MENON ECONOMICS

REPORT

COST-BENEFIT ANALYSIS OF INCREASED PRODUCTION AND IMPROVED AVAILABILITY OF MARINE GEOSPATIAL DATA

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Foreword

On behalf of the Hydrographic Service in the Norwegian Mapping Authority, Menon Economics in cooperation with DNV GL has conducted a cost-benefit analysis that assesses the benefits of increased production and improved availability of marine geospatial data in Norway. The Norwegian Institute for Food, Fisheries and Aquaculture (Nofima) has also contributed to the analysis.

The project was led by Sveinung Fjose (Menon), with Kaja Høiseth-Gilje (Menon), Kay Erik Stokke (DNV GL), Peter Aalen (Menon) and Peter N. Hoffmann (DNV GL) as project members. Heidi Ulstein (Menon) has been the project owner, and Magnus U. Gulbrandsen (Menon) acted as quality assurer. We have also had good help from Gjermund Gravir (DNV GL), Karl John Pedersen (DNV GL), Svein Erik Endresen (DNV GL), Jens Laugesen (DNV GL), Audun Iversen (Nofima), Øyvind Stene (previously Director-General of the Norwegian Mapping Authority) and Jens F. Skogstrøm (Menon).

Menon Economics is a research-based consultancy operating at the interface of economics, politics and the market. The company provides economic analyses and advice to enterprises, organizations, municipalities, counties, directorates and ministries. The main focus is on empirical analyses of economic policy, and our employees have economic expertise on a high scientific level.

DNV GL is a leading classification and consultancy enterprise with special focus on the maritime, oil and gas and energy sectors, as well as certification services and software. DNV GL has 300 offices in 100 countries. In the head office at Høvik, experts work with uncertainty analysis for projects, modelling and risk management. They have wide experience from quality assurance and reviews of projects.

Nofima is Europe's largest institute for food research, and engages in applied research within aquaculture, fishing and the food industry. Nofima's social mission is to develop knowledge that can help to improve the competitiveness of the Norwegian food industry, with particular emphasis on innovation and social and environmental sustainability.

Menon and DNV GL would like to thank the Mapping Authority for an interesting assignment. We also thank all interviewees who have generously given us of their time, and for valuable contributions and discussions in the course of this study from everybody in the Mapping Authority, especially Hermann Iversen, Evert Flier and Sven Peder Klungtveit.

The authors are responsible for all content in this report.

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Summary

In this report, we have carried out a cost-benefit analysis of a potential scale-up of the rate of collection and processing of marine geospatial data in Norway. Based on the findings from this analysis, it appears most profitable to scale up production to a rate where all remaining unmapped sea areas will be mapped within 25 years (alternative 1). This is most likely economically profitable, based on assessments of the non-priced effects' magnitude and impact. At the same time, we would like to point out that there is considerable uncertainty with regards to economic profitability, partly because the benefit for the aquaculture industry is indirect and hard to calculate.

In line with the technological progress within the collection and processing of data, we recommend to conduct a new assessment of the costs and benefits of a scale-up once new technologies have been commercialized. This may be at a point between five and ten years from now. A further scale-up should then be considered in the light of new cost reductions resulting from technological development.

Independently of a potential scale-up, the Mapping Authority should prioritize the mapping of areas with dense ship and boat traffic, areas with potential for growth in the aquaculture industry, and areas with a large population or considerable population growth. This will trigger the biggest possible benefit overall.

Mapping of the Norwegian coastal zone with modern methods of measurement is insufficient.[1] At the present rate of data collection, it will take approximately 35 years to map the Norwegian coastal zone up to one nautical mile beyond the baseline (including Svalbard).[2] A lack of knowledge about the seabed contributes to a higher accident risk for commercial shipping, fishing vessels and leisure craft, suboptimal placement of economic activity, most often in the form of aquaculture installations, and less than ideal use of resources within mapping activities carried out by public actors.

The mapping of the coastal zone is carried out by the Hydrographic Service division in the Norwegian Mapping Authority, which is responsible for the production and maintenance of nautical charts. The Hydrographic Service division's work includes the collection and administration of depth and bathymetric data and other maritime information.[3] The charts provide the basis for safe and efficient maritime transport along the Norwegian coast and on Svalbard, and are an important part of the infrastructure for Norwegian society. In addition, there are many other user groups that make use of these data, for example for the modelling of ocean currents, natural habitats and the distribution of marine species, the management of fisheries and aquaculture, and spatial planning within the coastal zone. Furthermore, the oceans are a source of economic growth with ever-growing significance. Mapping of seafloor conditions with modern methods is seen, in international research studies, as one of the key factors for the efficient management and exploitation of this part of our ecosystem.[4]

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[1] *Modern methods of measurement mean measurements by multibeam echo sounder.*
[2] *The Mapping Authority has calculated that with today's resources and at the present rate, it will take 44-45 years to map the coastal zone to the extent of one nautical mile beyond the baseline (including Svalbard). We assume an annual productivity growth of 1.3 percent, in accordance with the figures from the most recent white paper on the long-term perspectives for the Norwegian economy by the Norwegian Ministry of Finance ('Perspektivmeldingen'). With productivity growth at this rate, it will take around 35 years to map this area.*
[3] *Mapping of ocean depths and the terrain under water.*
[4] *OECD (2016), The Ocean Economy in 2030, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264251724-en*

Based on the benefits mentioned above, Menon Economics and DNV GL have calculated the economic profitability of scaling up the rate of data collection.[5] In the analysis, we calculated the costs of the Mapping Authority and the Geological Survey of Norway (NGU)[6] for a scale-up, as well as priced benefit for commercial shipping and the leisure fleet in form of reduced accident risk and benefits for public actors related to reduced costs for their own mapping. The benefits related to maritime safety can be realized independently of NGU's geological survey and the costs for NGU's activities. As several of the potential benefits are difficult to calculate, the assessment of economic profitability is uncertain. If only costs and priced benefits are compared, none of the scale-up measures are economically profitable. The non-priced effects include optimal placement of aquaculture installations, more efficient fishing and less damage to fishing equipment, reduced travelled distance for ships and more efficient maritime transport, and a better knowledge base for research and development related to natural habitats and marine ecosystems. We see the impact of optimal localization of aquaculture installations as the largest and most important of these effects. If the benefit deriving from non-priced effects equals NOK 339 million over an analysis period of 35 years, a scale-up from the zero alternative to reduce mapping time by ten years to 25 years will be economically profitable. This implies that map data must contribute to at least 0.24 percentage points of value creation growth in the aquaculture industry.

The benefits for aquaculture are realized mainly in the form of depth data being used in ocean current modelling, which is important for an optimal and environmentally sustainable placement of fish farms.[7] Detailed depth data are the most important component of models that predict ocean currents. Better mapping of the seabed will therefore help to make these models more accurate. In consequence, it will be easier to predict how infection with salmon lice is spread between installations and thus reduce the extent of this problem. The new area-based regime for aquaculture approved by the Norwegian parliament states that future growth in the aquaculture industry is contingent on the fact that the risk for the spread of salmon lice is reduced. Since the map data are of essential importance for the calculation and management of this risk, we believe it likely that more detailed maps will contribute to more than 0.24 percent of the future value creation growth in the aquaculture industry. Yearly production growth in the industry from 2004 to 2014 has been more than 7 percent, and the Norwegian government prepares for this growth to continue, under the premise that it is environmentally sustainable. In our opinion, it is therefore very likely that mapping the seabed at a somewhat faster rate will be economically profitable.

There is however an additional aspect that needs to be taken account when considering economic profitability. Technological development within both the collection and the processing of collected data is expected to progress quickly. As early as 2017, the Mapping Authority will take an improved processing technology into use.

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[5] *The reason we have looked at a scale-up of mapping activity and not directly at the net economic benefit in the zero alternative is that the map data's potential life span is very long. There will be large benefits in the future, but the related uncertainty makes it very difficult to conduct an analysis where we look at the relationship between absolute costs and benefits. With a scale-up, the benefits will be equal for all alternatives after the analysis period, and thus not affect the decision. It is likely that carrying out the mapping in the zero alternative is economically profitable, but this is very difficult to calculate. Areas with dense maritime traffic and a large and/or growing population will experience especially large benefits from the mapping. It is highly likely that these areas are profitable to map. In case of further technological progress at a fast rate, the probability that it is economically profitable to also map areas with less traffic will increase significantly. This means that if one starts with the busiest areas first, marginal utility will decrease for each additional area that is mapped.*

[6] *NGU carries out a geological survey and produces thematic maps related to the data collected by the Mapping Authority. These maps are necessary in order to trigger some of the benefits related to marine geospatial data.*

[7] *Type and topography of the sea bottom and anchoring conditions are also important in order to be able to assess the carrying capacity of relevant locations for aquaculture installations.*

This will reduce manual processing of the collected data material. Technological progress in areas such as self-driving vessels, data collection and processing will likely help to reduce the costs for collection and processing of data at a quicker rate than the 1.3 percent productivity growth assumed in the most recent white paper on the long-term perspectives of the Norwegian economy by the Ministry of Finance.[8] A scale-up that is too fast may reduce this potential «waiting gain». The assessment of economic profitability must therefore also include a consideration of the benefits for the aquaculture industry vs. the likelihood of cost savings from technological development. As we believe that there will be further technological progress in the coming years, while there is uncertainty related to the benefits for aquaculture, we do not recommend scaling up too fast.

To strengthen the economic gains from mapping, the Mapping Authority should concentrate even more expressly on mapping areas with considerable maritime traffic, areas with significant potential for growth in aquaculture, and areas with a large population or considerable population growth. The Oslofjord area and the sea areas from Western Norway to the county of Troms in Northern Norway should therefore be given priority.

There is large uncertainty related to the benefits of faster mapping. This applies especially to the benefits for public actors and the aquaculture industry. One necessary premise to be able to realize the benefits in these areas is availability of more detailed maps. The uncertainty in the benefit calculations means that the benefits might be significantly larger or smaller than what is demonstrated in our calculations. In addition, the Armed Forces' classification regime for depth data has considerable impact on the benefits for many of the actors. This means that the total benefit that is triggered may be lower than calculated in this analysis. This will depend on the degree to which each of the actors will be able to apply to have classified data released for their purposes.

[8] *Report to the Storting Meld. St. 12 (2012–2013). Long-term Perspectives on the Norwegian Economy 2013 ('Perspektivmeldingen').*

1. Background

In this report, we conduct a cost-benefit analysis of a potential scale-up of the collection and processing of marine geospatial data in Norway. Activities related to maritime and marine industries are expected to increase in the future, while more and more actors are showing an interest in developments in the coastal zone. The main objective of this analysis is therefore to identify whether mapping the coastal zone at a faster rate is economically profitable.

Ocean-based industries are an important source of revenue for Norway, and have great potential to grow and become even more important in the future. On behalf of the Norwegian Ministry for Trade, Industry and Fisheries, Menon has calculated total value creation in the Norwegian ocean-based industries to NOK 815 billion, or approximately 27 percent of GNP, in 2013.[9] These industries include oil and gas, maritime and seafood. A working group appointed by the Royal Norwegian Society of Sciences and Letters and the Norwegian Academy of Technological Sciences in 2012 has estimated the potential for marine value creation (i.e., for part of these industries only[10]) in 2050. According to this report, marine value creation might exceed NOK 500 billion in 2050. This means that the ocean is seen as a more and more important source of economic growth. Mapping of seafloor conditions with modern methods is viewed as one of the key factors for efficient management and exploitation of this part of our ecosystem in international studies.[11]

In Norway, the production of oil and gas stands for the biggest share of the value creation from ocean-based industries, but there is also significant (and increasing) value creation from industries such as fisheries and seafood, shipping and tourism, as well as exports of technology for these sectors. In its maritime strategy «Maritime Opportunities – Blue Growth for a Green Future» from 2015, the Norwegian government has defined blue growth as a central topic.[12] Blue growth means higher value creation in the ocean-based industries. To increase this value creation, it is important to have a solid knowledge base with regard to the coastal areas.

For the ocean-based industries, better and more accessible marine geospatial data can play an important role, both in form of reducing costs and optimizing production, but also in the shape of new activities or increased production as well as accident prevention. Several studies indicate that the number of accidents can be reduced with the help of improved chart material.[13] In addition, changes in the Norwegian Planning and Building Act in 2009 mean that municipalities are now required to draft and pass a new planning strategy at least once within each election period. This also includes plans for the coastal zone, which increases the need for better maps and more detailed knowledge of the conditions in the coastal zone.[14]

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[9] *Menon Business Economics (2015).*

[10] *Report by working group appointed by the Royal Norwegian Society of Sciences and Letters and the Norwegian Academy of Technological Sciences (2012): Verdiskapning basert på produktive hav i 2050 [Value creation based on productive oceans in 2050 - Norwegian only]. In this report, marine value creation is defined as including all enterprises/activities that exploit the production material of living marine resources in a sustainable way.*

[11] *OECD (2016), The Ocean Economy in 2030*, OECD Publishing, Paris. *http://dx.doi.org/10.1787/9789264251724-en*

[12] *Maritime strategy of the Norwegian government (2015): Maritime Opportunities – Blue Growth for a Green Future*

[13] *Cf. the following studies [available in Norwegian only]:*
Rambøll (2011). En analyse av sannsynligheten for ulykker på Øst-Svalbard
DNV GL (2014). Analyse av sannsynlighet for akutt oljeutslipp fra skipstrafikk Svalbard og Jan Mayen
DNV (2010). Analyse av sannsynligheten for oljeutslipp fra skipstrafikk langs kysten av Fastlands-Norge

[14] *The Norwegian Planning and Building Act defines a municipality's administrative area as extending one nautical mile beyond the baseline.*

These benefits however do not come for free. Not all sea and coastal areas in Norway have been mapped with modern technology[15], and a scale-up of mapping activities will require resources, irrespectively of whether the Norwegian Mapping Authority continues to carry out these tasks itself or decides to delegate them to other actors. The key question in this analysis is therefore whether the benefits such as higher value creation, improved maritime safety or cost savings in both the public and the private sector exceed the economic costs of such a scale-up.

The main challenge with regard to a cost-benefit analysis of this issue is related to the quantification of benefits from mapping. There are relatively few existing studies of the topic, but an especially relevant Norwegian study is related to the mapping of Astafjorden. Vista Analyse executed a cost-benefit analysis of this project in 2013, but because benefit estimates were highly uncertain, it was not possible to conclude whether the project was economically profitable or not.[16] If there is a great deal of uncertainty related to the quantification of benefits, the analysis will not deliver a clear answer. Vista's analysis nevertheless identifies many categories of benefits that are important to consider. In this analysis, we have focused intensely on the quantification of benefits to be able to reduce uncertainty as much as possible and to arrive at a clearer conclusion.

The Astafjord project was limited to the mapping of one fjord, while this analysis focuses on the mapping of the Norwegian coast in its entirety. PwC has carried out a similar analysis for the coastal areas of Ireland (the INFOMAR-programme), while a study from the US also assesses the effect of a large-scale mapping program (Coastal Mapping Program).[17] Both studies find significant benefits that exceed the costs of these programmes. All the same, these analyses have considerable weaknesses, also here related to the quantification of benefits. Very general methods have been used to quantify benefits. One method was to look at the contribution of relevant sectors to GNP and trying to show to which degree improved map data are likely to affect these sectors. The problem with this method is that it is very difficult to substantiate how the individual sectors will be affected by the mapping, and to decide which estimates should be used. This means that the analyses contain elements of great uncertainty.

In our analysis, we will identify the benefit categories that are affected on a level of detail that is more in keeping with Vista's analysis, but we go further in quantifying the identified benefits. DNV GL has developed a model for the calculation of benefits related to maritime safety. This means that in our analysis, we are able to quantify the value of the risk reduction resulting from improved maritime safety. These are effects that often remain non-priced in cost-benefit analyses.

In chapter 2, we present a detailed overview over the question at hand and the current production of marine geospatial data. In chapter 3, we describe the proposed measures, while we examine costs and benefits in chapters 4 and 5 respectively. In chapter 6, we juxtapose benefits and costs and calculate the economic profitability of the individual measures. Chapters 7 and 8 contain an assessment of uncertainty and distribution effects. In chapter 9, we provide a summary of the analysis in combination with our recommendations. This chapter also includes some reflections around the realization of benefits, and assessments of this in the light of the Norwegian Armed Forces' security classification regime for marine geospatial data. A more detailed description of the method for and the approach to this analysis can be found in the appendix.

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[15] *Modern technology refers to measurements by multibeam echo sounder. Older methods/measurements are all other measurements carried out with the help of single beam echo sounder or hand lead.*
[16] *Vista Analyse (2013). Samfunnsnytte og kostnader ved gjennomføring av Astafjordprosjektet [Norwegian only].*
[17] *PriceWaterhouseCoopers (2008) INFOMAR – Marine Mapping Study – Options Appraisal Report: Final Report*
Leveson Consulting (2012) Socio-Economic Study: Scoping the Value of NOAA's Coastal Mapping Program

2. Problem statement

The mapping of the Norwegian coast with modern measurement methods (multibeam echo sounders) is incomplete. At the current rate, it will take 35 years to map the whole coast from the coastline to one nautical mile beyond the baseline (including Svalbard). Marine geospatial data are useful for many actors. They are especially important for municipalities that are required to draft coastal zone plans, and for maritime safety. Without publicly funded mapping activities, access to modern map data will be insufficient, both because there are positive externalities deriving from the mapping activities and because there are coordination problems related to data collection. This results in a situation where the amount of map data collected by private actors is too small, and will not trigger the overall benefit potential for the actors.

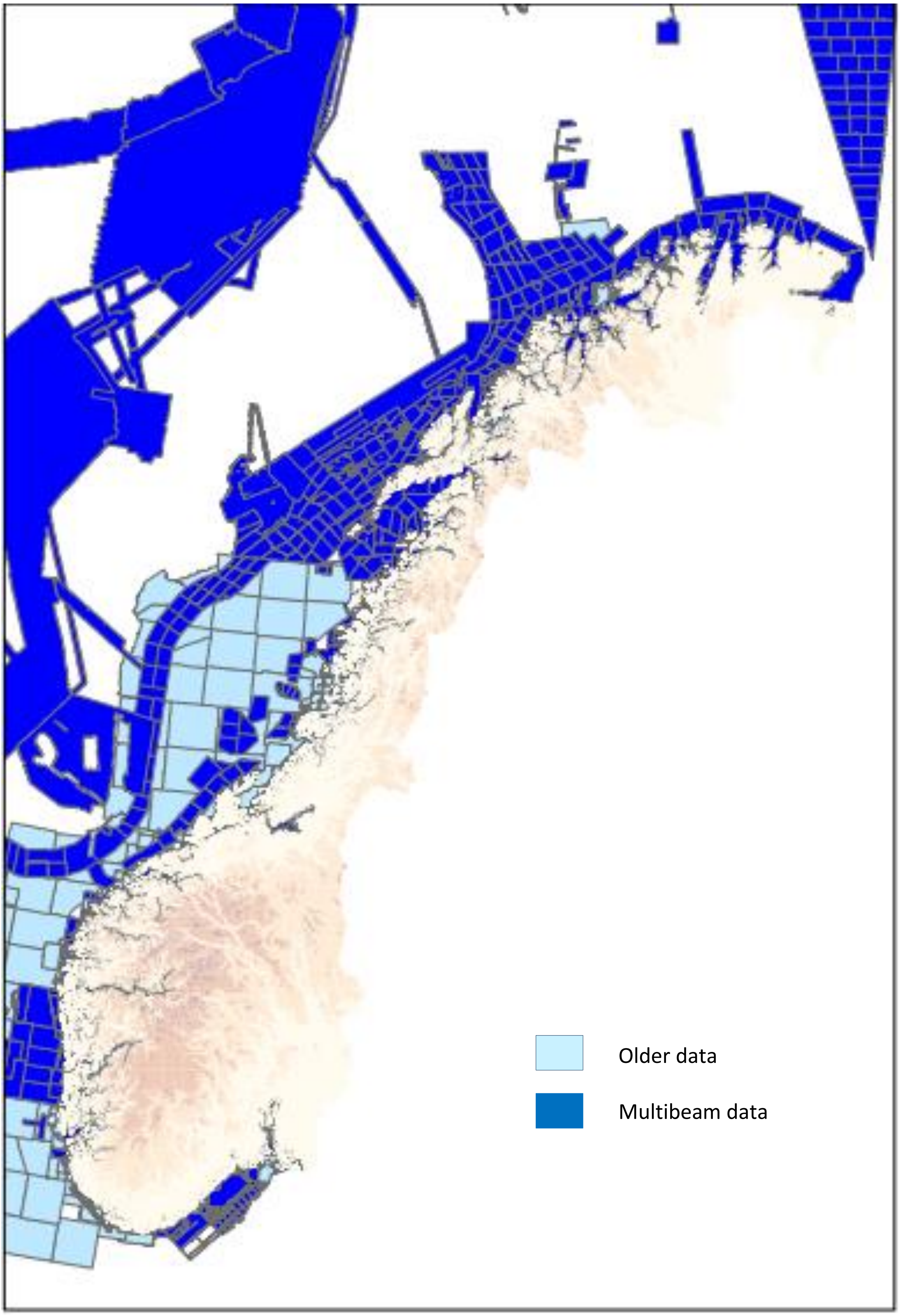
2.1. Mapping of the Norwegian coast and Svalbard with modern methods is insufficient

Mapping of the Norwegian coast with modern methods is incomplete. The Norwegian Mapping Authority has already worked on mapping the coastal zone with modern technology for 15 years. Despite this, there are large areas that remain unmapped, and at the current rate of data collection, it will take 35 years to map the whole coast to an extent of one nautical mile beyond the baseline. Areas that have not been mapped by multibeam echo sounder contain undiscovered shallows and might give an incorrect impression of the bathymetry. As there is an increasing need for marine geospatial data from various actors, the current rate of data collection means that collection of these data takes too much time.

2.1.1. Unmapped areas

The illustration below shows which coastal areas in Norway have been mapped by multibeam echo sounder and by older measurement methods. Especially on the south coast of Norway, in parts of the Oslofjord area, the region of Trøndelag in central Norway and the county of Nordland in Northern Norway there are areas which have not been mapped by modern methods. A large part of the areas where mapping is incomplete, especially on the south coast, consists of shallow areas with a depth of 0-5 meters. These areas are very resource-demanding to map with today's measurement methods, and this is part of the reason for the long time horizon for data collection. In addition, the mapping situation around Svalbard is unsatisfactory, too. This is partially due to the fact that the season for surveying is short, and ever-changing ice conditions mean that measurements are outdated within a short time. Svalbard is also an area of greater uncertainty, because there is simply less information about depth conditions in these areas due to a lack of existing measurements.

Figure 1: Areas covered by multibeam data and data from older measurement methods. Source: Norwegian Mapping Authority and DNV GL



2.1.2. Description of current production of marine geospatial data

For the collection of map data, the Norwegian Mapping Authority owns and operates a specialized vessel, M/S Hydrograf. M/S Hydrograf is 43.6 m long, equipped with an Em170 multibeam echo sounder, and accommodates 13 people. The vessel was built in 1985, remodeled in 2000 and renovated in 2004. It is old, but in a good state of repair. It can be used for mapping in the depth interval from 20-1500 meter, and is most efficient at depths between 50 and 1000 meters. M/S Hydrograf is usually accompanied by two survey launches[18] with a length of approximately 11 meters. These are built in 2014 and equipped with Em2040 multibeam echo sounders, which allow them to take measurements in depths from 2-400 meters. They are most efficient in areas shallower than 100 meters. The survey boats do not have facilities for overnight accommodation and are lifted up on deck on M/S Hydrograf during transit. Expected lifetime for these vessels is 10-15 years.

M/S Hydrograf has a crew of 11 people per shift. The main vessel and the survey launches are used in combination, i.e., the survey boats take measurements in the shallowest areas, while M/S Hydrograf works in greater depths, typically in the fjords. The crew is large enough to allow for round-the-clock operation of M/S Hydrograf. M/S Hydrograf and the survey boats operate year-round, only interrupted by maintenance and crew changes (every 4th week). Capacity for M/S Hydrograf and the survey boats is allocated as follows: for approximately 10 weeks a year, the vessels take measurements around Svalbard. 6 weeks per year are spent on the open sea collecting data for the Mareano-program. For the rest of the year, the vessels take measurements according to the general mapping plan and in other prioritized areas along the Norwegian coast. In addition to actual data collection, the Mapping Authority also needs to process the collected data material before it can produce terrain models, nautical charts and other products.

To be able to realize the benefits from marine geospatial data, with the exception of those effects that are related to maritime safety, thematic maps produced by the Geological Survey of Norway (NGU) are needed. At present, NGU employs three marine geologists and a research vessel, F/F Seisma, that is engaged in a geological survey of the coastal zone.[19]

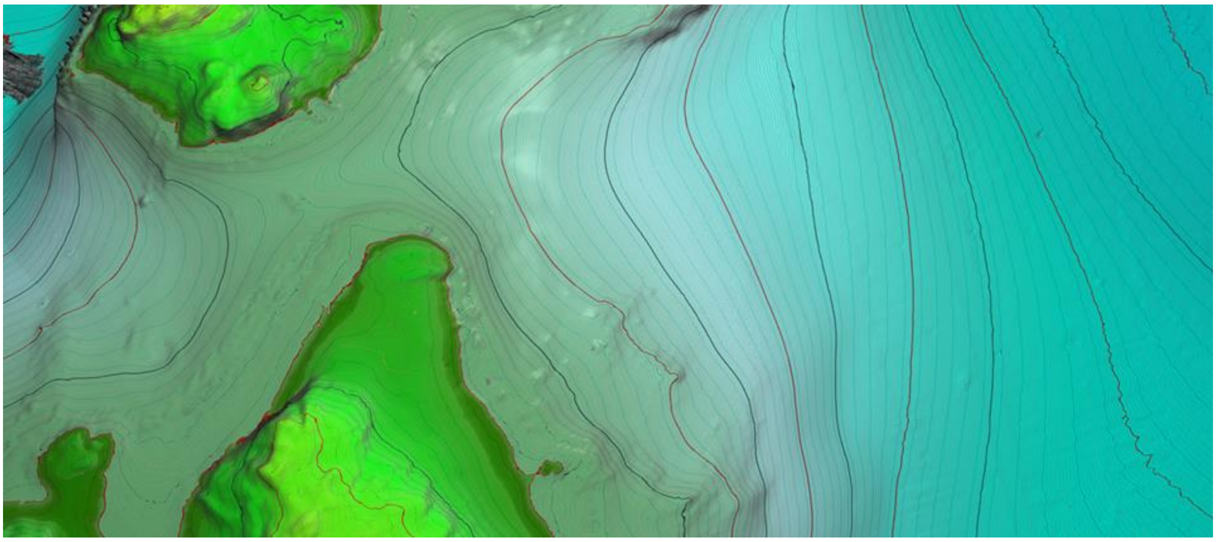
2.1.3. Future growth in the production and processing of marine geospatial data

At present, map data are collected exclusively by means of survey vessels and echo sounders. This is very efficient in deeper areas where the echo sounders can measure large areas within a relatively short time because the sound waves they emit spread in a wide fan shape. Shallower areas are more resource-demanding to measure, because the sound waves spread at a much smaller angle. This means that the survey boat needs to use a long time and move over the same area several times to get satisfactory data. In addition, the boat needs to move slowly to avoid running aground. The boats cannot operate in the shallowest areas close to land, because the boats have too much draft. This shows up as white patches in the charts.

There are other possibilities for mapping shallow waters. There have for example been pilot projects with aerial surveys using green laser for the shallowest areas. In addition, there is now a tender out for this type of survey in Søre Sunnmøre in western Norway. With this method, it is possible to get a contiguous overview over the topography on land and the bathymetry in sea areas. Bathymetric lidar-systems operate in the same way as aerial lidar on land, with one exception: bathymetric systems use two pulses of laser light, one in the infrared and one

[18] The Mapping Authority has three survey launches at its disposal, one of which is purchased and funded by the Norwegian Coastal Administration; however, only two boats can work together with M/S Hydrograf at any given time.
[19] In addition, there are 7-12 FTEs that mainly work on the MAREANO-program.

in the green specter, and are able to collect return signals in order to delimit the water surface and the sea bottom. The infrared pulse is reflected off the surface, while the green pulse penetrates the water and is reflected off the bottom. The results from these types of measurements depend on the water quality. If the water is very clear, the laser manages to collect data from deeper areas than if the water is more turbid. The illustration below shows laser data (in intense colours) on land and a few meters below the water surface, in combination with multibeam data (in lighter colours), which together create a seamless model of terrain and bathymetry.



