where many concepts have closed or semi-closed cages, discharge can be collected and reused. Discharge is also a nutrient for algae, something in which Ocean Forest has taken advantage of. This is in line with circular economy thinking.
	Feed raw materials	Not a critical challenge today. Still, responsible sourcing and alternative raw materials are on the agenda. Ingredients such as soy and fish oil are bottlenecks that prohibit the industry from growing. Although salmon can transform plant omega-3 to marine omega-3, the latter is necessary to protect the health of farmed salmon - especially in a demanding environment in pens at sea.[84] In 2015, the Global Salmon Initiative launched a global tender to identify viable, alternative sources of omega-3 fatty acids. Feed companies are currently working with suppliers in incorporating resources into commercial fish feed.[85]	An adjustment in production capacity in Norway will not change the global demand for, and pressure on, raw materials such as soy and fish oil.1 However, alternatives are in the making and may be commercially available in the future: CO2Bio in Mongstad is injecting CO2 into tanks growing algae. A tonne of CO2 will produce a tonne of algal mass, which may result in 300-400 kg of oil.[86] Also, every year 340,000 tonnes of whitefish bycatch are discarded in Norway. Nordic Wildfish and Firmenich Bjørge Biomarin have developed a new hydrolysis technology on board fishing vessels that can exploit almost 100% of the cod, pollock and haddock.[87] Recent studies also show that genetically modified camelina oil has no negative effects on farmed salmon.[88] The question is: will the consumer accept GM-feed ingredients?

PwC's Point of View:

As the problems related to salmon lice and escapes are solved, we believe the industry will be allowed further growth. Increased volume and feeding will however lead to a new potential constraint. The increased feeding may result in a risk of eutrophication in certain areas, and could potentially be a future traffic light indicator.

In addition, we will need new feed ingredients. Algae seem promising, and we may see a boom in commercial algae production in Norway towards 2050.

Government initiative

Government initiatives to facilitate production growth have been executed - but are they sufficient to reach 5 million tonnes?

To better understand the new government initiatives, we will briefly look at the historical development of the licence regime and growth regulations of aquaculture production in Norway.

In the 60s and early 70s no licence was required
In the 60s and early 70s no licence was needed. It was not until 1973 that a licence requirement was established. Since local ownership and jobs were key goals for the industry, each company could only own one licence[89].

During the late 70s and early 80s, a high number of licences were granted, and since the industry was new and the profitability still relatively low, no remuneration was charged for the licences[90].

Most of today's licenses were issued free of charge during the 80s
In 1981 and 1985, the first and second Aquaculture Acts was passed[91]. It was also suggested that new licences should be granted through national licensing rounds[92]. In addition to granting many new licences during the 80s, the capacity within existing licences was also increased during this period.

With the rapid growth in production, problems started to appear; first diseases, later falling prices and increased international competition. This resulted in the collapse of the national sales organisation (FOS) and dumping accusations from both the US and the EU.

The 90s - Consolidation and dumping accusations
The FOS-collapse resulted in a wave of bankruptcies, and the limitation of one licence per company was removed, starting the consolidation process.

In 1991, the ten largest companies controlled only 8% of

the production, but since then, this number has increased almost annually, to ~ 70% today.[93]

During the 90s the production capacity was regulated with feed quotas imposed due to dumping accusations. However, production still grew rapidly, and the production cost was decreasing.

In the early 2000s new licences were again issued - price 5 MNOK

In 2002, salmon prices reached a near all time low, with prices below 20 NOK per kg, leading to new dumping accusations from the EU. This resulted in minimum prices, export duties and further consolidation in the industry. 2002 and 2003 also marked the years for the first national application rounds for new licences[94]. This was also the first time remuneration was paid for the licences, 5 MNOK per licence[94]. In total, 90 new licences were granted in these rounds.

To counter the rapid consolidation, issuing authorities decided to favor small and new companies, as well as local activity[94]. This opened up to judgement in the proceedings and complaints were filed on the results.

New regulation based on MAB, new licenses more politically influenced

In 2004, the feed quotas were replaced with the current MAB-regime[95,96] (780 tonnes MAB per standard licence).

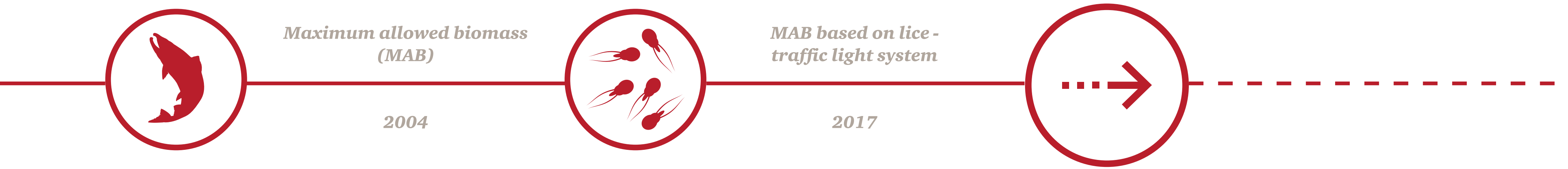
In 2009, new licences were again issued. However, this time salmon prices had improved and the remuneration per licence was increased to 8 MNOK per licence[97].

The political footprint in the process was clear, more growth in the north, more local ownership, more eco-farming and more processing. The most promising applications were chosen, but a lack of sanctions for unfulfilled promises combined with an increasing licence value, the issuing quickly became controversial.

Current focus on salmon lice as indicator for growth potential

The last licence round took place in 2013[98]. Green and very green was the key. Green in this regard means lower risk of escapes and lower salmon lice levels (<0.25). Very green means significantly lower risk of escapes and significantly lower lice levels (<0.1). 15 green licences were issued in the north for 10 MNOK a piece, 15 were sold at auction for 55 - 66 MNOK a piece, and 15 very green licences were issued for 10 MNOK a piece.

Since november 2015, development licences focusing on innovation and new technology, have been issued[99]. Starting in 2017, the traffic light criterion for salmon lice will be the new system for future growth[100]. We will discuss the system in more detail in this chapter.



Traffic Light System

With the new traffic light system, the Norwegian government has provided a framework for sustainable, long-term growth in MAB capacity

Going forward, the risk of mortality on wild salmon, due to salmon lice levels per production area, will be the indicator for growth in MAB. In the 2017 assessment, 8 out of 13 areas got a green light.

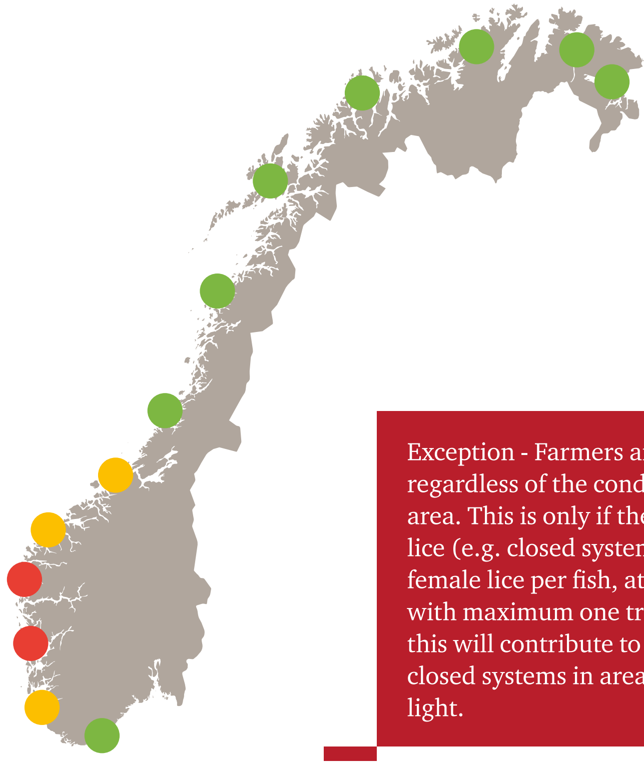
A goal with the new regime is to provide a predictable opportunity for long-term, sustainable growth in production. This is to be achieved using an environmental indicator for growth (the traffic light).

Today, the key indicator for sustainable growth is determined to be the risk of mortality on wild salmon populations, due to the impact of salmon lice from fish farming. In future assessments, other indicators may apply.

The coastline is divided into 13 production areas. In the 2017 assessment 8 out of 13 areas got a green light, while two of the areas got a red light. The Ministry of Trade, Industry and Fisheries have decided that capacity in red-lighted areas will not be reduced as a result of the assessment in 2017.

In the suggested new regime, 6% growth in MAB can be offered against a remuneration every 2nd year if the indicator for that production area is green.

A red light can lead to 6% reduction in MAB (remuneration already paid is not refunded, but you will not have to pay to get back to status quo if the area again gets a green light in a later assessment).



Exception - Farmers are offered growth regardless of the condition in the production area. This is only if they can document zero lice (e.g. closed systems) or below 0.1 adult female lice per fish, at all weekly counts, with maximum one treatment. We believe this will contribute to a shift from open to closed systems in areas with a red or yellow light.

The new growth system provide the industry with great opportunities for growth, but at a higher cost than expected and with considerable risks

The 120 000 NOK/ton price for increased production are higher than expected, and may lead to a higher volume share to auction which may favour larger farmers and boost consolidation.

A total of 6% growth/reduction is offered/required within an area when the area receives a green/red light. Farmers within areas receiving a green light will be offered a 2% growth. Farmers operating within the exceptions (see info box on previous page) will be offered a full 6% growth. The residual growth volume (~4%) for the area will be auctioned.