Further technological progress within data collection is expected, especially with regards to unmanned surface vehicles (USVs). This type of vehicle can operate around the clock, and will significantly reduce the cost of collecting marine geospatial data. This technology is not available for commercial use yet, and it is uncertain when it will be possible to employ it. For this reason, we cannot take this type of technological shift into account in either the zero alternative or in the other alternative measures we present. In all alternatives, we assume a general productivity growth of 1.3 percent per year, in accordance with the figure quoted in the Norwegian Finance Ministry's White Paper *Long-term Perspectives on the Norwegian Economy 2013*. This means that data collection in the zero alternative will take 35 years to complete. It is likely that technological progress will contribute to a productivity growth that is higher than 1.3 percent. This indicates that there might be a "waiting gain" from postponing decisions about major mapping projects. However, as the uncertainty associated with future technological developments is so large, we have chosen to base our calculations on the conservative assumption of the Norwegian Ministry of Finance, despite the fact that our interviews with experts indicate that more efficient technologies are in the pipeline.[20]

With regards to processing and terrain modelling, technological development has progressed even further. Industry and a scientific community have jointly developed an algorithm for the auto-processing of measuring assignments that produces approved terrain models. This technology is so close to implementation that it is highly probable that it will start to reduce costs from 2017 onwards. Experts say that costs for these specific processing tasks may be reduced by 50 percent. Even though the processing takes less time, the mapping project as such will not be completed any sooner, because the time needed for data collection stays the same.

[20] If there is a technological shift, it will be possible to collect more data faster and/or at a lower cost. This will reduce costs in the zero alternative.

2.2. Consequences of insufficient mapping

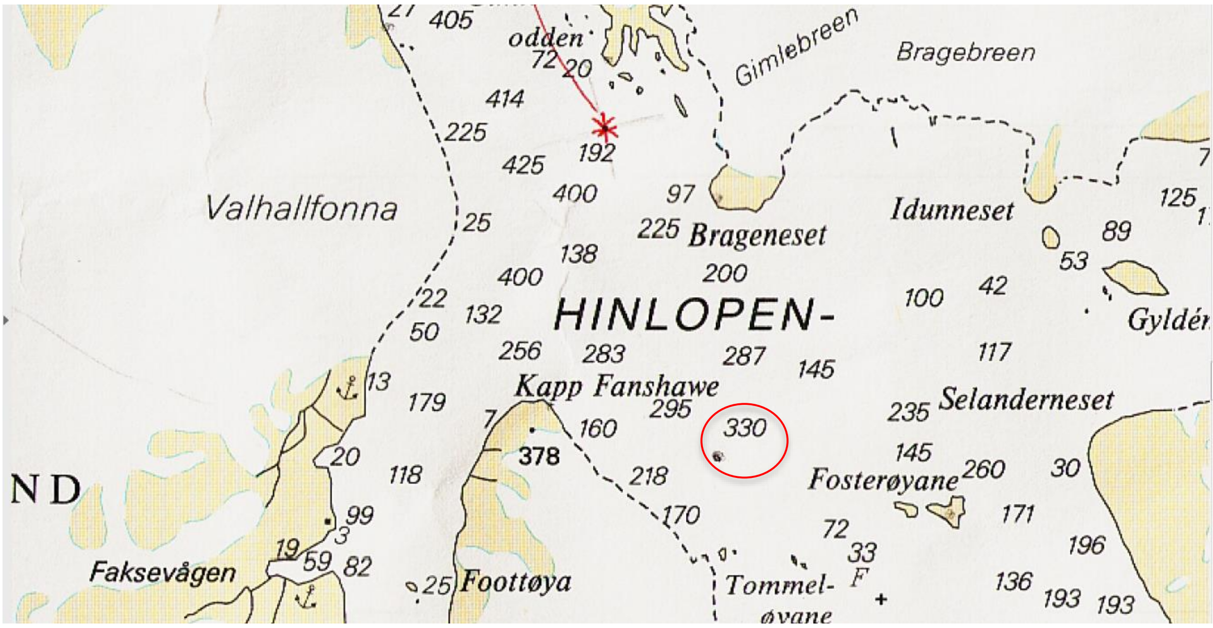
The need for marine geospatial data is increasing, and there is demand for such data from many different actors. Insufficient mapping leads to suboptimal resource management in the coastal zone, because the authorities' knowledge base is not good enough. The coastal municipalities, which have the responsibility for drafting coastal area plans, require detailed marine geospatial data for an optimal administration of the coastal zone. The Government's main objective for the maritime industry is sustainable growth and value creation, avoiding negative effects on the environment and especially vulnerable areas. With an increasing number of commercial actors in the coastal zone, good-quality marine geospatial data are needed to ensure that these considerations are addressed. In addition, the needs of consumers in the coastal areas, such as inhabitants, owners of leisure craft and others that use the coastal zone for recreation, must also be taken into account.

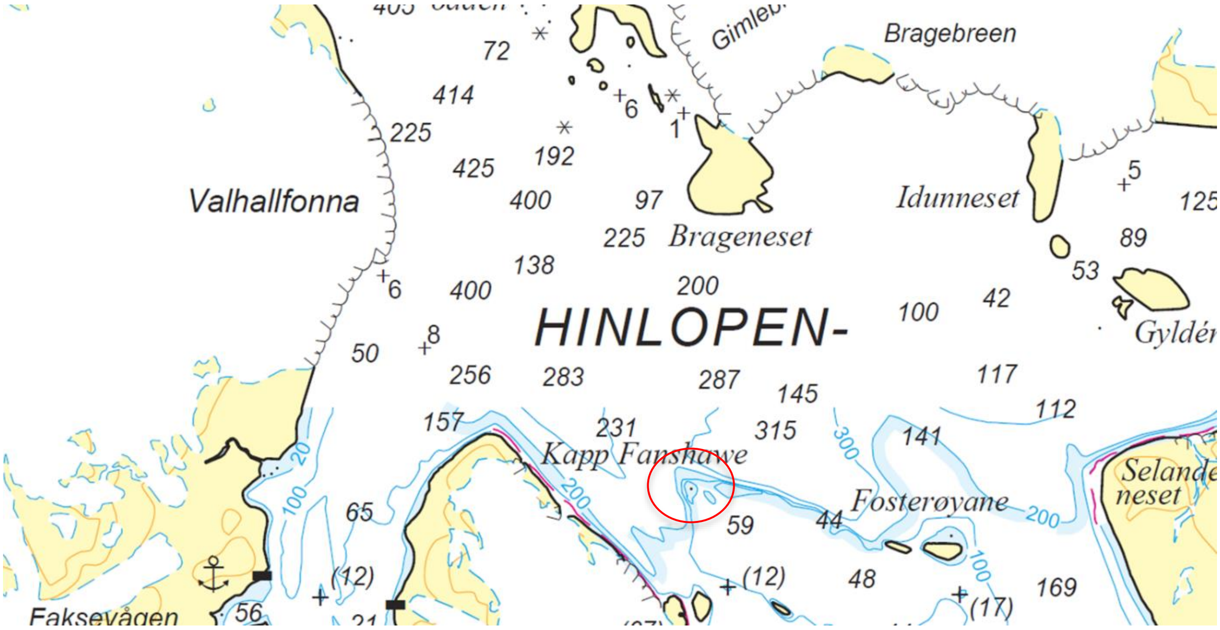
Commercial shipping must have access to updated nautical charts at all times in order to ensure the biggest possible degree of maritime safety. This is important both with regards to avoiding injuries and loss of human lives, but also for environmental reasons and to avoid potential pollution, for example in the form of oil spills. Insufficient mapping is a safety risk for all forms of maritime traffic, both for commercial shipping and for the recreational fleet. Areas for which only old data are available have a significantly higher level of risk than areas which are covered by modern measurements with multibeam echo sounder. Modern multibeam data provide an exact reproduction of the seabed with a high degree of detail with regards to both resolution and depth information. Commercial shipping has developed, and today's ships are both bigger and have deeper drafts than they used to have. This is an additional reason to update old measurements and charts where some shallows might not have been marked because they were considered irrelevant to shipping due to being in fairly deep water.

Updated map data help to prevent especially grounding accidents, but this requires that the maps correctly reproduce depth and terrain information. The Mapping Authority has estimated that currently, there are around 30,000 shallows that have not been mapped. Some areas are particularly high-risk. Svalbard is an area that is poorly mapped; this is partly due to challenging weather conditions and the fact that the season for data collection is short. In addition, its geography changes at a fast rate due to melting ice, which means charts are outdated quickly and safety risk increases. There is relatively little traffic in these areas, but this, in combination with challenging temperature and weather conditions, also means that the consequences of a potential accident will be more serious, since rescue operations are more difficult to carry out. Report to the Storting Meld. St. 32 (2015-2016) *Svalbard* states that it is an explicit goal of the Norwegian government to reduce the risk of unwanted events related to maritime transport on Svalbard, so that damage to life, health and the environment can be avoided. Further work on mapping key sea areas in Svalbard will contribute to achieving this goal.

Below, we show how older nautical charts can mislead users. At the spot shown in the picture, the chart shows a depth of 330 meters; older measurement technology has not managed to detect the shoal the man is standing on, which is consequently not marked in the chart. The picture is from Hinlopen on Svalbard.

The illustration below shows the chart of the relevant area as it looked in 1994. The man in the picture above stands directly south of the point marked «330» in the chart. The following illustration shows the current nautical chart of the area.





Recreational craft do not use chart data to the same degree as modern shipping, and there is no official requirement for them to do so either. Nevertheless, it is a problem that leisure craft run aground on underwater reefs and large rocks that are not marked in the charts. Many leisure craft use sea marks installed by the Norwegian Coastal Administration for orientation. To be able to mark relevant shallows, the Coastal Administration needs reliable map data. This applies mainly to shallow areas that are currently unmapped, especially on the south coast of Norway and in parts of the Oslofjord, which are much used by leisure craft.

With an increasing number of stakeholders in the coastal zone, a detailed knowledge base will be necessary to avoid conflicts between stakeholders. This will enable municipalities to administrate the coastal zone in an optimal way, and may at the same time reduce the number of appeals by stakeholders, which are resource-demanding to handle. This means municipalities will be able to avoid time-consuming appeal procedures and delays in planning and development work related to the coastal zone. Better quality of coastal area plans will also lead to more predictability for all actors, since there will be fewer changes to plans in subsequent years. The Government has also proposed to establish an aquaculture fund that will divide the revenues from concessions for salmon and trout farming. 80 percent of all revenues from future aquaculture permits will go to municipalities and county municipalities through the aquaculture fund. This will reward municipalities that allocate new areas to fish farming. To be able to make good decisions with regards to the location of fish farms, there will be an increased need for marine geospatial data in coastal municipalities.

It is not only the shipping industry and actors in the public sector who benefit from better mapping of the Norwegian coast. Both the aquaculture and the fishing industries need access to good marine geospatial data. The aquaculture industry must uphold acceptable environmental conditions in their pens to be allowed to uphold and potentially increase the number of concessions at a site. Better information about the terrain and conditions on the seafloor are important in order to be able to model ocean currents, which affect environmental conditions in the fish farms. Good quality marine geospatial data will therefore help to choose optimal locations for the fish farms, and thus lead to increased production and value creation in the industry. For the fishing industry, better data will help to avoid damage to fishing equipment, because equipment can be placed more correctly in relation to conditions on the seabed, and to more precise fishing because better information on currents and depths will reduce the amount of resources needed to locate good fishing grounds.

There are also other public bodies in addition to municipalities that need precise marine geospatial data. The Norwegian Public Roads Administration and Statnett (the system operator in the Norwegian energy system) for example carry out infrastructure investments in the coastal zone. Such investments are dependent on very good and detailed marine geospatial data. If these are not available in existing maps, operators must collect these data with the help of private suppliers. Telenor is another example of an operator that also depends on marine geospatial data, for example for the installation of sea cables.

In its maritime strategy, the Norwegian government focuses both on blue growth and on research and development within the ocean-based industries. Other official government documents that emphasize research related to the coastal zone include Report to the Storting Meld. St. 16 (2014-2015) *Forutsigbar og miljømessig bærekraftig vekst i norsk lakse- og ørretoppdrett* [Predictable and environmentally sustainable growth in Norwegian salmon and trout farming], Report to the Storting Meld. St. 7 (2014-2015) *Long-term plan for research and higher education 2015–2024* and Report to the Storting Meld. St. 14 (2015-2016) *Nature for life — Norway's national biodiversity action plan*. The National Biodiversity Strategy and Action Plan is also relevant in this context. Good access to marine geospatial data is of key importance for high quality research, because these data are an input-factor in this type of research. All reports to the Norwegian parliament focus on the necessity of having a detailed knowledge base for further research and development of the coastal zone.

Another area wherein marine geospatial data is likely to provide benefits is preparedness for acute pollution. Bathymetric data are important to develop better ocean current models. These can in turn be used to help predict for example oil spill drift. In addition, the data can be useful when trying to locate suitable areas for depositing waste from mines and cleaning up areas with old environmental pollution. Mapping is also important for the prediction of tides, and can provide indications where to place renewable energy sources at sea, for example offshore wind farms. A last actor that also profits from the mapping, which also collects its own data, is the Norwegian Armed Forces. For this reason, the results of the mapping effort carried out by the Mapping Authority constitute classified information. This limits the amount of map material that is available to the civilian actors mentioned above, which in turn has an impact on the potential benefit for these actors.

2.3. Market failure with regard to the collection of marine geospatial data

The map data are valuable for public and private actors, and there is reason to ask why the private market does not generate a higher rate of collection and production. The map data collected for the coastal zone are defined as classified information for a resolution higher than 50*50 meters and for some contour lines.[21] This means that private actors without security clearance are not allowed to collect map data with a higher degree of detail. However, this still occasionally happens. But even without any restrictions on the collection and production of map data, private actors would not have produced an economically optimal amount of map data. The reason for this is that there are several market failures in this market. The two most important ones are the following:

- There are coordination problems related to data collection
- There are external effects that are not reflected by the market, for example the effects of avoided oil spills and avoided accidents

[21] *Svalbard is not covered by the security classification regime. All multibeam data for Svalbard are provided with a resolution of 10*10 meters or more. Contour lines that can be shown on maps, and which are not classified, are the following (in meters): 2, 3, 5, 10, 20, 30, 40, 50 and 100 m. Beyond 100 meters of depth, there are 50 meters between the depth curves.*

Lack of coordination is a form of market failure that is related to the collective action problem.[22] In short, this means that the costs and the complexity of coordinating an activity that is for the common good can be so large that nobody has an incentive to bear these costs. Even though many actors benefit from the map data, and the actors' total willingness to pay is higher than the cost of collecting the data, it can be difficult and/or expensive to coordinate joint data collection. In addition, there may be coordination challenges related to the fact that the actors do not know who else is going to benefit from the same data. One coordinator (the Mapping Authority in this case) who takes the responsibility for collecting the map data can thus trigger benefits related to the data which otherwise would not have been triggered.

Another argument related to market failure, developed by Kenneth Arrow (1962), makes the point that private actors and companies cannot fully internalize the positive effects of their investments going to other actors, and, in this case, society as a whole. Such positive externalities are for example avoided accidents and avoided environmental catastrophes, for example oil spills from grounded ships. Since private actors do not take these positive externalities into account, a perfect competition stuation will lead to an equilibrium with underproduction of map data and an efficiency loss for society. The details of this efficiency loss are shown in appendix 2. If the market suffers from market failure, this indicates that the state can try to correct this market failure either by means of public policy measures, like subsidies for increased production, or by public production that takes the external effects into account.

Based on the consequences described above, and the arguments for the existence of a market failure that makes it likely that there will be an underproduction of marine geospatial data, we have assessed whether it would be economically profitable to increase the rate at which marine geospatial data are collected. A description of the relevant measures to achieve this follows in the next chapter.

[22] *See Hardin, Russell (1982). Collective Action. Baltimore, MD: Johns Hopkins University Press. A purely economic approach to the collective action problem can be found in: Sandler, Todd 1992 Collective Action. Theory and Applications. Hertfordshire, Harvester Wheatsheaf.*

3. Description of the proposed measures

The main challenge in relation to the collection of marine geospatial data is that the process takes a long time. Therefore, the time dimension for the collection and processing of map data is the decisive factor for the choice of measure. The alternatives presented here are construed based on at what rate (how fast) it is economically profitable to collect these data.

3.1. Description of measures

The general problem statement is based on the fact that the need for marine geospatial data is increasing, and that collecting them takes a long time. Above, we have listed a number of actors that use this type of data, and pointed out the potential consequences of unsatisfactory mapping. It is, however, important to consider the cost aspect of this type of data collection, and how fast collection activities should be scaled up. The main challenge is that mapping with modern methods is unsatisfactory, and that it will take 35 years to map the coastal zone to a modern standard at today's rate of collection. There are several potential reasons why data collection takes a long time. Here, we have looked at the following dimensions that influence the amount of mapping that is produced:

- Rate of collection – how quickly the coast is being mapped
- Organization of collection – how mapping is organized
- Form of collection – how mapping is carried out

The rate of collection is the most obvious factor affecting the amount of mapping that is produced. If the Norwegian Mapping Authority had had more resources, such as more survey vessels and crew to operate them, and to process and produce maps, the areas would be mapped more quickly.

As far as the organization of data collection is concerned, the Norwegian Mapping Authority collects the lion's share of map data, but also the Norwegian Armed Forces and, to some degree, NGU engage in data collection. The Mapping Authority and the Armed Forces share data, but there is no coordination with regards to the areas that are mapped. Another influcencing factor is the Norwegian Mapping Authority's internal organization with regards to the collection of map data. For example, M/S Hydrograf and the associated survey launches spend 10 weeks collecting marine geospatial data in the Svalbard archipelago every year. The season for surveys around Svalbard is short, therefore these activities must be carried out in summer. This means that both the main ship and the smaller vessels are moved away from the Norwegian coast at a time when the conditions for measuring are optimal there. The Mapping Authority also has a separate list of priorities for how they plan which areas are to be mapped. This list looks as follows:

1) Shipping lanes for commercial traffic should be covered by multibeam data. This applies to both official shipping lanes and to other areas that experience considerable maritime traffic.
2) Important areas for Norway's leisure fleet should be covered by multibeam data.
3) If possible, the measured areas should be covered in their entirety (all the way in to the coast).
4) Areas that have never been measured before should be measured.

The map data are collected with the help of vessels (M/S Hydrograf and two survey boats) with multibeam echo sounders. This is efficient in deep water, but resource-demanding in very shallow areas (0-5 meters). Thus, there might be other methods, such as using planes, that are more efficient in shallower waters. The possibility of surveying by plane however depends on various factors, including water quality.

Based on discussions with the Mapping Authority, we have arrived at the conclusion that the time dimension is the most important factor when trying to increase output of map data. It is necessary to decide on the rate of collection first, and then find the optimal way of achieving it. As far as the organization of data collection is concerned, it is difficult to coordinate collection between a civilian and a military actor where considerations of national security have to be taken into account. It is obvious that the Mapping Authority and the Armed Forces have different priorities for data collection, and that these priorities are difficult to align. As regards internal organization and prioritization within the Mapping Authority, these issues can partially be solved by increasing mapping capacity. If the number of survey vessels is increased, the Mapping Authority will be able to collect marine geospatial data more efficiently. One reason for this is that less time will be spent in transit from and to Svalbard, and because the weather window in summer can be utilized more efficiently. The measures presented below therefore differ from the zero alternative with regards to the time dimension, and entail faster data collection than the zero alternative. The alternatives are as follows:

- Alternative 1: All mapping completed within 25 years
- Alternative 2: All mapping completed within 20 years
- Alternative 3: All mapping completed within 15 years
- Alternative 4: All mapping completed within 10 years

All alternatives imply increasing the general rate of data collection.[23] The only difference between the four measures is *how much* the rate of collection is scaled up. In the first alternative, collection time is reduced by ten years, from 35 years to 25 years. After this, collection time is reduced by 5 years in each of the three following alternatives, so that all data will be collected within a period of 20 years, 15 years and 10 years respectively. Currently, the Mapping Authority sees a period of 10 years as a realistic lower limit for how quickly it will be possible to gather all data. Once an area has been mapped, the data will in principle be available in perpetuity. The value of mapping more quickly than planned derives mainly from the fact that more people will benefit from the data (as the data are available for more years), but the economic value also rises because the benefits are realized earlier (effects further out in the future have a lower value because of discounting[24]). It is for example possible to say that if an area is mapped earlier than it would otherwise have been, this can help to prevent a larger number of accidents and thus increase total realized benefit.

Both in the zero alternative and in the other alternatives, we assume that mapping activities happen linearly over the time period in the alternative. Mapping progress is shown at five year intervals for each of the alternatives in the table below.[25]

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[23] We have also assessed an alternative that implies a scale-up of activities for a shorter period (5 and 10 years), but this would entail some training costs one would not get the full benefit of with a short-time 'boost' to mapping. We have therefore focused on a general scale-up in the alternatives we present.

[24] To discount means to convert an amount of money to another point in time than the actual date of payment. One krone in the future is worth less than one krone today because of lost interest, inflation and risk. The discount rate is therefore a risk-adjusted rate of return.

[25] We assume that the size of the area mapped will increase by 1.3 percent each year due to technological improvements while the amount of available resources stays constant. In our model, we do not make allowances for the fact that some areas are more resource-intensive to measure than others. In addition, we do not consider at what time mapping activities are carried out in which specific areas. We assume that unmapped areas will be mapped linearly, meaning that a small part of these is mapped each year. This has been a necessary simplification to enable us to calculate the benefits.

Table 1: Percentage of the total unmapped area as per 2016 that will be mapped in the different alternatives over time. Source: Menon Economics, Geological Survey of Norway (NGU) and Mapping Authority

	5 years	10 years	15 years	20 years	25 years	30 years	35 years
Zero alternative Mapping Authority	12	24	37	52	67	83	100
Zero alternative NGU	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Alt. 1: 25 years	17	35	56	77	100		
Alt. 2: 20 years	21	46	72	100			
Alt. 3: 15 years	31	66	100				
Alt. 4: 10 years	44	100					

The zero alternative assumes that the Mapping Authority will map all areas within 35 years, with the same amount of resources that are available today, and a yearly productivity growth of 1.3 percent.

The Geological Survey of Norway (NGU) currently has three marine geologists and one research vessel, F/F Seisma, at its disposal. These are employed in a geological survey of the coastal zone. The vessel is old and NGU expects that it will have to be retired as of 2022. It will not be possible to continue the geological survey without a functioning vessel suited to NGU's requirements. Since no funding has been allocated for the purchase of a new ship for NGU yet, we assume in our zero alternative that NGU's geological survey will terminate after 5 years.[26] As NGU's activities will stop after five years, NGU will only map 4.3 percent of the remaining areas in the zero alternative, assuming a productivity growth of 1.3 percent.[27] In the alternative measures, we assume a scale-up that will allow both the Mapping Authority and NGU to finish their data collection within 25, 20, 15 and 10 years respectively.

3.1.1. Scale-up for Mapping Authority

Our starting point for all alternatives is the basic capacity of the Mapping Authority in the zero alternative, consisting of M/S Hydrograf, two survey boats with crew, 64 FTEs within data processing and 10 FTEs within administrative tasks. In addition, we have calculated for each alternative how large the scale-up of activity must be to enable the Mapping Authority to complete data collection within the respective number of years in the individual alternatives. The extent of this scale-up will be different for collection and processing of marine geospatial data, because there will be economies of scale in processing due to the scale-up and technological development differs within departments. The Mapping Authority assumes that it will take half a year to charter survey vessels and consultants before start-up of contracts. In addition, it reckons with half a year of training time before these can start production. This means that the faster the rate of data collection, the bigger the share of the allocated time that is spent on hiring and training resources. This means that the use of resources in

[26] *It is fairly unlikely that NGU will not receive funding for the purchase of a new vessel. Alternatively, it may get funding for other solutions such as chartering from private actors. However, at present there are few realistic options for charter, since NGU will need a highly specialized vessel. Even though NGU will probably receive funding that will enable it to continue its data collection, we must assume that collection stops in the zero alternative when F/F Seisma is retired. This is due to the fact that as per today, no funding has been approved, and according to the guidelines for cost-benefit analyses by the Norwegian Government Agency for Financial Management, the zero alternative must not contain budget allocations that have not been confirmed.*

[27] *More details on NGU's scale-up and costs are available in appendix 3 (12.3).*

relation to the area that is mapped increases the higher the collection speed. With regards to data collection, we base our calculations on a linear scale-up. This means that if the target is to double the amount of collected data, resources for data collection need to be doubled.[28] The necessary scale-up for the collection of data in each of the alternatives is presented in the table below.

Table 2: Scale-up of mapping activity in the different alternatives

Alternatives	Scale-up of mapping activity (in percent)
Alt. 1: 25 years	50
Alt. 2: 20 years	95
Alt. 3: 15 years	175
Alt. 4: 10 years	340

To map everything within 25 years, activity needs to be scaled up by 50 percent. This means that the Mapping Authority needs one additional survey boat for 25 years. For alternative 2, a scale-up of 95 percent is required to map everything within 20 years, i.e., two additional survey vessels. Alternative 3 entails a scale-up of 175 percent. This means an average 3,5 survey boats are needed during the survey period. We have modelled this in the form of 4 additional survey boats in the first half of the period and 3 additional survey boats in the second half of the period. The scale-up for alternative 4 is 340 percent, which translates into 7 additional survey boats during a mapping period of 10 years.

Where processing work is concerned, costs do not rise proportionally with the scale-up. The reason for this is threefold: The need to train new/contract workers increases unit costs when the collection period is shortened. In addition, there is ongoing development within technology/productivity throughout the period, which also raises unit costs when data are to be collected within a shorter time span. There are, however, certain fixed costs related to data processing that make it possible to exploit economies of scale when more data are collected in less time. This has a dampening effect on cost increases. More detailed information on how we have modelled the scale-up of data processing is available in chapter 4.

We have assumed that the scale-up of both collection equipment, crew and processing workers is effectuated by chartering/contracting, not by investing into own equipment and expanding the number of permanent staff within the organization. The reason for this is that the scale-up is temporary, and therefore it does not make sense to create permanent positions for these extra resources within the Mapping Authority.

The Mapping Authority's main survey vessel, M/S Hydrograf, was built in 1985, and maintenance costs are expected to increase during the analysis period. The Mapping Authority assumes that M/S Hydrograf will pass its next class renewal survey in 2020, but that the following survey five years later in 2025 might present challenges if maintenance spending is not increased considerably. All alternatives are therefore based on the assumption that M/S Hydrograf will be replaced by a chartered vessel in year 9 of the analysis period (2025). Alternative 4 is an exception to this, as there is only one year of mapping time left when M/S Hydrograf is replaced by another vessel in alternative 1-3. It is not realistic to expect that a vessel can be chartered for one year, since it will most likely have to be customized to the Mapping Authority's requirements. In this particular case, we assume that the Mapping Authority will bear the additional maintenance costs for M/S Hydrograf for the one year until

[28] *There are certain exceptions to this, see appendix 3 (12.2.) for a more detailed discussion.*

mapping is completed. The smaller survey boats are replaced after a period of approximately 15 years, and their echo sounders every 7th year. This has been taken into account in the Mapping Authority's budget and accounting figures.

3.1.2. Scale-up at NGU

NGU expects the vessel it uses for geological surveying to be retired in 2022. All alternatives therefore assume that it will be necessary to procure a specialized vessel at a cost of NOK 45 million after 2022. The exception to this is an assumed data collection period of 10 years, in which case NGU will have to purchase two vessels. Currently, NGU employs 3 marine geologists (zero alternative) that are mapping the coastal zone; the capacity of its remaining marine geologists is tied up in the MAREANO-program. NGU estimates that it will need 15 marine geologists to survey the coastal zone if the target is to map the whole Norwegian coast within a period of 15 years. There are still approximately 80 000 km^2 of unmapped areas left along the Norwegian coast (excl. Svalbard[29]). This means that NGU will map approximately 427 km^2 per man-year. Based on this, we calculate the number of man-years that will be needed to map 80 000 km^2 given the number of years that are available for mapping in each of the alternatives and assuming that one man-year equals 427 km^2 of mapped area.[30]

3.2. Scale-up of resources in the individual alternatives

In the table below, we show the differences in resource use in the five alternatives in form of equipment and man-years. The first alternative entails a reduction of total mapping time by 10 years, to 25 years in total. This implies a 50 percent increase in data collection capacity, and mapping will be completed in 2041. In the remaining alternatives, mapping will be completed in the years 2036, 2031 and 2026 respectively.

Table 3: Scale-up of resources in the individual alternatives

	Zero alt.	Alt. 1	Alt. 2	Alt. 3[31]	Alt. 4
Scale-up of data collection capacity	0	50	95	175	340
Mapping completed	2051	2041	2036	2031	2026
No. of chartered survey boats (incl. crew)	0	1	2	3.5	7
No. of hired consultants for data processing	0	20	38	74	150
Replace M/S Hydrograf	Yes	Yes	Yes	Yes	No
No. of new vessels for NGU	0	1	1	1	2
No. of marine geologists	3 in 5 yrs.	8	11	15	25

The extra capacity described in the table above comes in addition to the Mapping Authority's and NGU's capacity in the zero alternative. After nine years, in 2025, maintenance costs for Hydrograf are expected to exceed the

[29] The benefits for Svalbard are mainly related to maritime safety. These are benefits that are triggered by the Mapping Authority's activities alone. It is therefore sufficient to look at NGU's costs for the geological mapping of the Norwegian coast excluding Svalbard in this analysis.

[30] More details about our calculations regarding the scale-up at NGU are available in appendix 3.

[31] A scale-up of 75 percent would correspond to chartering an additional 3,5 survey boats. To charter a survey boat for half of each year for each year of the analysis period would be inefficient, and it would likely be difficult to find a supplier willing to enter into such a contract. We have therefore modelled the scale-up as 200 percent in the first half of the analysis period and 150 percent in the other half. Thus, 4 survey boats and 85 consultants will be hired for the whole year during the first 8 years, while 3 vessels and 63 consultants will be contracted for the remaining seven.

costs for chartering a comparable vessel. At that point, M/S Hydrograf will be replaced by a chartered vessel in the first three alternatives.

3.3. Cost-benefit analysis of faster rate of data collection compared to the zero alternative

Costs will run for 35 years in the zero alternative, while the benefits of the map data will last much longer; in principle, their lifespan is unlimited. This makes it challenging to calculate the total benefit deriving from the fact that the whole coast has been mapped. However, the more specific question we are trying to answer is whether it will be profitable to scale up the rate of data collection compared to the zero alternative. This means we carry out a *relative* analysis where we relate the changes in costs to the changes in benefit by scaling up the rate of data collection. If resource use continues as today, which is the basic assumption for the zero alternative, the whole Norwegian coast will be mapped within 35 years.[32] All other alternatives entail a faster rate of collection. This means that after 35 years, costs and benefits for all alternatives are equal. We therefore set the length of the analysis period to 35 years.[33] In this way, we analyze if the increased benefits of mapping the coast within 25, 20, 15 or 10 years respectively instead of within 35 years as in the zero alternative are higher or lower than the cost increase caused by speeding up the rate of data collection. If the increased benefit resulting from a measure is higher than the cost increase caused by the implementation of the measure, the measure will result in a positive net economic benefit. If the net economic benefit is positive, it is economically profitable to scale up the rate of data collection.

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[32] *The Mapping Authority has itself estimated that data collection for the remaining areas (including Svalbard) will take 44-45 years. Assuming annual productivity growth of 1.3 percent, it will take 35 years to complete the mapping. The figure for productivity growth is based on Report to the Storting Meld. St. 12 (2012-2013) Perspektivmeldingen 2013. The geological survey will not be completed in the zero alternative because no official decision has been made with regards to funding for a new vessel that is needed to finish the survey. The benefits, except for the effects related to maritime safety that depend on the Mapping Authority alone, will therefore be realized only to a small extent in the zero alternative. The geological survey of NGU will only run for a period for 5 years as NGU's survey vessel will be retired in 2022. This assumption may seem fairly unrealistic, but since funding for a new vessel has not been officially approved yet, we have chosen the most conservative version of the zero alternative.*

[33] *A longer analysis period will not have any effect on the ranking of measures.*

4. Analysis of economic costs

The costs for a scale-up in the rate of collection and processing of marine geospatial data can be roughly divided into the Norwegian Mapping Authority's internal costs for production and administration, and costs for hiring external resources. In addition, there are also expenses for geological surveying and the production of thematic maps for NGU, and tax funding costs following from increased use of public resources. Naturally, there are increased costs associated with implementing the measures, compared to the zero alternative, because they entail increased use of external resources which are more expensive than the Mapping Authority's own production.

4.1. Calculation of economic costs

The economic costs for the five alternatives consist basically of the same components, and can be divided into the following categories:

- Costs related to the collection of marine geospatial data at the Mapping Authority (M/S Hydrograf and two own survey boats, plus chartered vessel as a replacement for M/S Hydrograf after nine years)
- Internal employees at the Mapping Authority working with data processing
- Administration costs and fixed costs related to taking measurements at sea and processing these data
- Chartered survey boats with crew
- Hired consultants for data processing
- Costs at NGU for geological survey and production of thematic maps
- Tax funding costs

The difference between the alternatives is how many external resources are needed to be able to complete the mapping within the given time horizon for the respective measures. Below, we explain in more detail what is included in each of the cost items above.

4.1.1. Collection of marine geospatial data at the Mapping Authority

The Mapping Authority owns a survey vessel (M/S Hydrograf) and two survey launches. The number of FTEs allocated to M/S Hydrograf and the survey boats is presently 22. The costs for the operation of these boats have been obtained from the Mapping Authority's result report for the Hydrographic Service division in the first half of 2016, which also includes the budget for 2016 as a whole. After nine years, we expect that there will be a transition to the long-term charter of a vessel. This is the point at which the Mapping Authority assumes that the costs of continuing to use M/S Hydrograf will exceed the costs for chartering. For long-term charter, a cost estimate has been obtained from a company that offers similar vessels. The costs for the Mapping Authority's operation are presented in the table below.

Table 4: Yearly costs related to the Mapping Authority's internal collection of marine geospatial data. Source: Mapping Authority

Mapping Authority's production of marine geospatial data	Costs 2016 (NOK mill.)
Costs related to Hydrograf (incl. crew and operation of survey boats)	34.6
Costs for chartered vessel (incl. crew and operation of survey boats)	52.6

Costs will rise once a vessel has to be chartered, but they are still lower than the estimated costs for keeping M/S Hydrograf in operation after nine years.[34] A more detailed description of the total costs for chartering and how costs for M/S Hydrograf will increase in the period up to the transition to chartering is available in appendix 3 (12.1).

The Mapping Authority has a close cooperation with the Norwegian Coastal Administration. The Coastal Administration owns a survey launch, which the Mapping Authority operates on behalf of the Coastal Administration. This survey boat carries out measurements in the areas prioritized by the Coastal Administration. This can for example be related to improvements to shipping lanes. Operation of this survey boat is constant for all alternatives, and thus does not affect costs across the alternatives.

4.1.2. Processing and administration costs for the Mapping Authority

Some of the processing of the data material is done by hydrographers on board M/S Hydrograf, but a lot of the processing work and the map production is carried out at the offices of the Hydrographic Service division in Stavanger. Like all organizations and activities, the hydrographic survey and processing unit in the Mapping Authority has some fixed costs related to its activities.

The employees are distributed within the following areas within processing and chart production as per today:

Table 5: FTEs distributed between activities within processing, chart production and administration in 2016. Source: Mapping Authority

Activity	No. of FTEs
Processing	9
Oceanography	5
Bathymetry	7
Terrain modelling	3
Updating	11
Chart production	19
Technology support	10
Administration	10
Total	74

In total, there are 64 employees working with processing and map production and 10 in administrative positions in the Mapping Authority related to hydrographic survey activity. The calculated costs for these activities in 2016 are shown in the table below and estimated based on the 2016 budget for the Hydrographic Service.

[34] *It is important to point out that the charter rate will depend both on required adaptations for the vessel, length of the contract period and the general market situation for ship charter.*

Table 6: Costs related to the Mapping Authority's internal data processing, map production and administration in 2016. Source: Mapping Authority

Activity	Costs (NOK million)
Processing and map production	84.4
Administration and fixed costs	36.1

An efficiency improvement of the processing tool will affect some of the activities above. Especially processing, terrain modelling and partly also bathymetry will be affected by this technological change. The estimates are that the technological improvement will result in a cost saving of 50 percent within the two first activities, while bathymetry will achieve an efficiency gain of 12.5 percent.[35]

At present, there are 13 FTEs in the Mapping Authority that will be affected by this change. That means that on average, during the analysis period, only 6.5 FTEs are needed to carry out processing work once the new technology has been implemented. Presently, there is some backlog of processing work, and it is therefore not realistic that the Mapping Authority will reduce the number of FTEs in processing already by 2017 and hold this constant over the period. We assume a steady reduction in the number of FTEs to 6 in year 8 (2024) of the analysis period and hold this constant in the period from 2025-2040, before a further reduction to 5 FTEs from 2040-2051. This results in an average of 7 FTEs per year within processing work. The development in FTE-reduction in processing is shown in the table below.

Table 7: Reduction in FTEs for the units that are affected by technological development in the area of processing in the zero alternative

	2017	2018	2019	2020	2021	2022	2023	2024-40	2040-51
FTEs	13	12	11	10	9	8	7	6	5

How exactly this change of technology will affect the number of FTEs associated with the individual activities in the different alternatives is shown in appendix 3.

4.1.3. Chartered survey boats and hired consultants

Internal production at the Mapping Authority is the same in all alternatives.[36] The scale-up in the different alternatives is carried out by hiring external consultants and equipment, both for collection and processing. Since the scale-up in the Mapping Authority's capacity is not meant to be permanent, we assume in this analysis that the most appropriate solution is to hire this capacity on a temporary basis. The Mapping Authority has experience with this from the mid-2000s through a project to speed up the mapping of the seabed ('Forseringsprosjektet'), where private actors were hired to assist for a limited period. An overview over important rates for the hire of external consultants and equipment and the timeline for procurement and training is presented in the table under.

[35] The estimate of 50 percent cost savings is a net effect where costs for purchasing and use of the program have been taken into account.
[36] With the exception of adjustments for FTEs within processing related to technological development.

Table 8: Specification of costs and time periods related to hire of resources

Specification	
Daily charter rate for survey boat incl. crew (NOK)	65 000
Yearly rate for survey boat incl. crew (NOK million)	23.7
Cost per FTE for hired consultants (NOK million)	1.2
Time required to hire consultants and procure equipment	6 months
Training time per consultant	6 months

The charter rate for a survey boat (including crew and operation) as per today is estimated to NOK 65 000 by the Mapping Authority. The charter cost for a survey boat for one year is therefore approximately NOK 23.7 million. For consultants, the Mapping authority estimates a cost of NOK 1.2 million per FTE per year. This is based on the rates for hire of consultants on previous occasions. The Mapping Authority estimates that it will take approximately 6 months to organize the necessary tender processes and procure consultants and equipment. Thereafter, there will be a training period of 6 months for the external consultants. This means that in all alternatives, increased production will first start in year 2 of the analysis period. The costs for consultants and equipment will begin to run after 6 months, when the contracts are signed and the training period has started.

As discussed above, a scale-up of collection activity will also lead to a scale-up of processing and administration costs. The Mapping Authority has itself estimated how much it expects these activities must be scaled-up if the rate of data collection is doubled. Detailed information about this scale-up for the different activities is available in appendix 3.

4.1.4. Tax funding costs

In cost-benefit analyses, in addition to calculating the administrative costs, it is also necessary to consider what kind of loss society incurs because of funds having to be raised through taxes and fees to finance a good or a service. This cost is often called tax funding cost. The Norwegian Ministry of Finance informs in its circular R-109/14 that a tax funding cost of 20 percent of tax revenue should be assumed in cost-benefit analyses. This is the basis for the calculation of total costs in this analysis.

4.1.5. NGU

As mentioned earlier, the users of marine geospatial data, with the exception of effects related to maritime safety, also need access to a number of thematic charts produced by NGU in order to be able to realize maximum benefit. This includes sediment maps and maps showing anchoring conditions. NGU's costs for geological surveying therefore have to be included in the analysis. NGU's costs are modelled in a simpler way than the costs for the Mapping Authority,[37] and these estimates are therefore somewhat less certain.

NGU has calculated its costs for the production of thematic maps to NOK 500 million for the whole length of the Norwegian coast if this project is completed within 15 years. These calculations were carried out in connection with the compilation of a memorandum where the Mapping Authority and NGU advocate the establishment of a national map program covering the coastal zone (MAGIN). The estimate assumes that an area of 80 000 km^2

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[37] *The reason for this is that we have received cost estimates from NGU, while we have been able to get more detailed information from the Mapping Authority.*

remains to be charted, and that the average cost per square meter will be NOK 6250. This calculation of remaining km^2 to be mapped does not include Svalbard.

Per today, NGU has a research vessel, F/F Seisma, that is used for geological surveying. This vessel is old, and, amongst other drawbacks, not well suited to winter use. NGU assumes that this vessel will be in operation until 2022. To be able to continue mapping after this point in the zero alternative and the scale-up alternatives, NGU needs a new vessel. In the zero alternative, we assume that the geological survey (and the related costs) will terminate after 2022, because no funding for a new vessel has been approved yet. At present, NGU's assessment of the situation is that chartering a new vessel is not a viable solution, because this will require so many special adaptations that it will not be possible to find a supplier that will offer such a ship.[38] NGU estimates that a suitable vessel will cost approximately NOK 45 million. If the mapping is supposed to be completed within a ten-year period, NGU assumes that it would have to invest in two vessels to ensure sufficient capacity.[39]

With regards to crew, a somewhat longer training period will be required than for the Mapping Authority. The training is a combination of theoretical instruction and «learning-by-doing», with a duration of 1.5 years. In addition, there is uncertainty with regards to exactly how many marine geologists are needed to carry out the mapping.

NGU estimates that it will be necessary to employ 12 FTEs in addition to the three internal FTEs working on mapping the coastal zone today if the whole Norwegian coast is to be mapped within 15 years. This is the basis of our calculations.[40] Subsequently, we calculate how many square kilometers must be mapped per FTE to be able to cover 80 000 km^2 within 12.5 years (i.e., 15 years minus the training time of 1.5 years and one year needed for the recruiting process). Based on this, we make a calculation of how many marine geologists are needed in each of the scale-up alternatives, and calculate a training cost for each alternative. If the mapping is to be carried out at a faster rate, more marine geologists need to be trained. Since NGU assumes the same cost per square kilometer mapped in all alternatives, it is the cost related to training that makes up the extra cost for scaling up data collection. A more detailed review of how NGU's costs have been modelled is available in appendix 3.

4.1.6. Real wage adjustment of costs

The main rule with regards to price adjustments in a cost-benefit analysis is to keep all prices unchanged during the analysis period. This entails an assumption that all prices increase at the same rate (i.e., at the rate of the consumer price index). This follows from circular R-109/14 by the Norwegian Ministry of Finance. There might however be technical reasons to adjust calculation prices, because we expect a development that differs from that of the consumer price index. Such changes are called real price adjustments.

The value of time is one of the goods that cannot be observed in a market; therefore, the circular by the Norwegian Ministry of Finance provides guidelines for how it should be calculated. The value of time at work

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[38] *If a suitable ship comes onto the market within five years, a long-term charter will be possible. Since there is significant uncertainty associated with this possibility, we can however not take this into account in our analysis.*

[39] *The residual value of the ships is not included in the analysis due to lack of information on the sales value. The sales value will probably be the higher the quicker the mapping is completed. This is a non-priced effect that will somewhat reduce the cost increases associated with the different alternatives at NGU.*

[40] *If the mapping is supposed to be completed within 15 years, we have assumed that the number of marine geologists needed is 15. Hereafter, the necessary number of marine geologists in the remaining alternatives is calculated on this basis. In the uncertainty analysis, we have used a respective number of 10 and 20 marine geologists as an upper and lower estimate.*

shall be adjusted by expected growth in GNP per inhabitant as stated in the Finance Ministry's white paper *Long-term Perspectives on the Norwegian Economy 2013*. This means that wage costs are to be adjusted by 1.3 percent per year in cost calculations. This is based on the assumption that an expected productivity growth of 1.3 percent per year will allow a corresponding yearly growth in real wages. Based on the Mapping Authority's result report for the first half of 2016 and its budget for 2016, we have split all administrative costs, costs related to M/S Hydrograf (and later an equivalent chartered vessel) and costs for processing into wage costs and other costs. Costs for hired consultants are adjusted in the same way.[41] We have not made a real price adjustment for wage costs for the crew operating chartered survey boats and vessel(s) equivalent to M/S Hydrograf. These are persons that are employed by the suppliers of long-term charter for these vessels. The relevant charter contracts will probably be structured based on year-round operation of the vessels, but without any specific requirements with regards to the number of person-hours worked on each boat. It will therefore be possible to realize productivity improvements in the form of reduced person-hours rather than higher wages.[42]

4.2. Comparison of costs for the different alternatives

As mentioned above, we start from the zero alternative and look at changes in costs and benefits for each of the alternatives compared to the zero alternative. Here we show how the costs change within each of the cost categories outlined in the introduction to this chapter compared to the zero alternative.

Table 9: Economic costs at net present value, difference from zero alternative (NOK million, fixed prices 2016)

Cost category	Alt. 1: 25 yrs.	Alt. 2: 20 yrs.	Alt. 3: 15 yrs.	Alt. 4: 10 yrs.
Collection Mapping Authority	-176	-291	-429	-587
Processing Mapping Authority	-268	-432	-675	-961
Administration Mapping Authority	-89	-145	-211	-288
Chartered survey boats	359	622	905	1 267
Processing - hired consultants	414	672	1 079	1 495
NGU	350	376	411	492
Tax funding costs	118	160	216	284
Net cost	**708**	**963**	**1 296**	**1 702**

The table shows that all measures will result in increased costs compared to the zero alternative. This is to be expected, since a scale-up requires external resources and these resources are more expensive than the Mapping Authority's own internal production. In addition, significant investments are needed to scale up NGU's activity. In all alternatives, we see that costs for the Mapping Authority's internal production are lower than in the zero alternative. This is natural, because the number of years for which the Mapping Authority is supposed to collect and process data with internal employees is lower. The costs for the use of external consultants rise over the four alternatives. The reason for this is that an increasingly steeper scale-up of capacity leads to an increased need for external resources. We also see that costs for NGU's activities are increasing. Since NGU has such low

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[41] *The yearly cost of hiring a consultant does not only consist of wage cost, but also profit and administrative costs. Despite this, we have made a real price adjustment of 1.3 percent per year for the whole annual cost per consultant. The reason for this is that only adjusting the wage cost would imply a constantly falling profit margin in the companies that hire out the consultants.*

[42] *Similar contracts are normally price-adjusted in line with price indices for ship costs. We do not have any reason to assume that this will differ from the development in the consumer price index.*

mapping activity in the zero alternative and needs to invest into at least one new vessel in the alternative measures, costs for NGU in the different alternatives increase considerably compared to the zero alternative. The tax funding cost also rises, because more tax revenue must be used to scale up mapping. The net cost for each alternative is shown in the bottom row of the table. This shows how much more the mapping will cost in each of the alternatives compared to the zero alternative. To go from the zero alternative to for example alternative 2, where mapping is completed within 20 years, will cause additional costs of about NOK 1 billion (in addition to the costs accumulating in the zero alternative).

5. Analysis of economic benefits

The economic benefits related to marine geospatial data affect actors within a wide range of sectors, both public and private. The main, and quantified, effects, are related to risk reduction for commercial shipping, leisure craft and cost savings for public actors such as municipalities, the Norwegian Public Roads Administration (NPRA) and Statnett. In addition, we have tried to quantify the effects on the aquaculture industry. There is so much uncertainty related to these particular estimates that we have chosen to classify the effects on aquaculture as non-priced effects here.

A wide range of actors benefit from marine geospatial data, from industry actors to owners of leisure craft, public bodies and research institutions. In this chapter, we chart who these actors are and how marine geospatial data increase benefit for the various actors. In addition, we explain how we calculate the value of these benefits for those actors for whom this is quantified.

5.1. Benefit in terms of improved maritime safety for commercial shipping and leisure craft

In this chapter, we quantify the alternative measures' benefit for maritime safety. Grounding accidents impose considerable costs on society, and more detailed bathymetry can potentially reduce the likelihood of such accidents. This is due to the fact that the operator of the ship or boat will have more detailed information on depth conditions and is thereby able to select safer routes (reducing uncertainty). The benefits accrue as a consequence of a reduction in the number of groundings in areas for which more detailed charts can be made available.

The following cost components are part of the calculation of the quantified effects on maritime safety:

- Loss of human life (death)
- Personal injury
- Material damage to the vessel (repair costs)
- Damage to/loss of cargo
- Cost of rescue operations
- Cost of acute oil spills

The calculated reduction in the number of accidents over the analysis period caused by the introduction of more detailed charts, multiplied with given unit costs per cost component, gives the expected benefit in monetary terms.

The equation is as follows: *Priced benefit = Accident frequency within the area of analysis (U_F) x Effect of better charts on the accident rate (E_V) x Unit cost (E_K)*

5.1.1. Accident frequency within coverage area (U_F)

The same basis of calculation for the accident frequency is used as in DNV GL and Menon's report "Samfunns-økonomisk vurdering av forebyggende sjøsikkerhetstiltak og beredskap mot akutt forurensning" [Cost-benefit assessment of preventative maritime safety measures and preparedness for acute pollution] (2015). The calculation of accident frequency is described in detail in Appendix A to this report.[43]

The basis for our calculations will only be summarized in brief in this chapter.

Traffic data:

Traffic data, including distance travelled and specification of vessel types, is important for the analysis. It is uncertain how traffic growth will develop, both in the short and in the long term. In this analysis, AIS-figures from 2013 have been used, and in accordance with projections in DNV GL's report "Prognoser for skipstrafikken mot 2040" [*Projections for ship traffic up to 2040*], a linear development of traffic volume in the period from 2022 to 2047 has been assumed.[44]

Loss of human life:

The estimated number of fatalities per year, within the area covered by the analysis, is calculated as follows:

Number of annual grounding accidents x probability of fatalities in case of a grounding accident = Estimated number of fatalities.

Loss of human life is calculated based on the percentage of accidents that are expected to cause fatalities, and the number of fatalities expected in an accident. Both factors differ between the various vessel types, and a passenger vessel will naturally have potential for a higher number of fatalities than a fishing vessel.

Injury:

The expected number of injuries per year, within the area covered by the analysis, is calculated as follows:

Number of annual grounding accidents x Expected number of injuries at a grounding accident = Expected number of injuries

Injuries are calculated based on the percentage of accidents that are expected to result in injuries, and the number of injuries expected in an accident. Both factors differ between the various vessel types, and a navigational accident involving a passenger vessel will naturally have potential for a higher number of injuries than a similar accident involving a fishing vessel.

Material damage of vessels (repair costs):

Material damage is calculated based on the number of annual grounding accidents and the incidence of serious accidents with severe damage that have been reported.

Damage/loss of cargo:

For damage or loss of cargo, the annual frequency of grounding accidents is used.

Rescue operations:

Rescue operations are calculated based on the number of annual grounding accidents.

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[43] *DNV GL and Menon (2015) «Samfunnsøkonomisk vurdering av forebyggende sjøsikkerhetstiltak og beredskap mot akutt forurensning», Rapport Nr. 2015-0692, Rev. 2, vedlegg A. [Norwegian only]*
[44] *DNV GL (2014) «Prognoser for skipstrafikken mot 2040». Rapport nr.: 2014-1271 Rev. F [Norwegian only]*

Acute oil spills:

For the calculation of acute oil spills, the analysis model is based on accident frequency. Moreover, the probability of spills and the expected quantities of spilled oil are calculated based on the extent of damage caused by the accident and the expected amount of oil cargo and fuel oil on board, broken down by vessel type and oil type.

Underreporting

The model for analysis is based on shipping accidents recorded in the Norwegian Maritime Authority's (NMA) accident database (SDU). Potential under-reporting must therefore be considered. In "Samfunnsøkonomisk vurdering av forebyggende sjøsikkerhetstiltak og beredskap mot akutt forurensning" (2015) underreporting is discussed and set to an expected level of 50 percent. This is based on information in several studies which point out that historically, the level of underreporting in the NMA accident database has been as much as 60 percent, but this has been adjusted to 50 percent due to improved reporting in recent years. Underreporting of 50 percent is therefore assumed in this analysis. Underreporting of casualties or oil spills has not been included into the calculation.

Loss of lives in accidents involving the recreational fleet

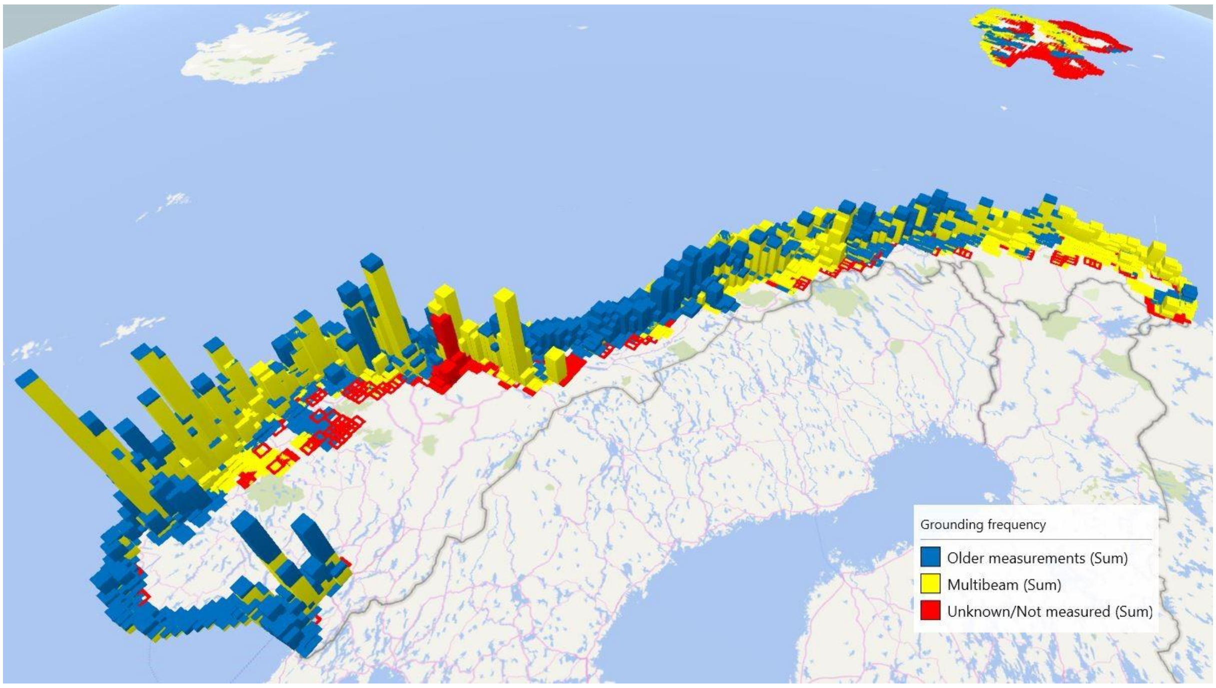
DNV GL also assessed the likelihood of loss of life in the recreational fleet in DNV GL (2015) "Analyse av sann-synligheten for ulykker med tap av menneskeliv og akutt forurensning fra skipstrafikk i norske farvann." [45] In the analysis, an overview of grounding accidents involving fatalities was compiled. The analysis shows that in the period 2006 to 2011, there were 17 grounding accidents with 23 fatalities. Altogether, there were 49 people on board the vessels, and it is assumed that all people who survived suffered injuries in the accident, i.e., a total of 26 injuries in the period.

Proportion of older measurements and multibeam data

We have received an overview of the status for the bathymetry of Norwegian waters from the Norwegian Mapping Authority. Based on this overview, we have calculated the proportion of area within each computational cell in the maritime safety analysis which is covered by older bathymetry and multibeam data respectively. This has then been used to determine the proportion of grounding risk relevant for the measure, see figure below. This is further used as the basis for calculating the benefits for maritime safety.

[45] *DNV GL (2015) «Analyse av sannsynligheten for ulykker med tap av menneskeliv og akutt forurensning fra skipstrafikk i norske farvann». Rapport nr.: 2014-1060 [Norwegian only]*

Figure 2: Geographical illustration of the grounding frequency for different levels of detail for the chart material. Source: DNV GL and Mapping Authority



5.1.2. Effect of more detailed charts (E_V)

The effect of more detailed map data on the probability of grounding accidents was assessed by two different methods. A workshop with experts was held, where the effect of various alternative measures to obtain more detailed map data was evaluated. Details of this workshop are described in Appendix 4 (13.1.). The experts' assessments are shown in the table below.

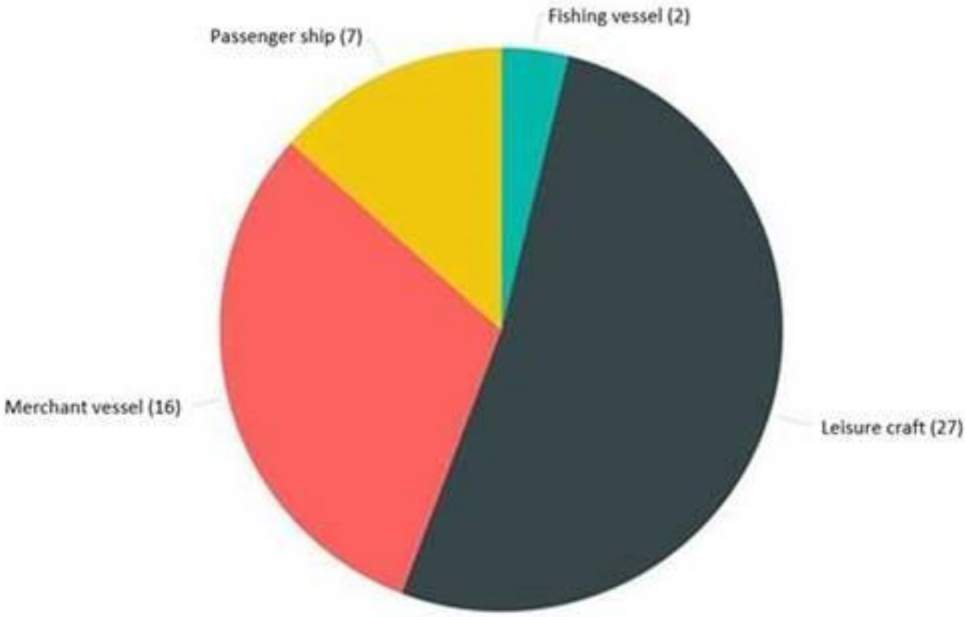
Table 10: Experts' evaluations of the effect of better map data on accident risk

Transition from older bathymetry to:	Prediction for reduced accident risk (average)	Prediction for reduced accident risk (average for commercial shipping)	Prediction for reduced accident risk (average for recreational fleet)
Multibeam measurements, classified	8%	6.5%	10%
Multibeam measurements, not classified	13%	11%	15%

In their attempts at quantification, the experts did not distinguish explicitly between commercial shipping and the recreational fleet, but they believed the effects to be highest for the recreational fleet, medium for fishing vessels, and lowest for merchant and passenger ships (which usually do not sail outside the main shipping lanes). Therefore, we have looked at the upper and lower average of the experts' estimates when we have determined which effect for maritime safety to use in the calculation of benefits. For commercial shipping this average was 11 percent, and for the recreational fleet 15 percent. The analysis is based on the assumption that there will be a move from older bathymetry to multibeam measurements that are not subject to classification, since it is most likely that this will be applicable for depths from 0-30 meters from 2017.[46]

In addition, we received an overview of all grounding accidents along the Norwegian coast where shoals that were not marked in the Mapping Authority's charts were reported as the cause of the accident. In total, the overview showed that 52 such incidents had been reported, about half of which involving leisure craft while the rest involved merchant vessels, fishing vessels, or passenger ships. The actual distribution of vessel types in these accidents is shown in the figure below. The registration of accidents covers a period of 7 years and gives an average of 4 accidents per year involving merchant vessels, passenger ships, or fishing vessels.