The price for growth are set to 0.12 MNOK/ton and is higher than expected, as it is 20% higher than the estimated MAB value of the most recent transaction (Fjordlaks Aqua)[101]. This may disfavour small to medium-sized businesses.

The value of a licence is assumed to increase by 2.5 MNOK per year or 5 MNOK per assessment period. If a red light reduces the capacity, amounts paid previously will not be refunded, but you will not have to pay twice for the same volume if the situation changes.

In our growth illustration, we assume that 100% of the capacity offered and auctioned will be accepted. In our calculations, we also assume the auction price to be equal to the price for the 2% growth. However, the the growth distribution and prices may be subject to change in the future. The illustration below is based on the guidelines of november 2017.

Illustrative example of potential development in growth and remuneration (for a standard license of 780 tonnes in 2017)

2017	2019	2021	2023	2025	2027
1.87 MNOK, + 2 %	2.0 MNOK, + 2 %	0 MNOK, - 6 %	0 MNOK, + 0 %	0 MNOK?, + X %*	
780	796	812	763	763	876

2017 - 2019
With a green light in 2017, a 2% growth is offered, equalling a price of 1.87 MNOK for a standard licence growth. In 2019, the 2% growth price could be 2.0 MNOK due to interest effects and a higher licence value.

2021 - 2023
With a red light in 2021, the previous growth is more than reversed. However, since the price is already paid for, the growth is not refunded. With a yellow light in 2023 the situation remains as status quo.

2025 - 2027
With a green light in 2025, a growth back to the 2021-level is offered. The farmer will not have to pay twice for the same volume, but if the licence valuation has increased one might have to pay for the difference in value.

**growth assumed to be a reversal of the latest reduction in our calculations*

PwC's Point of View:

PwC did welcome the new growth regime and its opportunities based on previously indicated specifications. However, we perceive the price set for growth to be too high in order for farmers to apply new and more expensive technologies in the production. Thus, the price for growth may create a barrier for development of new technology.

Our main concern is that the current pricing strategy, where the majority of the growth volume offered are set to auction, will be in favour to the larger farmers and boost consolidation.

A concern for the farmers at this point is how the potential future volume reduction will be handled in case of a red light. We have assumed a 6% haircut on all licenses. As the example scenario on the previous page shows, the regime comes with considerable risks, and will largely be in disfavour for red-lighted areas.

We believe that a key to the success of the growth regime is a predictable and transparent process of determining the overall growth indicator and traffic light colour in an area - not being subject to short term political gains.

The long-term growth potential is substantial.

With 100% green lights the capacity may be increased by ~2 million tonnes. A more realistic scenario, with ~50% green lights, may increase total capacity by ~0.8 million tonnes.

Best case (all green)

This scenario is based on indicators equal to the assessment in 2017 (6% growth in 8 out of 13 areas and zero reductions) and all green lights in the future assessments. In this scenario, the Traffic Light System may provide a maximum growth of ~2 million tonnes from today until 2050. Even though 100% green lights is not realistic, the scenario is included in the figure as it sets the limit for the maximum growth the system can provide with the current setup.

Our base-case scenario assumes, on average, 3% growth every second year (50% green, 50% yellow)

Base case (~50% green lights)

This scenario is based on indicators equal to the assessment in 2017 (6% growth in 8 out of 13 areas and zero reductions) and 50% green lights with zero growth in the remaining areas in the future assessments - on average 3% growth every second year. In this scenario, the Traffic Light System may provide a maximum growth of ~0.85 million tonnes from today and towards 2050.

Low case (zero growth)

This scenario assumes either all yellow lights (no growth) and/or an equal amount of green and red lights resulting in status quo within the capacity for current licences.

Worst case (all red)

We could also end up with a net reduction of MAB capacity if either:

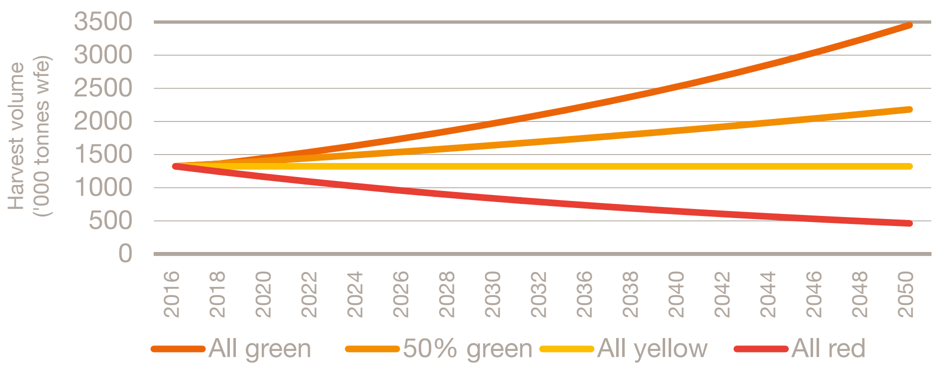
1. The number of red lights exceed the green/yellow lights over time, or
2. The price for growth is set too high (red lights result in a MAB-reduction, but green lights do not result in equal MAB-growth as not all farmers are able/willing to pay the asking price)

PwC's Point of View:

We believe a scenario with ~50% green lights, with 100% of the offered growth accepted and/or auctioned, is the most realistic one. This will result in a growth of 0.85 million tonnes on existing licences from 2017 - 2050.

Maximum growth, with 100% green lights, represent ~2 million tonnes towards 2050, while 100% yellow lights will result in status quo

Traffic light growth potential 2050



Source: PwC estimate

Main assumptions:

1. A green light will result in 6% growth within a given area. This requires that growth is offered for all green lights by the government and accepted by fish farmers in green areas.
2. A red light will result in 6% reduction within given areas. This requires that a reduction is implemented by the government for all red lights after 2017.
3. No exceptions: we assume zero exceptions and deviations from the rule (the scenario where an individual farmer may grow despite negative environmental impact, does not apply).
4. The growth rate (6%) is constant throughout the forecasted period
5. Growth in MAB of 1% equals 1% growth in harvested volume

Development Licences

Development licences will not increase volume growth significantly, but may contribute to a higher long-term production capacity - most likely at a higher cost level

An important incentive for innovation, but with high costs

Aquaculture licences in Norway are a scarce commodity, and our estimated values indicate prices of around 100 MNOK per licence. During the most recent transaction in Norway (Fjordlaks Aqua 2016), the licence value was estimated to ~78 MNOK per licence,[101] while current stock prices of listed companies indicate an implied licence value well above this level. With this in mind, it is not surprising that the battle for new licences is tough.

The threshold is narrow. In addition to solving the industry's challenges, both significant innovation and investments are required. On top of that, the Directorate of Fisheries does not want to repeat history by awarding valuable licences to fish farming companies that are already wealthy enough, at least in the eyes of some. To avoid this, the risk and investment cost in the project is compared to the estimated market value of the licences.

As a result, we observe applicants competing to present the highest investment costs and the most innovative solution, as opposed to rewarding the solutions that may help solve the challenges in a more cost-effective way.

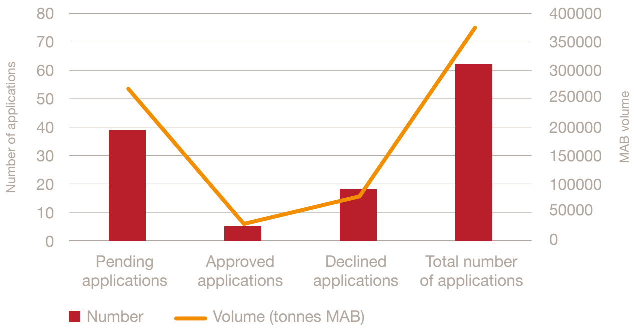
This may very well boost innovation, but will also contribute to the rapidly increasing cost level in the industry, with the parallels to the Norwegian oil industry in 2012 becoming ever more apparent.

In our opinion, the government deserves credit for creating a new and innovative licence model. We also believe the initiative will help boost innovation and increase the long-term growth. The question that remains, however, is - at what cost?

- Out of a total of 62 applications, 5 are approved, 18 declined, and 39 still pending. Out of a total applied MAB volume of 366,000 tonnes, only 21,000 tonnes are approved so far, while 78,000 tonnes are declined. If the approval rate remains the same, the total volume will reach 74,000 tonnes, hence an approximate 6% growth potential from the development licences.
- Out of the 44 pending and approved applications, 27% of the applications and 50% of the volume are related to offshore concepts, while 34% of the applications and 26% of the volume are closed and semi-closed concepts.
- Nordlaks and Salmar received 18 licences in total (14,000 tonnes) for their offshore solutions, while MNH, Marine Harvest and AquaDesign received a total of 9 licences (7,000 tonnes) for their closed/semi-closed solutions.