Figure 3: Distribution of accidents where unsatisfactory chart material was reported as the main cause or a contributory cause



In a report prepared by DNV GL in 2015, it was further discovered that annually, there are around 100 grounding accidents involving commercial vessels, fishing vessels or passenger ships.[47] Given an average of 4 groundings per year due to poor chart material, this indicates a maximum effect of better maps of 4 percent for merchant vessels, passenger ships and fishing vessels. Based on these two point estimates (4 percent and 11 percent), we chose a value in the middle, at 7.5 percent, for commercial shipping. This average considers the probability of under-reporting within the figures submitted to the Mapping Authority. On the other hand, it is possible that the experts overestimate the effects of better maps. For the recreational fleet, the estimate of an effect of 15 percent is exclusively based on the expert evaluation. There are no overall statistics of the groundings involving leisure craft, and hence it is not possible to make a statistical estimate. Thus, our analysis is based on the following estimates for the effects of better map data:

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[46] *At present, a working group is discussing a revision of the classification regime for marine geospatial data. The group has proposed that data for depths from 0-30 meters should be exempt from classification. This is very likely to be implemented as of 2017.*

[47] *DNV GL (2015) «Analyse av sannsynligheten for ulykker med tap av menneskeliv og akutt forurensning fra skipstrafikk i norske farvann». Rapport nr.: 2014-1060 [Norwegian only]*

Table 11: Effect of transition from older, non-classified measurements to multibeam data on grounding frequency

	Merchant fleet, passenger ships and fishing vessels	Recreational fleet
Multibeam with current classification regime	7.5%	15%

Calculation of accident reduction: *Reduction in the number of accidents due to introduction of better charts = Number of grounding accidents per year x Effect of better charts on accident rate*

5.1.3. Unit cost (E_K)

This chapter presents the unit costs used to calculate the priced benefit. The same basis for the calculation of unit costs is used as in "Samfunnsøkonomisk vurdering av forebyggende sjøsikkerhetstiltak og beredskap mot akutt forurensning» (2015). The table below shows the unit costs used in this analysis.

The unit costs differ from the above-mentioned report in that they are CPI-adjusted from 2014 prices to 2016 prices. In addition, the unit costs for loss of life, injury and oil spills are adjusted for the actual real growth of mainland GNP up until 2015. For each year after 2015, the same unit prices are increased by the annual expected real wage growth as stated in the Government's most recent white paper on the long-term perspectives of the Norwegian economy.[48]

Table 12: Unit cost (E_K), NOK thousand (fixed prices 2016)

Accident component	Unit cost (NOK thousand)	Comments
Loss of human life (fatalities)	35 575	Per number of fatalities per year
Injuries	4 114	Per number of injuries per year
Material damage of vessel (repair costs)	13 603	Per no. of shipping accidents per year
Damage/loss of cargo	386	Per no. of shipping accidents per year
Costs for the vessel being out of service after an accident (loss of income)	3 656	Per no. of shipping accidents per year
Cost of rescue operations	95	Per no. of shipping accidents per year
Costs of acute oil spills	436/315/178	Per amount of oil spills per year (tons)[49]

[48] *Report to the Storting Meld. St. 12 (2012–2013). Long-term Perspectives on the Norwegian Economy 2013 ('Perspektivmeldingen').*

[49] *The monetary value depends on the amount and type of oil in the spill. The three unit costs refer to bunker, oil products, and crude oil respectively.*

5.1.4. Benefits for commercial shipping and the recreational fleet

The benefits of the measures related to maritime safety are shown in the table below. The benefits in the table are discounted to 2016, using a discount rate of 4 percent.

The calculations are made with different time horizons for the mapping, respectively 25, 20, 15 and 10 years, in addition to the zero alternative. This is achieved by adjusting the effect according to the proportion of the area that has been mapped in a given year. This means that in a year in which 10 percent of the area which is currently still unmapped has been mapped, the benefit is equal to 10 percent of the annual benefit that is expected when 100 percent of the Norwegian coast has been mapped. The net economic benefit is then calculated as the difference between the benefits that are triggered in the zero alternative in a given year, and the benefit that is triggered by each of the measures. See Table 4 for a summary of how fast the mapping will proceed in the zero alternative and in the four alternative measures. After 10 years, for example, 24 percent of the remaining area will have been mapped in the zero alternative, while 35 percent will have been mapped if mapping is completed within 25 years. Thus, an area that is larger by 11 percentage points is mapped in this alternative than in the zero alternative after 10 years. Net economic benefit in year 10 for alternative 1 (25 years) is therefore 11 percent of the annual benefit that is expected when 100 percent of the coastline is mapped. Net economic benefit for other years and in the other alternatives is calculated in a similar manner:[50]

Table 13: Benefit of maritime safety at net present value and difference from the zero alternative (NOK million, fixed prices 2016)

	Alt. 1: 25 yrs.	Alt. 2: 20 yrs.	Alt. 3: 15 yrs.	Alt. 4: 10 yrs.
Commercial shipping	90	137	190	234
Recreational fleet	129	201	287	359
Sum	219	337	477	592

In all of the alternatives, there is a higher triggered benefit for the recreational fleet than for commercial shipping. The reason for this is that a large part of the areas not yet mapped are shallow waters with a high risk of accidents for the recreational fleet. This is also the reason why the experts thought that there was a higher probability of accident reduction among recreational craft than for professional shipping. Main and secondary shipping lanes, where ship traffic moves, are mapped to a much greater extent. Compared with the zero alternative, a scale-up to a collection rate of 10 years (alternative 1) will lead to NOK 219 million more in triggered benefit. For the remaining alternatives, the figures are respectively NOK 337, 477 and 592 million for alternatives 2, 3 and 4.

5.2. Benefit for public actors

Public actors are responsible for the administration and the improvement/development of the coastal zone. This applies to both municipalities' and county municipalities administration of and investments into infrastructure,

[50] *Number of percentage points larger mapped area in the alternative than in the zero alternative in the given year, multiplied by the expected effect when 100 percent of the coast have been mapped.*

for example into water and wastewater systems, and other government agencies' investments into infrastructure related to roads, the power grid and telecommunications.[51]

5.2.1. Municipalities

In its maritime strategy, the Norwegian government defines blue growth as a central topic. Changed needs and requirements from commercial stakeholders, infrastructure development and other considerations such as the protection of vulnerable natural and recreation areas can easily lead to an increased level of conflict between users of the coastal zone, and are challenges public administration bodies are faced with in their work. In addition to the overall increase in interest in the coastal zone, changes in the Norwegian Planning and Building Act in 2009 have led to stricter requirements for municipalities' design of coastal zone plans for their respective administrative areas. Municipalities are now required to draft and pass a new planning strategy at least once within each election period. This also includes plans for the coastal zone.[52]

Both the general increase in interest for the coastal areas and the requirement for more frequent updates to coastal zone plans indicate a bigger need for maps of and knowledge about the coastal zone. In 2015, Norconsult compiled a report on challenges related to land-use planning in sea areas close to the coast.[53] The report points out that different geographical areas experience different challenges with regards to land-use planning in the coastal zone. On the Southern coast of Norway and in the eastern part of Southern Norway, a lot of space for small craft harbours and recreational activities is required, while Western Norway and central and Northern Norway need areas for aquaculture. Furthermore, the report states that impact assessments for new land use in the coastal zone are challenging to carry out because of a lack of good data. This is a problem especially with regards to the regulation of areas for aquaculture, where it is necessary to have more information on how fish farms are likely to affect ecosystems in their surroundings.

Knowledge-based administration will therefore be able to help reduce potential conflicts, but also lead to a more sustainable development of the coastal zone. If the existing chart material is old and/or of bad quality, the municipalities either have to collect relevant data by themselves, or plan on the basis of insufficient information. One possible solution is to procure missing data from private actors. Potential benefits for the municipalities therefore take the form of cost savings for their own mapping efforts. In its analysis of the Astafjord-project, Vista Analyse calculated that Gratangen municipality saved approximately NOK 1 million by using existing maps when installing a water pipe. This did not only include cost savings for mapping, but also cost savings because of better planning and project preparation before the actual development started.

Some municipalities are also engaged in environmental initiatives in the form of clean-up measures in their coastal zone. Each year, the Norwegian Environment Agency receives funding for sediment clean-up through the national budget. In practice, the municipalities apply for funding to carry out such environmental measures. They

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[51] *Telenor is not a public actor on the same level as municipalities, the Public Roads Administration and Statnett, but also carries out major infrastructure investments in the coastal zone in the form of sea cables. Telenor has made use of map data from the Mapping Authority in connection with the installation of sea cables, but has not been available to help us price this benefit. Telenor's effect derived from map data therefore needs to be treated as a non-priced effect in this analysis.*

[52] *A municipality's administrative area is defined as extending one nautical mile beyond the baseline by the Norwegian Planning and Building Act.*

[53] *Norconsult (2015): «Analyse av utfordringer for arealplanlegging etter plan- og bygningsloven i kystnære sjøområder» [Norwegian only]*

receive funding for 75 percent of the cost of the measure, while the remainder needs to be financed by the municipality itself. The municipality is responsible for planning and implementation. To be able to carry out such environmental measures on the seabed, detailed multibeam data are needed. In areas that have not been mapped by the Mapping Authority, the municipalities need to buy such data from private actors.

With the help of interviews with several municipalities, we have tried to determine the municipalities' costs in connection with planning processes, infrastructure investments and environmental measures.[54] Even though municipalities are required to revise their coastal area plans every fourth year, our impression is that this is not carried out in practice, potentially because the costs are too high. Costs for mapping of the seabed are usually not separate cost items in the municipalities' budgets, which means that it is difficult for the municipalities to provide exact cost estimates for this. Due to this, there are relatively few municipalities that can provide information on this type of costs. Our estimates for potential cost savings are based on the statements we received, but have been placed in the lower range of the potential because of the associated uncertainty. All municipalities have been attributed the same effect, independently of their size and number of inhabitants. This is due to the fact that coastal municipalities' size and population varies widely, and we do not have detailed information that would enable us to see that some municipalities spend more or less on this type of mapping. The effect has been fixed to NOK 100 000 per year per municipality.[55]

For some of the coastal areas belonging to the municipalities, bathymetric data already exist. A scale-up of the mapping activities will therefore not result in any additional benefits for the areas that have already been mapped. With the help of data from the Mapping Authority, we have calculated the percentage of area that has been mapped by multibeam measurements for each coastal municipality. Subsequently, we adjust the maximum effect, NOK 100 000 per year, by this figure, so once the whole area in the municipality is mapped, the realized benefit will be NOK 100 000 multiplied by the percentage of area that was not mapped. Thereafter, this number is adjusted by the proportion of area mapped in each year and alternative, as shown in Table 1. In that way, the benefits are realized linearly throughout the analysis period in relation to how much of the coastal zone will be mapped in each of the years. The benefit is defined as the difference between the benefit in the zero alternative and each of the four alternative measures. Since it is not possible to know exactly when municipalities will carry out investments in infrastructure, where those might be located and if these areas will be mapped at the time the investments are carried out, this is the most neutral way of calculating the benefits. A more detailed description of how the benefits are calculated is available in appendix 4 (13.2.1).

5.2.2. The Public Roads Administration

The Norwegian Public Roads Administration (NPRA) needs marine geospatial data when building roads, tunnels, ferry piers and bridges along the coast in locations where construction takes place either completely or partially on/under the seabed. It is important to map factors such as depth and reflectivity and develop terrain models in order to be able to plan correctly. Traditionally, the Public Roads Administration has not used data from the Mapping Authority, but run tender processes with private actors for this type of mapping. This means that for the Public Roads Administration, there are potential benefits in the form of cost savings for the procurement of mapping services from private actors.

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[54] *Even though we contacted more than 60 municipalities, there are relatively few that can provide information on costs related to mapping.*
[55] *Due to a high degree of uncertainty, we have carried out a series of uncertainty analyses in chapter 7.*

The Directorate of Public Roads however does not provide reports that can be filtered according to the criterion of whether a given project has made use of data for the seabed. Neither is there any information on how many projects each year use this type of mapping, or how many projects are being planned where such data will be used. In the individual projects, mapping of the seabed is included as part of the project cost, but not reported as a separate cost item to the directorate by the individual regions. It is therefore difficult to establish how much the Public Roads Administration currently spends on this type of mapping.

Our method of estimating this amount is therefore based on road projects that will be started and opened in the period from 2014-2017 and where the cost estimate exceeds NOK 500 million.[56] We have charted which of these projects we believe has a need for marine geospatial data based on the information that is available. This is related to location (in the coastal zone/not in the coastal zone) and the type of investment being made (road, tunnel, bridge, foot- and bicycle path etc.). In addition, we have included planned fjord crossings in the Norwegian National Transport Plan for the period 2018-2029. Based on this overview, we calculate that there are on average 1.6 projects per year that use marine geospatial data. Subsequently, we have tried to contact the project managers for projects that are likely to use marine geospatial data to get an estimate for the costs of procuring these data. On the basis of these interviews, we have estimated the potential savings to NOK 200 000 per project.[57] More details on our approach and the calculation of benefits for the Public Roads Administration are available in appendix 4 (13.2.2).

5.2.3. Statnett

Statnett is a state-owned enterprise responsible for operating, owning and developing the power grid in Norway. This includes the installation of subsea cables where necessary. When laying new subsea cables, Statnett carries out detailed mapping of the relevant area. Mapping is also carried out when old routes are upgraded in areas where map data are lacking. The mapping assignments are put out to tender and executed by private actors. As with the municipalities and the Public Roads Administration, there are potential benefits related to savings in the procurement of mapping services from private actors. In any case, Statnett will have to do some mapping of its own because of factors like level of detail and data selection, but there will also be potential savings.

Statnett will carry out two improvements of existing routes in 2017. For these two projects, Statnett estimates a potential cost saving of NOK 1 million per project if the Mapping Authority had mapped the areas by multibeam echo sounder, and the data had a resolution of 1*1 meter. Potential other future cost savings for Statnett are more difficult to estimate. An upgrade of existing installations that has been ongoing for the last 10 years is almost completed. In that way, the scale-up of the collection of marine geospatial data comes somewhat late for this actor. There is large uncertainty related to the future benefits for Statnett, but based on planned investments and upgrades, the best estimate is that it could save approximately NOK 10 million within 35 years if all coastal areas were mapped by modern methods.

[56] *http://www.vegvesen.no/vegprosjekter/Om+vegprosjekter/Vegprosjekter+2014-2017*

[57] *The estimate is based on a small number of statements where the cost estimates vary widely. We have therefore decided to use an estimate on the lower end of the scale. It is likely that the Public Roads Administration will have to purchase some separate mapping services anyway, and therefore it can be difficult for the project managers to ascertain exactly which part of the mapping has been saved and how big a share of the mapping costs this constitutes.*

5.2.4. Total benefit for public actors

In the table below, we show the discounted net present value for public actors in the different scale-up alternatives compared to the zero alternative. In the same way that we had to add a tax funding cost to the increased costs for data collection, we here have a saved tax funding cost, because costs for the public actors are reduced. This is also included in the table under.

Table 14: Benefit for public actors at net present value and difference from zero alternative (NOK million, fixed prices 2016)

	Alt. 1: 25 yrs.	Alt. 2: 20 yrs.	Alt. 3: 15 yrs.	Alt. 4: 10 yrs.
Municipalities	120	140	166	188
Public Roads Administration	2.9	3.4	4.0	4.5
Statnett	2.5	2.9	3.4	3.9
Saved tax funding cost	25	29	35	39
Sum	150	176	208	236

These benefits can perhaps be interpreted as somewhat modest. It is therefore important to underline that these effects are based on relatively few estimates. In addition, we have only looked at cost savings for the actors' own mapping efforts. It is likely that there are other non-priced benefits that will apply to all actors. This can for example include better planning of infrastructure investments, thus reducing planning costs and planning time. In addition, the number of appeals related to land use planning and route selection may decrease once stakeholders realize that these decisions are made on the basis of more detailed information. Predictability for the actors will also most likely rise, because there is less need to change plans in the future.

It is important to point out that there might also be additional public actors that will benefit from this mapping effort. The Norwegian Coastal Administration is an obvious candidate. The effects for this body are discussed in section 5.3.6.

5.3. Non-priced effects

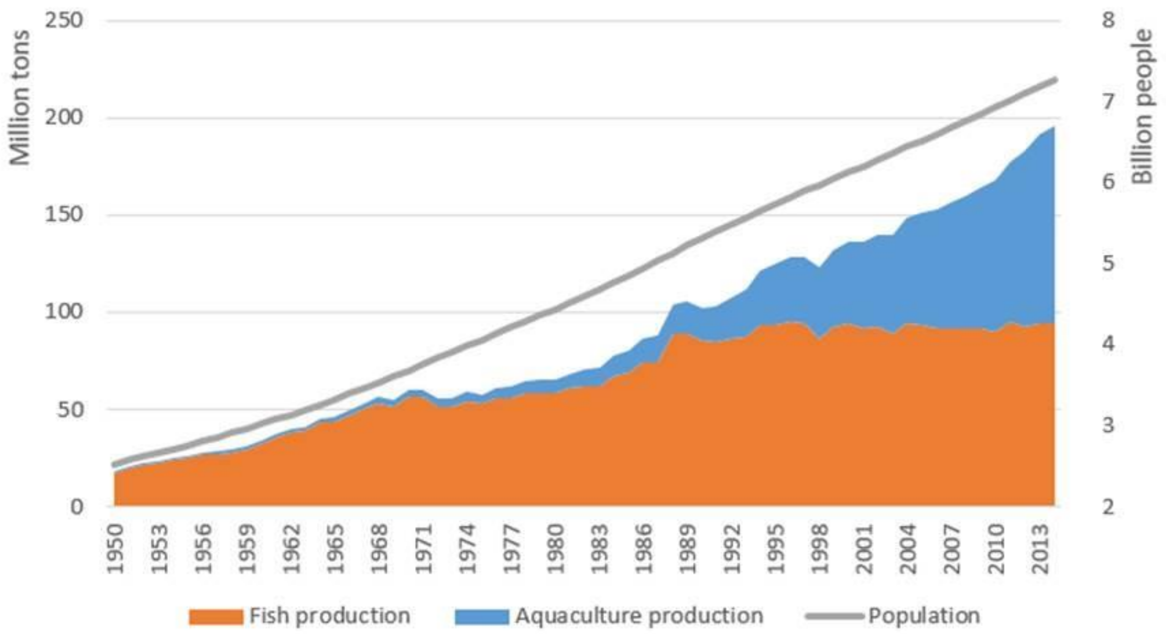
It is very demanding to quantify the effects of marine geospatial data. Therefore, we describe most of these effects in the form of non-priced effects. Despite this fact, we believe that we have managed to quantify the most important effects, with one exception: the effects on the aquaculture industry. The reason we include the aquaculture industry under non-priced effects is because there is great uncertainty around these effects.

5.3.1. Aquaculture industry

The aquaculture industry has experienced strong growth in recent years. Average yearly growth in the industry has been more than 7 percent in the period from 2004 to 2014. The industry itself and the Norwegian government are preparing for this growth to continue also in the coming years. The planned growth is a response to a growing global demand for seafood. The increased global growth can be partially explained by three factors:

- Increased global population growth
- Increased demand for healthy proteins
- Increased emphasis on environmentally sustainable production

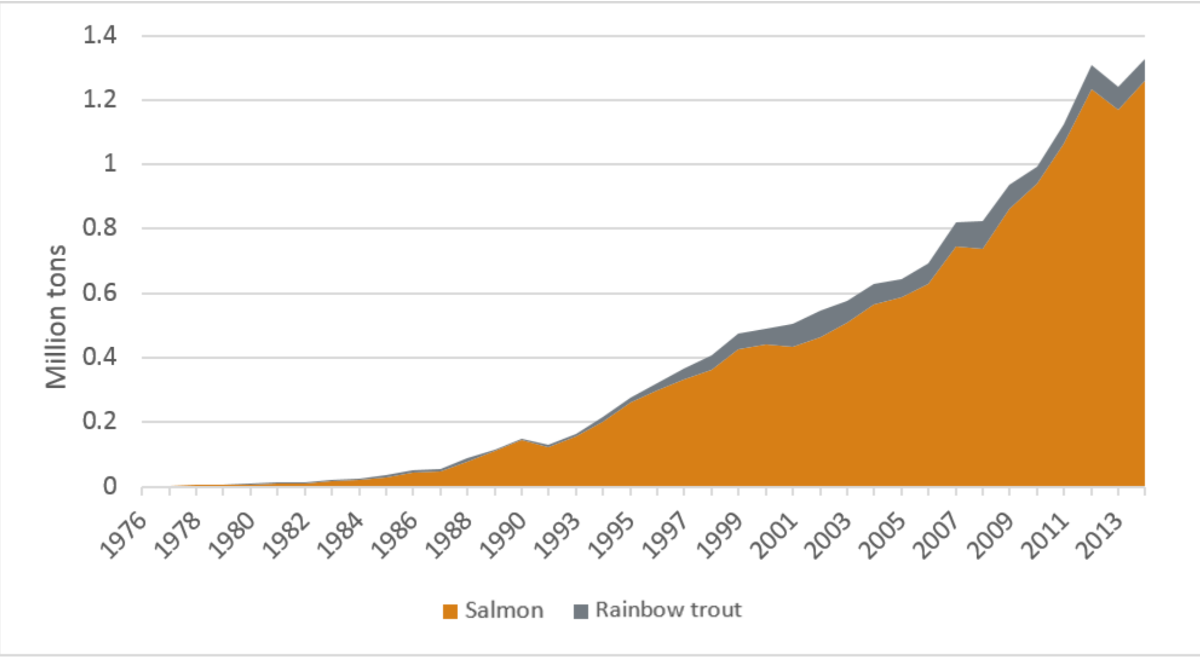
Figure 4: Global fishing, aquaculture production and population growth. Source: FAO UN



As can be seen from the illustration, there is an almost linear relationship between global population growth and aquaculture production. At the same time, we see that growth in global fish production has stalled. This is a consequence of the fact that several of the world's fish stocks are overfished already. To satisfy expected global growth in demand, aquaculture production needs to increase.

The figure below illustrates the growth in the production of salmon and rainbow trout in the period from 1976-2014.

Figure 5: Production of salmon and rainbow trout in Norway in the period from 1976-2014 in million tons. Source: Norwegian Directorate of Fisheries



As can be seen from the figure above, there has been considerable growth in the period, interrupted by shorter periods of decline mostly due to global macroeconomic conditions. During the period, average yearly growth in the industry has been 17 percent for the period as a whole, and in excess of 7 percent from 2004-2014.

In Report to the Storting Meld. St. 16 (2014-2015) *Forutsigbar og miljømessig bærekraftig vekst i norsk lakse- og ørretoppdrett* [Predictable and environmentally sustainable growth in Norwegian salmon and rainbow trout farming], the Government prepares for continued higher growth in aquaculture also in the future. To create favourable conditions for this growth, the Government is preparing an action guideline with regards to reducing the environmental impact resulting from production.

At the same time, the Government also confronts the significant variation in the criteria for the allocation of new concessions in past years. In the foreword to the above-mentioned report, it is pointed out that in the past, important criteria for granting concessions have included:

- Geographic distribution (i.e., avoiding large concentrations of fish farms)
- Local ripple effects
- Local or domestic ownership
- Female management or ownership

The report to the Norwegian parliament states that variations in the weighting of criteria for concessions have been a challenge for the industry, since this has created unpredictable framework conditions for growth. It therefore proposes the implementation of an action guideline for the allocation of concessions and permits for increased production within existing concessions. The Government, with the approval of Parliament, will implement the following measures:

- Create favourable framework conditions for predictable and environmentally sustainable growth in the aquaculture industry for salmon and trout
- Make environmental sustainability the most important criterion for regulating further growth in the aquaculture industry
- Tie capacity changes to a module-based system on the basis of the action guideline, which will define different classes of production zones classified according to the risk level for spread of salmon lice
- Consider a capacity adjustment of 6 percent in salmon and trout farming every other year
- Allocate new capacity both through new licenses and increased MAB[58] for existing licenses.
- Open up for exceptions to the action guideline in cases where it can be documented that the form of operation does not impact the environment-related challenge that triggers a reduction in production capacity in the area
- Let a large share of the revenue from the allocation of increased capacity go to the municipalities

In line with the recommendation by the Norwegian parliament, the Ministry for Trade, Industry and Fisheries has obtained a proposal for production zones. This proposal for production zones has been drafted by the Norwegian Institute for Marine Research. In line with the instructions from the ministry, the zones have been drafted with the aim of limiting the spread of infection with salmon lice between installations as much as possible. The zones have therefore been set up based on ocean current modelling.

[58] *MAB stands for maximum allowed biomass and determines how much live fish the license holder can have in the ocean at any given time.*

The Institute of Marine Research has stated in interviews that map data are the most important basis for the hydrodynamic model that is used to develop ocean current models. In addition, the Institute informs that a lack of updated maps means that the modelling will be less precise, one of the reasons for this being that error margins are larger. For this reason, better map data will have the effect that it will be possible to model to a larger degree how infection is spread between individual fish farms and production zones.

In combination with the large emphasis the Government puts on the fact that growth in the industry must be combined with environmental sustainability, increased knowledge of current conditions will contribute to more efficient production in several ways:

- In high-risk areas, it will be possible to impose measures to reduce the spread of infection. This can help to reduce environmental impact, which in turn may enable higher growth in the longer term.
- Areas with especially favourable current conditions can be identified more quickly and thereby contribute to increased production without increasing environmental risk.
- Installations where the actual risk of infection is low will find it easier to substantiate arguments in favour of production increases, also in those areas where reduced production can be imposed under the new regime. This may result in more expansion projects being realized.

The administrative bodies involved in granting licenses express that they adhere to the precautionary principle in their recommendations, which is in line with Norwegian administrative policy. They also say that a more detailed knowledge base will make it easier to allocate more licenses and allow higher production in localities where spread of salmon lice is not a problem.

The Government is planning for the recent years' production increase to continue, but under the premise that this must be environmentally sustainable. With a yearly growth in the aquaculture industry of more than 7 percent in the period 2004-2014, a continuation of today's growth rate will mean that production is doubled every seven years, and increase six-fold in the period up to 2045. This is in line with forecasts by SINTEF (2013) and the Norwegian Academy of Science and Letters (2014).

It is very uncertain whether such a marked increase in production will be feasible. Amongst other factors, this will depend on development in global demand, access to capital, competitive situation in the form of potential new technologies that might offset Norway's natural competitive advantage, issues related to fish health etc. The significant expected population growth and increased emphasis on healthy food and less environmentally damaging production methods however point in the direction of a substantial increase in demand. With regards to a production increase, there is, based on interviews with the Institute for Marine Research and the Directorate of Fisheries, reason to believe that better ocean current modelling will influence how much production can be increased by.

At the same time, an increase in production also depends on other factors which are discussed above. It is very difficult to quantify how much of a potential production increase can be attributed to better mapping of the seabed. This indicates that we should treat the effect in form of increased production as a so-called non-priced benefit. At the same time, the economic benefit from increased aquaculture activity may be considerable. To illustrate the significance of this, we have therefore calculated the economic benefit related to a production increase of respectively 0.2, 0.5 and 1 percent up to 2051. Given that Sintef and the Norwegian Academy of Science and Letters estimate that growth during this period might reach 600 percent, we consider that our illustration of the potential effects of better map data on the aquaculture industry, as presented in the table below, can be viewed as modest.

Increased value creation in one industry, however, leads to reduced value creation in other industries as a result of displacement, in the sense that resources such as labor and capital are moved from one industry to another. To assess the economic benefits of increased value creation in aquaculture, it is necessary to correct for the value creation transferred resources would have provided in alternative uses. For this to be economically profitable, the economic resources labor and capital must produce more in aquaculture than in other parts of Norwegian business and industry. It is therefore the additional return created by moving resources from alternative uses into aquaculture which provides the basis for the calculations below. In addition, we adjust the realized benefits by the proportion of mapped area in each year and alternative, as shown in Table 1. In that way, the benefits are realized linearly throughout the analysis period in relation to how much of the coastal zone will be mapped in each of the years. A detailed description of the calculation of the benefits for the aquaculture industry is available in appendix 4 (13.3). In the table under, we show example calculations of what the benefit for the aquaculture at net present value looks like in the alternative measures compared to the zero alternative.