Many applications, but few approved so far

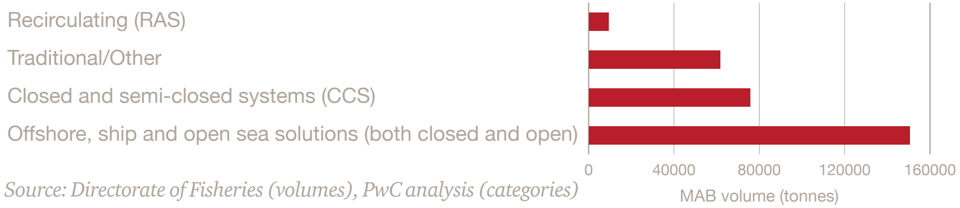
Development applications



Source: Directorate of Fisheries (as of 18.07.2017)

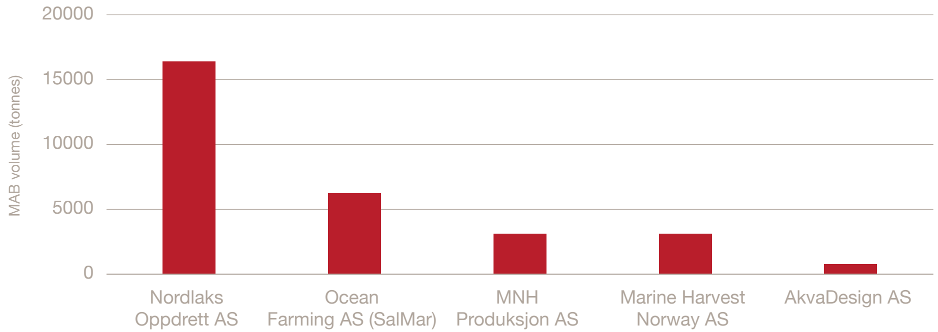
Most of the applied volume is in offshore and closed solutions

Development applications



Source: Directorate of Fisheries (volumes), PwC analysis (categories)

Development applications



Source: Directorate of Fisheries

Foto: Ocean Farming AS

Illustration: Nordlaks AS

Improved operations

Improved operations and utilisation of the current capacity may theoretically boost the production of the current licenses by up to 325,000 tonnes (~23%)

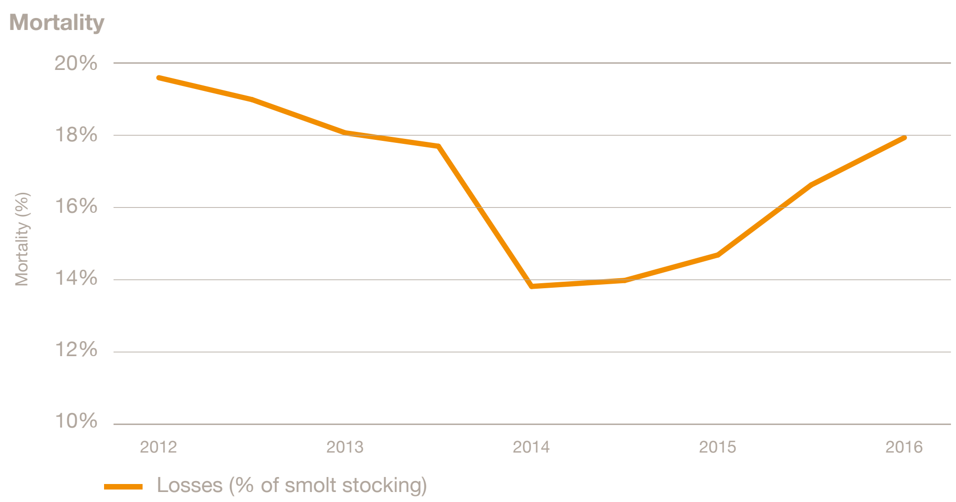
Three production factors have caused reduction in harvest volumes over the last 5 years:

1) Increased mortality due to mechanical lice treatment
The mortality rate (losses in percent of smolt stocking) in Norwegian net pens has increased with approximately 4 percentage points between 2012 and 2016.

~5%
70k

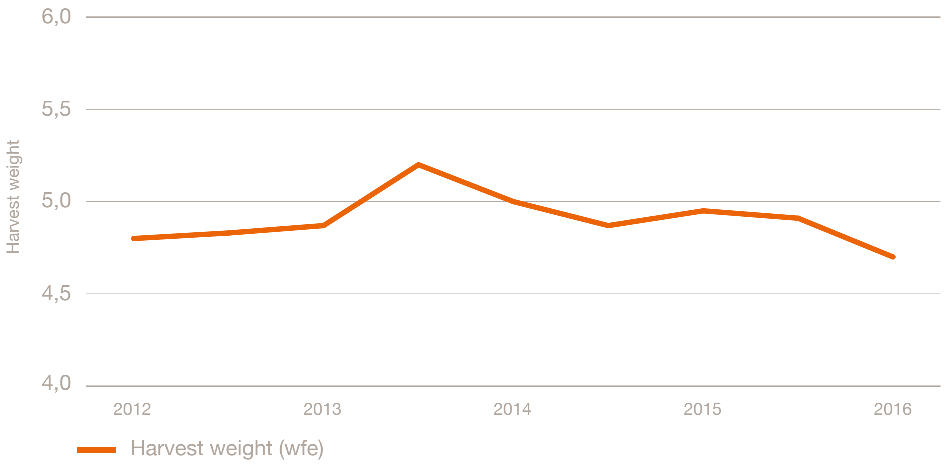
However, considering a 14% mortality rate (2012) to be fairly high, a return to this level will result in an increase in production volumes of 5% from the 2016 level. This alone will result in an annual production growth of ~70,000 tonnes.

Improved operations and utilisation of current MAB may boost production with 325,000 tonnes!



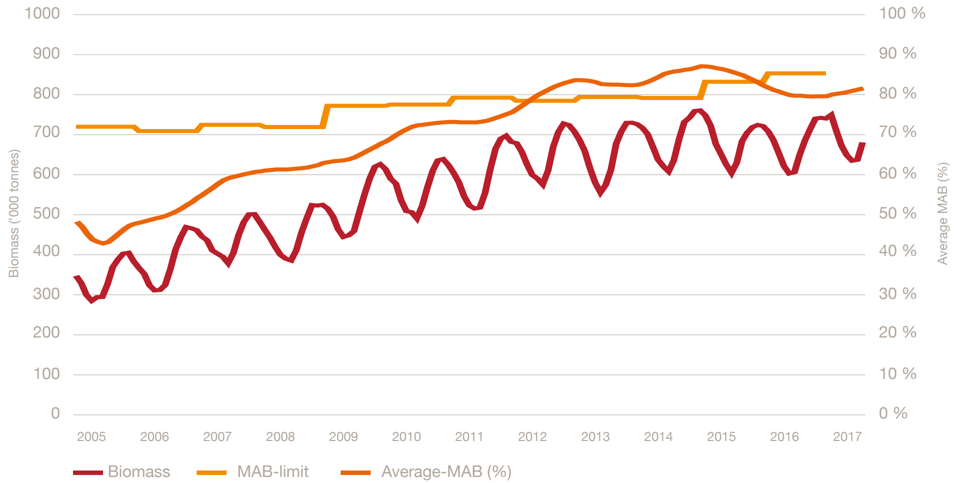
Source: The Norwegian Directorate of Fisheries, PwC Analysis

Harvest weight



Source: The Norwegian Directorate of Fisheries, PwC Analysis

MAB utilisation



Source: The Norwegian Directorate of Fisheries, PwC Analysis

2) Reduced harvest weights due to early harvesting

~11%
155k

Biological threats are frequently forcing producers to harvest the biomass too early, reducing the harvest weight (wfe*) and thus the yield of the smolt (kg harvested per smolt stocked). The decrease has since 2014 caused an average reduction of 0.3 kg (-6%), representing 84,000 tonnes.

If the Norwegian industry manages to increase the harvest weight by 10%, or about 0.5 kg, this will increase the annual production with up to 155,000 tonnes per year. Bear in mind that the average harvest weight at the Faroe Islands is currently over 1 kg higher than in Norway[102].

** wfe = whole fish equivalent*

3) Unutilised MAB-capacity

~7%
100k

Decreased average utilisation in MAB-capacity after 2015 represents a potential for future growth within existing licences.

Also, according to the Bremnes model the producers are allowed to exceed the MAB-level in periods, as long as the annual average biomass level is within the limits of MAB. This provides the industry with possibilities to grow within existing MAB capacity.

Returning to the same average utilisation level as in 2015 (increased by 5 to 7 percentage points) the industry may boost its annual production by 70-100,000 tonnes.

Note that the calculated volume utilisation by the three factors above cannot occur simultaneously, as they will be limited by the current MAB-restrictions. The current growth potential within existing MAB-limits are only about 15%, equaling about 210,000 tonnes as seen in the graph to the right, plus the extra potential volume provided by the Bremnes model.

New Recirculation Aquaculture Systems (RAS) facilities enable significantly larger smolt to be deployed, providing benefits like reduced lead time and more resilience towards viruses and lice-attacks

Deployment of larger smolt in the sea provides two major efficiency advantages:

1) Reduced lead time and higher turnover ratio
Norwegian authorities have recently repealed the maximum smolt size restrictions, allowing farmers to produce a larger share of the biomass on land in modern RAS facilities.

In these facilities, smolt producers are able to provide ideal conditions for sustainable biomass growth, with complete control over temperature, nutrition levels, fish health and the quality of the water.

By deploying post smolts of 1,000 grams, producers may be able to reduce production time in sea from 16-22 months to only 10 months.[103]

Reducing lead time in sea also enables producers to reduce the spread in biomass throughout the year. This may be one of the most sustainable ways of maximising utilisation of licenses. However, there are several barriers that may halt the development of post-smolt production in RAS facilities.

2) Increased resilience towards viruses and lice-attacks
Larger post-smolts are considered more resilient towards virus attacks than their "smaller siblings."[103] This may in turn reduce the mortality rate and will contribute to increased utilisation of the MAB capacity.

Theory also indicate that shorter lead time in sea reduces the number of reproduction cycles for each louse. This may halt the downward spiral of resistant lice.

PwC's Point of View:
Land-based RAS production has higher direct costs than sea-based production. The economic deployment weight optimum must therefore be considered a function of the biomass growth rate, the market price, the direct costs of land and sea-based production, and the monetary value of the biological benefits of larger smolt, among other things. Given the natural and seasonal fluctuations of these values, we believe this optimum will be a highly dynamic value that must be calculated with sophisticated Big Data models.

Increased smolt size *is the* ***most important factor*** *for increased* ***efficiency*** *in the current aquaculture production, according to*

75% of the leaders in the industry.

New farming technology

New solutions for farming in open cages

New solutions like submersible cages may represent a new concept of open-cage farming

New technology for farming in closed systems

Closed and semiclosed systems in the sea combine aspects from both open-net and land-based farming

Offshore farming - both open and closed

Offshore farming, ships and installations, offer a new and exciting growth potential in the future

RAS systems - both land and sea-based

RAS systems, on land and at sea, offer a controlled environment with a lower CAPEX than before

Other farming technologies

In 30 years from now we may see other concepts not yet imagined

New solutions for farming in open cages

New farming solutions with open cages (ONP) will enable volume growth, but also reduce the current cost advantage over time

89% of industry leaders believe traditional fjord-farming will still be competitive in 2050, but is there room for volume growth?

New technology for sludge collection and lice prevention may make ONP farming viable also in the future

Over the last 25 years, the amount of licences for aquaculture has not increased much, and the number of active sites has dropped by 14% in the last ten years alone. Yet, harvest volume continued to grow steadily until 2012 due to higher utilisation of the existing sites and licences. Growth from further increase in efficiency will be covered later in this section, but for now, let's briefly discuss the growth potential in open cages in Norway. Today, open cages have a production cost of ~37 NOK/kg HOG, which seems high from a historical perspective, but is still lower than competing technologies. The question is, why is ONP farming still competitive considering the high lice treatment costs? Because the significantly lower investment costs (CAPEX) reduce both depreciation, other OPEX and finance costs.[104]

Open cages, are in many ways, the symbol of everything that is both good and bad with aquaculture. The cost-efficient nets, clean water and unique fjords are all part of the foundation for the industry's success. On the other hand, ONP is associated with challenges like lice, escapes and nutrient discharge. Although access to adequate sites is becoming a scarcity in Norway, we believe there is room for growth if the aforementioned challenges are addressed properly.

The development licence-applications are promising, and we see many potential directions for the future. Common for them all is the focus on new technology to address one or more challenges, most frequently salmon lice or discharge. These challenges are relatively easy, but expensive, to solve with a closed cage, but more complicated to solve with an open net. In solving these, we believe ONP farming will continue to grow, but the cost advantage will decrease over time as new technology is adopted.

89%

of industry leaders ***believe traditional fjord-based***

2050.

PwC's Point of View:

Current cost for open cages of approximately 37 NOK/kg HOG is still the lowest of the four different farming concepts (ONP, RAS, CCS and Offshore). But costly air freight will open up to large-scale RAS close to end markets in the US and Asia.

Cost estimate 2017 (NOK/kg HOG)	ONP Open nets
Smolt cost	3.2
Feed cost	17.1
Personell cost	2.4
Depreciation	2.0
Other OPEX	7.6
Net finance cost	0.8
Cost of production	**33.2**
Harvesting cost	3.5
Total cost	**36.7**
Air Freight cost (Asia/US)	14.0
Total cost to Asia/US	**50.7**

Source: PwC estimates, Kontali (air freight)

Although traditional, open net pens (ONP) are the current preferred solution, the outlook seems more uncertain

ONP - An analysis of cost drivers compared to CCS, Offshore and RAS

Current cost drivers	Rating	Assessment
Salmon lice/ fish health	Disadvantage	We believe the current salmon lice challenge will be solved, also in open cages, reducing both mortality and lice-related costs well before 2050. However, we do not believe that lice will ever disappear as the salmon lice is highly adaptive and has been around since well before salmon farming started. Lice will continue to drive costs, in open cages in the years to come. Naturally, this is a disadvantage with traditional, open-cage farming.
Regulations and technical requirements	No clear advantage or disadvantage	New standards and regulations, which are more strict and complex, have to some extent contributed to the cost increase in recent years.[16] These are both mandatory, such as the "lice counting regime," and the NYTEK-regulations, and voluntary, such as Global GAP and ASC-certifications. However, these regulations apply to all farming solutions and there are no clear advantages or disadvantages between the four solutions.
Commodity prices	No clear advantage or disadvantage	Commodities, like soy, rapeseed and fish oil, are important cost drivers in salmon feed, regardless of the farming technology. We expect feed prices to continue to increase in the future, with a relatively equal biological feed conversion rate across the different techno-logies, resulting in no clear advantages or disadvantages.

- The solution has a disadvantage compared to one or more of the other
- The solution has no clear advantage or disadvantage compared the other solutions
- The solution has an advantage compared the other solutions

Future cost drivers

☺	We have already explained that certain feed resources are limited. Other resources, including construction materials like steel and aluminum, are also limited. We assume equal feed costs for all solutions, but ONP-farming require less construction materials, energy and equipment. This result in a lower CAPEX, resulting in a lower depreciation cost, less maintenance and finance cost. This represents an advantage when it comes to scarcity of resources both today and in the future.
☹	Towards 2050, we expect to see more costs related to environmental impact, charged as national fees or in other forms. Examples of such impact represent release of nutrients in the sea, CO2-emissions, and other negative effects on the local ecosystems. Such costs, or fees, are likely to be higher in an open system. Exposure to microplastics in the ocean could also further increase risks.
☹	Today, ONP licences are valued at ~70-120 MNOK per licence in the 2nd-hand market. This cost is not reflected in the accounts for Norwegian farmers as licences are not depreciated. In the future, we believe farmers with high profitability, using public areas and resources for farming, will have to pay more for this right. The amount will probably increase with higher environmental footprint. This is a disadvantage with traditional ONP farming.

PwC's Point of View:

In 2050 we expect licence-related costs, environmental costs and lice-related costs to be higher for ONP than the competing solutions. This will reduce the competitive advantage of open net farming in 2050.

On the other hand, we expect that the significantly lower CAPEX associated with farming in open nets will continue, partly offsetting the above mentioned costs.

Although the competitive advantage will gradually decrease, we believe ONP will still be a competitive solution, at least for the EU market.

New technology for farming in closed systems

Closed Containment Systems (CCS) solve many of the current challenges, and still utilise the fjords - making them less controversial. We believe this will lead to both new volume growth and a partial shift from ONP to CCS on some sites.

Most CCS-systems are still at the R&D stage, but some full scale cycles have been completed and the results are promising

Closed and semi-closed farms at sea are still at the R&D-stage

Most CCS systems are still at the R&D stage. Only a few cycles of full scale production have been completed. Despite some problems, the overall results are promising. Two concepts that have been tested so far include Sulefisk's "Ecomerden" and Lerøy Seafood's "Tubefarm." They have completed several cycles in a semi-closed system. The results include a significantly lower salmon lice level, although not zero. The growth also appear to be good in these systems, but some challenges must be solved for them to be fully competitive with open cages[105, 106]. Going forward, the next system we expect will be tested on a commercial scale is the "Egg," produced by Hauge Aqua for Marine Harvest, and the "Aquatraz," by Midt Norsk Havbruk. They have both been granted development licences, and will be important tests for the competitiveness of closed systems. When we asked leaders in the industry, they responded, on average, that 21 % of the production volume would be Closed Containment Systems (CCS) within 2050. If we reach 5 million tonnes by 2050, this will equal more than one million tonnes!

There are limited cost data available, as only a few full scale cycles have been completed. In 2013 Nofima found production costs, for sheltered CCS of NOK 33/kg (NOK 38/kg for exposed CCS) while the production cost for traditional ONP was estimated at NOK 27/kg.[107] The main reason for higher cost, was higher depreciation and finance cost due to higher CAPEX. Since then, lice costs has increased the cost of ONP significantly. We estimate that CAPEX, and hence also depreciation and finance costs, are still significantly higher in CCS than ONP. On the other hand, lice-related costs will be lower, but this is partly offset by costs related to treatment of water and feces. Personnel costs are also assumed to be slightly higher than ONP, due to the complexity of the system. We estimate the COP to be ~41 NOK/kg for 2017.

Even though CCS is still likely to have a cost disadvantage, we believe that closed sea-based systems are part of the future. As a product reaches commercialization, CAPEX is normally reduced due to economies of scale. As a result we expect the competitiveness and attractivity of these systems to increase over time.

21%

Share of total ***production in sea-based closed cages in 2050****, according to aquaculture leaders.*

PwC's Point of View:
Farming in closed cages is still more expensive than ONP, but may help solve several challenges in Norway, like salmon lice and nutrient releases, making them attractive, future concepts.

Cost estimate 2017 (NOK/kg HOG)	CCS Sea based
Smolt cost	3.2
Feed cost	17.1
Personell cost	3.1
Depreciation	4.0
Other OPEX	7.7
Net finance cost	2.4
Cost of production	**37.5**
Harvesting cost	3.5
Total cost	**41.0**
Air Freight cost (Asia/US)	14.0
Total cost to Asia/US	**55.0**

Source: PwC estimates, Kontali (air freight)

Most closed sea-based systems are still at an R&D stage and the uncertainty is high

CCS - An analysis of cost drivers compared to ONP, Offshore and RAS

Current cost drivers

Salmon lice/ fish health	As the completed cycles with semi-closed systems has shown, these still have some lice, and likely therefore also some lice related costs[105, 106]. However, as the lice levels are significantly lower than in ONP we expect significantly lower lice costs. This is an advantage compared to farming in an open environment
Regulations and technical requirements	As mentioned most CCS solutions are still in an R&D-testing phase and reliable cost estimates are few. However the regulatory environment and the technical requirements that has contributed to the recent cost increase in ONP-farming will also apply for closed solutions.
Commodity prices	Some producers of closed sea-based systems argue that the CCS solutions achieve a lower biological feed conversion ratio (bFCR)[108]. If this is proven over time on a larger scale this might be an advantage compared to ONP. However, at the current stage, we believe more cycles are needed to conclude and that the effect will also depend on which CCS solution one use. For now, we assume no difference in feed costs between CCS and ONP.