Table 15: Benefit for the aquaculture industry at net present value and difference from zero alternative (NOK million, fixed prices 2016)

Alternatives	0.2 percent increase	0.5 percent increase	1 percent increase
Alternative 1: 25 years	281	703	1 407
Alternative 2: 20 years	330	824	1 648
Alternative 3: 15 years	390	976	1 952
Alternative 4: 10 years	443	1 107	2 214

The effects are significant in all three example calculations. We have however not had sufficient information to estimate empirically how much of this growth can be attributed to better map data. As the uncertainty related to the significance of map data for increased production is large, we have therefore chosen not to include these calculations in the priced benefits. The quantification will however be part of an economic break-even analysis presented in subchapter 6.1.7.

5.3.2. Fishing industry

The effects of marine geospatial data on maritime safety for fishing vessels are discussed in subchapter 5.1 and included in the analysis on improved maritime safety for shipping. There are, however, also other effects of marine geospatial data on the industry.

These effects are related to:

- More efficient fishing
- Less damage to equipment

In this context, fishing can be divided into two categories; fishing with passive equipment placed on the seabed such as nets, longlines and traps, and fishing with active equipment such as purse seines and trawl. This subchapter will give a short introduction to relevant fisheries in Norwegian waters, and identifies and describes relevant effects of better availability of marine geospatial data.

Seine fishing

Fishing with a seine, often called a purse seine or draw net, is an active way of fishing where the vessel makes use of sonars and echo sounders to find a shoal of fish. Before the shoal is encircled by the seine, the vessel often circles the shoal to examine factors such as seafloor conditions, currents and the shoal's extent and speed. Then, the shoal is circled by the purse seine and closed in. In several fisheries, shoals often stand by an underwater edge or close to a shallow ground. The seine, which is normally deepest in the middle, is then usually set from the shallow, towards deeper water, and back to the shallow.

In cases with significant depth variations on the seabed between interpolated points in the chart, the catch operation needs to be advanced earlier than planned after observing true seabed formations on echo sounder or sonars. As a consequence, the net may need to be pulled in much earlier than planned in order to avoid too much contact between net and seabed, with the consequence that the shoal of fish will not get caught in the net. If the net gets stuck on the bottom, it might get damaged. In Norwegian waters, this example is especially relevant for saithe (pollachius virens) fishing.

Another example is mackerel fishing with purse seine in waters such as the North Sea, where the seine is placed at some distance in front of the fish due to the speed the fish are moving at. If the captain realizes halfway into the process of casting the net that the water is shallower than indicated by the chart, it will be necessary to draw and haul up the net early, which will likely reduce the catch.

In the case of seine fishing, better information about the seabed can result in more precise casting of the net and less damage to equipment. Both more detailed mapping, as in the case of mackerel, and higher resolution of the data, as in the case of saithe, will be relevant in this context.

Seine fishing takes place at all depths, but the types of seine fisheries which would benefit most from better chart data, e.g. fishing for saithe, usually take place at depths of 40-100 meters. A seine for saithe fishing for a typical coastal fishing vessel of 30 meters costs approximately NOK 1 million. The extent of damage to nets resulting from contact with the seafloor varies a lot, but if parts of the net in the seine need to be replaced, costs of NOK 50 000-100 000 are not unusual.

Trawl fishing

When trawling, one to three trawls are towed behind the vessel, either midwater or along the seabed. With more detailed charts, it would be possible to plan better when to haul in the trawl, thus avoiding objects or challenging seabed formations. This will reduce damage to trawling gear and reduce the probability for hazardous situations such as getting the trawl stuck in the seabed, thus improving safety for ship and crew.

Trawl fishing often takes places in areas where the shape of the seabed is known from experience. However, it is likely that better charts would reduce barriers for trying out fishing in other areas.

In addition of the effects deriving from reduced damage to fishing gear, a better overview over the seabed will also lead to more environmentally friendly trawl fishing. Two main effects can be discussed; more energy-efficient fishing by trawling *along* the formations of the sea floor rather than *across* them, and less damage to coral reefs due to better information about their location. Trawling gear for coastal vessels, for example 15 meters of coastal shrimp trawl, costs approximately NOK 100 000. Large ocean-going trawlers have bigger and more expensive gear, but their main activity normally takes place more than one nautical mile beyond the baseline.

Fishing with nets

The traditional way of fishing with passive equipment such as gill nets and longlines is still very relevant, and constitutes the basis of the Norwegian coastal fleets' fishing for species like cod and saithe. More than 35 percent of the landings of cod in the Norwegian Fishermen's Sales Organization, covering the coast from Nordmøre to Finnmark, was in 2015 caught with gill net and longline.[59] The fishing takes place close to the seabed, typically at depths of 50-100 meters, both along the coast and further out to sea.

When fishing with nets, a chain of nets is set in an area where fish can either be observed on the echo sounder, or where it is expected to come in. The nets are usually left for 24 hours. The fish gets stuck in the nets, and is hauled on board the vessel.

If nets are placed in areas where the seabed is very uneven, for example close to a wreck, coral reef or generally challenging seafloor conditions, they might get stuck and be lost or damaged. The same can happen when nets are placed in areas with a lot of current, because the nets are pushed to the seabed. Lost nets are a major concern with regards to waste of resources and negative environmental impacts, because they stay in place and keep fishing for a long time. This is called «ghost fishing». The Directorate of Fisheries does not have any exact figures on the extent of ghost fishing, because there are too many uncertainty factors. In addition, there are costs associated with recovering lost nets, and in recent years the Directorate of Fisheries has collected approximately 1000 such nets.[60] The directorate's costs for cleaning up are budgeted to around NOK 4 million in 2016. Better information about the seabed may be able to reduce this kind of undesired resource waste.

Quotations from September 2016 indicate a price of NOK 1300-1500 excl. VAT for a new net with new ropes, and NOK 400-600 for a new net with used ropes. When a net is lost, it can be assumed that in approximately 75 percent of cases only the actual net disappears. In addition, anchor, ropes, floats and other equipment might also be lost. The value of a lost net can thus be estimated to NOK 750 on average.[61] The total value of the lost nets taken up by the Directorate of Fisheries would consequently be around NOK 750 000. This is probably only a small proportion of the total, but there are no good estimates on overall losses available.

The size of the effect from better charts on reducing the rate of lost nets is highly uncertain. According to information from representatives of the fishing fleet and the Directorate of Fisheries, it is possible that this effect will be most relevant for net fishing outside of the main season when new fishing grounds are tested, and fishermen miscalculate with regard to current or depth. This will likely apply to a smaller share of the total amount of lost nets.

Improved efficiency in net fishing is also a possible effect of better marine geospatial data. The effects will differ for main fishing seasons and more marginal fishing between the seasons. In the best seasons for instance, when it is not difficult to find fish, chains of nets may be placed relatively close to each other. In such situations it is important to have information about the speed, directions and variations of currents. Larger vessels often have a current indicator on board, but the typical vessels in the coastal fishing fleet do not have such equipment and are more dependent on current information from other sources, for example current charts.

Between the main seasons, there is less fish to be found. At that time, the vessels tend to go to fishing grounds they are familiar with. These are often places where the fishermen know from long experience at sea where the fish are, or where this knowledge has been inherited from other fishermen. With better information about the

[59] *Statistics database of the Norwegian Fishermen's Sales Organization*
[60] *Annual report of the Directorate of Fisheries 2015*
[61] *Estimate based on the following calculation: 25 percent nets with new ropes at a price of NOK 1400+, 75 percent nets with old ropes x NOK 500 + share of costs for anchor, ropes, floats etc. NOK 25. All numbers excl. VAT.*

seabed, currents and biological conditions, it will be possible to identify suitable locations in a more efficient way, and thus fish with more precision, in a shorter time and using fewer resources.

Effect of improved availability of marine geospatial data

It is obviously useful for the fishing fleet to get access to more and better marine geospatial data. The main effects are related to reduced damage to expensive gear, less time and effort spent on fishing, increasing precision in several fisheries, reducing the extent of so-called «ghost fishing», and, in some cases, also reduced risk of damage to vessels. Less need for detailed local knowledge, with a consequent increase in efficiency for a more mobile fishing fleet, is part of this effect.

Effects can be ascribed to both *better* mapping and increased availability of existing data. Considering that the Mapping Authority's aim is to map areas from the coastline to one nautical mile beyond the baseline, the effects will mostly be limited to the coastal fleet.

The extent of the effects is challenging to isolate, as many other factors influence the same indicators as better charts, such as e.g. skippers' experience and knowledge of fishing grounds, development in technical equipment of vessels, variations in fishes' behavior pattern, fisheries regulation and the competitive situation in the fishing grounds. This makes it difficult to quantify the effect on the fishing industry. Our interview objects however express that better map data will be of significant value to the fishermen.

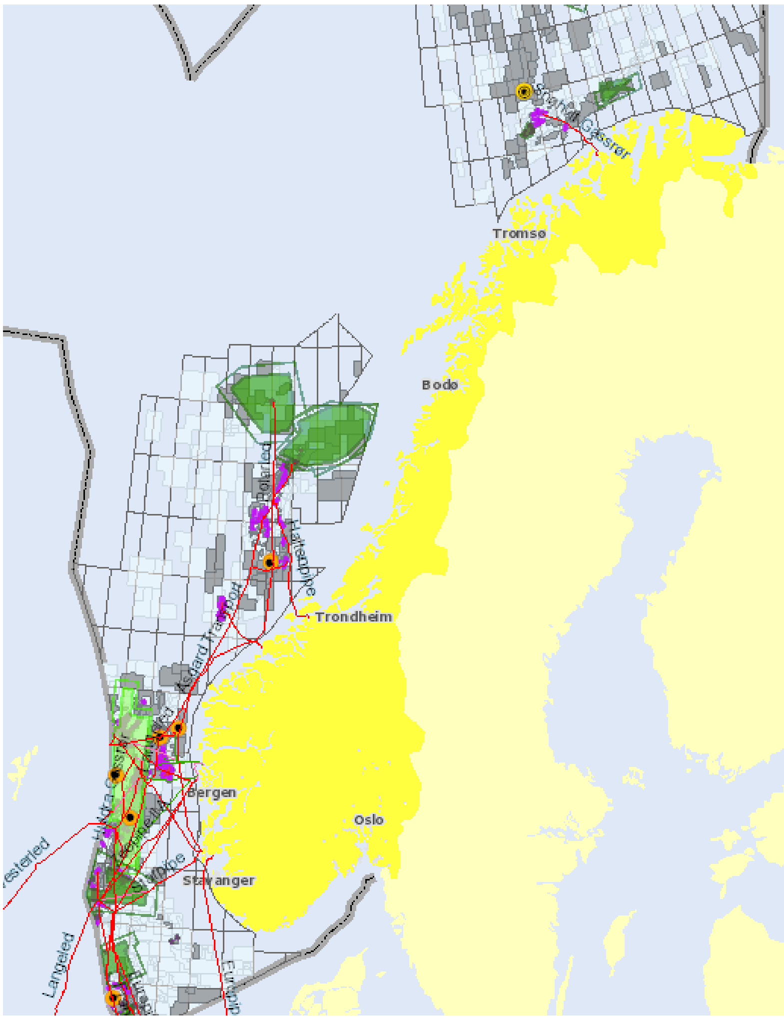
5.3.3. Petroleum industry

The Norwegian oil and gas industry is by far the largest and most productive industry in the country. Since production on the Norwegian continental shelf started in the early 1970s, the petroleum industry has contributed more than NOK 12 000 billion to Norway's GNP, measured in current value. At the same time, only 47 percent of estimated total recoverable resources on the Norwegian continental shelf have been produced so far.

Norwegian petroleum activity takes place far out at sea, as can be seen from the illustration below. This analysis focuses on the mapping the Mapping Authority is carrying out up to one nautical mile beyond the baseline.[62] At present, there are no blocks on offer so close to land, and there is no interest in opening any such areas either. This is due to the fact that there are no promising geological structures so close to land.

[62] *The Mapping Authority is also mapping the sea bottom in deeper areas, for example in connection with the Mareano-program, but this is not part of this analysis.*

Figure 6: Petroleum activity on the Norwegian continental shelf. Source: Norwegian Petroleum Directorate



The potential benefits of detailed mapping of the seabed for the petroleum industry are limited to those cases where resources are brought ashore for processing on land. As illustrated in the map below, resources are brought ashore north of Stavanger (Kolstø), north of Bergen (Sture), north of Ålesund (Nyhamna), west of Trondheim (Tjellbergodden) and in Hammerfest (Snøhvit). At these terminals, gas is landed and then either converted to liquid natural gas or sent to the continent via pipelines. At present, there are no plans for new onshore processing facilities. This is due to the fact that the existing facilities have large capacity, that no new major gas fields have been discovered on the Norwegian continental shelf in recent years, and that new technology has made offshore processing possible. In those cases where major oil and gas fields are discovered at a long distance from existing infrastructure for oil and gas (either landing terminals or pipelines), it is thus far from certain that these resources will be landed.

If the areas outside Lofoten, Vesterålen and Senja are opened for petroleum activities, bringing resources ashore might be a possibility. Landing of resources can contribute to the creation of more jobs in the region, which is seen as an important precondition and argument in favour of opening these areas. There is however large uncertainty with regards to whether these areas will be opened.

For the petroleum industry in itself, better mapping of the seabed therefore has very limited benefits. There might be significant benefits if the areas outside Lofoten, Vesterålen and Senja are opened for petroleum activities, given that recoverable resources are discovered in these areas and these are brought ashore.

The petroleum industry will however benefit from better current modelling. This is shown in the next subchapter.

5.3.4. Meteorology

The Norwegian Meteorological Institute presently has several models for ocean currents. The models are used for tidal forecasts and to predict storm surges. In addition, they model emissions from ships or petroleum installations, and can help facilitate the search for persons that have fallen overboard from vessels or ocean-based installations. The Meteorological Institute states in interviews that better map data will help to improve the models, in the sense that it will be possible to predict storm surges with more accuracy, model the spread of oil spills more precisely, and work out where currents are likely to take persons that have gone overboard. Potential positive economic effects resulting from this may take the form of more effective measures to reduce the negative effects of storm surges, more efficient measures against emissions, and faster rescue efforts to save human lives.

At the same time, the Meteorological Institute states that map data are only one of several data sources for the models. In order to be able to build good models, data about other meteorological factors are also needed.

It is therefore not possible to quantify the effects of better map data in the form of better modelling of ocean currents at the Meteorological Institute.

5.3.5. Shipping

Earlier in this report, we have quantified the effects of better map data on shipping in the form of risk reduction. There are however additional effects resulting from better marine geospatial data for the maritime industry. Non-priced effects may come in the form of resources for accident preparedness being utilized more efficiently, reduced waiting time, reduced sailing time and/or better utilization of the area and lower fuel consumption. These are caused by improvements to the system of shipping lanes. If better map data lead to more efficient shipping lanes, it is possible to reduce the distance ships have to travel, and thereby save costs and reduce environmental effects. In addition to helping to plan safer routes in advance, map data can also contribute to making the actual voyage safer. Alarms on the bridge are a big challenge for navigators on advanced ships. DNV GL has during the last year led a joint industry project aiming to reduce the number and improve the quality of alarms on the bridge. Better information, also including marine geospatial data, will help to set more precise criteria for hazard notification, which will also contribute to improving the accuracy of alarms.

Other non-priced effects include the possibility of allowing larger ships into harbours if there is more certainty as to where shallows are located in the approach, which will make the maneuvering of larger tonnage safer. Better charts on anchoring conditions can potentially make emergency anchoring safer and easier and may reduce the extent of damage in emergency situations. Better and more detailed maps may also allow for a shorter approach to some harbours, where it ispresently necessary to sail a relatively long way around shallows. This could lead to savings in sailing time and fuel in addition to lower pilotage fees.

5.3.6. Norwegian Coastal Administration

The objective of the Norwegian Coastal Administration’s work is to ensure efficient maritime transport with a high degree of safety and reliability. Much of the benefit for the Coastal Administration will therefore be related to reduced accident risk and is calculated above in subchapter 5.1. With regards to efficient maritime transport, the system of shipping lanes along the coast is very important. The Coastal Administration is presently working on a review of this system to see if there is any need for changes. Knowledge about depth conditions is very important with regards to where shipping lanes can be placed. Thus, better mapping can contribute to changes in the shipping lanes resulting in reduced sailing distance and more efficient maritime transport. The Coastal Administration is also engaged in many improvement measures for shipping lanes, such as the removal of shallows and the installation of new sea marks and lights. Here, there is also some savings potential, seeing that the Coastal Administration will be able to utilize high-quality marine geospatial data earlier in the planning process, and thus for example more easily install markings or lights or calculate the extent by which shipping lanes need to be deepened. Better measurements also enable the Coastal Administration to draft a better plan of sea marks and lights along the coast, which will result in a better and safer voyage along the coast due to reduced accident risk. In addition, it may be possible to reduce the overall number of marks and lights, which would mean lower maintenance costs for the Coastal Administration.

5.3.7. Renewable energy

Renewable energy in the ocean space means the establishment of facilities such as wave power stations and offshore wind farms. Wave power stations are currently at the research and testing stage in Norway, for example at Runde Environmental Centre where a test project for wave power has been started.

With regards to offshore wind power such as offshore wind farms, at present there are no concrete plans for this along the Norwegian coast. There have been some minor trials, but there are no specific plans for either the short term or long term. There is only one offshore wind turbine on the Norwegian coast, Statoil's demonstration facility Hywind outside Karmøy. However, there are developments within offshore wind power in the UK, Denmark and Germany. The Norwegian Water Resources and Energy Directorate (NVE) points out that Norway has very good wind resources along the coast, but challenging depth conditions make development with existing technology more expensive than in other European countries.[63]

When setting up an installation, several different types of studies in the area are required, such as:

- Geological studies
- Geophysical studies
- Geotechnical studies

The geophysical studies include an assessment of elements such as seafloor conditions and bathymetry to identify dangerous and unsuitable areas on the seabed. In addition, anchoring conditions are analyzed. In this phase, marine geospatial data are an important factor in deciding where an installation will be placed.

Marine geospatial data are part of the analyses for optimal placement of an installation together with several other types of studies, and can help to find a better location for the installation. There are however other challenges related to the development of offshore wind farms that are more important than finding the optimal location for installation, especially conflicts with other user groups such as commercial actors, the Armed Forces and environmental interest groups. In addition, there are technological challenges related to the development of offshore wind turbines on Norwegian territory. In 2012, NVE assessed areas that may be suitable for the development of offshore wind power in Norway. According to NVE, it would be possible to open most of these areas for the installation of offshore wind farms. It is, however, demanding to develop the proposed areas compared to other locations in Europe that are under development. Part of the reason for this are challenging depth and wave conditions. NVE states that on the basis of today's technology, Norwegian sea areas will not be

[63] *NVE (2012) Havvind. Strategisk konsekvensutredning.*

cost-competitive compared to for example onshore wind power or European offshore wind power in the period up to 2020. In order for Norwegian sea areas to be able to compete on cost with sea areas elsewhere in Europe after 2020, there needs to be technological progress resulting in cost reductions also for Norwegian areas. Due to the large uncertainty with regard to the development of offshore wind in the Norwegian coastal zone, the benefits for renewable energy triggered by better marine geospatial data in the analysis period are likely to be relatively small.

5.3.8. Mining industry and disposal of mine waste

The mining industry comprises of activities related to prospecting, extraction and processing of minerals and rocks from bedrock and gobbing. Presently, extraction of metalliferous minerals takes place in land-based mines in countries over the whole world. According to the Norwegian Directorate of Mining, all Norwegian municipalities have one or more extraction sites, and the industry has an annual turnover of approximately NOK 13 billion. Of this, 50-60 percent consists of exports. Mineral resources are non-renewable, and therefore it has been necessary to look at potential alternatives to land-based mining. For this reason, interest in the extraction of metalliferous minerals from the seabed has increased in recent years. The seabed, just as land-based formations, holds large deposits of metalliferous minerals.

So far, there has not been any full-scale extraction of minerals from deep sea areas anywhere in the world. Activities have so far concentrated on surveying the deposits, but far from all areas have been mapped in detail. The discoveries are mainly located along subsea mountain chains, most of them in larger depths between 1500 and down to 7000 meters. Extraction of minerals in shallow water areas is going on in some places, such as Namibia and New Zealand. This however is not relevant with regards to shallow waters along the Norwegian coast, therefore there are no benefits to be derived from mapping the Norwegian coast with regards to the extraction of minerals.

Increased collection of marine geospatial data will be relevant in order to localize areas where waste from mines can be deposited in the sea. In Norway, significant amounts of mine waste have been disposed of in the sea over the years, and in 2015, new permits for such disposal were given for areas in Førdefjorden and Repparfjorden. Depositing mine waste in the sea poses considerable environmental challenges, due to the potential effects on local ecosystems and the way mine waste can be spread by ocean currents. When applying for a permit to dump mine waste into the sea, a rigorous assessment of the environment in the area where the waste is to be disposed of is required. Increased access to marine geospatial data will be able to contribute to cost savings associated with this process and provide a better fact base for decision-making. There are however few active and planned marine waste disposal sites in Norway today, and therefore we assume a relatively modest effect.

5.3.9. Knowledge and research

Norway as a nation is has strong links to the ocean. Report to the Storting Meld. St. 7 (2014-2015) *Long-term plan for research and higher education 2015–2024* states that important parts of higher education have been directed at the exploitation of resources on, in or under the ocean. In addition, the report points out that a long-term effort to develop knowledge and expertise related to the ocean and the ocean-based industries will enable Norway to exploit the resources in the ocean in a better way. The Government for example also makes it clear in its maritime strategy that research, development and innovation are of key importance for the maritime industry's competitiveness and capability to adapt.

Mapping and research into biological diversity and marine ecosystems are important for the development of commercial interest and sustainable management of the coastal zone. In Report to the Storting Meld. St. 7, there is an emphasis on three prioritized topics related to the coast and the sea:

- Values/assets from industries on the ocean, in the coastal areas and on the continental shelf
- Management of ecosystems and resources in ocean areas
- Clean ocean and healthy and safe seafood

Good access to marine geospatial data is of essential importance for research projects, and will improve the quality of the research that is done. It is especially important to map those areas where there are «holes» in the data material. The sea areas at a depth between 0-30 meters are most important for the research community, as it is this part of the ocean where the light permeates and production of fish and other living organisms is highest. The shallow areas all the way in to the shoreline, where mapping at present is insufficient, have an important role, and more detailed data will for example strengthen the modelling of stocks in the coastal zone. A scale-up of the collection rate of marine geospatial data will have benefits, because actors within research and knowledge development will have a better basis for their modelling of for example marine ecosystems.

Ocean current conditions are often part of different models for for example species distribution and the spread of salmon lice from fish farms. Ocean current models require good bathymetric data. Increased collection of such data will consequently increase the quality of research also through improved modelling of ocean currents.

Research and modelling of species and ecosystem provides a basis for the management of the coastal zone on the regional and the national level. The Norwegian Institute for Marine Research is an advisory body to the ministries and other parts of the administration that depends on good marine geospatial data for its models. In the same way as the Mareano-programme contributes to knowledge-based management of deeper ocean areas, mapping in areas close to the shore will be important for the management of these areas.

Improved availability of marine geospatial data can also increase investments in research and development related to the coastal zone from commercial actors. With better data, some industry actors may get a higher return from their R&D-efforts through better quality of the research. R&D has the potential to create positive spillover effects (knowledge externalities) for other actors in society, and can contribute to higher benefits within and outside of the marine and maritime sectors in society.

5.3.10. Norwegian Armed Forces

Bathymetric data, the resolution of maps and terrain models of the seabed are of great interest to the Royal Norwegian Navy. These data are so important that some depth curves and data at a resolution of more than 50*50 meters constitute classified information, which is only released on application. Presently, the Armed Forces are working on a new classification regime, where the possibilities for reducing the amount of data that is classified are being explored, but no decisions have been made yet. Due to the current classification regime, the opportunities to realize benefits for many of the actors mentioned above are somewhat reduced. A more detailed assessment and discussion of the realization of benefits will follow in chapter 9.

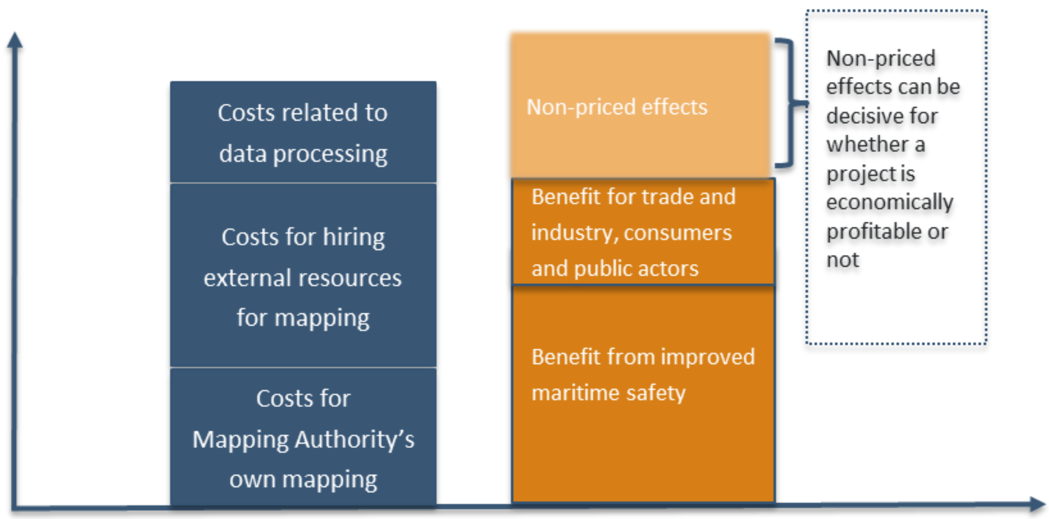
6. Assessment of economic profitability

The cost-benefit calculations show that a scale-up of the collection and processing of marine geospatial data is not economically profitable in any of the four scale-up alternatives when based exclusively on priced benefits and treating the benefit for the aquaculture industry as a non-priced effect. The results of a break-even analysis show that 0.24 percent of the growth in value creation in the aquaculture industry must be attributable to the effect of better map data to make it economically profitable to scale up the rate of data collection from the zero alternative at 35 years to 25 years. For the three other alternatives, the effect of better map data on value creation growth in the aquaculture industry must be a respective 0.27, 0.31 and 0.39 percent to justify a scale-up where mapping is completed within 20 years, 15 years and 10 years respectively. We consider it likely that the effect of map data on the aquaculture industry lies within this range, but there is considerable uncertainty related to this assumption.

To assess the overall economic profitability of a scale-up of the collection of marine geospatial data, in this chapter we examine the individual costs and benefits of the alternative measures. We analyze the different scale-up alternatives and compare them to assess their economic profitability. The calculations in this analysis are carried out in accordance with the guidelines in the Norwegian Ministry of Finance's circular R-109/14 for cost-benefit analyses and the guide for cost-benefit analyses published by the Norwegian Government Agency for Financial Management (DFØ). The calculations are carried out in the form of a cost-benefit analysis. In cost-benefit analyses, priced costs are juxtaposed with priced benefits. When calculating costs and benefits for different measures, these must be measured against costs and benefits in a reference scenario. The cost-benefit analysis is supplemented by a break-even analysis where we calculate how much of the value creation growth in the aquaculture industry must be attributable to better map data for the calculation of economic profitability to break even.

In this analysis, we assess the scale-up alternatives against a continuation of the present rate of collection for map data. In many cases, there are several forms of costs or benefits that cannot be quantified. This must be accounted for, and put into relation with the difference between priced costs and priced benefits (Norwegian Ministry of Finance, 2014). This will result in an overall impression of how valuable the non-priced benefits must be for the measure to be viewed as economically profitable. This process is illustrated in the figure below.

Figure 7: Illustration of weighting of priced and non-priced effects in the cost-benefit analysis. Source: Menon



6.1. Key premises for the analysis

Like all cost-benefit analyses, this analysis is based on a number of necessary premises and assumptions. Below, we briefly account for the general assumptions this analysis is based on. In the appendix to the report, we describe these assumptions and calculations in more detail.

6.1.1. Analysis period

The economic effects are calculated over a period from 2017 up to and including 2051, and discounted to 2016. We assume that a potential scale-up will start January 1, 2017. All NOK-values are in fixed 2016-prices. Marine geospatial data are likely to generate economic benefits way beyond 2051. We are still using maps based on measurements that were taken in the 19th century, and in principle, these data have a value until they are replaced by new updated map data. Ideally, the length of the analysis period should be as close to the measure's life span as possible (Norwegian Ministry of Finance, 2014). In the case of this particular analysis, this would be extremely difficult to implement, because the benefits will continue to exist for many years. Based on this, we calculate whether a scale-up of the data collection rate is economically profitable. The analysis period is set to 35 years. The reason that we choose a period of 35 years is that this is the time it takes to map the coastal zone in its entirety in the zero alternative. After this period, both costs and benefits will be equal in all alternatives. There will not be any relative differences between the zero alternative and the alternative measures, and thus no additional costs or benefits that will affect the calculation of economic profitability.

6.1.2. Discount rate

We use a discount rate of 4 percent throughout the analysis period, in accordance with the Finance Ministry's circular R-109/14 for cost-benefit analyses. The discount rate takes into account that a krone in the future is worth less than a krone today, due to factors such as lost interest, inflation and risk. By using a discount rate, it is possible to convert all priced effects to the value they have in a certain year. In this analysis, we have converted all priced effects to their 2016-values (discounted to 2016).

6.1.3. Tax funding cost

In cost-benefit analyses, in addition to calculating the administrative costs, it is also necessary to consider what kind of loss society incurs because of funds having to be raised through taxes and charges to finance a good or a service. This cost is often called the tax funding cost. The Norwegian Ministry of Finance informs in its circular R-109/14 that a tax funding cost of 20 percent of tax revenue shall be assumed in cost-benefit analyses. In other words, this means that the actual cost to society of a project that is tax-funded with 100 kroner is 120 kroner. In general, the payable costs for a public project must be covered through general taxation or user payments where this is practically possible. Taxes will normally lead to a situation where consumers and producers face different prices. A general tax on services will create a wedge between the price exclusive of tax, which is the base of producers' profitability calculations, and the price inclusive of tax, which decides how much consumers will buy of the service. In the same way, a tax on labour will create a wedge between the net wages the workers receive and the gross wage the enterprise has to pay. Such tax wedges distort production and consumption decisions in such a way that the consumers suffer a loss that is bigger than the actual amount of tax raised.[64]

[64] *The text in this paragraph is a translation from Official Norwegian Report NOU 1997: 27: Nytte-kostnadsanalyser. Prinsipper for lønnsomhetsvurderinger i offentlig sektor, p.86. [Norwegian only]*

The collection of map data is tax-funded. Both NGU and the Mapping Authority receive public funding. This means that all costs in this analysis are multiplied by 20 percent. In addition to costs, we calculate the benefit for public actors in form of cost savings for their own mapping. When public actors use their budgets to finance mapping of their own areas, this is also tax-funded. Therefore, the calculated benefit for these actors is also multiplied by 20 percent to take reduced efficiency loss into account.

6.1.4. Employment effects

Potential economic effects of changes in employment because of a scale-up in the rate of data collection and processing are not included in this analysis. The reason for this is that we do not expect that such a scale-up will affect the general employment rate in the economy. It is possible that some private enterprises that provide mapping services of the seabed to fish farmers and public actors may lose orders and consequently need to reduce staff. In all alternatives except the zero alternative, a scale-up means that the Mapping Authority will hire external consultants. This means that there will still be demand for this type of competence in the market, and if enterprises see that there are opportunities to win long-term contracts within data collection and processing, it is likely that the market will adapt to this increased demand from the Mapping Authority. Thus, there is little reason to believe that the overall rate of employment will be noticeably affected. It is however possible that a scale-up will result in a marginal change in industry composition because some resources are transferred to for example industries with higher or lower productivity. The potential economic effects of such changes in industry composition are notoriously difficult to predict, and are usually not included in cost-benefit analyses. For a scale-up in data collection and processing where employment will probably mostly stay within the same industry, such effects will anyway be limited and are therefore not included in our analysis.

6.1.5. Execution of the cost-benefit analysis

Costs will run for 35 years in the zero alternative, while the benefits of the map data will last much longer; in principle, their lifespan is unlimited. This makes it challenging to calculate the total benefit deriving from the fact that the whole coast has been mapped. However, the more specific question we are trying to answer here is whether it will be profitable to scale up the rate of data collection compared to the zero alternative. This means we carry out a *relative* analysis where we relate the changes in costs to the changes in benefit by scaling up the rate of data collection. If resource use continues at the same level as today, which is the basic assumption for the zero alternative, the whole coast will be mapped within 35 years. All other alternatives entail a faster rate of data collection. This means that after 35 years, costs and benefits for all alternatives are equal. We therefore set the length of the analysis period to 35 years. In this way, we analyze if the increased benefits of mapping the coast within 25, 20, 15 or 10 years respectively instead of within 35 years as in the zero alternative are higher or lower than the cost increase caused by speeding up the rate of data collection. If the increased benefit deriving from a measure is higher than the cost increase caused by the implementation of the measure, the measure will result in a positive net economic benefit. If the net economic benefit is positive, it is economically profitable to scale up the rate of data collection.

6.1.6. Calculation of economic profitability

The economic costs consisting of costs for the Mapping Authority's internal data collection, processing and administration, costs for hiring external consultants and equipment, costs for NGU's geological survey and tax funding costs were calculated in chapter 4.1.5. The priced benefits are quantified effects of risk reduction for commercial shipping and the recreational fleet, and cost savings for own mapping activities for public actors. The table under shows the net economic benefit for all alternatives. All values are relative to the zero alternative.

Table 16: Net economic benefit at net present value for alternatives 1-4 (NOK million, fixed prices 2016)

Alternatives	Costs	Benefits	Net economic benefit
Alternative 1: 25 years	-747	369	-339
Alternative 2: 20 years	-1 014	513	-450
Alternative 3: 15 years	-1 373	685	-611
Alternative 4: 10 years	-1 880	828	-874

The table above shows a negative net economic benefit for all alternatives. This means that costs increase more than benefits by moving from the zero alternative to each of the four scale-up alternatives. Based on the calculations above, none of the alternatives appear economically profitable. Thus, it is not economically profitable to scale up production compared to the zero alternative on the basis of priced economic costs and benefits alone.

In addition to the priced effects, there are non-priced effects as described in chapter 5.3. The largest and most important of these effects is, in our eyes, the effect on the aquaculture industry. The potential benefits for this industry may be so large that they outweigh the quantified negative net economic benefit. There is however considerable uncertainty related to these effects. Due to this uncertainty, we have carried out a break-even analysis that includes these effects in the calculation.

With regards to the remaining non-priced effects, we view these as significantly more modest than the effect for the aquaculture industry. There is of course a potential for several of these to result in a benefit. Improvements of the system of shipping lanes for example might lead to considerable time savings for shipping, or research and knowledge development based on better data could result in significant improvements in Norwegian marine and maritime competitiveness, and better administration of the coastal zone. We believe however that this type of effects is based on some assumptions that are very uncertain, and/or that it will take considerable time before these benefits can be realized. Due to this, it is our view that these effects (non-priced effects except for aquaculture) are not sufficiently large to alter the conclusion based on priced effects above.

6.1.7. Break-even analysis

There are three basic types of economic analyses.[65] Cost-benefit analysis, as shown above, goes furthest in the quantification of cost and benefit elements. Because of the considerable uncertainty related to the effect of better map data on the aquaculture industry, we chose to treat this effect as a non-priced effect in the main analysis. This results in significant uncertainty in the calculation of economic profitability, because the effect on aquaculture is potentially very large. To be able to say something more on how large this effect must be to make the alternative measures economically profitable, we have supplemented the cost-benefit analysis above with a break-even analysis for the effects for the aquaculture industry. The table below shows to what extent better map data will have to increase value creation in aquaculture to reach break-even in the different alternatives.

[65] *More detailed information about the different types of economic analyses is available in appendix 1.*

Table 17: Break-even analysis for the effect on the aquaculture industry (NOK million, fixed prices 2016)

Alternatives	Costs	Benefits	Benefit aquaculture	Increase in percent
Alternative 1: 25 years	-747	369	339	0.24
Alternative 2: 20 years	-1 014	513	450	0.27
Alternative 3: 15 years	-1 373	685	611	0.31
Alternative 4: 10 years	-1 880	828	874	0.39

It follows from the calculations above that the benefit for the aquaculture industry must be equal to the negative net economic benefit in each alternative for the measure to break even. The last column shows how much of the growth in value creation in the aquaculture industry must be attributable to better map data for the measures to be economically profitable. The growth is in the range of approximately 0.24-0.4 percent for the individual measures.

To understand how we have arrived at this effect, an example might be helpful. Let us assume that once the Mapping Authority and NGU have produced maps for the whole Norwegian coast, this will have the effect in a given year that the aquaculture industry will be 0.4 percent larger than today. Aquaculture is a large industry, and value creation is significantly higher than for the average commercial activity in Norway. Therefore, the net gain from moving a sufficient amount of labour and capital to the aquaculture industry from other industries in order to achieve 0.4 percent higher value creation in aquaculture results in a net value creation gain of NOK 65 million per year. If mapping is completed within 25 years, approximately 50 percent of the coast will be mapped within 14 years. We therefore assume that half of the net value creation gain of NOK 65 million is realized in the aquaculture industry in that year. If mapping is completed within 10 years, the whole benefit will be realized in the same year, while 95 percent will be realized in year 14 if mapping is completed within 15 years. As NGU will not map more than around 4 percent of the coast in the zero alternative, we assume that the zero alternative will trigger 4 percent of the value creation benefit. The benefit in the alternatives is the value creation gain resulting from the area that is mapped in the alternatives, minus the approximately 4 percent that would have been realized in the zero alternative. Thus, the net economic benefit of mapping within 25 years in year 14 is that 46 percent more of the value creation gain of NOK 65 million is realized. If mapping is completed within 10 years, the benefit is that 96 percent more is realized etc. The discounted sum of the value creation effects that are realized *in addition to* the benefit realized in the zero alternative over the years in the analysis period is thus the benefit of the measures for the aquaculture industry. If 0.24 percent additional value creation in the aquaculture industry are triggered by the Mapping Authority and NGU when all areas are mapped, this sum will be large enough for the measure to break even. Appendix 4 contains a more detailed description of how we have calculated the benefit for the aquaculture industry.

We think it is probable that the benefit for the aquaculture industry may be within this interval. Our assessment is based on the fact that acceptable environmental conditions will be the most important precondition for increased growth and development in the aquaculture industry. This also means that ocean current modelling is the most important tool in order to ensure favourable environmental conditions and especially to predict the potential spread of salmon lice. Depth data are the most important input factor for the quality of ocean current models.

It is important to point out that we have only assessed *one* non-priced effect here. Other non-priced effects within the fishing industry, meteorology and knowledge and research, as well as non-priced effects for shipping will also increase the benefit in the four scale-up alternatives. This means that the effect on the aquaculture industry may not have to be quite as large as demonstrated in the calculations above. It is however likely that this will be the largest non-priced effect because of the industry's size and expected growth potential. Therefore it is necessary that the magnitude of this effect is close to what we have calculated here for an increased rate of data collection to be economically profitable.

On the cost side, technological developments are expected in the next ten years that will most likely lead to a productivity growth higher than the 1.3 percent assumed by the Norwegian Finance Ministry in its outlook for the Norwegian economy.[66] This is related to the development of technological solutions such as unmanned surface vehicles (USVs) and higher efficiency within data processing. This indicates that it might be unwise to scale up «too fast», because the costs for society related to this process will fall significantly in the near future.

The calculations above are characterized by great uncertainty. Both on the cost and the benefit side, there are large uncertainty factors for several of the parameters. We have therefore carried out a series of uncertainty analyses in the following chapter.

[66] *Report to the Storing Meld. St. 12 (2012–2013). Long-term Perspectives on the Norwegian Economy 2013 ('Perspektivmeldingen').*

7. Assessment of uncertainty

Assessments of economic profitability are always characterized by large uncertainty. This also applies to this analysis. To ensure that our conclusions are as robust as possible, we have therefore carried out several uncertainty analyses that show how different assumptions about the uncertain parameters affect the calculations. Within each of the cost and benefit categories, we have looked at those parameters we believe are most uncertain, and conducted uncertainty analyses where we look at an upper and lower value for these parameters.

7.1. Cost side

The costs of the Mapping Authority are modelled in a very detailed way, and we have collected a significant amount of information related to these costs. Much of this information is based on real values from the Mapping Authority's result report and budget, and on experience with this type of activity over several years. There still is one parameter which is more uncertain than others, and that is the efficiency gain resulting from the use of new technology within the processing of map data. In our analysis, we have estimated this net effect to 50 percent, based on statements from experts on this technology. The technology has progressed far, and is now being tested by several different actors. However, this early in the process it is still difficult to provide precise estimates of how big the cost savings will be. In addition, the technology will work better in some sea areas than in others, depending on the area's complexity. For example, for the time being cost savings are lower for uneven terrain compared to flat ground. Despite this, several of the experts expect cost savings of 50-90 percent. One of the experts also believes that this is a conservative estimate. Based on these estimates, we reckon that uncertainty at the lower limit of this range is not very large. Our estimate of 50 percent efficiency gain for the main analysis is probably on the conservative side. For the uncertainty analysis, we set the lower net effect to 40 percent. Even though some experts expect effects of as much as 90 percent, we believe it is too early in the development process to assume effects of this size. It is also important to consider that there are variations in bathymetry, and that the efficiency gain may not be equally large in all areas. Based on this, we put our upper estimate between the estimate used in the main analysis and the experts' high estimate, i.e., at 70 percent.

The Mapping Authority's costs are, as mentioned above, modelled in considerable detail. To be able to say anything about economic profitability, it was necessary to take NGU's costs into account as well, because its products are important for the realization of the total benefit. NGU's costs are modelled somewhat more simply, and therefore uncertainty is greater. The largest uncertainties, in our opinion, are related to training time for marine geologists and how many marine geologists must be hired for mapping to be completed within 15 years (and thus to the basis for the calculation of the number of marine geologists in the other alternatives).[67] In the main analysis, training time is set to 1.5 years. Since the training consists of both theoretical instruction and «learning-by-doing», there is a fluent transition to the point where the marine geologists will be fully operative. In the uncertainty analysis, we therefore operate with a shorter training time, set to 1 year, and a longer training time, set to 2 years.

For NGU, there is also uncertainty related to how many marine geologists will be needed to complete mapping within 15 years. NGU estimates from 10-15 FTEs in addition to the existing FTEs, three at present. We have

[67] *NGU has only estimated how many marine geologists will be necessary to map the whole Norwegian coast (excl. Svalbard) within 15 years. This estimate is therefore the base for our calculations of how many will be needed at a faster or slower collection rate.*

therefore set the total number of FTEs for marine geologists to 15 for a collection period of 15 years. In the uncertainty analyses, we have set an uncertainty range for the number of FTEs for marine geologists from 10 to 20 to accommodate this uncertainty.

7.1.1. Uncertainty analyses on the cost side

How the uncertainty parameters change in the different scenarios is summed up in the table below:

Table 18: Uncertainty parameters on the cost side

Uncertainty parameter	Scenario	Main analysis	Uncertainty – low estimate	Uncertainty – high estimate
Efficiency gain Mapping Authority	Efficiency gain	50%	40%	70%
Training time NGU	NGU	0 (1.5 years)[68]	2 years	1 year
FTEs marine geologists NGU	NGU	3 (15)[69]	20	10

The assumptions from the main analysis are shown in the first column as a basis for comparison. "Scenario" denotes the changes that are made. That means that we develop a scenario where we change the rate of efficiency gain (in percent) for processing at the Mapping Authority while everything else stays the same. In the scenario called NGU, we change both the training time and the number of FTEs for marine geologists simultaneously, while everything else stays the same. "Low estimate" denotes a change in the uncertainty parameters that will result in higher costs. "High estimate" denotes a change in parameters that will result in lower costs. The different scenarios for uncertainty with regards to the Mapping Authority's and NGU's costs are shown in the table below.[70]

Table 19: Uncertainty analysis on the cost side (Net economic benefit in NOK million, fixed prices 2016)

		Low estimate		High estimate	
Alternatives	Main analysis	Efficiency gain Mapping Authority	NGU	Efficiency gain Mapping Authority	NGU
Alt. 1: 25 years	-339	-348	-333	-333	-343
Alt. 2: 20 years	-450	-472	-445	-434	-452
Alt. 3: 15 years	-611	-642	-611	-562	-611
Alt. 4: 10 years	-874	-911	-886	-806	-866

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[68] *In the zero alternative, there is no training time for the three marine geologists working at NGU at present. In the alternative measures, training time is 1.5 years.*

[69] *In the zero alternative, we have counted in the three FTEs for marine geologists that work at NGU today. If NGU had to complete mapping with 15 years, we would have assumed 15 marine geologists, and it is this number of FTEs which is the basis for the calculation of the number of marine geologists in the different alternatives.*

[70] *Since NGU's estimate of a cost of NOK 500 million for mapping within 15 years, adjusted for wage growth, is fixed, NGU's costs in alternative 3 are not affected by changes in the assumptions for cost calculations for NGU. Shorter training time and fewer marine geologists needed result in lower potential savings if mapping is completed at a slower rate than 15 years. Therefore, the assumption of a bigger efficiency gain in NGU leads to higher cost estimates for alternative 1 and 2, and lower cost estimates for alternative 4, and vice versa for the assumption that the efficiency gain will be smaller.*

In the table above, we have shown how the net economic benefit in the different alternatives changes with the changes in the parameters described above. The main analysis is included in the first column as a basis for comparison. We see that the size of the effects within the different alternatives varies to some extent. The net economic benefit in alternative 1 for example is within the interval of NOK -333 and -348 million at net present value. For the other alternatives, net economic benefit is within the following intervals: NOK -434 and -472 million, NOK -562 and -642 million and NOK -806 and -911 million for alternatives 2, 3 and 4 respectively. This means that for alternative 1, there is a difference of only NOK 15 million, while there is a difference of more than NOK 100 million between the highest and the lowest estimate in alternative 4.

7.2. Benefit side

On the benefit side, there is especially large uncertainty related to the nautical charts' ability to help reduce accidents within commercial shipping and for leisure craft, and to the estimates of the effects for public actors.

When estimating the effects of better map data on the reduction of accident risk, we based ourselves on an average of expert statements and statistics for reporting accidents caused by insufficient/bad chart material. In the uncertainty analysis, we look at the two point estimates that this average was calculated from. An upper and lower limit for the reduction of accident is risk is therefore 11 percent and 4 percent respectively for commercial shipping. The upper limit of 11 percent is an average based on the expert statements, while the lower limit of 4 percent is based on accident statistics. For leisure craft, we base our estimate on expert statements only. For the upper limit, we choose the upper level of expert statements, resulting in an estimate of 20 percent. For the lower limit, we take the lower level of expert statements, leading to an estimate of 5 percent.

Uncertainty related to the effects on public actors is particularly large, both because there are few statements on benefits relative to the number of affected actors, and because it can be difficult to know exactly *what* needs the data may fulfill. Some actors say that they have not needed to purchase data in connection with for example coastal zone plans, while other actors claim that millions of kroner have been spent on mapping in connection with infrastructure investments. That actors have such different perceptions of the use, and maybe also the utility, of map data is a challenge with regards to the generalization of benefits for this group.

In this uncertainty analysis, we try to demonstrate some of the divergence in effects between the actors. We set up a scenario with a high estimate of the benefits for the public actors, and one with a low estimate. While we, in the main analysis, have chosen to use a conservative average for the benefits, in the uncertainty analysis we will base our upper and lower estimates on the more extreme points of the scale in the statements we received in interviews. How the parameters change in the different scenarios is summed up in the table below.

Table 20: Uncertainty parameters on the benefit side

Uncertainty parameter	Scenario	Main analysis	Uncertainty – low estimate	Uncertainty – high estimate
Maritime safety shipping	Maritime safety	7.5%	4%	11%
Maritime safety leisure craft	Maritime safety	15%	5%	20%
Municipalities	Public	NOK 100 000 per year	NOK 25 000	NOK 200 000
Public Roads Administration	Public	NOK 200 000 pr project	NOK 100 000	NOK 500 000
Statnett	Public	NOK 10 000 000 in total	NOK 2 000 000	NOK 20 000 000[71]

As shown in column two of the table, we set up two scenarios. In the first, we change the probability for the map data's effect on maritime safety for both commercial shipping and leisure craft. In the other scenario, we change the benefits for all of the three public actors. The uncertainty analyses for the benefit side is shown in the table below.

Table 21: Uncertainty analysis for the benefit side (NOK million, fixed prices 2016)

		Low estimate		High estimate	
Alternatives	Main analysis	Maritime safety	Public	Maritime safety	Public
Alt. 1: 25 years	-339	-468	-451	-254	-116
Alt. 2: 20 years	-450	-647	-580	-319	-188
Alt. 3: 15 years	-611	-891	-766	-426	-301
Alt. 4: 10 years	-874	-1 222	-1 049	-645	-522

The table over shows the range of uncertainty on the benefit side for the higher and lower estimate of the uncertainty parameters. The estimates largely follow the same trends. The faster the rate of scale-up, the larger the difference in realized benefits, i.e., the bigger the effect of the uncertainty parameters.

7.3. Uncertainty analysis for cost and benefit side in total

To compare all effects, we have set up two scenarios including the respective high and low estimates for all uncertainty parameters. This means there will be a «best-case» and a «worst-case»-scenario based on the quantified effects. An overview of the net economic benefit of scaling up the data collection rate to the different alternatives is shown in the table below. In addition, we have calculated how big the effect of map data on aquaculture needs to be in all alternatives to achieve break-even.

[71] It was difficult for Statnett to provide an upper limit. The high estimate in the scenario is therefore based on a doubling of the estimate in the main analysis.

Table 22: Summary of uncertainty analyses with «worst-case» and «best-case»-scenario (NOK million, fixed prices 2016)

Alternatives	Main analysis	«Worst-case»	Break-even aquaculture	«Best-case»	Break-even aquaculture
Alt. 1: 25 years	-339	-582	0.41%	-29	0.020%
Alt. 2: 20 years	-450	-797	0.48%	-45	0.027%
Alt. 3: 15 years	-611	-1 077	0.55%	-68	0.035%
Alt. 4: 10 years	-874	-1 447	0.65%	-218	0.098%

From the results above, we see that going from the zero alternative to alternative 1-4 in «Best case» results in a negative net economic benefit in the interval from NOK -29 to -218 million for priced effects. This indicates that there needs to be an effect on the aquaculture industry in the range of 0.02-0.1 percent to reach break-even. For alternatives 1-3, the effect ranges from approximately NOK -30 million to -70 million and somewhat below 0.04 percent for aquaculture in all alternatives. Assuming the «worst case»-scenario, we see that the effects of map data on the aquaculture industry vary from approximately 0.41-0.65 percent.

The assumptions the analysis is based on affect how large the effect on the aquaculture industry and other non-priced effects must be for the measures to be economically profitable. The variations in the percentage-wise change for the effect on the aquaculture industry between the different alternatives and scenarios are however not particularly large. With a scale-up of the collection rate to 10 years (alternative 4) in the «worst case»-scenario, the effect of map data on value creation growth in the aquaculture industry needs to be approximately 0.65 percent. This is a change of around 0.4 percentage points compared to the main scenario.

8. Assessment of distribution effects

In addition to the economic effects of the measures, it is also necessary to assess the distribution effects resulting from the measures. In a cost-benefit analysis, the calculations must be based on unweighted willingness to pay. It is however also important to discuss potential distribution effects and conflicts of interest, so that these can be taken into consideration in the assessment of measures.[72] Distribution effects are transfers of resources between actors that do not have a cost or benefit for society as a whole.

In this case, it is the Norwegian state that will bear the costs for scaling up the collection of marine geospatial data. This could be interpreted as a redistribution from the state to coastal municipalities, as the municipalities save money because they do not have to carry out the mapping themselves. This effect is however relatively modest, as the municipalities do not use a significant proportion of their budgets for this type of mapping.

To a large degree, it is individual industries that will benefit from the measure. Actors within the coastal and ocean-based industries such as shipping, fisheries and aquaculture will gain an advantage with regard to the operation and development of their industries compared to non-ocean-based industries. In addition, there is a redistribution effect between those who own leisure craft and those who do not, in the form of reduced accident risk for the boat owners. One could say that these groups in society (ship-owners, fish farmers, fishermen, owners of leisure craft) to some extent already command a lot of resources. On the other hand, these are industries that traditionally have been important for Norway, and also face strong international competition.

As far as public actors are concerned, coastal municipalities and infrastructure investments related to coastal areas will benefit from the measures. This can be seen as a redistribution effect from inland areas to coastal areas, in the same way as there is a redistribution from inland industries to coastal industries. There are however no large vulnerable groups that will be noticeably worse off if this type of measure is implemented; therefore, we believe the potential negative effects with regards to the politics of wealth distribution are not large enough to have an impact on the outcome of the cost-benefit analysis of measures based on priced and non-priced effects presented above.

[72] *The reason this is important is that a cost-benefit analysis does not take into account that different stakeholders in society can value one krone differently. The analysis is based on unweighted willingness to pay. In reality, one krone will usually be valued relatively higher by a person that has little to start with compared to a person that has a lot.*

9. Overall assessment and recommendations

In this report, we have carried out a cost-benefit analysis of a scale-up of the rate of collection and processing of marine geospatial data in Norway. Based on the findings from this analysis, it appears most profitable to scale up data production to a rate where all areas will be mapped within 25 years (alternative 1). This will most likely be economically profitable, based on assessments of the non-priced effects' size and impact. At the same time, we would like to point out that there is considerable uncertainty with regards to economic profitability, partly because the benefits for the aquaculture industry are indirect and hard to calculate.

Based on the priced effects alone, we cannot conclude that a scale-up of the collection of map data is economically profitable. By carrying out a break-even analysis with regards to the effects on the aquaculture industry, we find that a scale-up is economically profitable if the effects of map data for this industry are in the interval between 0.24-0.39 percent growth in value creation. We believe that this may be likely due to the map data's importance for ocean current modelling and calculations of environmental effects, which affect the potential for growth and development in the industry. There is also large uncertainty with relation to the total benefits that will be triggered, due to the Armed Forces' classification regime for marine geospatial data and potential future changes to this.

In line with the technological progress within data collection and processing, we recommend to conduct a new assessment once new technologies have been commercialized. This may be at a point between five and ten years from now. A further scale-up should then be considered in the light of new cost reductions resulting from technological development. The combination of uncertainty about the calculation of benefits for the aquaculture industry, the uncertainty related to the overall benefits that can be realized due to the Armed Forces' classification regime and the effects of potential technological progress in the next few years is the reason why we do not recommend a scale-up to a collection rate of either 20, 15 or 10 years.

Independently of a potential scale-up, the Mapping Authority should prioritize areas with dense ship and boat traffic, areas with potential for growth in the aquaculture industry, and areas with a large population or considerable population growth. This will trigger the most benefits overall.

Based on the above calculations, we cannot say that a scale-up of the collection rate for marine geospatial data is economically profitable based on the quantified effects alone. The overall effect depends on the non-priced effects, where we believe the effect of map data on the aquaculture industry is the largest and most significant one. We have carried out a break-even analysis where we have examined how significant the effects on value creation growth in the aquaculture industry would have to be for a scale-up to be economically profitable. These effects are in the interval between 0.24-0.39 percent in the main analysis. It is likely that the effects on the aquaculture industry are indeed within this interval because of the bathymetric data's significance for ocean current modelling and assessment of the environmental impact of fish farms on their surroundings. Environmental sustainability is most likely the most important factor for growth and development of the aquaculture industry in the future. There is however considerable uncertainty related to the calculation, and the benefits may therefore be significantly higher or lower than what is presented in the analysis above.

Priced and non-priced effects are however not the only important factor when assessing the economic profitability of the measures. For this analysis, it is especially important to discuss the realization of benefits. The reason for this is that there are legal limitations with regards to triggering the full benefit potential for some of the actors. As mentioned above, depth and bathymetric information is subject to a classification regime. According to the Norwegian Security Act, depth data within the territorial boundary of continental Norway with a resolution of more than 50*50 meters are classified as confidential. Svalbard is not covered by the classification regime, and all data for Svalbard are available with a resolution of 10*10 meters or higher. In addition, some contour lines are classified. Contour lines that can be shown on a map (and are not classified information) are the following: 2, 3, 5, 10, 20, 30, 40, 50 and 100 meters. At depths of more than 100 meters, the distance between depth curves is 50 meters.

At present, a working group consisting of representatives for the civilian population and the Norwegian Armed Forces is working on a revision of the classification regime. The work of this group has not been concluded yet, but it is likely that the classification regime will be relaxed somewhat compared to today's standards. One likely outcome is that areas from 0-30 meters in depth will be exempt from classification both with regards to resolution and depth data. For depths of more than 30 meters, a resolution higher than 50*50 meters will be classified (as under the current regime). Government agencies and institutions will likely be given limited access to data with a resolution of between 50*50 and 25*25 meters for depths of more than 30 meters. Data with a higher resolution will be confidential, and only released on application. The potential new classification regime is illustrated in the figure below.

Figure 8: Probable new classification regime. Source: Working group for new classification regime

Resolution (m)

Depth (m)	50x50	25x25	10x10	5x5	1x1	<1x1
0 -10						
10 - 20			Not classified			
20 - 30						
30 - 50						
50 – 100		Limited		Classified		
> 100						

It is important to point out that thematic maps and ocean current models based on classified data are not classified information.

The classification regime influences the benefit that is triggered for the actors. In the cost-benefit analysis above, we have mostly looked at the potential benefit resulting from availability of the data for the actors, without considering how the classification regime may limit the actual benefits for the individual actors. We will therefore discuss which requirements the actors have with regards to data resolution to be able to realize benefits. This is put in relation to the proposed new classification regime above.