PwC's Point of View:

The closed systems score very high on paper, providing a potential solution to both escapes, lice and nutrient discharge.

However, the solutions are still at an R&D stage, and the investment costs are high. The operating costs are also high due to the complexity of many of the systems, with water treatment, sludge collection and oxygenation adding to the cost.

On the other hand, future environmental costs and licence costs will probably be lower in a closed system, increasing the competitiveness of CCS. This may increase further if CAPEX is also reduced due to economies of scale.

Future cost drivers			
	Scarcity of resources	☹	Closed systems require more equipment and construction materials than an open cages, resulting in a higher CAPEX. Even though we expect this to fall as one or more closed solutions are commercialized, CAPEX will still be far higher per kg than ONP, due to water treatment, sludge collection etc, but probably not more than a RAS-system or an offshore farm.
	Environmental focus	☺	We expect lower environmental costs, due to lower impact on ecosystems, and no nutrient release as the system is closed. A potential x-factor for closed systems in Norway is fish health and animal welfare, concepts that in itself are difficult and constantly changing. Will the fish welfare be better or worse in a closed cage? Will it lead to low exposure to ocean microplastics?
	Licence to farm	☹	Closed cages in the fjords also use public ocean space, and will have a cost related to the use of this area. Either through an area fee, a licence cost, or both. However, as closed cages are generally more accepted and may potentially have a lower environmental footprint, we expect this cost to be lower than for open cages.

Closed sea-based systems have a higher CAPEX than ONP and still need to use public spaces. In the end, future environmental costs and licence costs will probably be lower in a closed system.

Offshore farming - both open and closed

Offshore aquaculture*, if successful, will be a game changer - potentially opening up a plethora of farming areas across the world's oceans

Offshore aquaculture opens up vast new farming areas

How often have you heard that only 2% of the food we eat today come from the ocean? And why, do you think, is the reason for this? Part of it is that the ocean is a challenging environment to farm in. Actually, most aquaculture take place in ponds, rivers, bays or fjords. Almost nothing is farmed on "the seven seas."

With offshore farming, this picture may be different in the future. If offshore farming is successful, potential farming areas would increase dramatically. Offshore farming can play a key role in finding locations to produce the food of tomorrow.

We hope that, by moving farms further away from the shore, we will reduce problems caused by salmon lice on farmed and wild salmon. Offshore farming was on the drawing board long before the development licences, but these licences have certainly boosted the interest and the speed of innovation.

If all development licences, related to offshore solutions, are granted, the volume alone will result in ~10% growth (140,000 tonnes).

If one or more of these projects turn out to be both practically feasible and commercially profitable, long-term possibilities are endless. When we asked leaders in the industry, they responded, on average, that 10% of the production volume would be offshore within 10 years, and 17% within 30 years. If we reach 5 million tonnes by 2050, this will equal 850,000 tonnes or 85 offshore farms (assuming, on average, 10,000 tonnes of annual harvest volume).

Available cost data are very limited. In 2013, Nofima also estimated CoP for offshore production (31 NOK/kg compared to 27 for ONP at the time).[109] The main difference was also here higher CAPEX (depreciation and finance costs) and somewhat higher personnel costs. Lice and fish health related costs and are uncertain. Our high-level cost estimate of ~42 NOK/kg still indicate a disadvantage compared to ONP, but still attractive with the current salmon prices.

The growth potential is huge, but so are the risk and investment costs. We look forward to following the new concepts closely in the years to come!

Salmar's Havmerd is the first one out and will soon be ready for salmon production. The massive construction weighs 7,000 tonnes, and with 8 licences, the farm can hold up to 6,240 tonnes of biomass.

Photo: Ocean Farming AS

Nordlaks's Havfarm will probably be the second pilot as the company was granted 21 licences.

Illustration: Nordlaks AS

** We use the terms «offshore aquaculture» and «offshore farming» for all solutions, both closed and open, that has the potential to be used for aquaculture production in open sea far from shore.*

17%

Share of total ***production in offshore solutions in 2050****, according to aquaculture leaders.*

PwC's Point of View:

Farming in new areas, far from the shore, will likely bring new challenges and will probably not be the most cost efficient. Still, it opens a plethora of possibilities.

Cost estimate 2017 (NOK/kg HOG)	Offshore
Smolt cost	3.4
Feed cost	17.8
Personell cost	4.9
Depreciation	4.0
Other OPEX	5.6
Net finance cost	2.4
Cost of production	**38.1**
Harvesting cost	4.0
Total cost	**42.1**
Air Freight cost (Asia/US)	14.0
Total cost to Asia/US	**56.1**

Source: PwC estimates, Kontali (air freight)

Photo: Ocean Farming AS

In our opinion, offshore farming will probably not be the most cost efficient method, but will still be profitable at current price levels

Offshore - An analysis of cost drivers compared to ONP, CCS and RAS

Current cost drivers	Salmon lice/ fish health	○	Offshore farming is not a standardised concept. Some offshore concepts are closed, while others are open, and this will impact salmon lice costs. However, as the most advanced offshore concepts so far are open, we use this as a basis. We do expect lower lice related costs in open offshore than in traditional open farming, however not zero. Other fish health related costs are uncertain.
	Regulations and technical requirements	☹	Considering the offshore oil and gas industry, one might expect offshore farm regulations to be even more extensive and complex than for traditional farms. On the other hand, a mobile offshore farm in the shape of a ship might easily move to a country with less complex regulations. Overall, there are no clear advantages or disadvantages.
	Commodity prices	○	Like with closed systems, we do not expect any significant differences in feed costs between offshore and the current open cages. We believe that feed price will be the same, and the biological feed conversion and mortality rate will probably not be significantly different. Hence, neither CCS or Offshore will have a clear advantage in feed costs compared to traditional farms.

PwC's Point of View:
Although offshore farms open up massive new farming areas and exciting opportunities, they are likely to be expensive to build, operate and maintain.

In addition the offshore farm will still use public area, release nutrients and be exposed to salmon lice and other external factors.

As a result, we do not believe that Offshore farming will become the most cost efficient production method. However, constructions like the ocean farm might still play an important role in 2050 by opening up for more exposed sites than those currently in use.

Future cost drivers			
	Scarcity of resources	☹	Naturally, offshore farming requires more construction materials than ONP, and probably more equipment, transportation of feed, personnel and fish. They will therefore be more expensive to build than traditional open net farms. Offshore farms must withstand extreme weather conditions and we therefore expect a significantly higher CAPEX, with a corresponding higher depreciation and maintenance cost, than ONP farming.
	Environmental focus	😐	We expect offshore farms to have a lower impact on wild salmon populations, and a lower impact from nutrient release. Therefore, potential future costs from such factors should be lower than for ONP. On the other hand, there will probably still be salmon lice, and farming far from shore in new areas might lead to new challenges and costs.
	Licence to farm	☺	An offshore farm within the Norwegian economic zone will still use public space (ocean) and will have a cost related “the right to play.” However, as offshore waters are “endless” and the fight for area usage is currently not an issue, this cost will probably be lower than for traditional farms in the future.

Although offshore farms open up a plethora of new farming locations, they will still use public space, release nutrients and be exposed to salmon lice and other external factors.

RAS systems - both land and sea-based

RAS-technology solve many challenges. Still, it comes with a price and a dilemma for Norwegian fish farmers as full-cycle RAS-farms do not require a fjord

RAS technology - From Frøya to Beijing?

RAS technology has been around for decades. In recent years the CAPEX required has decreased and the salmon prices increased, making RAS investments very attractive. Since land-based RAS solve challenges with lice, escapes and nutrient releases, one could bank on this as the future gold standard.

Let's hold our horses (fishes), shall we? There are a few barriers to overcome. On average, the industry leaders in our survey believe only 8% of aquaculture production will happen on-land in 2050. At the same time, 67% of the same leaders believe production of large smolt will be most important in order to improve utilisation and efficiency in production.

In our opinion, this is a paradox as almost all large smolts are produced on land in RAS-facilities, and new RAS facilities are being built on a large scale. It may seem like Norwegian farmers, to some extent, either do not believe in full cycle RAS-production, or are afraid RAS will contribute to the extinction of our comparative advantage - the sheltered, pure fjords.

If the smolt size in 2050 is 1 kg, and the average harvest weight is 5 kg, 20% of the biomass will be produced in land-based RAS (not including planned, full cycle-projects).

The interest in RAS is, however, even higher abroad. RAS-facilities can be built close to end markets, eliminating costly air freight. Atlantic Sapphire is currently building a massive RAS-farm for Atlantic Salmon just outside Miami.[110] We believe similar projects will appear in the years to come, with or without the Norwegian farmers. In the future, it is difficult to see large scale air freight routes as a sustainable option.

Cost estimates for RAS-production are many, but mainly teoretical as there are very few commercial scale RAS-farms for salmon in use. Recent estimates range from 35 NOK/kg (Nofima 2013),[111] 37 NOK/kg (DnB Markets),[112] 39 NOK/kg (Liu et al., 2016) and most recently, 44 NOK/kg (38,7 NOK/kg WFE) according to Bjørndal & Tusvik.[113]

Our own estimate of ~41 NOK/kg falls between DnB and Bjørndal & Tusvik, but the uncertainty is high. Common for all the estimates is a decreasing cost of production for RAS over time, converging towards the ONP cost. However, it is important to remember that most theoretical estimates of cost fail to include events like disease resulting in mass mortality.