There are very few ships with a draft of more than 15 meters. If areas from 0-30 meters of depth are exempt from classification and depth curves for each meter are generated, this will ensure safe travel and trigger benefit for these actors. In addition, it is to be expected that ships will be able to choose more efficient routes, and thereby realize benefits related to reduced travelled distance and smaller impact on the environment.

Municipalities and other government agencies that design plans for the coastal zone will need map data with a resolution of 25*25 meters. When planning infrastructure investments, the actors need a much higher degree of detail. Here, a resolution of 1*1 meters is required, and even more in cases where routes for roads or subsea cables need to be determined. The Map Authority is able to deliver a resolution of 1*1 meters for its data, often also more. It is still very likely that actors such as the Public Roads Administration and Statnett will need to do some mapping of their own in addition to the data from the Mapping Authority in order to achieve an even higher level of detail. This has been taken into account in our calculations. Also for environmental protection measures on the seabed and in order to localize sites that are suitable for depositing mine waste, very detailed data with a resolution of 5*5 cm are needed. However, in these cases data with a lower resolution, between 10*10 and 5*5 meter, are relevant for the planning phase.

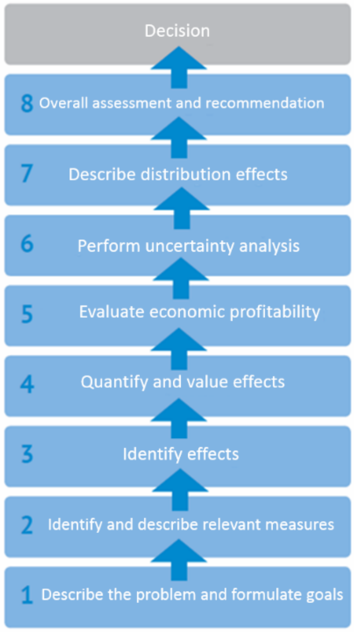
For the aquaculture industry, ocean current models are especially important in order to trigger the benefits. These models are not classified, even though they are based on classified data. A resolution of between 5*5 meters and 1*1 meters is seen as sufficient to develop current models. Otherwise, both the fishing and the aquaculture industries need bathymetric data with high resolution in order to be able to realize the benefits. The aquaculture industry uses marine geospatial data to plan the location and anchoring of its installations. The regulatory framework requires a resolution of 10*10 meters for this type of mapping of the seabed. The fishing industry needs high resolution data in order to be able to avoid damage to fishing equipment and plan for more efficient fishing. The discussed potential changes in the classification regime will not result in a full release of data on the most relevant depths for the fishermen, since most fishing takes place at depths of more than 30 meters.

Research and development activities in the coastal zone require good data as a basis for for example ocean current modelling. The resolution needed for data for current modelling is discussed above. In addition, wave modelling might also be relevant here. For this type of modelling, one will trigger benefits at depths of less than 100 meters at a resolution of 10*10 meters. Otherwise, research on and development of sea and coastal areas are related to modelling and distribution of marine species and natural habitats. For this type of research, a resolution of 10*10 meters in shallow areas and 25*25 meters in larger depths (more than 50 meters) will largely cover requirements.

The descriptions above make it clear that in order to trigger benefits for some of the actors, there needs to be a less strict classification regime that what is likely to be implemented in practice. Even under a classification regime, it will be possible to get access to data with higher resolution, but this means that the actors have to go through an application process. What this process will look like and how difficult it will be to have data released will also play a role for the benefits that can be realized. It is difficult to say what the overall impact of this will be, but it is important for the assessment of economic profitability to consider that there are legal limitations to the potential benefits for some actors, in form of the classification regime. This might indicate that the benefits could be somewhat overestimated in this analysis.

10. Appendix 1: Method for cost-benefit analysis

The cost-benefit analysis is based on the Norwegian Finance Ministry's circular R-109/14 describing principles and requirements for cost-benefit analyses.[73] We follow the model for cost-benefit analyses by the Norwegian Government Agency for Financial Management (DFØ) in its guidelines for such analyses from September 2014. An illustration of the recommended structure for this type of analysis is shown in the figure to the right.



1) DFØ's guide provides a structured approach and procedure for cost-benefit analyses. In brief, the main approach is as follows: To start with, there needs to be a thorough assessment and description of the issue to be solved before potential measures can be identified and evaluated (step 1 and 2).
2) The effects of the measures are identified, described and, as far as possible, quantified. Then the impact of the different alternatives is compared (steps 3-5).
3) The elements of uncertainty within the assessments are pointed out and described before other relevant elements such as distribution effects are taken into consideration and a final recommendation is provided (step 5-8).

On a general level, the methodical framework for cost-benefit analysis of public measures and policy instruments is very well developed. But even though the guidance material is detailed and well thought through, it is also relatively general so as to be able to encompass all types of analyses within very different sectors and topics. Some sectors have therefore developed specific sector guidelines, which often have a more operational focus. Especially in the transport sector, there is a long tradition for the use of cost-benefit analyses. The guidance material in this sector is therefore also detailed and operationally oriented when it comes to elements that are relevant for the large majority of analyses. Challenges related to risk reduction and preparedness for accidents and acute pollution are solved and standardized to a much lesser degree, which leads to a need for further operationalization of the framework.

Our methodology is based on the Norwegian Government Agency for Financial Management's (DFØ) guidelines for cost-benefit analyses, Official Norwegian Reports NOU 2012: 16 "Cost-benefit analysis" and the Norwegian Ministry of Finance's circular R-109/14 on principles and requirements for cost-benefit analyses. The guidance material defines three main forms of cost-benefit analyses:

- Cost-benefit analyses
- Cost-effectiveness analyses
- Cost-effect analyses

The different types of analysis have different areas of application, and provide different bases for decision-making. Cost-benefit analysis is the most comprehensive method, where all costs and benefits are valued in monetary terms as far as possible. In a cost-effectiveness analysis, only the cost elements are valued; these are

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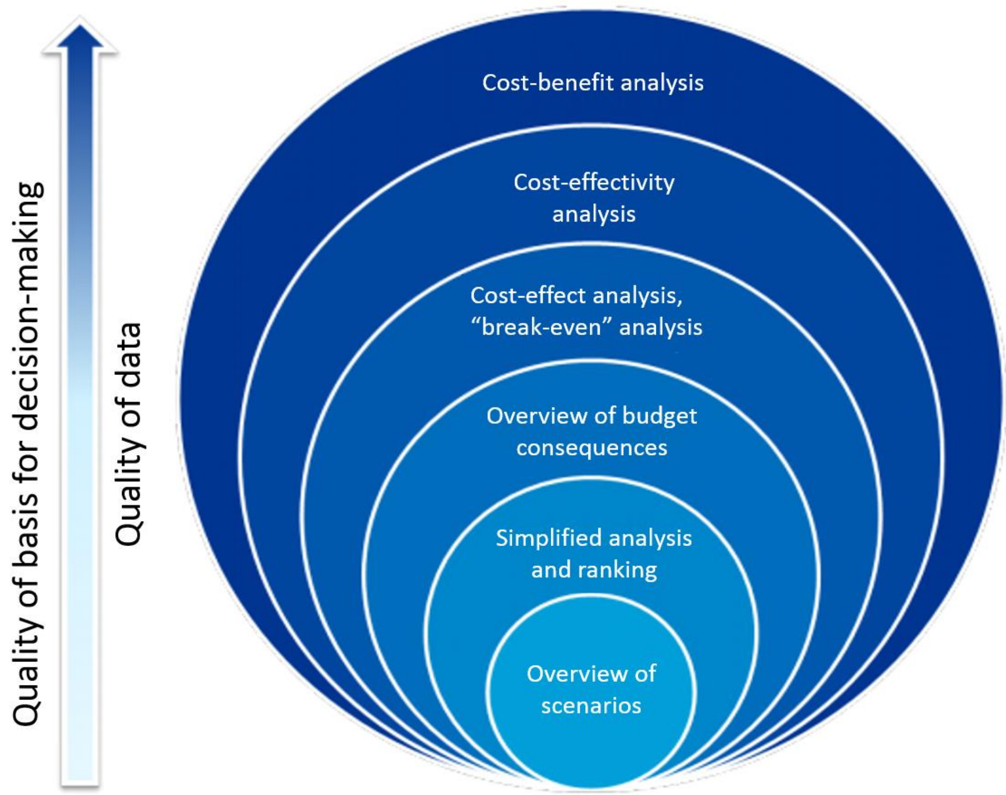
[73] *R-109/14 «Prinsipper og krav ved utarbeidelse av samfunnsøkonomiske analyser». The Norwegian Ministry of Finance, April 2014*

then used for an internal ranking of alternative measures with identical effects. Cost-effect analyses are the least comprehensive, and benefits are mainly assessed qualitatively.

Which type of analysis will be possible to conduct is seldom possible to know before work on the actual analysis has started. Therefore, there needs to be a sequential approach that results in the best possible basis for decision-making, even though availability of data might prove a limitation. How detailed the analysis can be, and how much sense it makes to proceed to the next step of the analysis, depends on available information, available resources for the study and the decisions to be made on the basis of the analysis. The principles of the sequential approach are illustrated in the figure below, which also shows what basis for decision-making is provided by each step in the analysis process.

Figure 9: Sequential approach to cost-benefit analysis



To start with, measures that are relevant in order to solve a specific problem are identified. Thereafter, the measures are described according to objective and type. Once this has been accomplished, the information base will describe the opportunity space of measures that decision makers can choose from. Once the measures are identified and categorized, a first qualitative assessment of the measures' effects is made. This allows a rough ranking of measures through a simplified analysis which can be used to select those measures that are expected to have the largest effect, are most likely to be implemented in practice, and should be assessed more thoroughly.

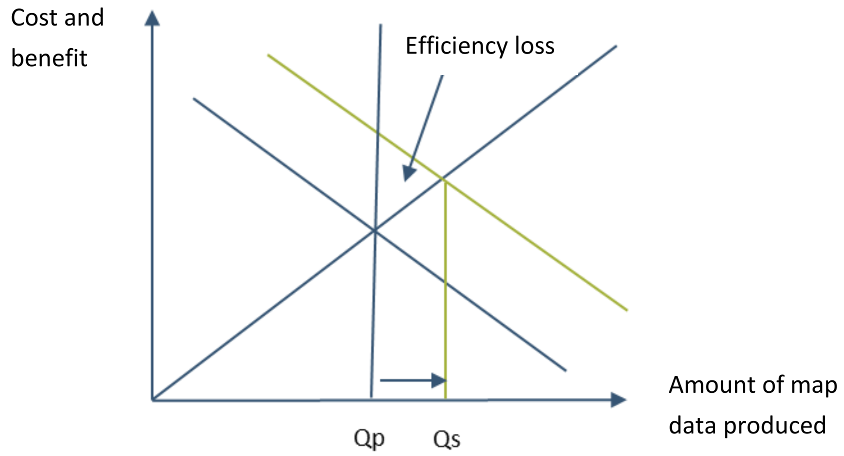
Furthermore, the costs for the measures are quantified. To start with, this provides an overview of the budgetary consequences for public and private actors. In addition, quantification of the costs will make it possible to conduct a cost-effect analysis which includes a qualitative description of the different benefits. This however is not sufficient to be able to rank the measures according to their economic profitability. Once the cost side has been quantified, the measures' economic impact will be calculated if possible. This makes it possible to rank measures that provide the same benefit according to their cost-effectiveness, and to conduct cost-effect analyses of measures with different economic benefits. From all experience, there will probably be effects which are difficult to quantify. If these make up a significant part of the measures' impact, it is necessary to rank the measures based on a cost-effect analysis. If necessary, this can be supplemented with break-even analyses to be able to say something about how large the remaining benefits can be while still being set off by cost savings.

Further calculation of the measures' real (physical) benefit will improve the basis for cost-effectiveness analyses, and facilitate the valuation of individual benefits in monetary terms. Once as many effects as possible, both on the cost and the benefit side, have been quantified, a cost-benefit analysis can be conducted. Here, economic profitability is calculated and weighted against non-priced elements.

11. Appendix 2: Efficiency loss

In chapter 2, we look at different forms of market failure that exist in the market for the collection of map data. We argue that private actors will not take the positive externalities deriving from these data into account, and that this will lead to underproduction and thus an efficiency loss for society as a whole. This is illustrated in the figure below.

Figure 10: Positive externalities of map data



The figure above shows the relationship between demand for and supply of map data. Qp is the market clearing quantity for private demand. Private actors do not consider the externalities valued by society. By taking these externalities into account, society demands a larger amount of produced map data, quantity Qs. This is illustrated by the demand curve for map data shifting outwards in the chart, from the blue to the green line. When production is too small, this creates an efficiency loss, because the realized economic surplus is smaller than the maximum economic surplus. If the market suffers from market failure, this indicates that the state can try to correct this market failure either with the help of public policy measures, like offering a subsidy for increased production, or by public production that takes the external effects into account.

12. Appendix 3: Method for cost calculation

12.1. Costs for chartering vessels and calculation of increased maintenance costs for M/S Hydrograf

The operating costs for M/S Hydrograf and two survey launches are set to approximately NOK 34.6 million in the Mapping Authority's result report for the first half of 2016. This includes a crew of 22 persons, i.e., two shifts with 11 persons. Presently, around 60 percent of this cost consists of wage costs for the crew. In other words, costs in 2016 can be divided into approximately NOK 20.78 million in wage costs and NOK 13.85 million in operating costs. As explained in section 4.1.6, wage costs have been adjusted to real wages at a rate of 1.3 percent per year. After the transition from M/S Hydrograf to a chartered vessel in 2025 in all alternatives apart from the one that assumes data collection to be completed within 10 years, only the wage costs for the crew members that are directly employed by the Mapping Authority will be adjusted.

M/S Hydrograf was built in 1985, and maintenance costs for the vessel are expected to increase in the future. In addition, the vessel must undergo a class renewal survey every 5th year.[74] The next class renewal for M/S Hydrograf is in 2020. The Mapping Authority assumes that the following class renewal five years later in 2025 will require such a massive increase in maintenance spending for M/S Hydrograf that replacing the vessel will make sense.

The procurement of a potential new vessel for the Mapping Authority can be done according to two main models: contract or buy an own vessel, or arrange a long-term charter of a privately-owned vessel. The costs for a new vessel depend on size, equipment and overall characteristics. However, the ongoing newbuild program by the Norwegian Coastal Administration can provide an indication of cost; investment cost for new vessels of approximately 40-50 meters is around NOK 150-170 million. A vessel for the Mapping Authority would probably be somewhat larger, for example 60 meters, suitable for use in the high north, equipped for use by a slightly higher number of people, but with somewhat simpler equipment on deck, and thus have an estimated investment cost of NOK 170-210 million. This size of vessel could be built by both the smaller shipyards that presently focus on mid-sized fishing vessels and service vessels for the aquaculture industry, and the larger shipyards that have built large advanced offshore vessels during the last years.

Charter costs for a vessel of this size will depend on length of contract and degree of specialization. If the vessel can be used for other types of assignments without significant adaptations, a period of 5 years can be viewed as a relatively long contract. If the vessel needs significant adaptations to fulfill the Mapping Authority's requirements, the period seen as a long-term contract will be longer. In addition, competitive situation and profitability in the market will influence costs. If the shipping companies are able use their resources for «ship management» in other highly paid segments, this will lead both to a higher price for the Mapping Authority and a higher cost level for the shipping companies because there will be less focus on cost-efficient operation and maintenance of ships than on business development in attractive segments. In the opposite situation, which the offshore shipping companies are experiencing now, a long-term contract with a public actor will be much more

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[74] Most vessels follow a five-year interval for follow-up and inspection by a classification society: yearly inspections, intermediate survey in year 2 or 3, and class renewal ('special survey') in year 5. Class renewal is the most comprehensive of these surveys, and includes thorough inspections of the hull, machinery and equipment by means of visual inspection, measurements and tests to examine whether the condition of the ship complies with national and international standards.

attractive, and this will result in a lower price for the Mapping Authority. The Mapping Authority will also need some residual capacity once the mapping is completed. This will be equal in all alternatives and does not influence the net economic benefit of the measures.

The Mapping Authority has been quoted a day rate of NOK 100 000 for a vessel similar to Hydrograf with a crew of 5 persons. The consultant's view is that this seems to be somewhat on the high side, but will depend on the factors mentioned above. Since the suppliers in principle are free to realize productivity increases in the form of a lower number of hours worked for the crew, the part of the charter cost that consists of wages for the hired crew has not been adjusted to real wages. The operating cost for the Mapping Authority's survey launches is approximately NOK 13 000 per day. The total cost for operating a vessel equivalent to Hydrograf, including hired crew, and the survey boats is thus NOK 113 000 per day, or NOK 41.25 million per year. This cost runs as of 2025 and until collection is completed in each of the alternatives, except for data collection within a timeframe of 10 years.

Furthermore, the Mapping Authority informs that wage costs in 2016 for the rest of the crew are NOK 5200 per person per day, which means approximately NOK 31 000 for the remaining six persons in the crew. With a real wage adjustment to 2025, wage costs for these will have risen to NOK 35 000. This cost rises by 1.3 percent per year and will run until data collection is completed. The wage costs for the 10 positions which have now been transferred to the company with whom the contract is concluded cease to apply from 2025. We assume that operating costs for M/S Hydrograf rise linearly until they reach the same level as operating costs for charter, minus the cost for the wages for the crew that is hired, from 2022 to 2025. Crew costs are assumed to be equal to the Mapping Authority's costs per day per person in 2016. In case of data collection being completed within 10 years, M/S Hydrograf will not be replaced, but we assume that the linear growth in operating costs for Hydrograf continues at the same rate in 2026. This means that the costs related to M/S Hydrograf in this alternative are more than NOK 9 million higher in 2026 than in the other alternatives. We have chosen to model costs in this way because the Mapping Authority would not have had any incentives to start chartering a vessel unless the costs of keeping Hydrograf in operation were at least as high as the costs for long-term charter.

12.2. Necessary scale-up

In Table 23 below, we show how much collection capacity in the Mapping Authority needs to be scaled up to be able to complete collection and processing of marine geospatial data for the whole Norwegian coast and Svalbard within the given timeframe in each of the alternative measures. To arrive at this, we base ourselves on the Mapping Authority's estimate that it will be able to complete the mapping within 45 years with the current technology and resources. This means that on average, 1/45, i.e., 2.2 percent, of the remaining area will be mapped each year. To take productivity growth and technological progress into account, we assume that the Mapping Authority will manage to collect and process 1.3 percent more data per year than it does at present. In the first column of Table 24, it can be seen how much of the area that is not mapped today the Mapping Authority will manage to map per year in selected years in the analysis period, given that resources stay the same. In year 35 of the analysis period, technological progress has led to a situation where 3.5 percent of the area remaining per today is mapped per year, compared to 2.27 percent in the first year. The fact that a bigger and bigger area can be mapped for each year means that everything is mapped after 35 years in the zero alternative, given this assumption with regard to technological progress.

Table 23: Necessary scale-up of the Map Authority's collection capacity in each of the alternatives

Alternatives	Scale-up (in percent)
Alternative 1: 25 years	50
Alternative 2: 20 years	95
Alternative 3: 15 years	175
Alternative 4: 10 years	340

If collection capacity is to be increased, the Mapping Authority estimates that it will take a year to hire the necessary additional capacity and train the external resources to the required level. For the first year, collection capacity will therefore be the same as in the zero alternative for all alternatives. As can be seen from Table 24, the area mapped in the first year will be the same for all alternatives. In order to arrive at the percentage by which the collection capacity of the Mapping Authority needs to increase in each alternative, the following question needs to be asked: How many percent larger than in the zero alternative does the area for which the Mapping Authority collects data need to be in year 2, if it hereafter collects 1.3 percent more for each year, in order to be able to complete data collection within a timeframe of 10, 15, 20 and 25 years respectively? Table 23 provides the answers to this question. The reason we chose this relatively complicated way of modelling the alternatives is that this allows us to take technological development into account, while the number of consultants and survey vessels that need to be hired will be constant over the period it takes to map the remaining areas.

Table 24: Proportion of remaining areas not mapped as per today that is mapped per year in the five alternatives

	1 yr.	2 yrs.	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.
Zero alternative	2.27%	2.3%	2.4%	2.6%	2.7%	2.9%	3.1%	3.3%	3.5%
Alternative 1: 25 yrs.	2.27%	3.5%	3.6%	3.9%	4.1%	4.4%	4.7%		
Alternative 2: 20 yrs.	2.27%	4.6%	4.7%	5.1%	5.4%	5.8%			
Alternative 3: 15 yrs.	2.27%	7.0%	7.3%	6.5%	6.9%				
Alternative 4: 10 yrs.	2.27%	10.3%	10.7%	11.4%					

Table 25 below shows how big an area the Mapping Authority will have mapped in selected years for each of the alternatives, given the rate of collection shown in Table 24 above. What determines the benefit from the alternative measures in a given year is how much bigger the mapped area is in each of the alternatives relative to the zero alternative.

Table 25: Proportion of the remaining area as per today mapped after selected years in the five alternatives (in percent)

	5 yrs.	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.
Zero alternative	12	24	37	52	67	83	100
Alternative 1: 25 yrs.	17	35	56	77	100		
Alternative 2: 20 yrs.	21	46	72	100			
Alternative 3: 15 yrs.	31	66	100				
Alternative 4: 10 yrs.	44	100					

Table 23 shows by how much the collection capacity of the Mapping Authority needs to be increased to complete the mapping within the intended timeframe. In some areas, however, there are economies of scale which entail that the number of positions at the Mapping Authority does not need to rise proportionally with the scale-up. Table 26 shows how the individual job categories are affected. The 13 FTEs within processing and terrain modelling (and one position within bathymetry) will be able to approximately double their production because of major technological progress. How we have modelled the development for this group will be explained in more detail in the following subsection. The table shows by how many percent the number of FTEs needs to rise in each category if the Mapping Authority wants to increase collection capacity by 100 percent. There are no economies of scale within updating and map production. Within oceanography and bathymetry, some resources are currently used on writing reports and similar tasks. This type of tasks will not increase if capacity is scaled up, and therefore it is not necessary to increase the number of FTEs within these groups proportionally to the scale-up. Since all new capacity will consist of hired consultants that may be able to get technological support from their own companies, there will be no need for a significant increase in FTEs within the group that delivers technological support. The Mapping Authority therefore estimates that there will be a need for one extra person in this field if data collection is to be completed within 15 years, two extra persons for data collection within 10 years, and no extra capacity if collection is completed within 20 and 25 years. For the same reasons, we also believe that administration costs will be somewhat lower for hired consultants than for direct employees. After all, this is one of the reasons why the yearly cost for a full-time consultant is approximately NOK 1.2 million, compared to approximately NOK 915 000[75] for an employee working with basic production in the Mapping Authority. The Mapping Authority reckons that one administrative employee per ten hired consultants will be needed. In addition, expenses for rent and other fixed costs will increase somewhat. We therefore estimate that a 100 percent increase in collection capacity will lead to a 15 percent increase in administrative costs. Presently, around 24 percent of expenses in the Hydrographic Service division are spent on administration.

Table 26: Number of FTEs and scale factor for different job categories

Activity	No. of FTEs	Scale factor
Processing, terrain modeling	13	Not linear
Oceanography	5	80%
Bathymetry[76]	6	90%
Updating	11	100%
Map production	19	100%
Technology support	10	Not linear
Administration	10	Not linear

The annual cost per consultant, as well as wage costs within administration and map production, are adjusted to real wages by 1.3 percent per year. Administration costs are divided into wages and other administrative costs based on the result report for the Hydrographic Service division for the first half of 2016, which shows a wage

[75] Gross wage cost per FTE, including other personnel costs, within map production excluding crew on Hydrograf and administrative positions. Obtained from the Mapping Authority's result report for the first half of 2016 and the budget for 2016, within the units 3020 Technology and Safety and 3400 Marine Infrastructure.
[76] Per today, 7 persons work with bathymetry in the Mapping Authority. In the table, we have included one of these in the processing group (9 positions) and terrain modelling (3 positions), since the newly developed algorithm for processing will not only affect these 12 positions, but also at least one position within bathymetry.

share of 44 percent within administration, while this share is around 69 percent for map production excluding Hydrograf. Table 27 shows the Mapping Authority's costs distributed between gross wage costs and other costs for processing and map production, M/S Hydrograf and administration in 2016.

Table 27: The Hydrographic Services' costs related to map production in 2016 (NOK million, fixed prices 2016). Source: Budget for the Hydrographic Service in 2016 and result report for the first half of 2016

Activity	Gross wage costs	Other costs
Processing and map production	58.5	25.9
Administration	15.8	20.2
Hydrograf	20.8	13.9

12.2.1. Development of FTEs within processing in the different alternatives

The Norwegian Defence Research Establishment (FFI) has together with Kongsberg Maritime developed an algorithm for autoprocessing of measurement assignments into approved terrain models. The technology is so close to implementation that it is extremely likely that it will reduce costs from 2017. Experts state that this may reduce costs related to these specific processing tasks by 50 percent. This affects 13 FTEs in the Mapping Authority. To calculate the average number of FTEs that will be needed in each of the alternatives, we multiply the 13 FTEs with the scale factor before halving this number because the technological leap forward will lead to an efficiency gain of 50 percent. Since it is somewhat unrealistic to assume that the Mapping Authority will significantly reduce the number of FTEs already from 2017, we assume that the number of FTEs will be reduced in accordance with the trajectories shown in Table 28 below. These trajectories ensure that on average over the whole period there will be sufficient capacity to complete mapping within the allocated timeframe for each alternative. We assume that hired consultants for processing will achieve the same efficiency gain as the employees in the Mapping Authority. In the alternatives where more than 13 FTEs within these areas are needed, we assume that the remaining FTEs are covered by hired consultants.

Table 28: Development in no. of FTEs affected by technological progress within processing employed by the Mapping Authority and hired consultants assuming 50 percent efficiency gain

	Zero alternative	25 yrs.	20 yrs.	15 yrs.	10 yrs.
Average no. of FTEs in Mapping Authority	6.5	9.7	12.7	13	13
No. of hired consultants	0	0	0	5	15.7
2017	13	13	13	13	13
2018	12	12	13	13	13
2019	11	11	13	13	13
2020	10	10	13	13	13
2021	9	10	13	13	13
2022	8	10	13	13	13
2023	7	10	13	13	13
2024	6	10	13	13	13
2025	6	10	13	13	13
2026	6	10	13	13	13

2027	6	10	13	13	
2028	6	10	13	13	
2029	6	9	13	13	
2030	6	9	13	13	
2031	6	9	12	13	
2032	6	9	12		
2033	6	9	12		
2034	6	9	12		
2035	6	9	12		
2036	6	9	12		
2037	6	9			
2038	6	9			
2039	6	9			
2040	6	9			
2041	5	9			
2042-2051	5				

At present, gross wage costs, including pension costs and other direct personnel costs, are on average around NOK 914 000 at fixed 2016-prices per FTE in the Mapping Authority's map production. For each FTE that disappears in relation to the table above, the Map Authority's costs are reduced by this sum adjusted for real wage growth of 1.3 percent per year as of 2017.

In the uncertainty analyses, we analyze what the effect will be if the efficiency gain is a respective 40 or 70 percent, rather than 50 percent. If the efficiency gain changes, the trajectories for personnel reduction, average number of FTEs in the Mapping Authority and number of hired consultants within processing and terrain modelling must also be changed accordingly. This is shown in the table below.

Table 29: Development in no. of FTEs affected by technological progress within processing, employees in the Mapping Authority and hired consultants, at 40 and 70 percent efficiency gain respectively

	Zero alternative		**25 yrs.**		**20 yrs.**		**15 yrs.**		**10 yrs.**	
Efficiency gain	**40%**	**70%**	**40%**	**70%**	**40%**	**70%**	**40%**	**70%**	**40%**	**70%**
Average no. of FTEs in Mapping Authority	7.8	3.9	11.7	5.8	13	7.65	13	10.7	13	13
No. of hired consultants	0	0	0	0	2.3	0	8.6	0	21.4	4.2
2017	13	12	13	13	13	13	13	13	13	13
2018	12	9	13	12	13	12	13	12	13	13
2019	11	7	12	10	13	11	13	12	13	13
2020	10	5	12	9	13	10	13	12	13	13
2021	9	5	12	8	13	9	13	12	13	13
2022	8	4	12	7	13	8	13	11	13	13
2023	8	4	12	6	13	7	13	11	13	13
2024	8	4	12	5	13	7	13	10	13	13

2025	8	4	12	5	13	7	13	10	13	13
2026	8	4	12	5	13	7	13	10	13	13
2027	8	4	12	5	13	7	13	10		
2028	8	4	12	5	13	7	13	10		
2029	8	4	12	5	13	6	13	10		
2030	7	3	12	5	13	6	13	9		
2031	7	3	12	5	13	6	13	9		
2032	7	3	11	5	13	6				
2033	7	3	11	4	13	6				
2034	7	3	11	4	13	6				
2035	7	3	11	4	13	6				
2036	7	3	11	4	13	6				
2037	7	3	11	4						
2038	7	3	11	4						
2039	7	3	11	4						
2040	7	3	11	4						
2041	7	3	11	4						
2042-2051	7	3								

12.3. Modelling of NGU's costs

NGU has estimated that in the zero alternative, it will cost NOK 500 million (at fixed 2016 prices) to produce thematic maps for the whole Norwegian coast to one nautical mile beyond the baseline if the timeframe for this is 15 years. NGU has presently not received any confirmed funding to do this. In all alternatives, we assume that NGU will follow the same rate of data collection as the Mapping Authority. In the zero alternative, NGU's data collection will stop after five years, because its vessel is so old that it needs to be retired, and no funding for the purchase of a new vessel has been approved yet. We assume that NGU will continue at the present data collection rate for these five years, which means it will map approximately 670km^2 per year. Up to now, these projects have been carried out with 50 percent external funding. In the zero alternative, we assume that NGU will manage to continue to secure sufficient external funding from other public actors in the next five years. NGU informs that the total cost to map one km^2 is around NOK 6250. We calculate the total mapping cost for NGU based on this. According to NGU, approximately 50 percent of its costs for mapping are wage costs, while the remainder are operating costs in the zero alternative and in all other alternatives. We therefore carry out a real wage adjustment for half of NGU's costs.