RAS is normally considered a technology for land-based production, but Eide Fjordbruk wants to use RAS technology for salmon production in the sea.
Illustration: Eide Fjordbruk AS

8%

Share of total ***production on land in 2050****, according to aquaculture leaders.*

PwC's Point of View:
Although current RAS costs are uncertain and likely higher than ONP, the post-smolt track, and the possibility to locate full-cycle facilities near end markets, make the technology seem very attractive.

Cost estimate 2017 (NOK/kg HOG)	RAS Land Based
Smolt cost	3.4
Feed cost	17.1
Personell cost	3.1
Depreciation	3.5
Other OPEX	7.6
Net finance cost	2.8
Cost of production	**37.3**
Harvesting cost	3.5
Total cost	**40.8**
Air Freight cost (Asia/US)	-
Total cost to Asia/US	**40.8**

Source: PwC estimates, Kontali (air freight)

RAS-technology looks favourable as CAPEX continue to decrease and the environmental focus increases

RAS - An analysis of cost drivers compared to ONP, CCS and Offshore

Current cost drivers

Salmon lice/ fish health	☺	As long as the water intake is filtered and treated, a land based RAS-farm should be 100% salmon lice free. This is currently a major advantage for land-based projects. Other fish health aspects are more uncertain.
Regulations and technical requirements	○	To a large extent, the same regulatory environment will apply for RAS solutions, as for other concepts. No significant differences are expected. Although a land-based farm does not need to withstand high waves, building on land is not necessarily much cheaper.
Commodity prices	○	Same as for the other concepts, we expect no significant differences in feed costs for RAS-production. Although RAS-farms may maintain a controlled environment, which is positive for bFCR, a special RAS-feed, at a slightly higher cost, is required.

PwC's Point of View:
With a lower environmental footprint, no salmon lice or licence cost, RAS looks like a potential winner in the future. This especially in the air freight markets like the US and Asia.

On the other hand, land based does not achieve the goal to produce more food in the oceans, and Norwegian aquaculture leaders are negative. The success stories with salmon in RAS so far, are also few.

We look forward to following the development both in Fredrikstad and in Miami the coming years.

Future cost drivers

☹	Closed systems require a lot more equipment and construction materials than open cages, and they are expensive to buy. Although CAPEX for RAS projects have been falling in recent years, average levels are still at a 60-100 NOK/kg capacity - a four to sixfold increase of the CAPEX required for an ONP farm. This level will likely decrease further, but probably not far below 50 NOK/kg. Technology for mechanical and biological filtering are expensive to buy and maintain.
☺	RAS facilities recycle the water and remove feces and nutrients from the waste-water. In other words, they reduce impact on the local ecosystems. We therefore expect such farms to have a future advantage. RAS farms located close to end markets offer an additional advantage with a lower CO_2-footprint and transportation costs.
☺	Land-based RAS farms are normally built on privately owned land, eliminating the need to pay for the use of public area. As the environmental impact is also potentially lower, licences are likely to be either free or have a low cost associated with them.

With a lower environmental footprint, no salmon lice or licence cost, RAS looks like a potential winner in the future. This especially in the air freight markets like the US and Asia

A high share of Norwegian smolt are already produced in RAS, and several full-cycle facilities for different species are being built globally

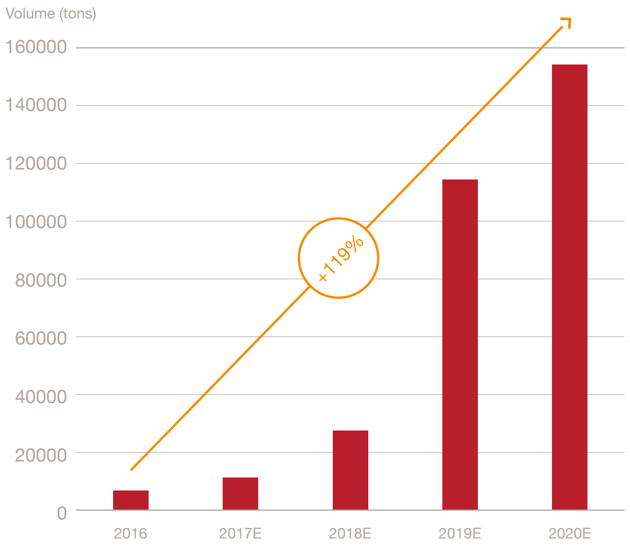
RAS systems already have a high adoption rate within smolt production

According to a recent PwC analysis, we expect 60% of the Norwegian smolt biomass to be produced in RAS within 2020. The same trend is expected in other salmon producing countries.

One important driver for this trend, is that the high investment costs for capacity are lower per fish with a lower average weight (smolt), than for harvest-ready salmon. The importance of a stable and controlled environment is even more crucial at the fry and smolt stages.

Several full-cycle projects will boost RAS production in the coming years

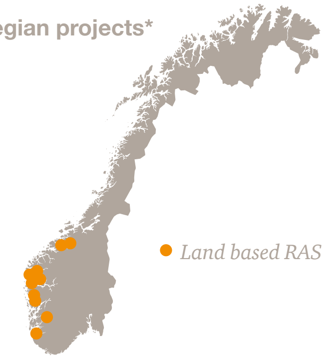
Planned production capacity of full-cycle salmon production in RAS (2016-2020E)



Sources: DnB Markets, Kontali

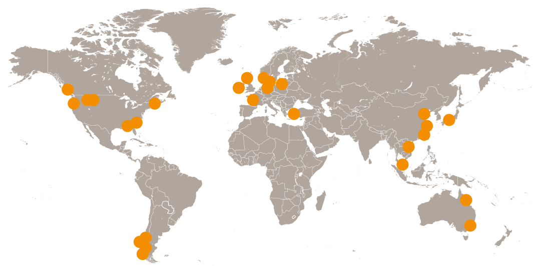
RAS technology is widespread globally, and is suited for a wide range of species

Overview of Norwegian projects*



Source: PwC Analysis

Overview of global projects*



**Not exhaustive*

Source: PwC Analysis

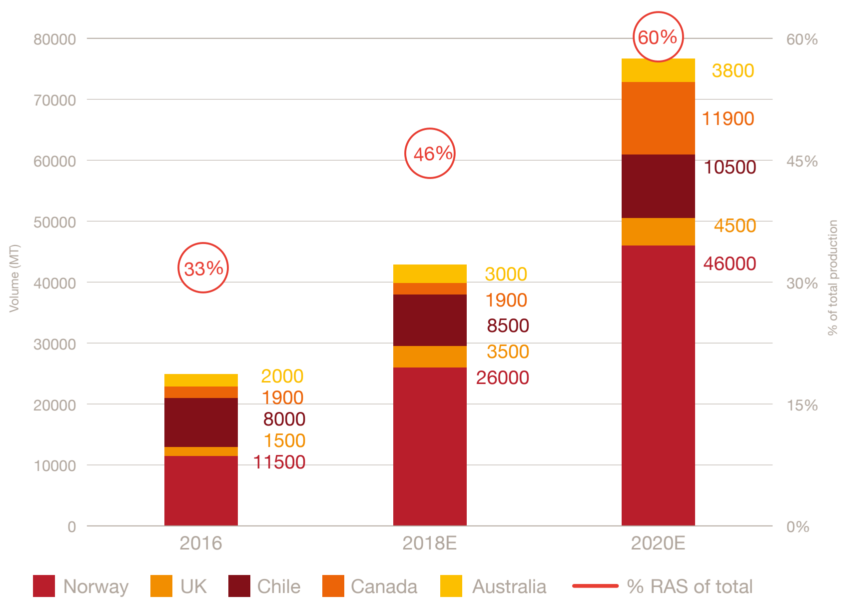
Current RAS technology can recycle up to 99% of the water

According to DNB Markets, the total planned full-cycle capacity will reach 154,000 tonnes in 2020.[114]

Internationally, the massive plant being constructed in Miami by Atlantic Sapphire seems the most promising. They recently raised 70 MUSD to build the first stage, and are now the first land-based fish farmer to list their shares on the NOTC-list.[115]

In Norway, Fredrikstad Seafood has started building a full-cycle, land-based farm with a goal of producing 9,000 tonnes of Atlantic Salmon.[116] Several other full-cycle projects are on the drawing boards across Norway. However, none of the large fish farmers are investing in full-cycle, land-based farming.

Volume of smolt production in RAS (2016-2020E)



Sources: DnB Markets, Kontali

Other farming technologies

The salmon roadmap to 5 million tonnes may be halted by a "black swan." It may be microplastics, but most likely it will be something else.

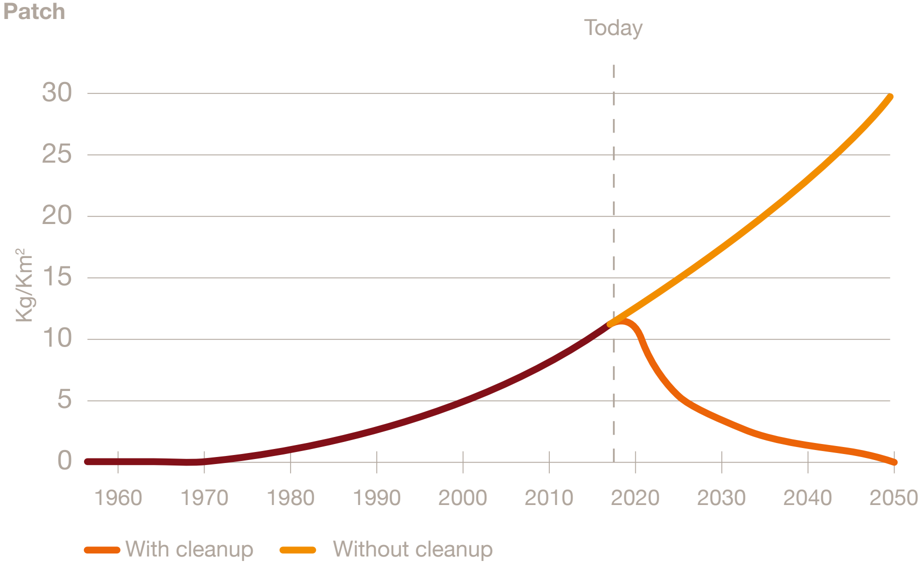
Microplastics in fish - a potential black swan?

In addition to the four technologies we have described, others we have not yet imagined may appear well before 2050.

On the other hand, there may be risks and challenges ahead we have not yet foreseen in which we are not able to forecast or take into account. This is often referred to as a black swan - something so rare that it from a statistical point of view should not exist, but yet it turns up from time to time.

One potential black swan for the aquaculture and fisheries industry, as we see it, is the rapidly growing amount of microplastics in the ocean. If, or when, the amount reaches a level that may pose a threat, either to fish health and welfare or food safety, it may already be too late.

Concentrtion of microplastics with and without cleanup in the Great Pacific Garbage Patch



Source: www.theoceancleanup.com

PwC's Point of View:
It is hard to predict the unpredictable, but it is probably safe to say that the future will continue to surprise us.

One potential black swan as we see it, is the potential impact from microplastics in the sea. Will fish catched or farmed in an open environment be safe to eat in the future?

One the other hand, if the salmon lice challenge is solved and we experience a global boom in e.g. algae production for fish feed production, the future of aquaculture may be brighter than we can currently imagine.

2%

Share of total ***production in other systems not yet invented in 2050****, according to aquaculture leaders.*

Potential growth

Only one out of three in the industry believe in a production volume of 5 million tonnes in 2050. Does this mean that the goal is unrealistic?

89% *of the respondents still* ***believe fjord-based farming*** *will be* ***competitive in 2050.***

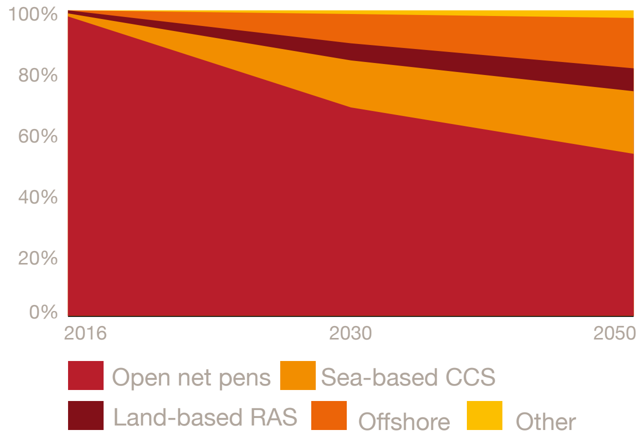
The current conditions, and situation, will not allow for the desired growth. The offered "Bremnes-model" may only provide marginal growth. Development licences will provide some growth, but not very much. As for the traffic light system, even with 100 % green lights every period until 2050, this system cannot provide sufficient growth to reach the goal. It can, in theory, help us halfway towards the goal, but only if the industry quickly solves challenges related to the current (and future) traffic light indicators, ensuring a high share of green lights every period.

As a result it will be necessary for the government to issue new licences in addition to the development licences and "traffic light" growth in order to be able to reach the goal. Apart from land-based licences, there are few indications so far as to how or when this will happen for the traditional sea-based licences. And given the limited growth in new licences since the 1980's, this might explain why most farmers do not see the goal as realistic.

Is the negative outlook of caused by humans' inability to predict the future? If, in 1970, one had asked a fish farmer if he or she believed in a production volume of 1.3 million tonnes 40 years later, the answer would probably have been no.

At the same time, respondents believe that only 53% of the Norwegian volume will be produced in open cages in 2050, 21% in closed, sea-based systems, 17% offshore, and 8% on land. Interestingly, this shows that the industry does believe in a shift towards closed and offshore systems, but not for land-based, full-cycle production in Norway.

Norwegian aquaculture in 2030 and 2050, according to industry leaders:

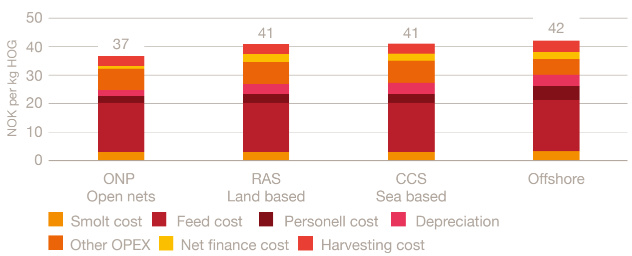


Tomorrow's cost drivers will favour closed systems, reducing the current competitive advantage of open net pens

Current status

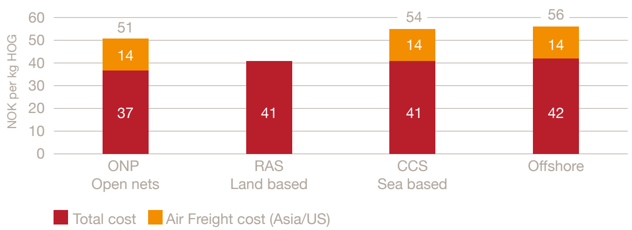
Today, ONP farming is the most cost-efficient, but also the only commercially proven method. The uncertainty regarding cost levels of the new methods is therefore large. The gap is reduced in recent years due to the lice related cost increase in ONP, and cost decrease in RAS from lower CAPEX.

Estimated Cost of Production (COP) 2017



If we include air freight, RAS seems even more favourable for end-markets in the US and Asia. Still, most Norwegian export goes to the EU where transport cost is low.

Estimated COP incl airfreight to Asia/US



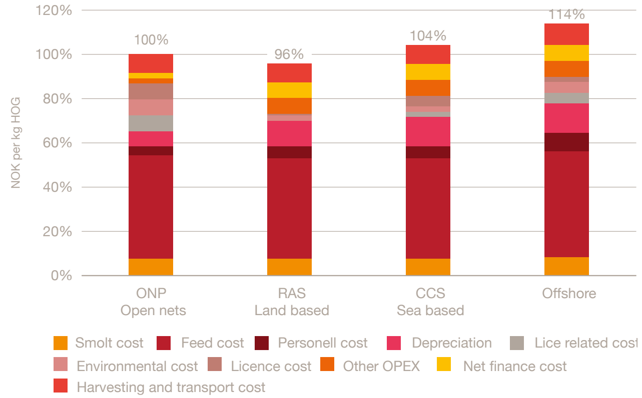
Trend going forward

Driver	ONP	CCS	Offshore	RAS
Salemon lice/fish health	🙁	🙂	😐	🙂
Regulations and tech. req	😐	😐	🙁	😐
Commodity prices	😐	😐	😐	😐
Scarcity of resources	🙂	🙁	🙁	🙁
Environmental focus	🙁	🙂	😐	🙂
Licence to farm	🙁	😐	🙂	🙂
PwC view on outlook	-	+	+/-	++

PwC view 2050

PwC expect tomorrow's cost drivers to favour closed solutions, leading to converging costs of production for the different methods.

Estimated Cost of Production in 2050



In 2050 we expect both RAS and CCS to be competitive, eliminating the current super-profit in open net farming.

In our opinion, a reduced super-profit in ONP salmon farming is inevitable in the long run, but this will primarily affect the licence valuation in ONP and not make fjord-based farming obsolete.

We believe in significant volume growth towards 2050, however our base case only suggest 3.3 million tonnes in 2050. In our most optimistic scenario it is possible to reach 5.2 million tonnes

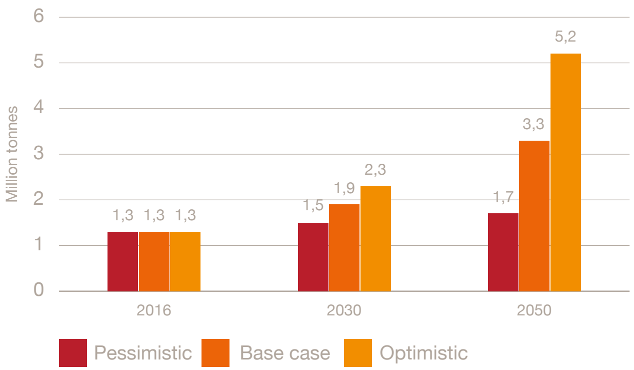
PwC's view on future growth scenarios:
We have not just asked industry leaders about their view on the growth potential, we have also made our own analysis. PwC's base-case indicates 3.3 million tonnes in 2050. However, in our optimistic scenario, 5 million tonnes is also possible. Our pessimistic scenario still indicates growth, from 1.3 million tonnes to 1.7 million tonnes in 2050.