In all alternatives, however, it will be necessary for NGU to purchase a specialized vessel at a cost of NOK 45 million in 2017. The exception to this is a data collection time of ten years, which means NGU will need two vessels. NGU estimates that it will have to employ approximately 12 marine geologists in addition to the three that presently work on mapping the coastal zone if mapping is to be completed within 15 years. Since NGU has only provided an estimate for data collection within a timeframe of 15 years, we base ourselves on this estimate to calculate the costs for the remaining alternatives.

NGU has informed that the market for marine geologists is tight, and that it therefore will take a year to recruit and employ additional marine geologists. Thus, we assume that costs in the first year will be the same as costs in the zero alternative for all alternatives. In addition, NGU estimates that a training period of 1.5 years will be needed before new marine geologists will fully contribute to production. In NGU's estimate for mapping within a timeframe of 15 years, 15 geologists will thus have 12.5 years in which to map the remaining 80 000 km^2. This means that they will map on average 427 km^2 per FTE. Hereafter, we calculate the number of FTEs that will be necessary to map 80 000 km^2 given the number of years that are available in each of the remaining alternatives, and that one FTE maps 427 km^2 per year.

Table 30 shows the number of FTEs per year that will be needed under these premises. For each additional person that is needed in the different alternatives relative to mapping within a timeframe of 15 years, 1.5 additional FTEs will be required for training. We assume that one FTE per year in NGU costs the same as one FTE in processing in the Mapping Authority. The additional costs in the alternatives will thus be the number of additional years used for training multiplied with NOK 914 000 per FTE. This cost per FTE is probably slightly on the high side, as NGU is likely to employ mainly new graduates rather than more experienced personnel. At the same time, a higher number of FTEs will probably also lead to higher operating costs which partly compensate for this effect. We assume that training costs have been taken into account in NGU's estimate for collection within 15 years, and that the estimate of NOK 500 million in total for data collection in 15 years, before real wage adjustment, is fixed. As the estimate for collection within 15 years is fixed independently of training costs, the factor that will affect the net economic benefit is the size of training costs relative to collection within 15 years.

Table 30: Overview of FTEs needed in NGU in each of the alternatives and net increase in training costs for each alternative relative to the zero alternative, main scenario

	Zero alternative	25 yrs.	20 yrs.	15 yrs.	10 yrs.
Remaining to be mapped	80 000 km^2	80 000 km^2	80 000 km^2	80 000 km^2	80 000 km^2
Marine geologists in NGU	3 for 5 yrs.	8	11	15	25
Yrs. for processing	-	22.5	17.5	12.5	7.5
Mapped per FTE	-	427 km^2	427 km^2	427 km^2	427 km^2
Training costs (NOK million, at fixed 2016 prices)	-	7.3	10.6	16.5	30.2
Training cost relative to collection within 15 years		-9.1	-5.9	-	13.7

How many marine geologists NGU will need for data collection within a timeframe of 15 years and how long the training period will need to be is very uncertain. We have therefore calculated what the extra cost in each of the alternatives will be if only 10 marine geologists are needed for mapping within 15 years and training time is one year, see Table 31. Since NGU's estimate of NOK 500 million for collection within 15 years, adjusted for wage growth, is fixed, NGU's costs in alternative 3 are not affected by changes in the assumptions for cost calculation for NGU. Shorter training time and fewer marine geologists needed will mean that there are fewer cost savings if mapping is completed within less than 15 years. Thus, the assumption of higher efficiency in NGU leads to higher cost estimates for alternative 1 and 2, and lower cost estimates for alternative 4, and vice versa for the assumption of lower efficiency.

Table 31: Overview of FTEs needed in NGU in each of the alternatives and net increase in training costs for each alternative relative to the zero alternative, upper estimate for efficiency in NGU

	25 år	20 år	15 år	10 år
Remaining to be mapped	80 000 km^2	80 000 km^2	80 000 km^2	80 000 km^2
Marine geologists in NGU	6	7	10	16
Yrs. for processing	23	18	13	8
Mapped per FTE	615 km^2	615 km^2	615 km^2	615 km^2
Training costs (NOK million, at fixed 2016 prices)	2.4	3.9	6.4	12.1
Training cost relative to collection within 15 years	-4.0	-2.5	-	5.7

In a similar way, we have also calculated the extra costs for NGU if 20 marine geologists are needed in the zero alternative and training time is four years, see Table 32 below. With the exception of the changes to these two parameters, the calculation method is the same as in the main scenario.

Table 32: Overview of FTEs needed in NGU in each of the alternatives and net increase in training costs for each alternative relative to the zero alternative, lower estimate for efficiency in NGU

	25 yrs.	20 yrs.	15 yrs.	10 yrs.
Remaining to be mapped	80 000 km^2	80 000 km^2	80 000 km^2	80 000 km^2
Marine geologists in NGU	11	14	20	34
Yrs. for processing	22	17	12	7
Mapped per FTE	333 km^2	333 km^2	333 km^2	333 km^2
Training costs (NOK million, at fixed 2016 prices)	14.5	20.3	31.1	57.2
Training cost relative to collection within 15 years	-16.6	-10.8	-	26.1

13. Appendix 4: Method for the calculation of benefits

13.1. Workshop to evaluate the effects of mapping on maritime safety

A workshop to evaluate the effects of mapping on maritime safety was held at DNV GL's headquarters in Høvik, Norway on June 7, 2016. A number of experts was invited, and the following participated in the meeting:

Table 33: Experts participating in the workshop

Name	Institution	Expertise
Thomas Axelssen	Norwegian Coastal Administration	Nautical expert and expert for navigational analysis
Trond Langemyr	Norwegian Coastal Administration	Nautical expert
Arnstein Ytterland	DNV GL	Nautical expert
Herman Iversen	Mapping Authority	Expert on marine geospatial data
Håvard Gåseidnes	Norwegian Maritime Authority	Nautical expert and expert for risk management

In the workshop, each of the experts was asked to quantify the effect of the availability of more detailed nautical charts on maritime safety, in form of a Delphi-session. The basis of comparison were older measurements classified according to the current classification regime for marine geospatial data. The experts were asked to assess the following three measures:

- Using older measurements where classification has been removed to a depth of 30 meters
- Using multibeam measurements under the current classification regime
- Using multibeam measurements where classification has been removed to a depth of 30 meters

13.2. Calculation of benefits for public actors

The calculation of benefits for municipalities and the Norwegian Public Roads Administration is explained in detail in the following sections. As it has been very difficult to obtain information from these actors, the estimates are based on relatively few statements. This implies that there is considerable uncertainty related to the effects.

13.2.1. Calculation of benefit for municipalities

For the calculation of benefits for the municipalities, we have looked at all coastal municipalities in Norway. We have contacted a large number of actors to try and chart the costs for mapping for different purposes in the municipalities. This proved to be very difficult, both because there are few people in the municipalities that know who could answer such questions, and because costs for mapping are often not a separate, specified budget item. Our estimates are therefore based on a relatively small number of statements.

From the Mapping Authority, we received an overview of the areas that have been mapped with multibeam echo sounder and the areas that have only been mapped with older methods. Based on this, we developed an overview over how big a proportion of the sea area of each municipality is covered by multibeam measurements. The purpose of this was to find a basis on which to calculate the maximum potential benefit in each municipality. If for example 98 percent of the sea area of a municipality is mapped already, the benefit of scaling up the rate of data collection for this municipality is very small. For another municipality, where only 2 percent of the sea areas are mapped, the potential benefits of scaling up the data collection rate are much larger. By taking into account the areas that have already been mapped, we manage to exclude benefits that have already been realized from our calculation.

Furthermore, we assume that the benefits are realized linearly in line with the rate of data collection. This means that we assume that a certain percentage of each remaining area in each municipality produces a benefit each year. In other words, for a municipality where only 2 percent of the sea area is covered by multibeam data, the remaining 98 percent will be measured in line with the respective collection rate in each alternative that is necessary to map the whole coast and Svalbard within the given timeframe in each alternative. In the zero alternative for example, 2 percent (mapping in year 1) of the remaining area will have been mapped after the first year, and 5 percent (mapping in year 1 and 2) of the remaining area after the second year etc.

The benefits for each municipality in each year are calculated by looking at how much has been mapped compared to what the maximum benefit is. In the main analysis, we put the maximum benefit to NOK 100 000 per year. For a municipality where 50 percent of sea areas were mapped with multibeam measurements at the start of the analysis period, the total realized benefit of 100 percent mapping will be NOK 50 000 per year.

The net economic benefit is thereafter calculated as the difference between the benefit that is realized in the zero alternative in a given year and the benefit that is realized in each of the alternative measures. See Table 1 for an overview of how fast the mapping will proceed in the zero alternative and each of the four measures. After 10 years for example, 24 percent of the area that is remaining as per today will be mapped in the zero alternative, while 35 percent will be mapped if data collection is supposed to be completed within 25 years. This means that an area that is larger by 11 percentage points will be mapped in this alternative than in the zero alternative after ten years. The net economic benefit for alternative 1 (25 years) is therefore calculated to 11 percent of the yearly benefit that is expected to be realized when 100 percent of the coast is mapped. The net economic benefit for the second year and the other alternatives is calculated accordingly: number of percentage points larger mapped area in the alternative than in the zero alternative in the given year, multiplied with the expected effect when 100 percent are mapped.

13.2.2. Calculation of benefits for the Public Roads Administration

The calculations for the Public Roads Administration are carried out on the basis of interviews with employees and project managers. Also for this actor, the estimates are based on few statements and therefore very uncertain. There is no separate reporting for costs related to hydrographic surveys to the Public Roads Administration, and that makes it necessary to look at each individual project to identify these costs. Based on interviews, we have estimated the benefit per project to NOK 200 000.

There is no general overview over how many projects have involved measurements of the seabed or how many planned projects are expected to make use of such data. We have therefore tried to classify road projects ourselves according to whether there was/will be a need for marine geospatial data in these projects. To do this, we looked at all road projects with a cost of more than NOK 500 million that will either be opened or started in the period from 2014-2017. Based on the information on the web pages of the Norwegian Public Roads Administration[77], we determined which projects are likely to have/have had a need for marine geospatial data in the planning phase. This survey is only based on the available information, which for examples shows maps of where investments are made and specify what type of project will be executed (for example bridge, pedestrian or cycling path, tunnel etc.). For some of these infrastructure projects, there are no available maps. Based on this work, we assume it is likely that approximately 5 projects over a 3-year period will require marine geospatial data. This means that approximately 1.67 projects per year require such data, and thus may generate benefits in the form of saved mapping costs for the Public Roads Administration. We have also taken the seven fjord crossings into account which are needed to realize the ferry-free E39 in the Norwegian National Transport Plan 2019-2029.

The benefit per project is therefore 200 000*1.67 projects per year. In addition, we take into account that we do not know whether the area where the Public Roads Administration is planning to build will be mapped at the time of building. This benefit is therefore adjusted for the collection rate of map data, in the same way as for the municipalities. This means that the benefit in the first year of the zero alternative will be 200 000*1.67 (projects)*percentage of area mapped in year 1. The benefit in the second year will be 200 000*1.67 (projects)*percentage of area mapped in year 1 and year 2. We thus adjust the benefit with the percentage of area mapped to accommodate the probability of the area where the Public Roads Administration will build being mapped. The further out in the analysis period, the bigger the area that is mapped and the bigger the probability for the area where the Public Roads Administration will build being mapped. This means that the benefit increases the closer one gets to the end of the analysis period.

The net economic benefit is thereafter calculated as the difference between the benefit that is realized in the zero alternative in a given year and the benefit that is realized in each of the alternative measures. See Table 1 for an overview of how fast the mapping will proceed in the zero alternative and in each of the four measures. After 10 years for example, 24 percent of the area remaining to be mapped as per today will be mapped in the zero alternative, while 35 percent will be mapped if data collection is supposed to be completed within 25 years. This means that an area that is larger by 11 percentage points will be mapped in this alternative than in the zero alternative after ten years. The net economic benefit for alternative 1 (25 years) is therefore calculated to 11 percent of the yearly benefit that is expected to be realized when 100 percent of the coast is mapped. The net economic benefit for the second year and the other alternatives is calculated accordingly: number of percentage points larger mapped area in the alternative than in the zero alternative in the given year, multiplied with the expected effect when 100 percent are mapped.

13.3. Calculation of benefit for the aquaculture industry

To calculate the benefit of increased value creation within the aquaculture industry, we have based ourselves on the most recent figures for total value creation within aquaculture from Statistics Norway. This figure was NOK 10.3 billion for 2014 (in fixed 2005 prices). This figure is CPI-adjusted to NOK 12.7 billion in fixed 2016 prices.

As pointed out in section 5.3.1 on the aquaculture industry, it is not necessarily the case that increased value creation within aquaculture is economically profitable. For this value creation to be economically profitable, the input factors labor and capital must produce higher returns in aquaculture than in other sectors of Norwegian

[77] *http://www.vegvesen.no/vegprosjekter/Om+vegprosjekter/Vegprosjekter+2014-2017*

trade and industry. It is therefore the additional return from moving resources from alternative uses and to the aquaculture industry that is the basis of the calculations below.

To calculate the additional return within aquaculture we base ourselves on an indicator deduced from a profit function: $\pi = PY(L, K, \overline{X}) - (wL + rK + \overline{pX})$ where:

- *π= social profit*
- *P= output price*
- *Y(L, K, $\overline{X}$)=Y= production*
- *w, r, $\overline{p}$= cost per input factor ($\overline{p}$ is price index for other input factors)*
- *L, K, $\overline{X}$= input factors ($\overline{X}$ is index for other input factors)*

The profit function is transformed into a function that shows the social profit from the industry where the alternative cost of resource use has been subtracted: $\pi^n = NVS^n - (w^s L^n + r^s K^n)$ where:

- *NVS= net value added (gross value added minus amortization and depreciation)*
- *s=society as a whole*
- *n=industry*
- *w^s= average labor cost per person engaged (employees and self-employed) for the whole economy*
- *r^s=average return on total assets for the whole economy*

The indicator is thus the following: $Indicator = \frac{\pi^n}{(w^s L^n + r^s K^n)} = \frac{NVS^n}{(w^s L^n + r^s K^n)} - 1$

If the indicator is greater than zero, growth in the industry will increase the total social profit. If the indicator is smaller than zero, growth in the industry will reduce the total social profit. Based on Menon's accounting database with accounting data for all Norwegian enterprises with a statutory duty to maintain accounts, we have calculated the additional return for the period from 2004-2014. When calculating the benefits, we have used an average for this period as a measure for the additional return in the aquaculture industry; we arrive at an average additional return of an impressive 128 percent compared to other representative trade and industry sectors. The additional return for the period is shown in the table below:

Table 34: Calculation of additional return in the aquaculture industry in the period 2004-2014. Source: Menon

Year	Industry	Social return index
2004	Aquaculture	-0.0797
2005	Aquaculture	1.1154
2006	Aquaculture	2.0229
2007	Aquaculture	0.7451
2008	Aquaculture	0.5429
2009	Aquaculture	1.0901
2010	Aquaculture	2.7126
2011	Aquaculture	1.2004
2012	Aquaculture	0.3409
2013	Aquaculture	2.2538
2014	Aquaculture	2.1316
Average		**1.2796**

Based on value creation in the industry in 2014 and the calculated additional return, we have calculated the benefit by increasing value added by x percent, for example by 0.2, 0.5 and 1 percent. The benefits are adjusted for the total mapped area in the same way as for the public actors. This means that the benefit in year 1 assuming 1 percent growth in value creation is as follows: value cration in 2014*additional return*1 percent increase in value creation*percent of area mapped in year 1. The larger the area that is mapped, the larger the benefits.

Hereafter, the net economic benefit is calculated as the difference between the benefit that is realized in the zero alternative in a given year and the benefit that is realized in each of the alternative measures. See Table 1 for an overview of how fast the mapping will proceed in the zero alternative and each of the four measures. After 10 years for example, 24 percent of the area remaining unmapped as per today will be mapped in the zero alternative, while 35 percent will be mapped if data collection is supposed to be completed within 25 years. This means that an area that is larger by 11 percentage points will be mapped in this alternative than in the zero alternative after ten years. The net economic benefit for alternative 1 (25 years) is therefore calculated to 11 percent of the yearly benefit that is expected to be realized when 100 percent of the coast is mapped. The net economic benefit for the second year and the other alternatives is calculated accordingly: number of percentage points larger mapped area in the alternative than in the zero alternative in the given year, multiplied with the expected effect when 100 percent are mapped.

14. Appendix 5: Detailed cost figures

To make sure that the analysis is transparent, we provide detailed cost figures distributed according to year and type of cost. All values are quoted in NOK thousand at fixed 2016 prices. To improve readability, the tables do not show the costs from year 11 and up to and including the second last year before the end of the analysis period. All cost components are either constant or adjusted to real wages by 1.3 percent for these years; the cost for the last year in which a particular cost accrues is quoted, and we have indicated if the cost component is constant or real price adjusted.

Costs 20 years	Sum net present va	Sum	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027-2035	2036
Total costs Mapping Authority	3 761 038	5 636 145	205 556	256 679	258 582	260 510	262 463	264 441	272 423	280 432	287 319	289 264	...	308 979
- Operation Hydrograf+Survey boats+(hired crew)	389 405	623 718	13 855	13 855	13 855	13 855	13 855	13 855	19 834	25 813	41 245	41 245	constant	41 245
- Crew Hydrograf Mapping Authority	241 317	340 622	21 053	21 327	21 604	21 885	22 169	22 457	22 749	23 045	12 743	12 908	real price	14 688
- Wages remaining map production	894 463	1 336 849	59 264	60 034	60 814	61 605	62 406	63 217	64 039	64 871	65 715	66 569	real price	74 564
- Other remaining map production	351 721	517 604	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	constant	25 880
- Fixed costs	312 704	460 789	21 661	23 112	23 112	23 112	23 112	23 112	23 112	23 112	23 112	23 112	constant	23 112
- Wages administration	276 947	414 950	17 200	18 590	18 832	19 077	19 325	19 576	19 830	20 088	20 349	20 614	real price	23 456
- Hired consultants	672 433	1 016 338	22 918	46 431	47 035	47 646	48 265	48 893	49 529	50 172	50 825	51 485	real price	58 584
- Chartered survey boats incl. operation	622 048	925 275	23 725	47 450	47 450	47 450	47 450	47 450	47 450	47 450	47 450	47 450	constant	47 450
Total costs NGU	391 990	571 970	49 215	25 862	26 032	26 205	26 379	26 556	26 736	26 917	27 101	27 288	...	29 290
- Wages	185 514	282 361	2 121	13 098	13 268	13 441	13 615	13 792	13 972	14 153	14 337	14 524	real price	16 526
- Operation	163 207	244 609	2 094	12 764	12 764	12 764	12 764	12 764	12 764	12 764	12 764	12 764	constant	12 764
- Vessel	43 269	45 000	45 000	-	-	-	-	-	-	-	-	-	constant	-
Tax funding cost	830 605	1 241 623	50 954	56 508	56 923	57 343	57 768	58 199	59 832	61 470	62 884	63 310	...	67 654
Sum	**4 983 633**	**7 449 738**	**305 724**	**339 049**	**341 537**	**344 058**	**346 611**	**349 197**	**358 991**	**368 819**	**377 304**	**379 862**	**...**	**405 923**

Costs 25 years	Sum net present va	Sum	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027-2040	2041
Total costs Mapping Authority	3 575 341	5 856 287	181 453	207 236	207 873	208 505	210 108	211 732	219 356	227 001	233 520	235 092	...	260 023
- Operation Hydrograf+survey boats+(hired crew)	473 205	829 943	13 855	13 855	13 855	13 855	13 855	13 855	19 834	25 813	41 245	41 245	constant	41 245
- Crew Hydrograf Mapping Authority	272 312	416 976	21 053	21 327	21 604	21 885	22 169	22 457	22 749	23 045	12 743	12 908	real price	15 668
- Wages remaining map production	1 006 196	1 646 445	59 264	59 096	58 914	58 717	59 481	60 254	61 037	61 831	62 634	63 449	real price	75 750
- Other remaining map production	404 303	647 005	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	constant	25 880
- Fixed costs	338 593	542 257	20 966	21 720	21 720	21 720	21 720	21 720	21 720	21 720	21 720	21 720	constant	21 720
- Wages administration	307 255	505 043	16 647	17 471	17 698	17 928	18 161	18 397	18 637	18 879	19 124	19 373	real price	23 514
- Hired consultants	414 250	687 355	11 926	24 162	24 476	24 794	25 116	25 443	25 773	26 109	26 448	26 792	real price	32 519
- Chartered survey boats incl. operation	359 228	581 263	11 863	23 725	23 725	23 725	23 725	23 725	23 725	23 725	23 725	23 725	constant	23 725
Total costs NGU	364 441	575 160	49 215	20 226	20 360	20 495	20 631	20 770	20 910	21 052	21 196	21 342	...	23 770
- Wages	172 808	288 484	2 121	10 244	10 377	10 512	10 649	10 787	10 927	11 069	11 213	11 359	real price	13 787
- Operation	148 364	241 676	2 094	9 983	9 983	9 983	9 983	9 983	9 983	9 983	9 983	9 983	constant	9 983
- Vessel	43 269	45 000	45 000	-	-	-	-	-	-	-	-	-	constant	-
Tax funding cost	787 956	1 286 289	46 134	45 492	45 646	45 800	46 148	46 500	48 053	49 611	50 943	51 287	...	56 759
Sum	**4 727 738**	**7 717 737**	**276 801**	**272 955**	**273 879**	**274 799**	**276 887**	**279 002**	**288 319**	**297 664**	**305 659**	**307 720**	**...**	**340 551**

Costs zero alternative	Sum net present va	Sum	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027-2050	2051
Total costs Mapping Authority	3 335 359	6 478 832	156 311	156 625	156 932	157 230	157 520	157 800	164 051	170 291	176 401	177 559	...	210 509
- Operation Hydrograf+survey boats+(hired crew)	598 694	1 242 393	13 855	13 855	13 855	13 855	13 855	13 855	19 834	25 813	41 245	41 245	constant	41 245
- Crew Hydrograf Mapping Authority	323 314	585 306	21 053	21 327	21 604	21 885	22 169	22 457	22 749	23 045	12 743	12 908	real price	17 828
- Wages remaining map production	1 195 424	2 332 383	59 264	59 096	58 914	58 717	58 505	58 278	58 035	57 776	58 527	59 288	real price	80 448
- Other remaining map production	483 044	905 808	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	constant	25 880
- Fixed costs	377 225	707 375	20 211	20 211	20 211	20 211	20 211	20 211	20 211	20 211	20 211	20 211	real price	20 211
- Wages administration	357 658	705 567	16 048	16 257	16 468	16 682	16 899	17 119	17 341	17 567	17 795	18 026	constant	24 897
Total costs NGU	19 002	21 353	4 215	4 242	4 270	4 299	4 327	-	-	-	-	-	...	-
- Wages	9 681	10 884	2 121	2 149	2 176	2 205	2 233	-	-	-	-	-	constant	-
- Operation	9 321	10 469	2 094	2 094	2 094	2 094	2 094	-	-	-	-	-	constant	-
- Vessel	-	-	-	-	-	-	-	-	-	-	-	-	constant	-
Tax funding cost	670 872	1 300 037	32 105	32 174	32 240	32 306	32 369	31 560	32 810	34 058	35 280	35 512	...	42 102
Sum	**4 025 234**	**7 800 222**	**192 630**	**193 041**	**193 443**	**193 834**	**194 216**	**189 361**	**196 861**	**204 350**	**211 681**	**213 070**	**...**	**252 611**

Costs 10 years	Sum net present va	Sum	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Total costs Mapping Authority	*4 261 451*	*5 308 975*	*341 202*	*529 612*	*533 424*	*537 285*	*541 197*	*545 160*	*555 153*	*565 198*	*575 296*	*585 448*
- Operation Hydrograf+survey boats+(hired crew)	154 417	198 340	13 855	13 855	13 855	13 855	13 855	13 855	19 834	25 813	31 792	37 770
- Crew Hydrograf Mapping Authority	180 348	223 282	21 053	21 327	21 604	21 885	22 169	22 457	22 749	23 045	23 345	23 648
- Wages remaining map production	507 674	628 534	59 264	60 034	60 814	61 605	62 406	63 217	64 039	64 871	65 715	66 569
- Other remaining map production	209 912	258 802	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880
- Fixed costs	242 944	300 489	25 389	30 567	30 567	30 567	30 567	30 567	30 567	30 567	30 567	30 567
- Wages administration	203 961	253 300	20 159	24 587	24 906	25 230	25 558	25 890	26 227	26 568	26 913	27 263
- Hired consultants	1 495 021	1 868 515	92 565	187 288	189 722	192 189	194 687	197 218	199 782	202 379	205 010	207 675
- Chartered survey boats incl. operation	1 267 173	1 577 713	83 038	166 075	166 075	166 075	166 075	166 075	166 075	166 075	166 075	166 075
Total costs NGU	*521 250*	*637 302*	*94 215*	*58 748*	*59 135*	*59 527*	*59 923*	*60 326*	*60 733*	*61 145*	*61 563*	*61 987*
- Wages	225 406	284 256	2 121	29 753	30 140	30 532	30 929	31 331	31 738	32 151	32 569	32 992
- Operation	209 306	263 045	2 094	28 995	28 995	28 995	28 995	28 995	28 995	28 995	28 995	28 995
- Vessel	86 538	90 000	90 000	-	-	-	-	-	-	-	-	-
Tax funding cost	*956 540*	*1 189 255*	*87 083*	*117 672*	*118 512*	*119 362*	*120 224*	*121 097*	*123 177*	*125 269*	*127 372*	*129 487*
Sum	***5 739 241***	***7 135 531***	***522 500***	***706 032***	***711 070***	***716 174***	***721 345***	***726 583***	***739 063***	***751 612***	***764 231***	***776 921***

Total costs Mapping Authority	*4 004 640*	*5 423 278*	*260 962*	*368 181*	*370 886*	*373 626*	*376 401*	*379 212*	*388 039*	*396 903*	*350 978*	*353 411*	...	*366 061*
- Operation Hydrograf+survey boats+(hired crew)	287 450	417 493	13 855	13 855	13 855	13 855	13 855	13 855	19 834	25 813	41 245	41 245	constant	41 245
- Crew Hydrograf Mapping Authority	205 965	269 043	21 053	21 327	21 604	21 885	22 169	22 457	22 749	23 045	12 743	12 908	real price	13 769
- Wages remaining map production	715 614	974 587	59 264	60 034	60 814	61 605	62 406	63 217	64 039	64 871	65 715	66 569	real price	71 010
- Other remaining map production	287 746	388 203	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	25 880	constant	25 880
- Fixed costs	281 018	379 912	22 857	25 504	25 504	25 504	25 504	25 504	25 504	25 504	25 504	25 504	constant	25 504
- Wages administration	242 512	330 925	18 149	20 514	20 781	21 051	21 325	21 602	21 883	22 167	22 455	22 747	real price	24 265
- Hired consultants	1 078 874	1 453 140	52 453	106 167	107 548	108 946	110 362	111 797	113 250	114 722	86 261	87 383	real price	93 212
- Chartered survey boats incl. operation	905 461	1 209 975	47 450	94 900	94 900	94 900	94 900	94 900	94 900	94 900	71 175	71 175	constant	71 175
Total costs NGU	*429 731*	*578 603*	*49 215*	*36 182*	*36 420*	*36 661*	*36 906*	*37 153*	*37 404*	*37 658*	*37 916*	*38 176*	...	*39 532*
- Wages	203 076	281 510	2 121	18 324	18 563	18 804	19 048	19 296	19 547	19 801	20 058	20 319	real price	21 675
- Operation	183 386	252 094	2 094	17 857	17 857	17 857	17 857	17 857	17 857	17 857	17 857	17 857	constant	17 857
- Vessel	43 269	45 000	45 000	-	-	-	-	-	-	-	-	-	constant	-
Tax funding cost	*886 874*	*1 200 376*	*62 035*	*80 873*	*81 461*	*82 057*	*82 661*	*83 273*	*85 089*	*86 912*	*77 779*	*78 318*	...	*81 118*
Sum	***5 321 245***	***7 202 258***	***372 212***	***485 236***	***488 767***	***492 344***	***495 968***	***499 639***	***510 532***	***521 473***	***466 673***	***469 905***	**...**	***486 711***