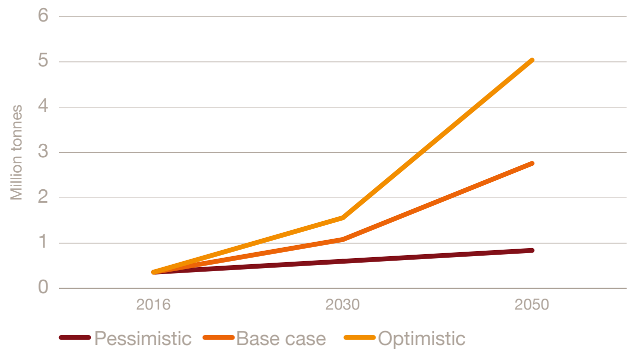
The uncertainty is high and growth depends on the success, including cost efficiencies, of new production methods like closed cages and offshore farming. In addition, the development in lice levels (and future traffic light indicators) must be positive.

Key takeaways

- New licences will be issued to farmers using technology that greatly reduces salmon lice levels (for example closed cages)
- New licences will be issued for land-based farming, and in Norway, mainly for post smolt production
- Attractive incentives to get a green traffic light will pivot new investments toward solutions that have a positive effect on the sustainability indicator, leading to significant growth from the traffic light system, as well as a shift from ONP to CCS
- Farmers in a red or yellow zone will have a particularly strong incentive to invest in "green light" technology to be eligible for growth despite the status of the zone

Three growth scenarios to 2050





Key assumptions in PwC's growth estimates:
Optimistic scenario: Current challenges are solved in a few years with new technology, and new challenges are solved as they arise. High traffic light growth on current licences, high growth from new licences based on new technology (ONP/CCS/Offshore) and for land-based (RAS). In addition, we have assumed some improvements in operations (mortality and harvest weight).

Base case: New technology solves the challenges, but these are not the most cost-efficient. Due to a slower shift to new technology, we expect only a moderate traffic light-growth and growth from new licences based on new technology (both sea and land-based). Some improvements in operations (mortality and harvest weight).

Pessimistic scenario: The biological conditions improve very slowly, and the shift towards new technology also goes slowly, resulting in only a limited growth from new licences with new technology (CCS, Offshore and RAS). The traffic light provide little or no growth as there are several red zones reducing MAB in some zones throughout the forecast period. No improvements in mortality and harvest weight.

We believe that the traffic light system will provide growth on current licences. In addition we expect new licences on land using RAS for postsmolt, and in sea using new farming technology

Base case scenario

In our base scenario the majority of the growth towards 2050 is expected to come from the traffic light system, as we estimate approx 50 % green lights, resulting in a net growth every two-year period.

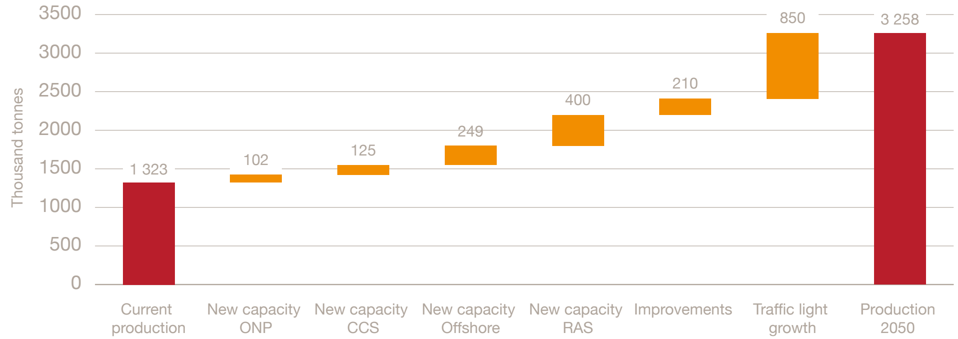
In addition we estimated 0.21 million tonnes from improvements in mortality rate and harvest weight, by returning to previous levels. New licence capacity outside the traffic light is expected to be highest on land and the estimate of 0.4 million tonnes assume 500 grams per smolt * 600 million smolts in 2050 + 100k tonnes from full cycle RAS-facilities. In addition we expect some growth from new licences mainly offshore and in closed sea-based systems. Note that we also expect to see a shift towards mainly CCS also within the current production capacity.

Optimistic scenario

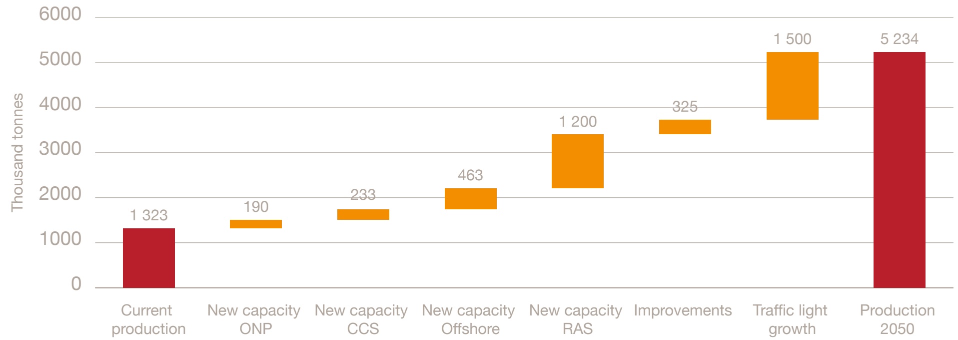
In our optimistic scenario the majority of the growth towards 2050 is expected to come from the traffic light system and land-based RAS production of post smolt. In this scenario most regions receive a green light every period, and the average smolt weight in 2050 is 1 kg (and close to 100 % of the smolt is produced on land in RAS).

In addition we estimate 0.33 million tonnes from improvements in mortality rate and harvest weight and a significant amount of new licences based on new technology, mainly offshore and in closed sea-based systems. Note that we also expect to see a shift towards mainly CCS also within the current production capacity

Base case - bridge from current production to 2050



Optimistic scenario - bridge from current production to 2050



Key assumptions in PwC's growth estimates:

New capacity in ONP, CCS and Offshore technologies:
Information from the Minister of Fisheries does not describe any additional growth for new farming technologies within ONP, CCS and offshore farming technologies, outside the current development licenses and the "traffic light" growth. However, we have in our scenarios assumed an additional future growth, or licences requiring use of specific farming technology like CCS.

Our growth estimate for such licences are based on the current pending and approved volume of development licences per category, an estimated approval rate of $^{1}/_{3}$ and an applied specific annual growth rate for new farming technology (5 % in base case and 7 % in high case).

Methodology - survey

PwC's first survey on the Norwegian seafood industry's future was executed in June and July 2017. Our intention with the survey was to unveil how the industry leaders perceive the industry's current and future status, especially regarding global megatrends, technology development and growth.

The survey is constructed in a manner enabling PwC to collect and share insight on how the industry leaders' perception develop over time, providing useful information for the industry to see shifts in trends and prioritisation within the industry.

Survey composition and questions

The survey is divided in two, one for respondents within the Aquaculture industry and one within the Fishery industry, each consisting of four parts.

Aquaculture	***Fishery***
- About the business (4-5 questions)	**- About the business** (4 questions)
- Global megatrends and seafood industry trends **- Regulatory changes** (20 questions) (17 questions) 11 of the questions are similar for both industry segments	
- Technology **- Growth** **- Production** (43 questions)	**- Technology** **- Growth** **- Production** (11 questions)
- Tabloid questions (3 questions)	**- Tabloid questions** (3 questions)

The number of questions includes sub-questions.

Sample size

Industry segment	*Distributed surveys*	*Respondents*	*Response rate*
Aquaculture	122	28	23%
Fishery	43	14	33%
Total	***165***	***42***	***25%***

Prospective respondent search and distribution

A lot of effort was put into receiving responses from both small and large companies from across the entire value chain, spanning from feed producers, through suppliers of broodstock, smolt and farmers, to exporters.

Prospective respondents was found using the publicly available database Proff Forvalt. We sorted companies by relevant industry codes and downloaded contact information for their CEO/ general manager. Note that not all of the companies had their contact info updated in the public database. These companies did not receive the survey request, unless PwC otherwise found their e-mail address.

The survey was distributed to the prospective respondents' e-mail addresses.

Responses

We received 28 responses from leaders in the Norwegian aquaculture industry, including small, family-owned companies and many of the largest, publicly listed companies in the industry.

Replies from leaders within the fishery sector are also incorporated in the survey. The reason for this is to provide a width in terms of general seafood trends, but also to provide data for future versions of the PwC Seafood Barometer. We received 14 answers from the fishery industry.

Answers are handled confidentially and will only be presented collectively.

The survey was produced and distributed by PwC using Qualtrics.

The results from the survey are for indicative purposes only, and should not be applied outside the intended use. The survey results are not intended for scientific purposes and any applications of the survey results should not be perceived as statistically correct.

Glossary of terms and abbreviations

ONP (Open net pen). Abbreviation and term used about fish farming in traditional open net pens and cages.
CCS (Closed containment system). Abbreviation and term used for fish farming in closed, seabased systems close to shore (not offshore)
Offshore. Term used for all fish farming solutions intended for use offshore. May include both open and closed offshore solutions.
RAS (Recirculating aquaculture system). Abbreviation and term used for land based farming of salmon and trout.
MAB (Maximum allowed biomass). Refers to the maximum allowed biomass for a salmon farming site or licence.
HOG (Head on gutted). Refers to the weight of the salmon after harvesting and gutting.
WFE (whole fish equivalent). Refers to the weight of the salmon before gutting.
COP (Cost of production).
CAPEX (Capital Expenditure). Refers to investment cost in equipment etc.
bFCR (Biological Feed Conversion Ratio). Refers to how much feed that is required to produce 1 kg fish.

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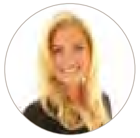

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